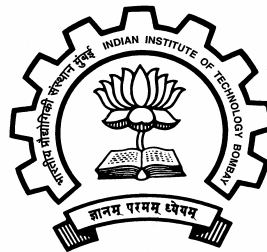


Geotechnical aspects of landfill design



Dr.-Ing. B.V.S. Viswanadham
Associate Professor,
Department of Civil Engineering
IIT Bombay

Email: viswam@civil.iitb.ac.in

Prof. B.V.S. Viswanadham,
Dept. of Civil Engg., IIT BOMBAY



Introduction

- Up to **75 %** the solid waste produced continues to be landfilled - in spite of vigorous efforts aimed at:
 - waste reduction,
 - recycling and
 - reuse.



Forms of land disposal

- Shallow burial vaults in soil
 - Deep chambers in rock
 - Deep well injection
 - Surface impoundments
 - Spray irrigation and composting
- First form of land disposal, more commonly known as **landfills**.



MSW landfill prime functions

- A solid waste landfill must be able:
 - to prevent ground water pollution,
 - to collect of leachate,
 - to permit gas venting

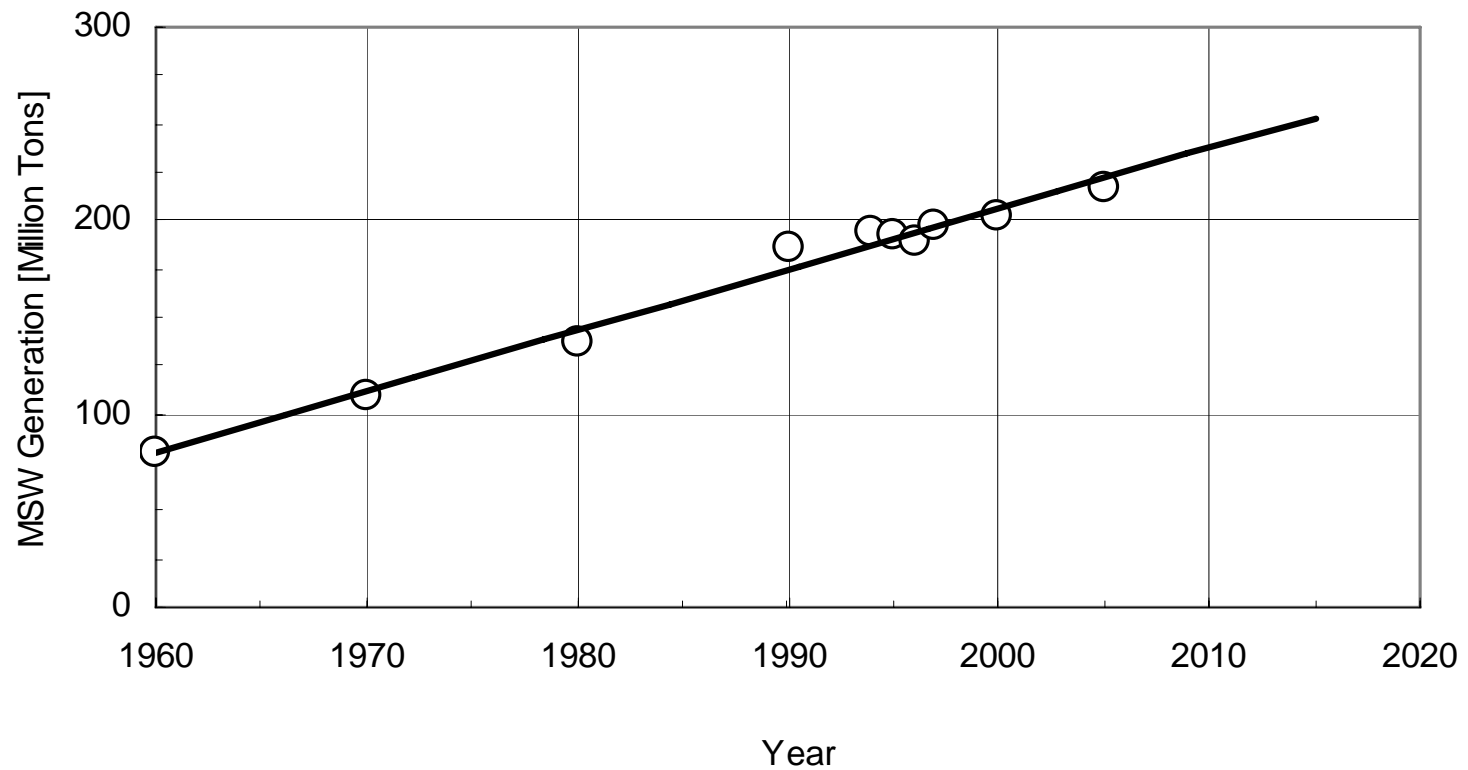


Need for landfills

- Three basic choices for handling or disposing of Waste
 - Bury it
 - Burn it
 - Recycle/Re-use it

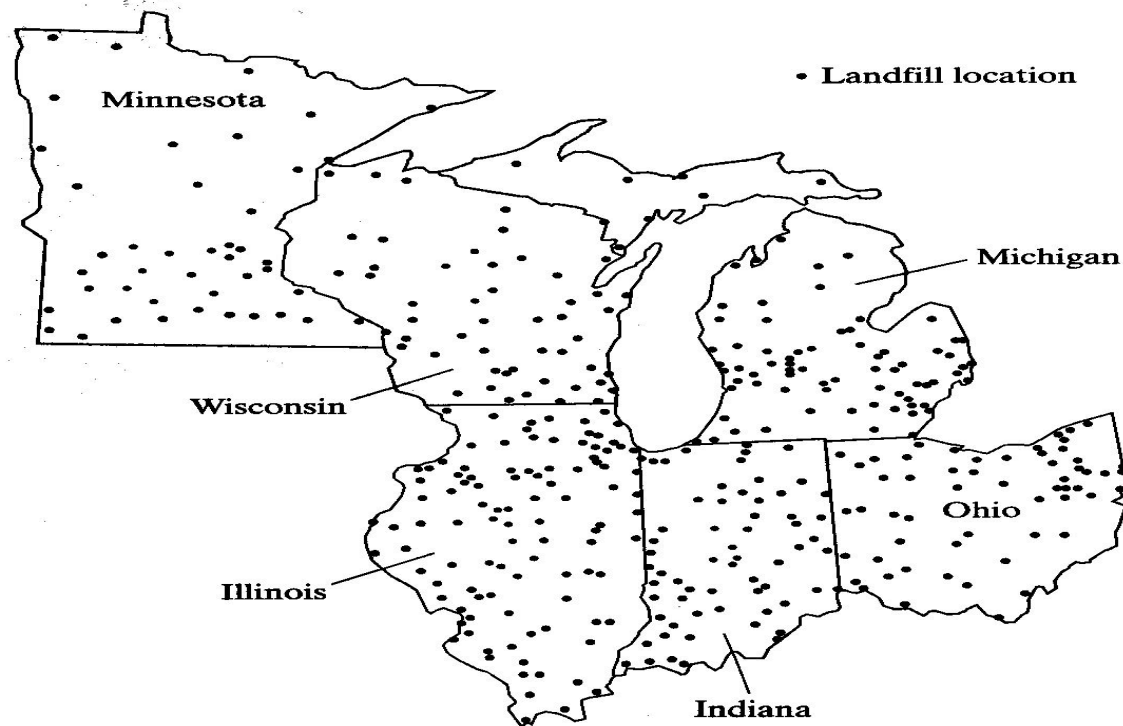


Generation of MSW in USA



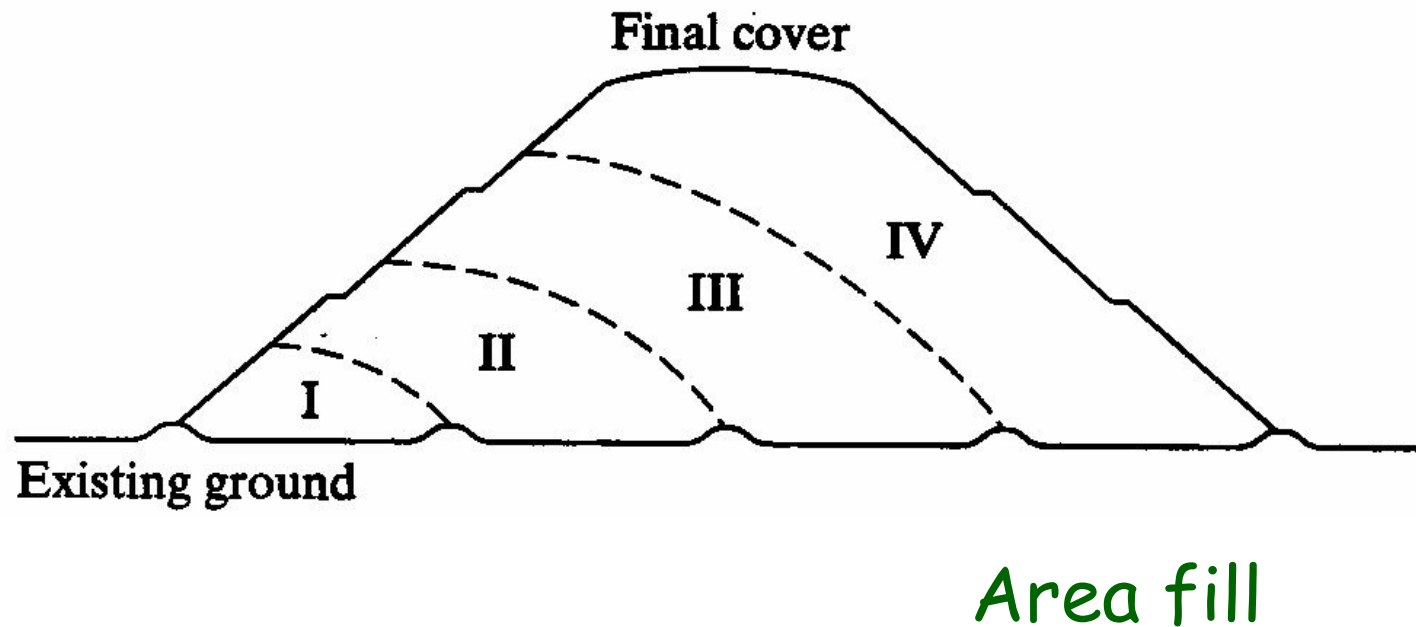
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MSW landfills in parts of USA



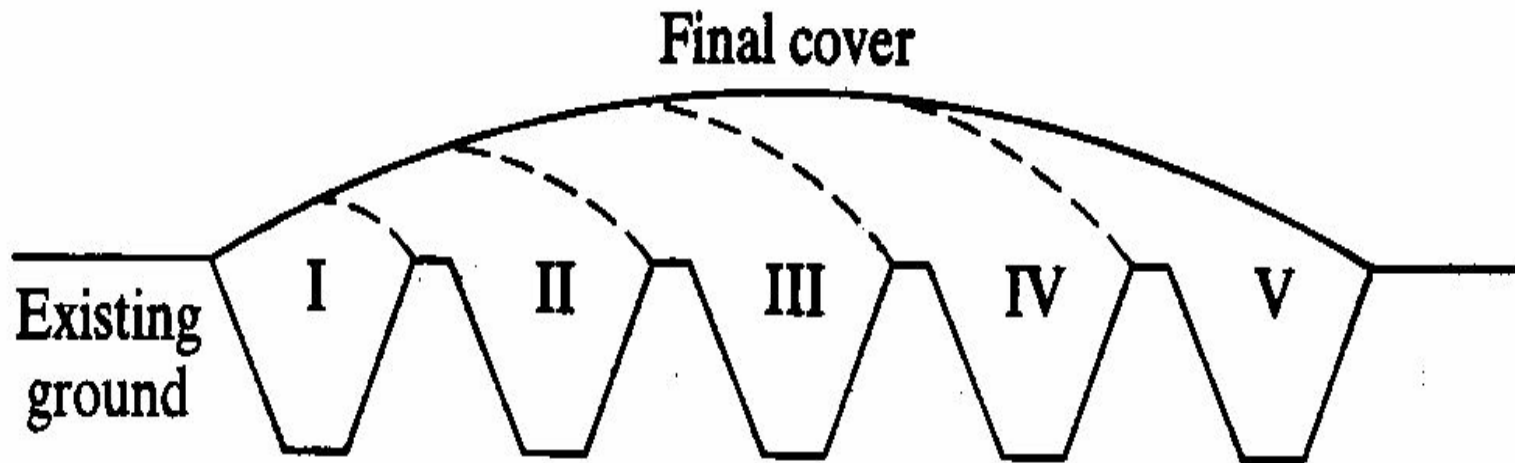
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Most common geometrical configurations include



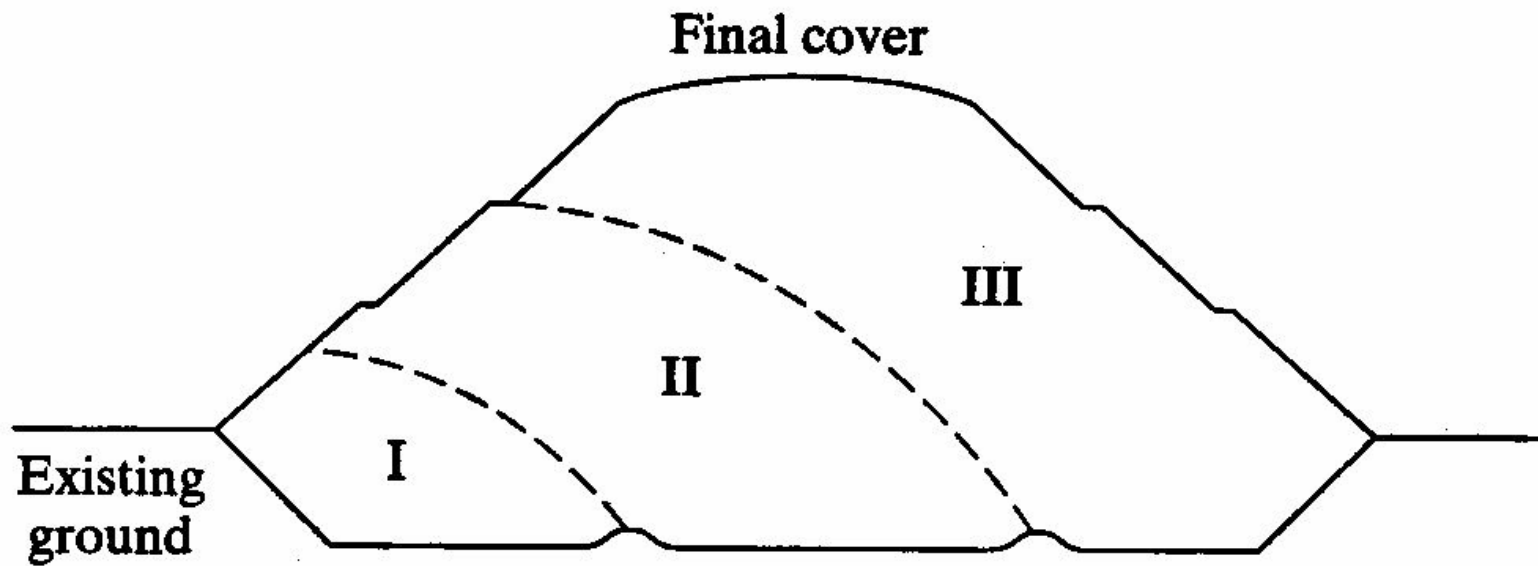


Trench fill



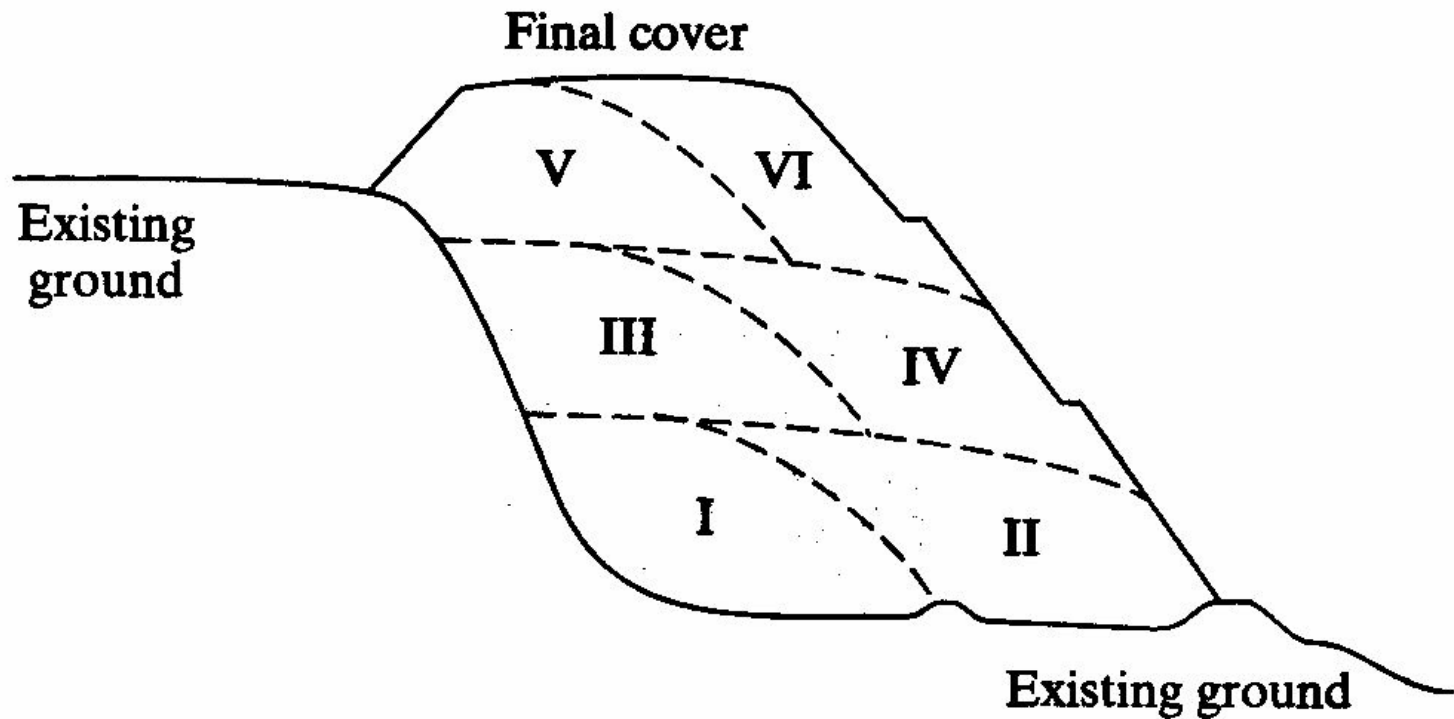


Above and below ground fill



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Canyon fill



Waste segregation at source



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Waste collection



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Waste compaction during collection



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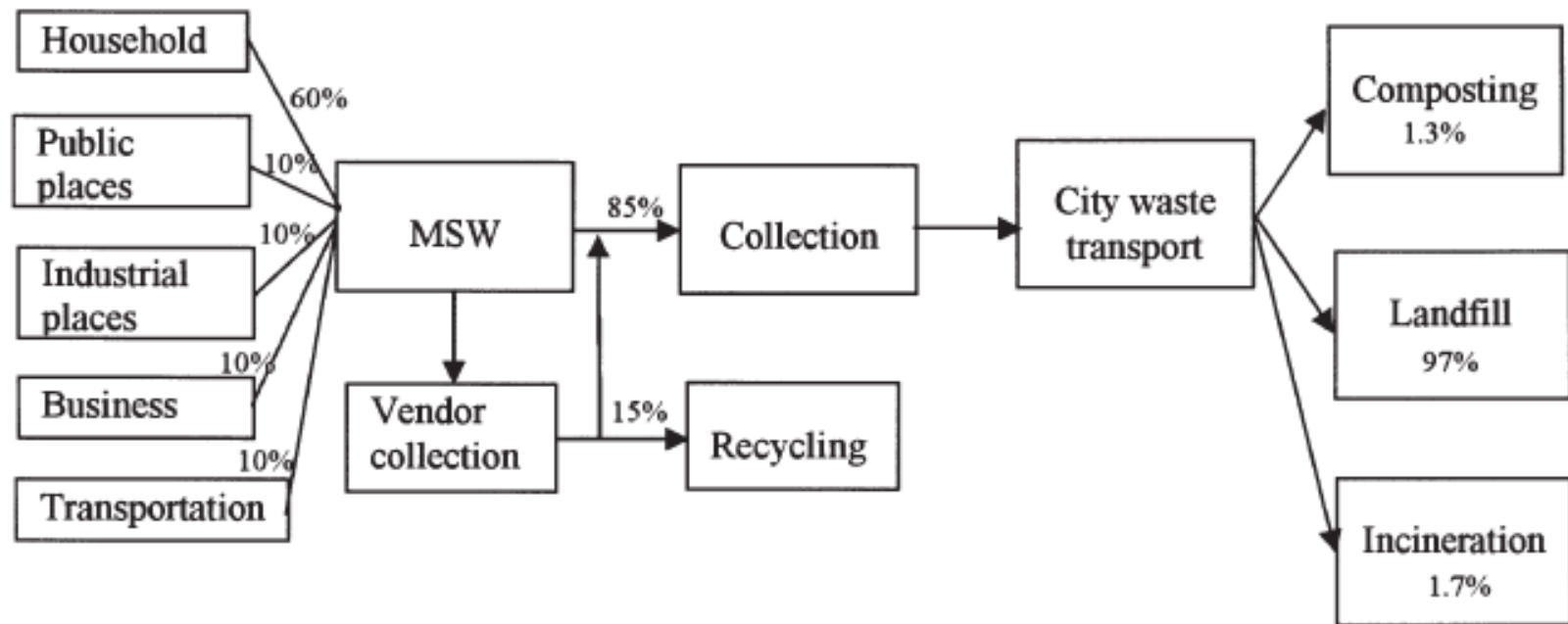
Waste handling



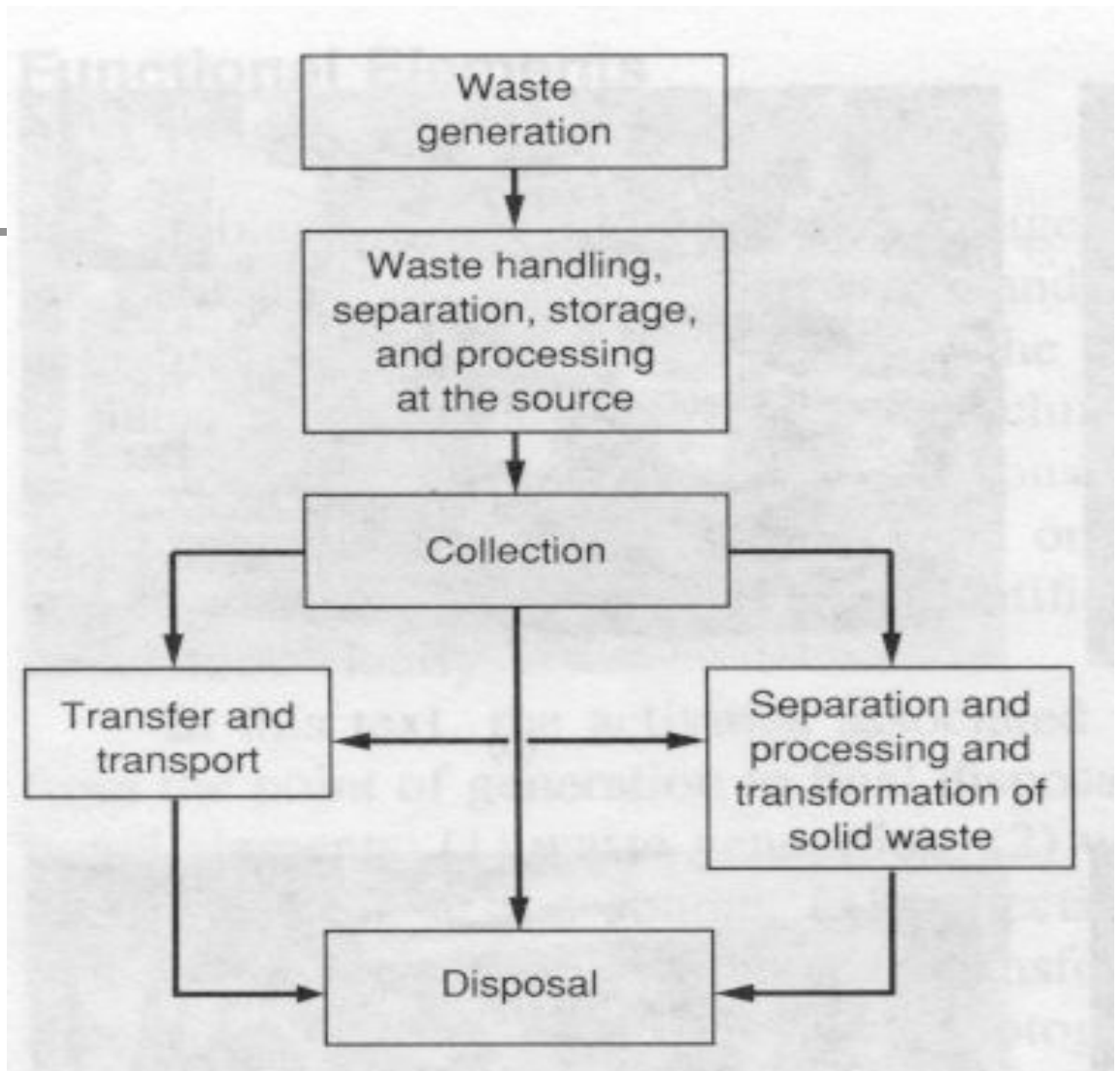
Packer

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Estimated waste stream route in Chinese cities



Flow chart from MSW generation to Disposal



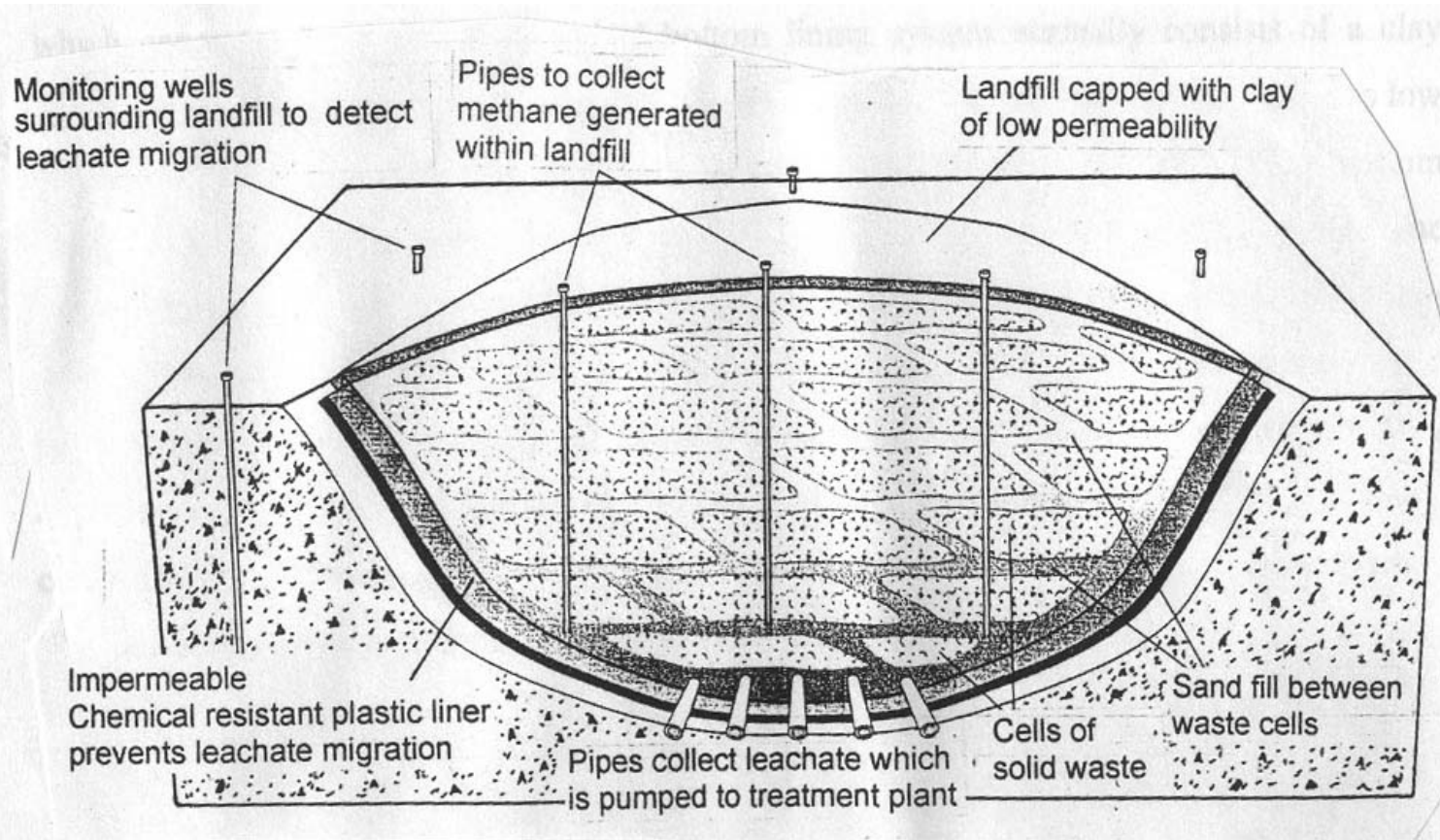
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Landfill

- A modern, well-constructed landfill can be characterized as an engineering structure that consists primarily of a liner, leachate collection and removal system, gas collection and control system and final cover.

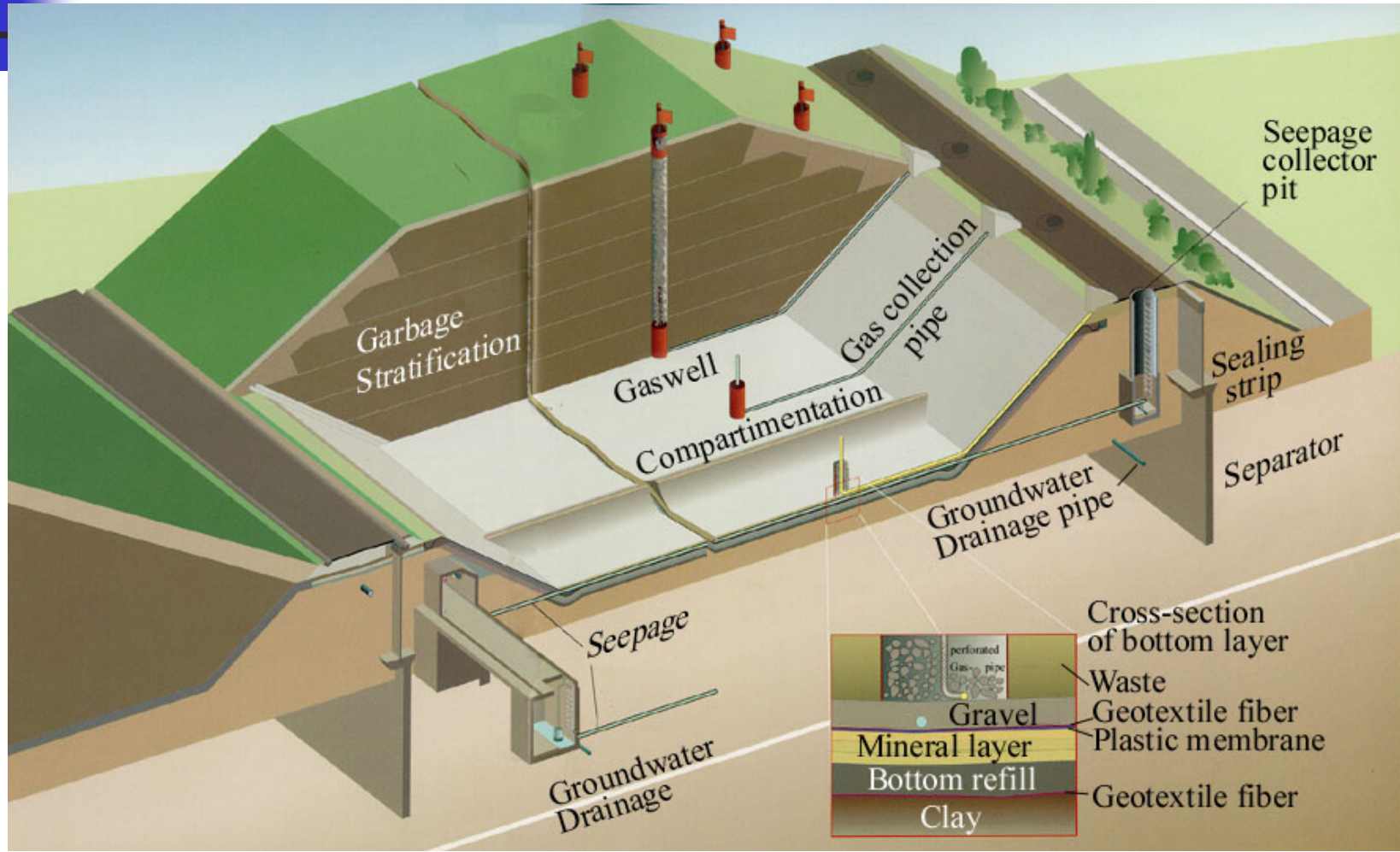
Systematically engineered landfill



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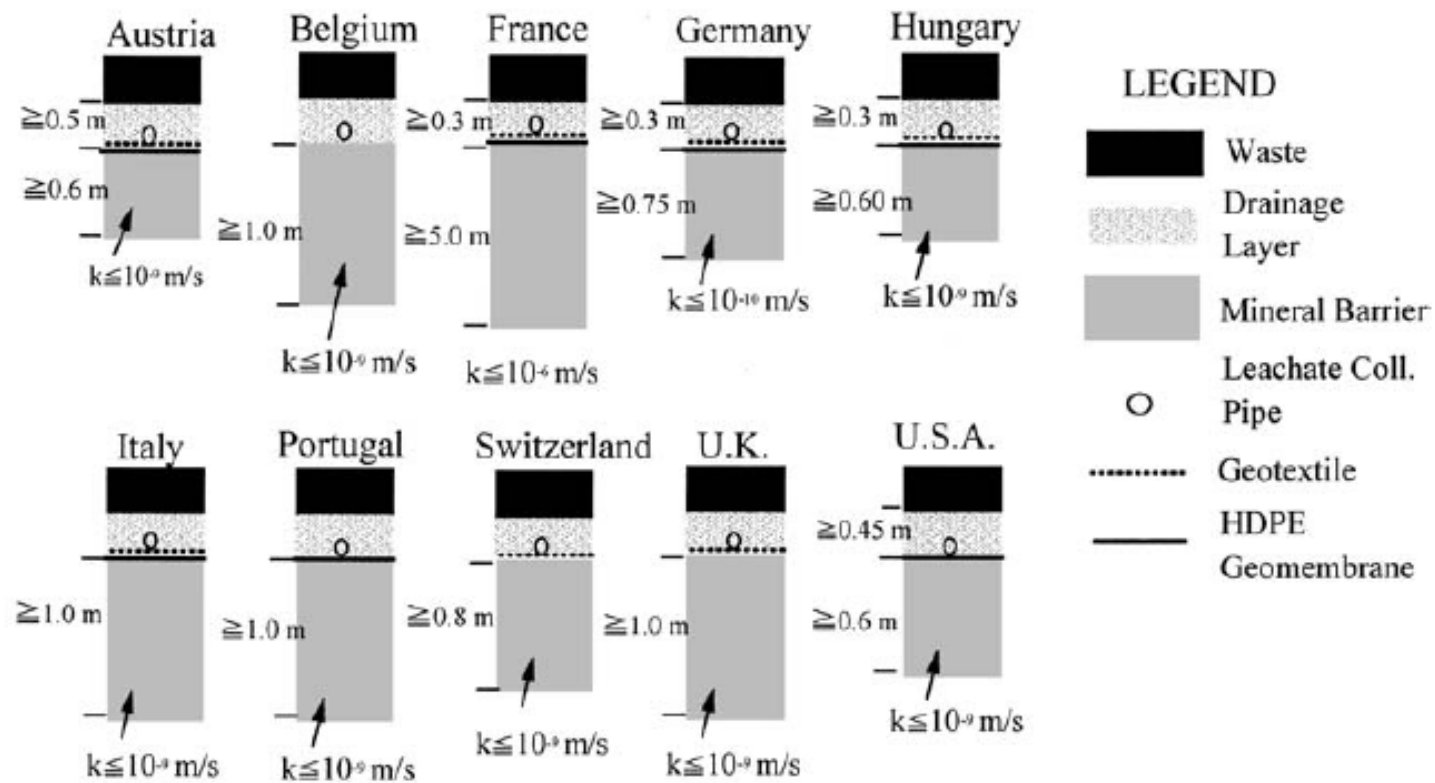
How Does Engineered landfills look like

www.makelengineering.com/...../power/power.htm

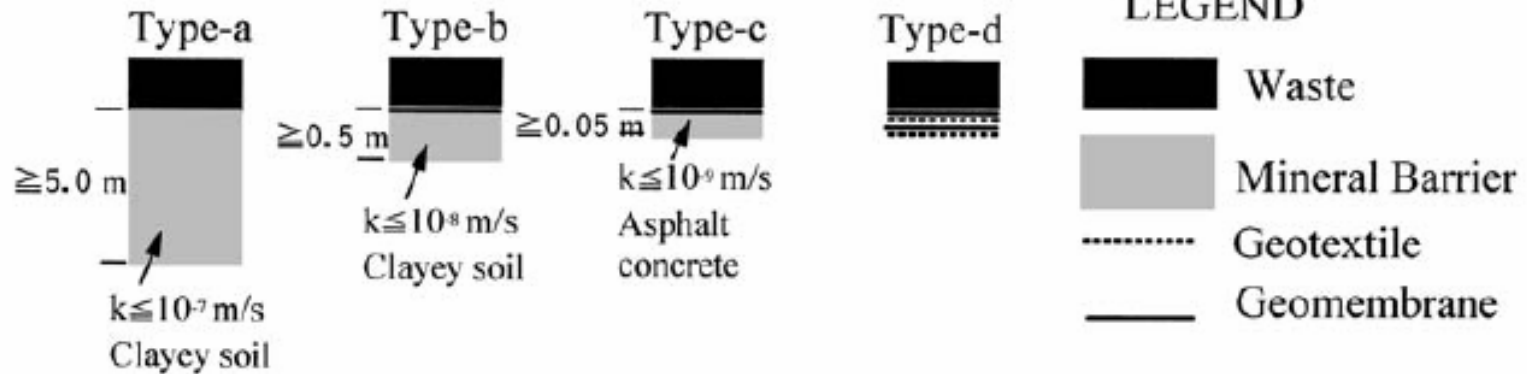


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European and American bottom liner systems for municipal solid waste



Japanese bottom liner systems





Merit for adopting suitable design and construction for landfills

- 1) To reduce design and construction costs,
- 2) To minimize long term operation,
- 3) To reduce maintenance and monitoring expenses.



A solid waste landfill must be able to:

- Prevent ground water pollution,
- Collect of leachate,
- Permit gas venting



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



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

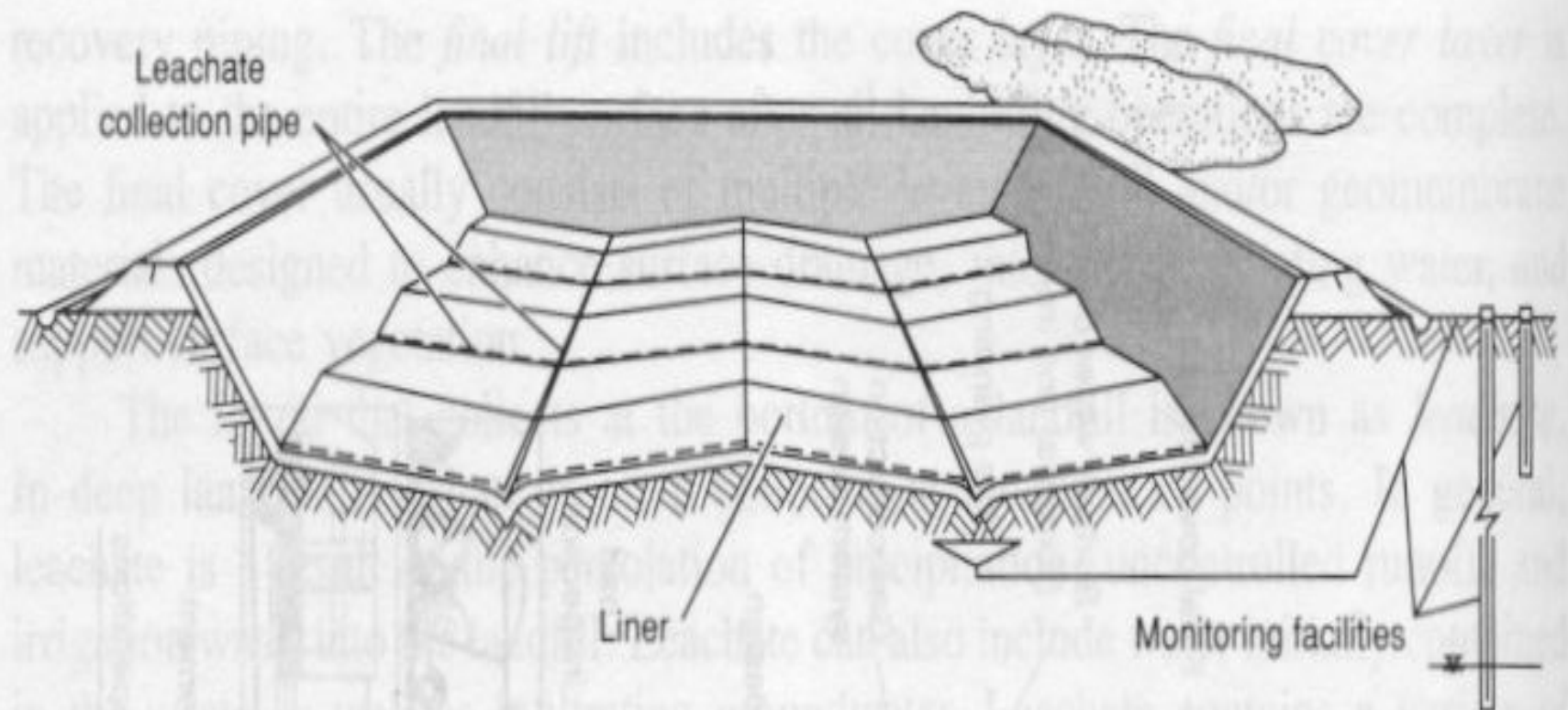
Landfill footprint

- A** Recycling Centers
- B** Scale House
- C** Access Road
- D** Sanitary Landfill-Closed
(No Liner-Clay-bottom)
- E** MSW Landfill
(Liner present)
- F** New Cell
Prep Area
- G** Cell Being Filled
- H** Storm Drainage
Collection
- I** Leachate Collection Pond
- J** Methane Vent
- K** Methane Piper
- L** Methane Station
- M** Monitoring Pipe
- N** Run-off Collection Basin
- O** Storm Drainage Basin
- P** Storm Water Pipe
- Q** To City Water Treatment



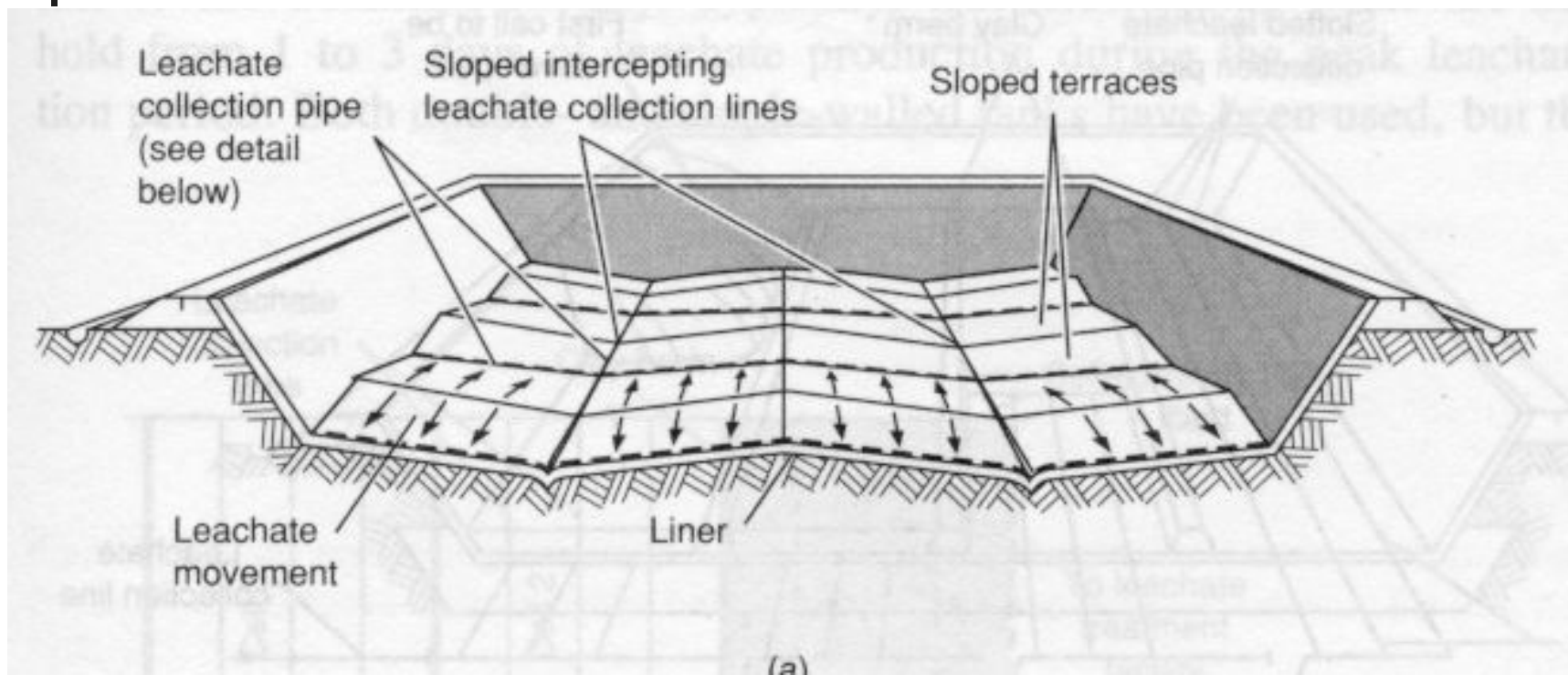
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Leachate drainage system



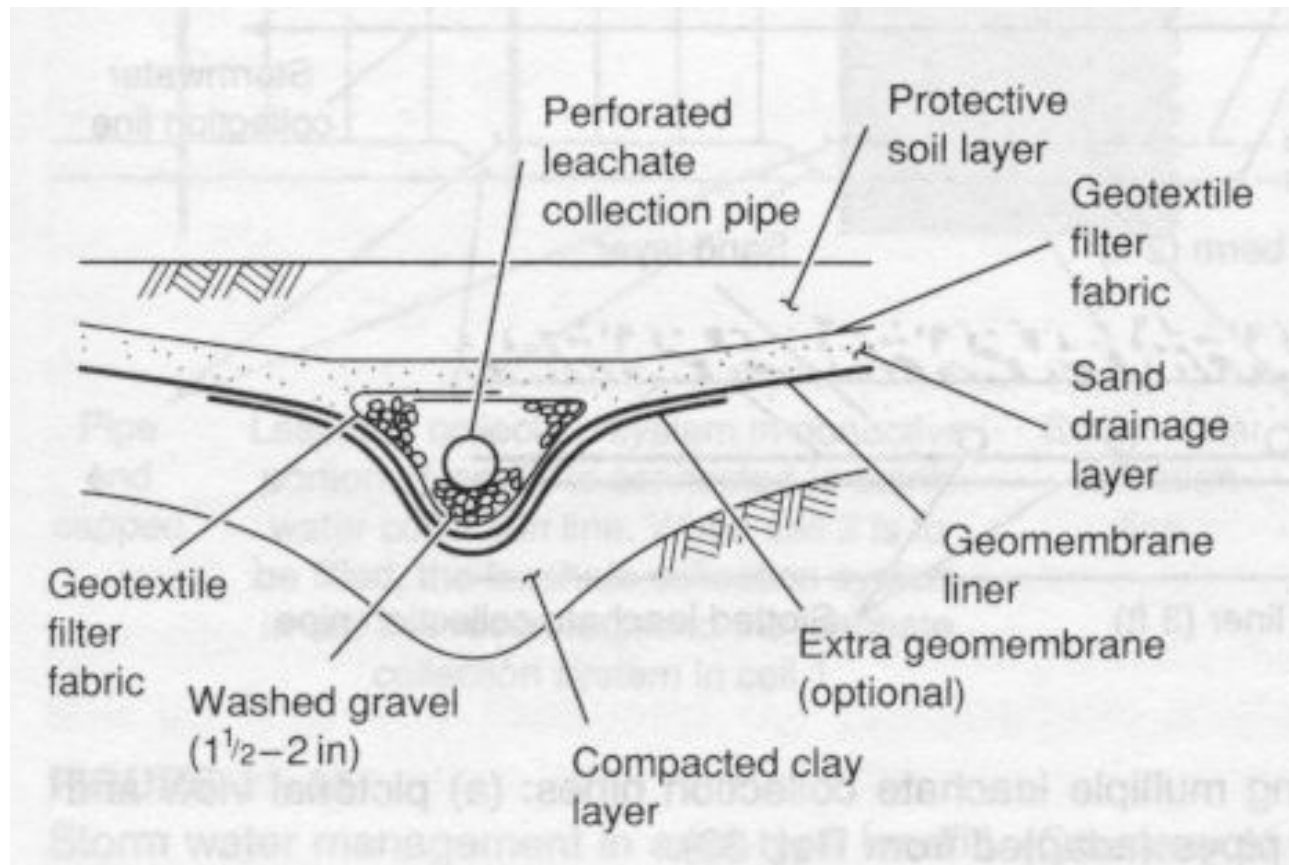
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Leachate drainage system



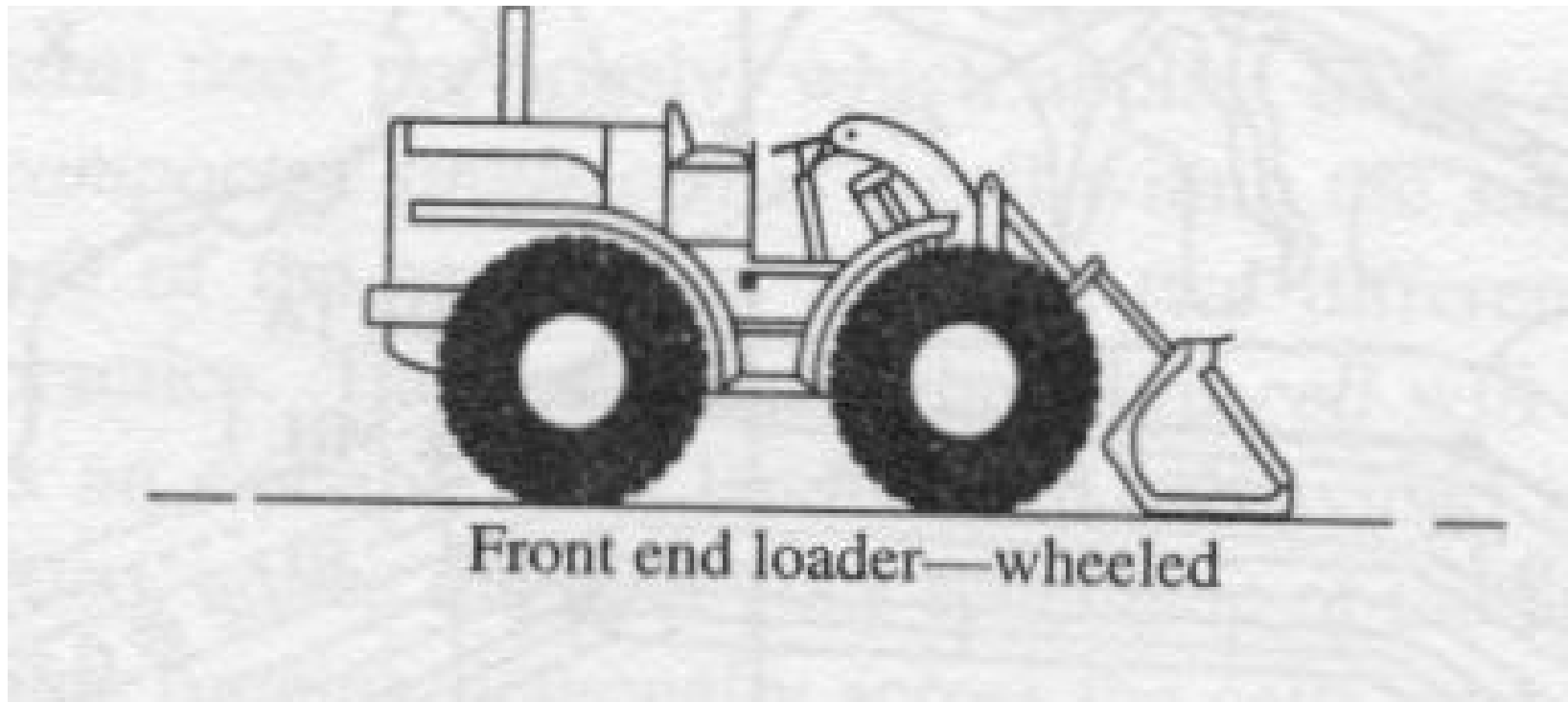
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Details of leachate drainage system



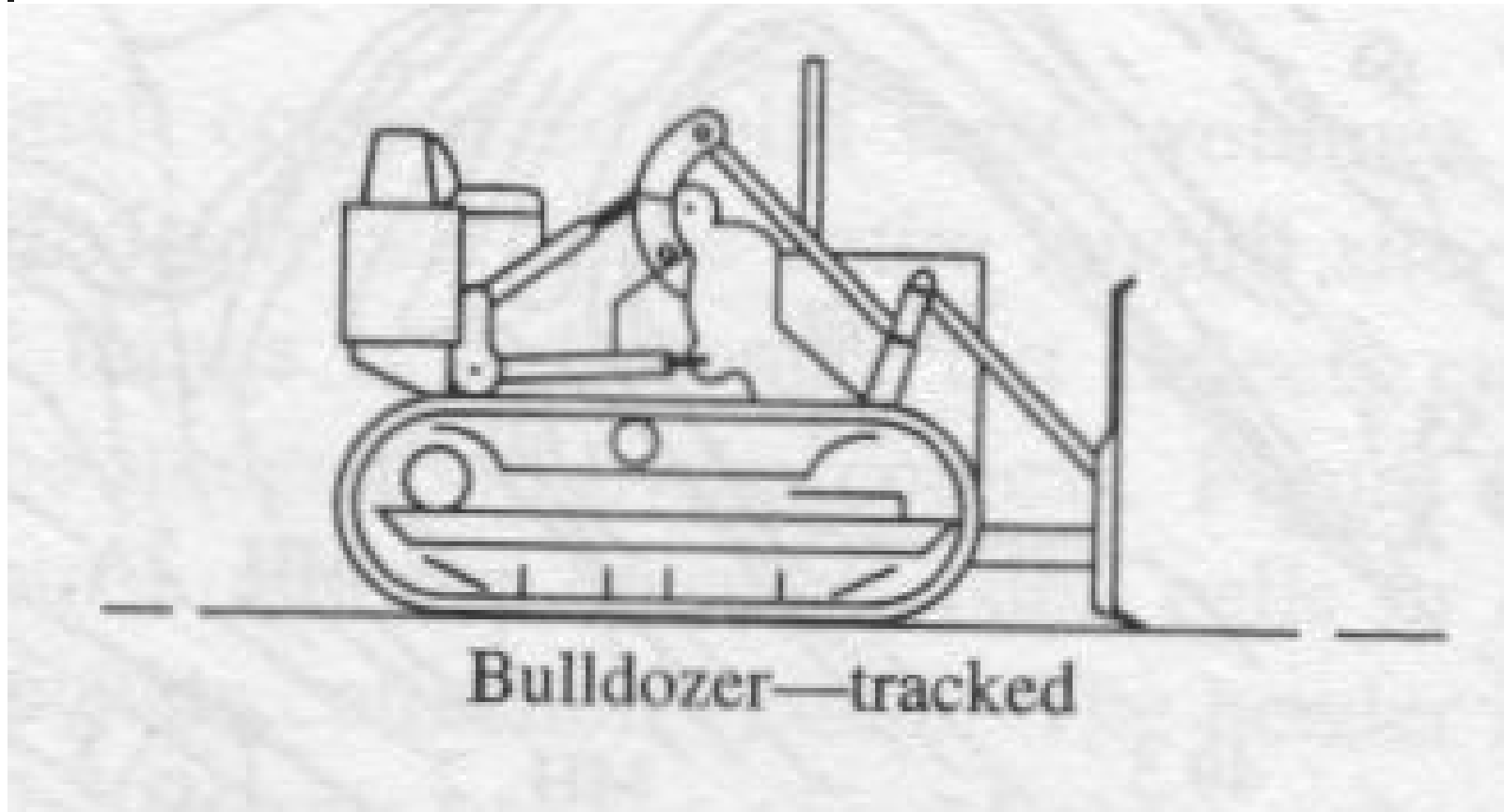
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Typical construction equipment



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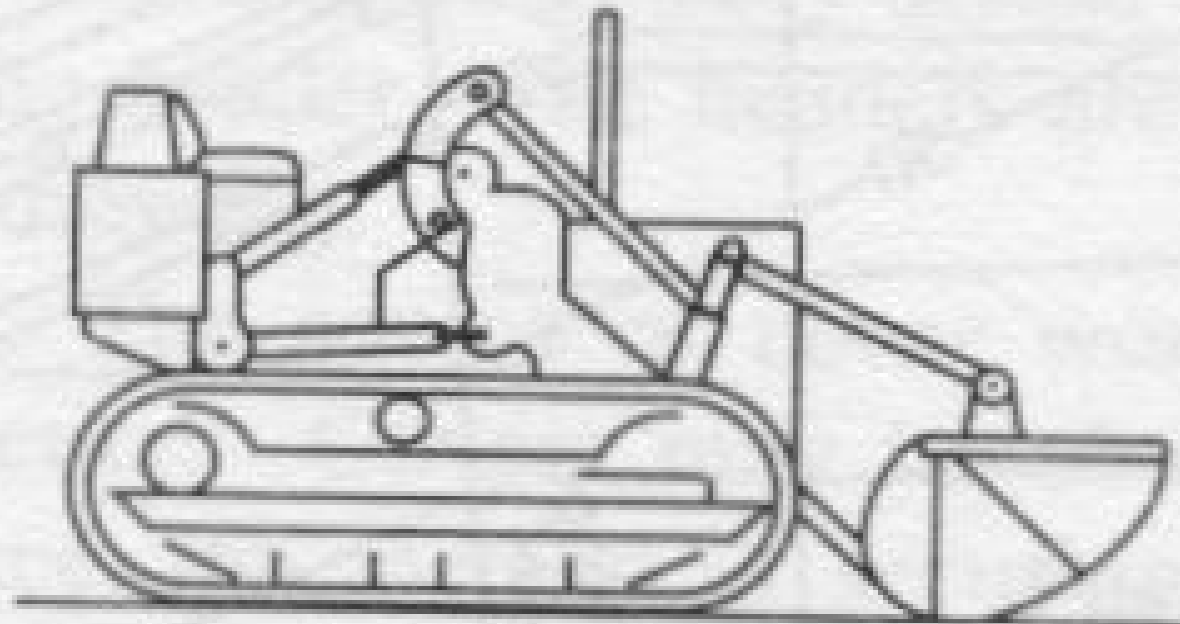
Typical construction equipment



Bulldozer—tracked

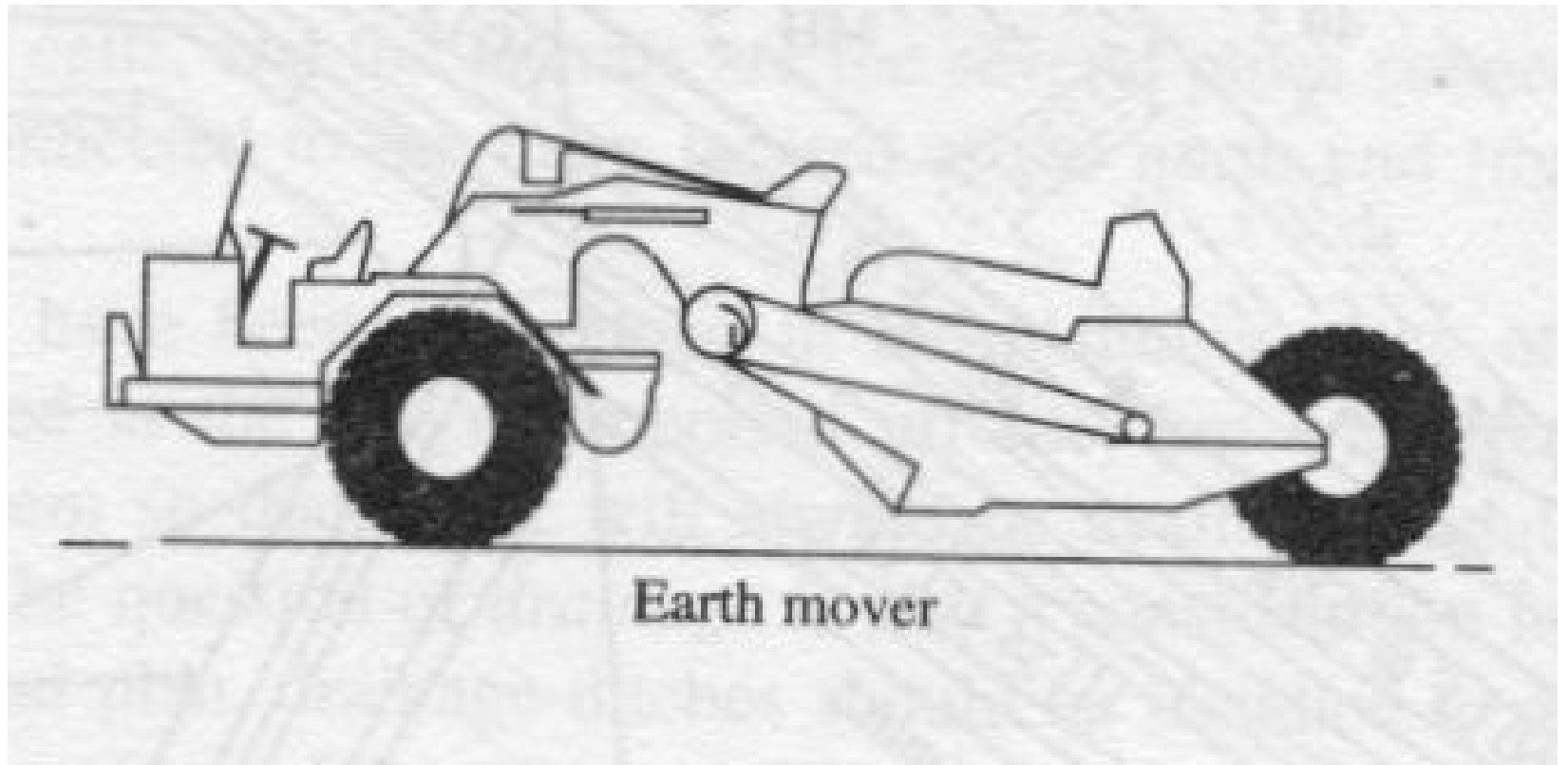
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Typical construction equipment



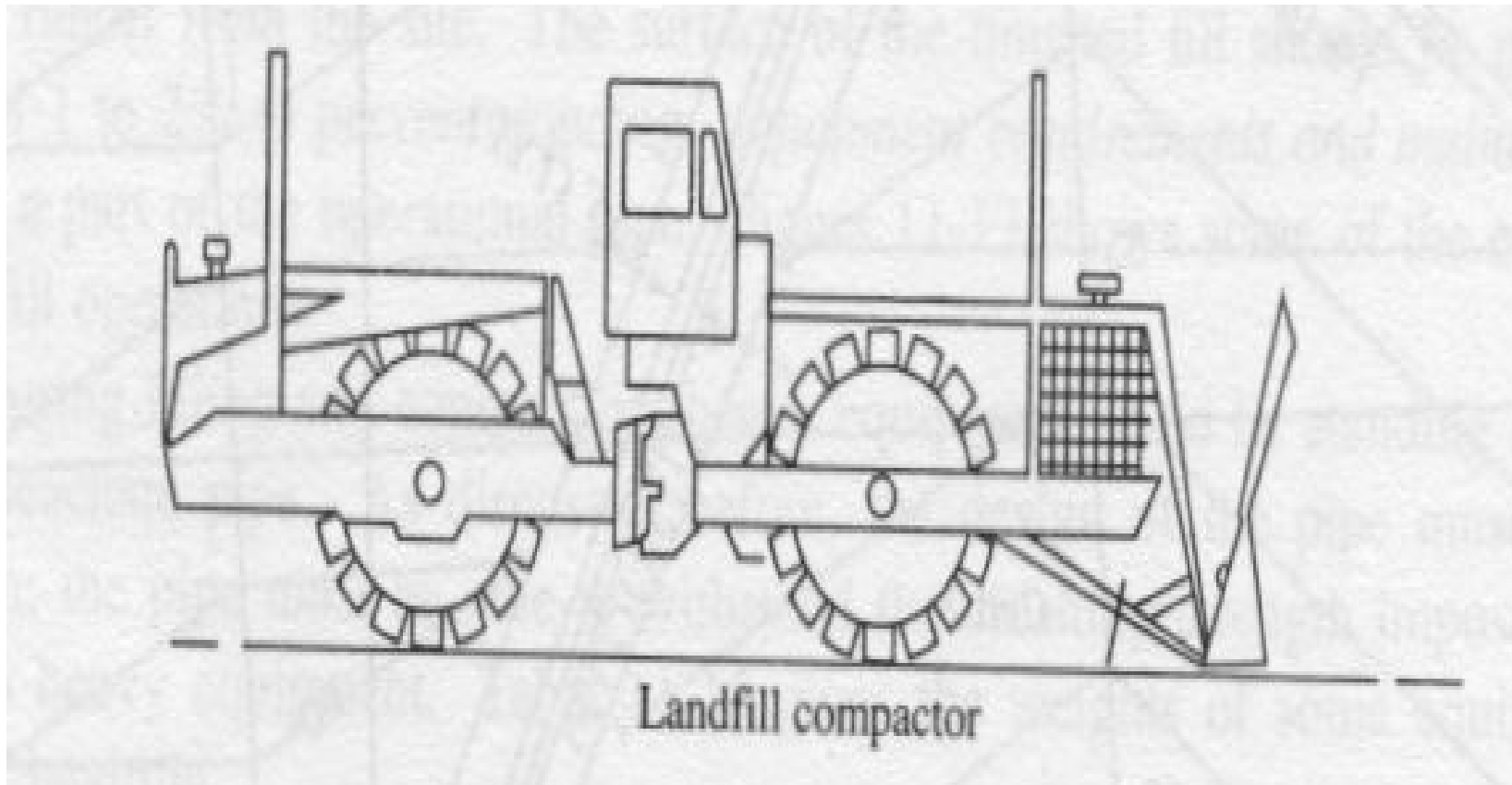
Front end loader—tracked
with bullclam

Typical construction equipment



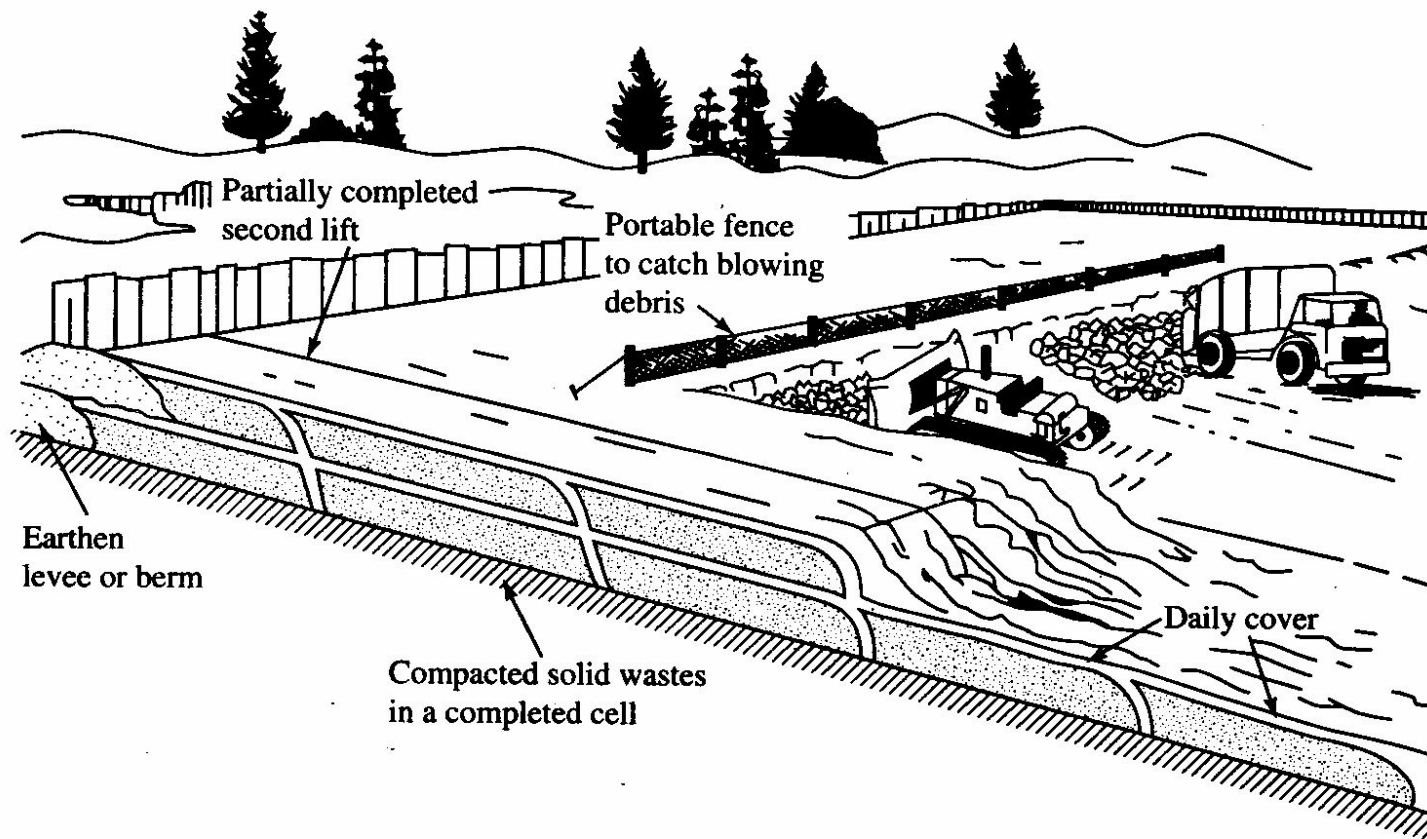
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Typical construction equipment



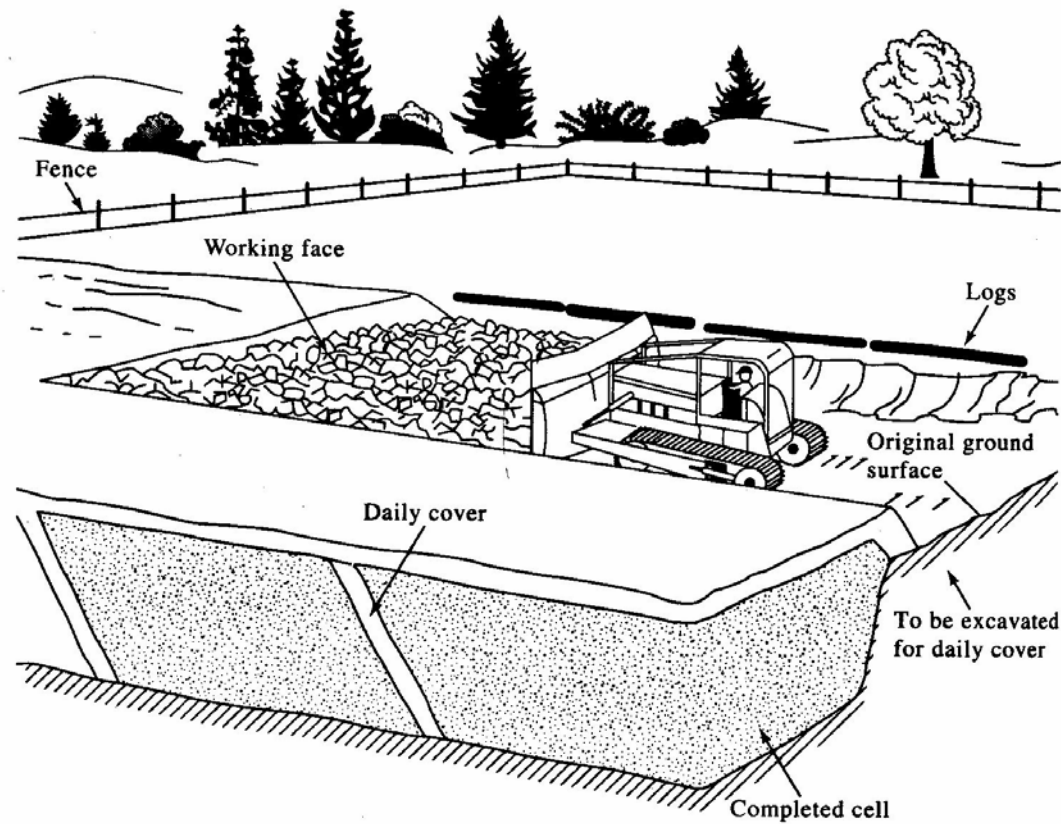
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Perspective view of cell type construction



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Close-look at cell construction



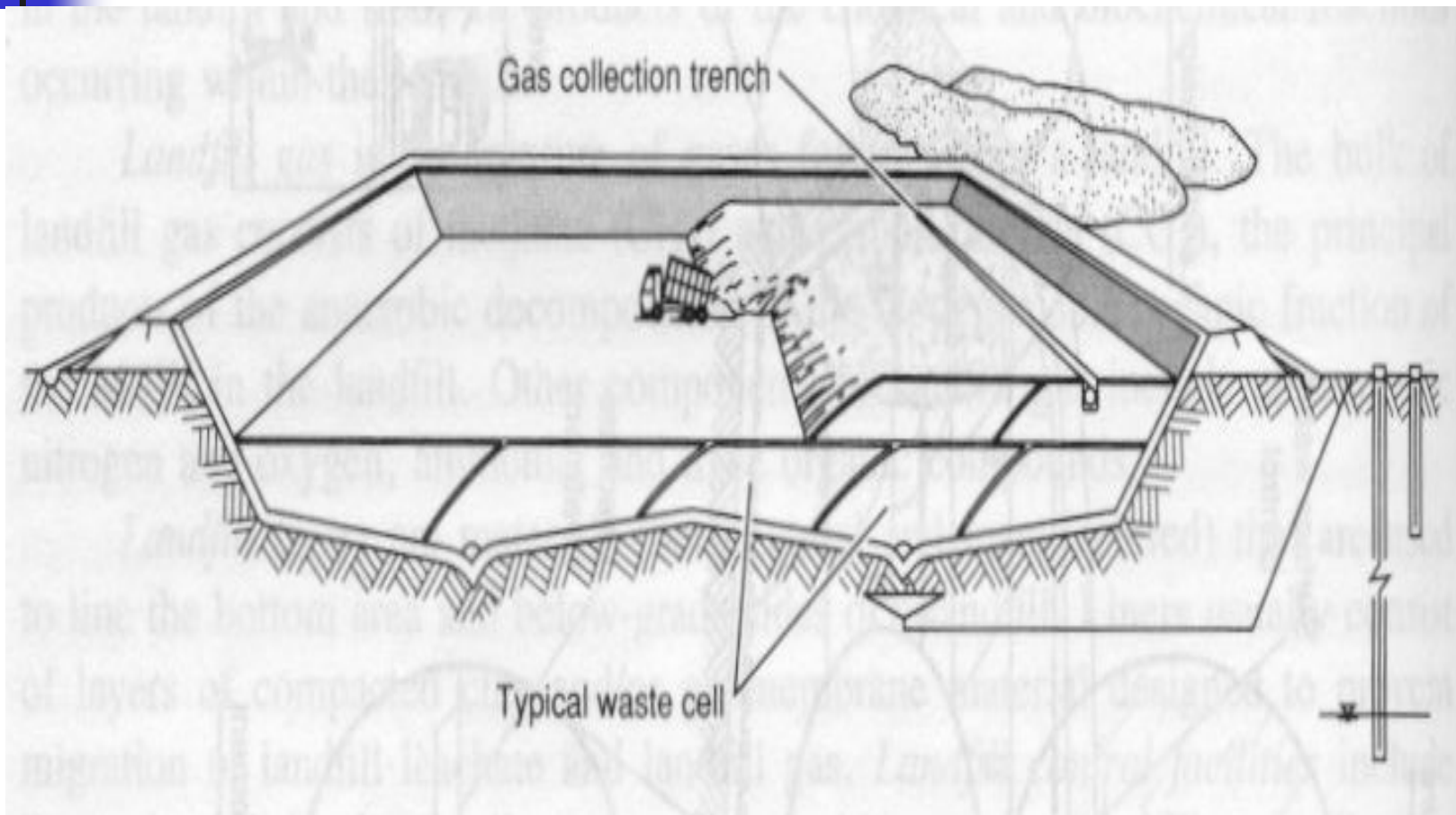
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Waste compactor



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Landfill during filling stage



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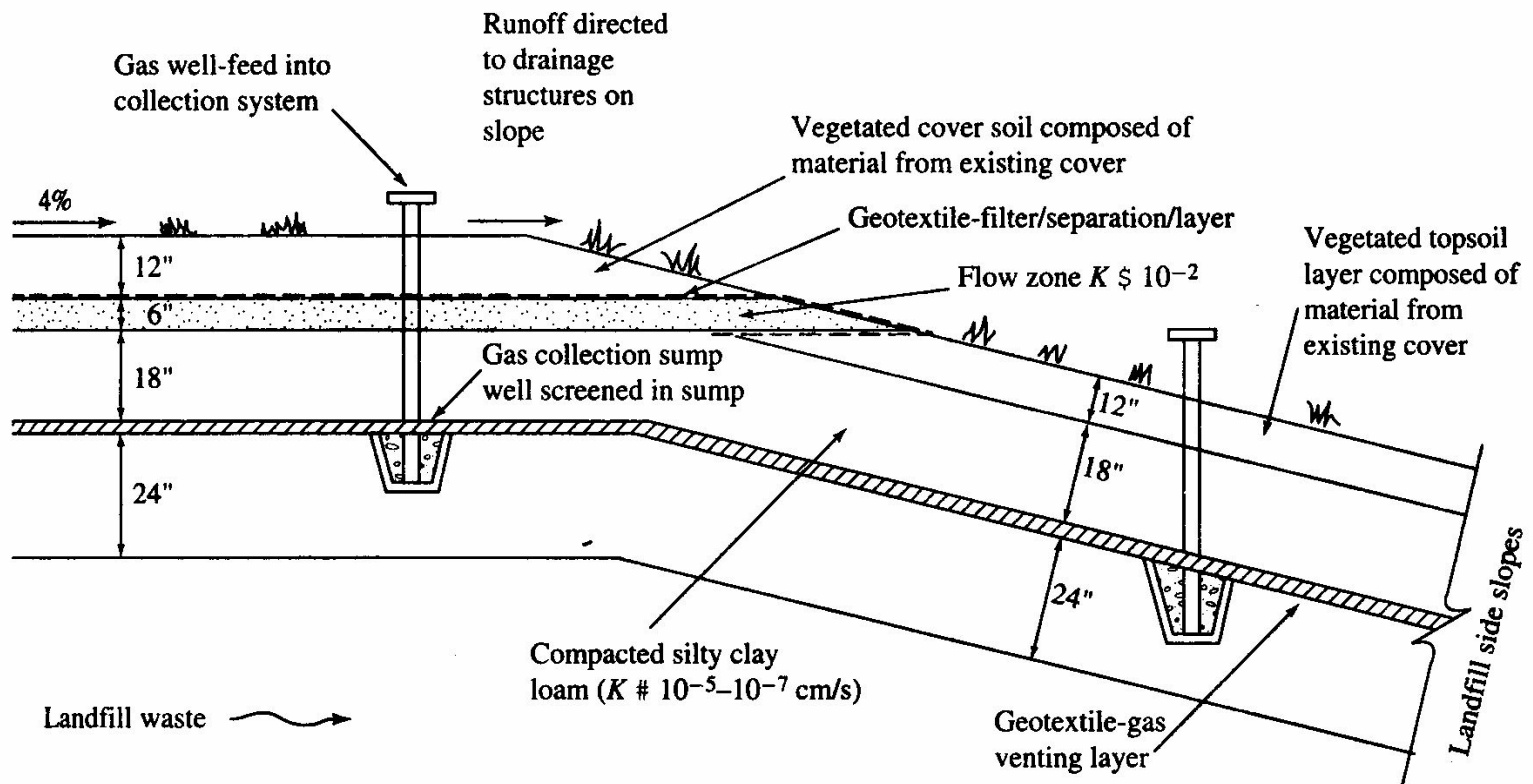


Landfill gas [CH_4 + CO_2]

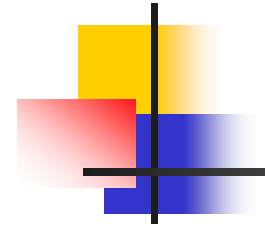
- A landfill also behaves as a giant in-situ bioreactor whose contents undergo complex biochemical reactions.
- The production of landfill gas is a major byproduct of waste decomposition processes.

Details of gas venting system

Disposal of Solid Wastes



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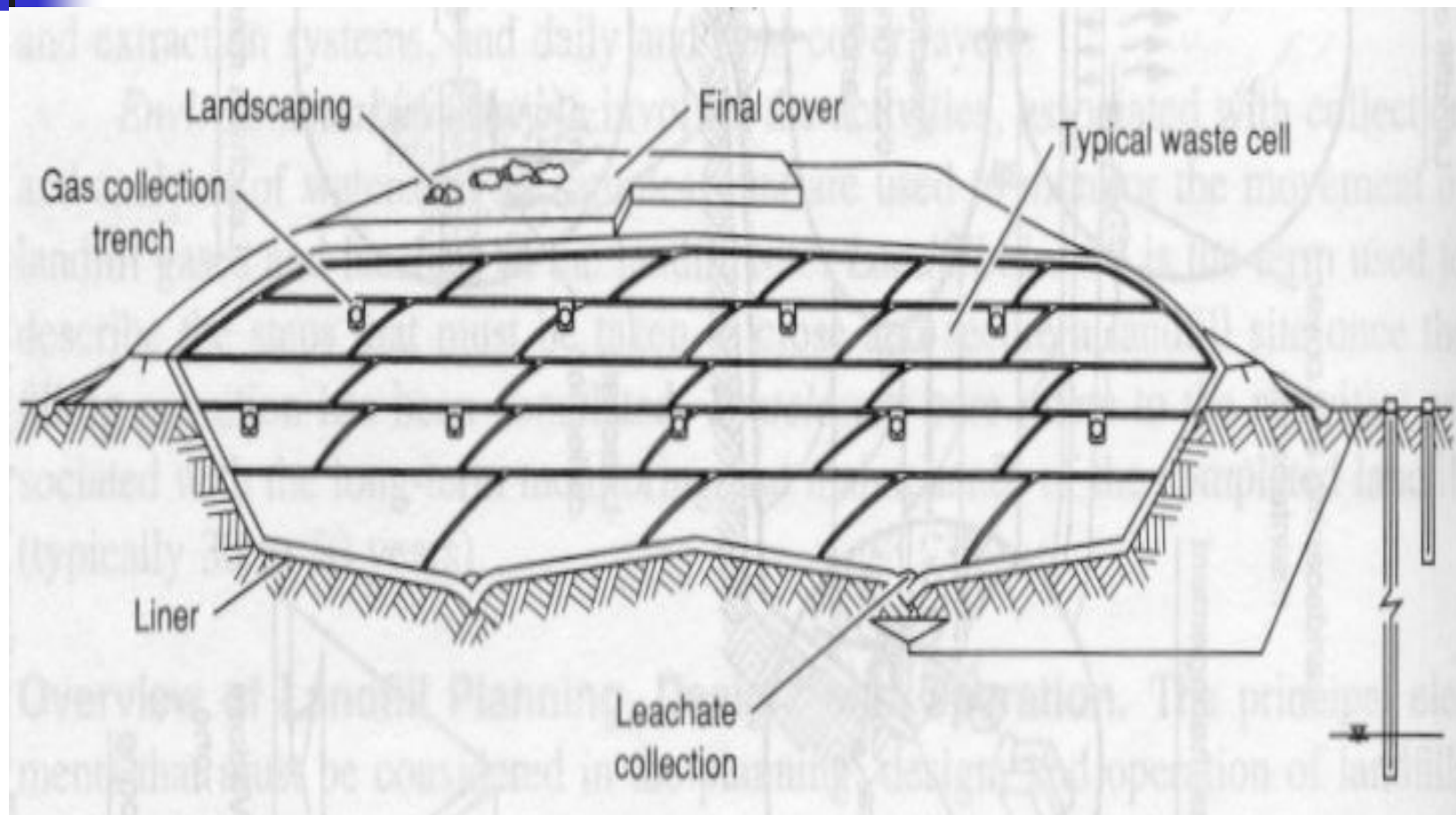


Gas venting system ready
for commissioning →



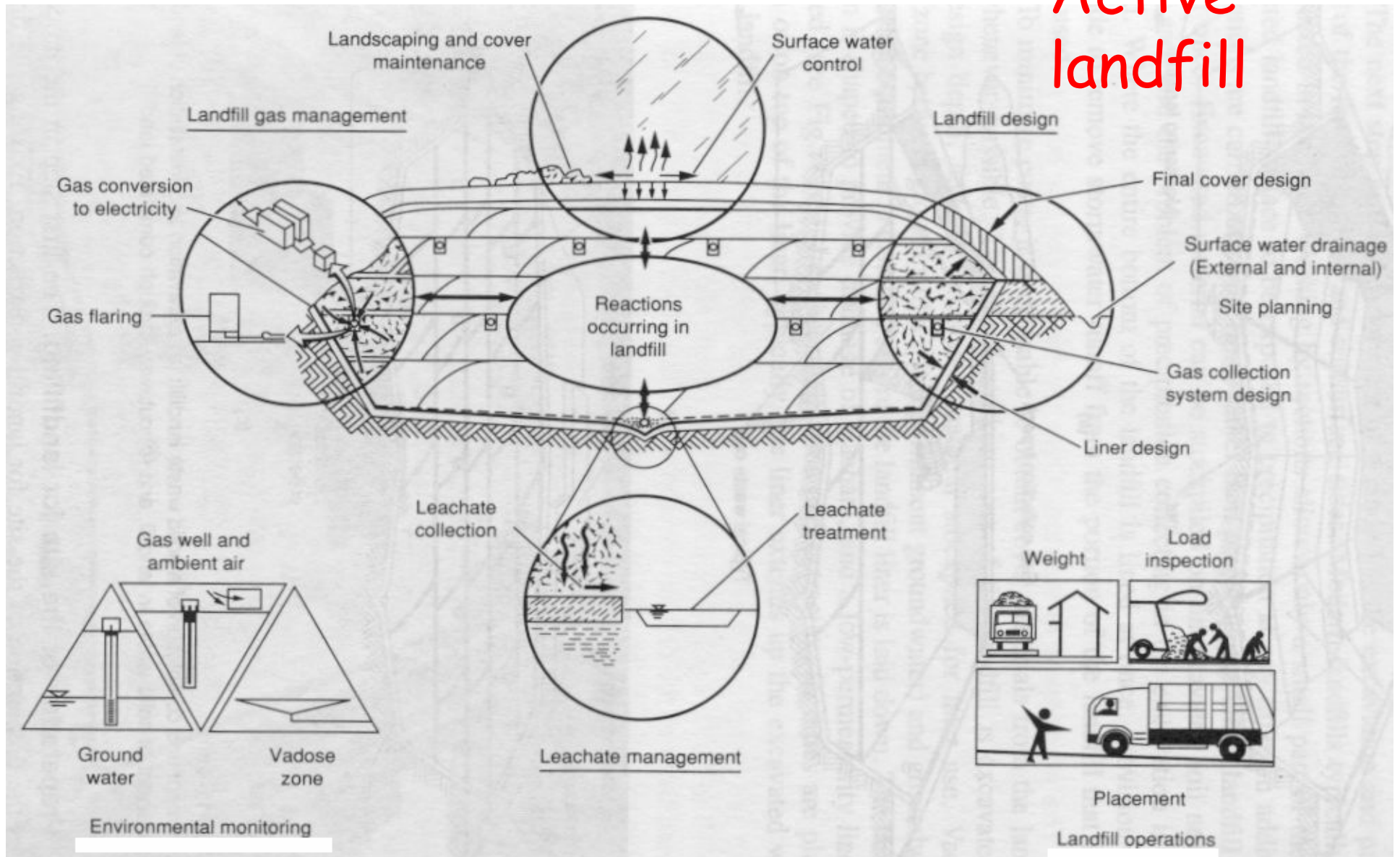
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Covered landfill



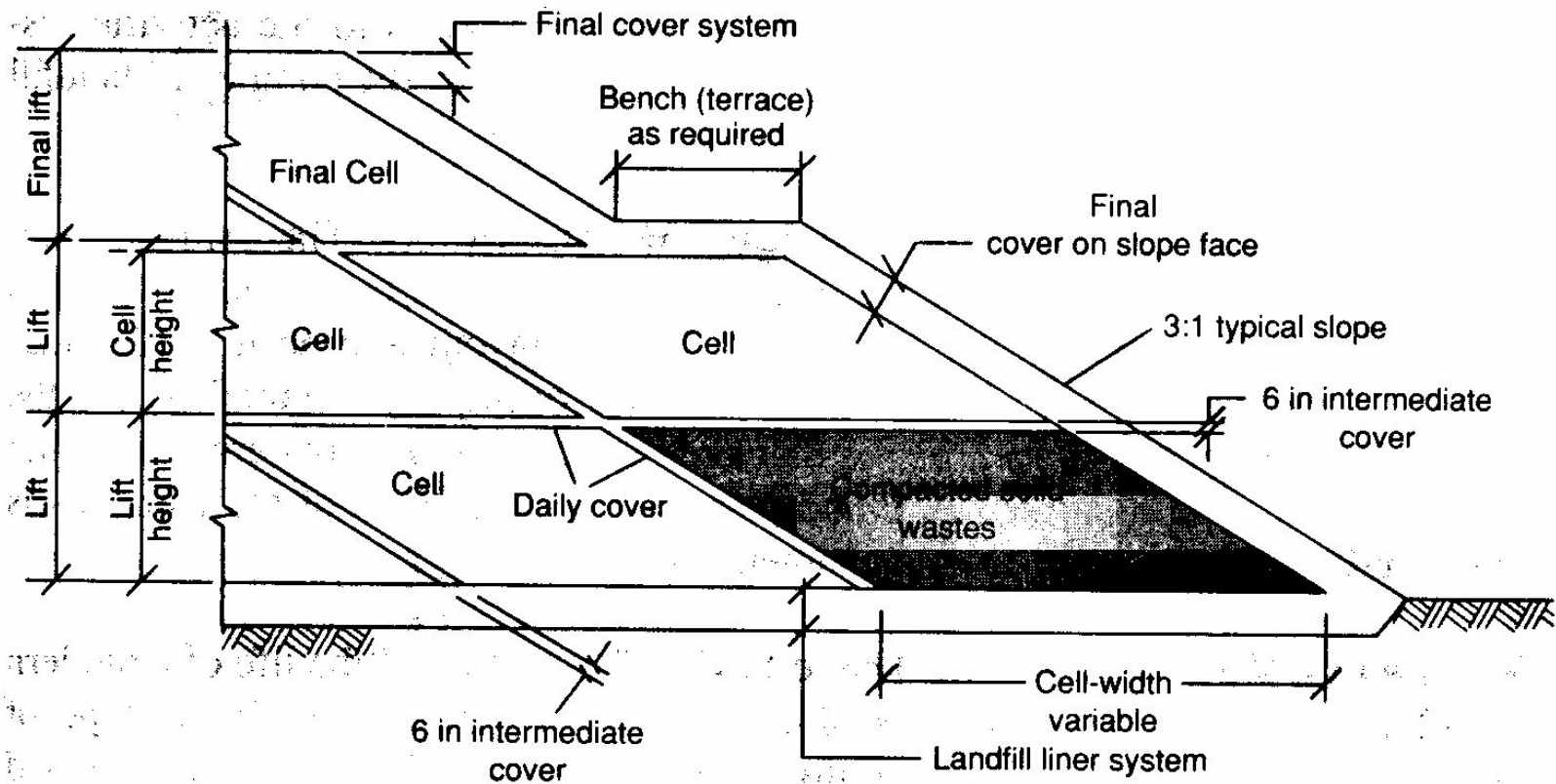
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Active landfill



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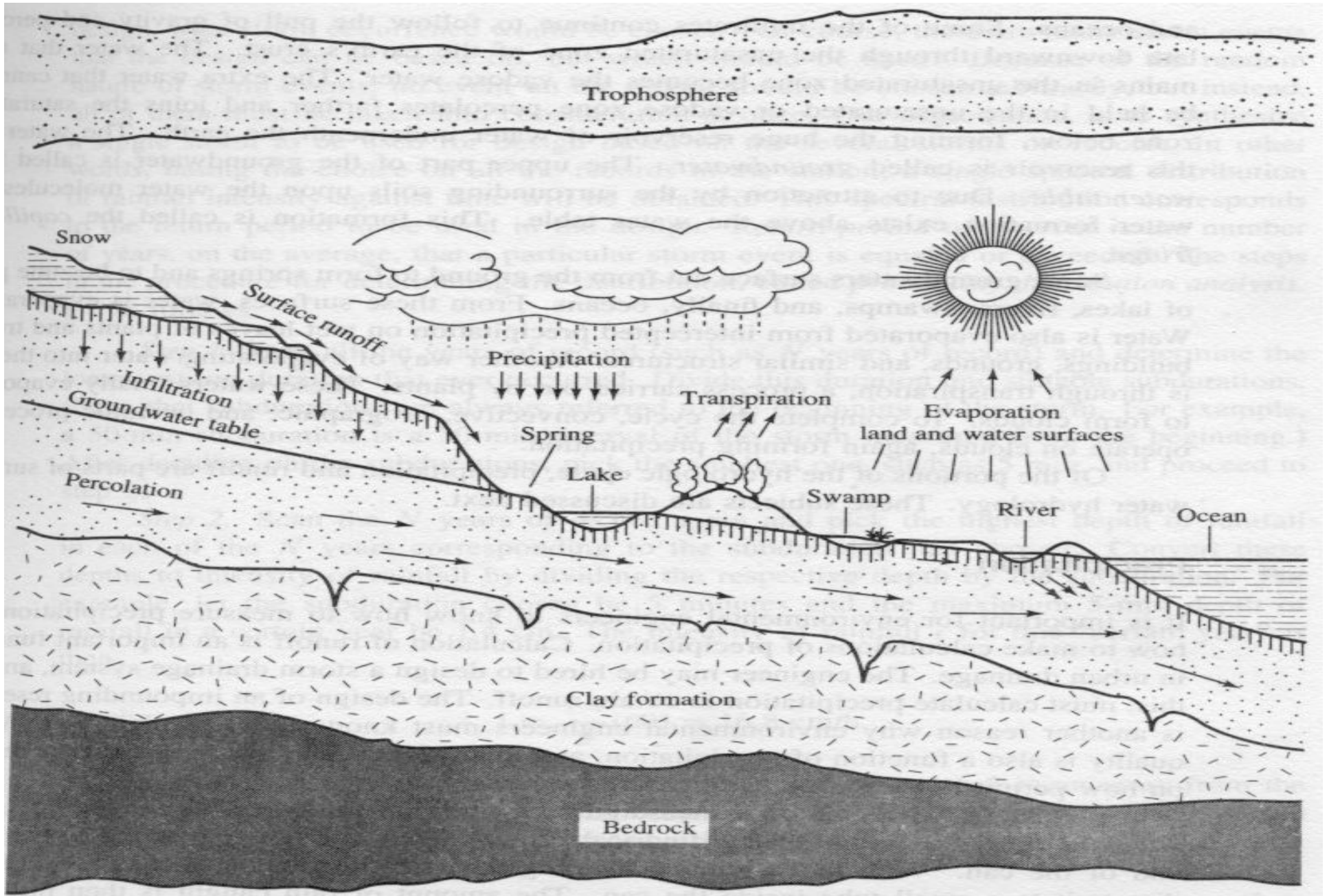
Cross-sectional view of the landfill



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Typical distribution of components in residential MSW for low-, middle-, and upper-income countries excluding recycled materials^{a,b}

Component	Low-income countries	Middle-income countries	Upper-income countries ^c
Organic			
Food wastes	40–85 ^d	20–65	6–30
Paper			20–45
Cardboard	1–10	8–30	5–15
Plastics	1–5	2–6	2–8
Textiles	1–5	2–10	2–6
Rubber			0–2
Leather	1–5	1–4	0–2
Yard wastes	—		10–20
Wood	1–5	1–10	1–4
Misc. organics	—	—	—
Inorganic			
Glass	1–10	1–10	4–12
Tin cans			2–8
Aluminum	1–5	1–5	0–1
Other metal			1–4
Dirt, ash, etc.	1–40	1–30	0–10



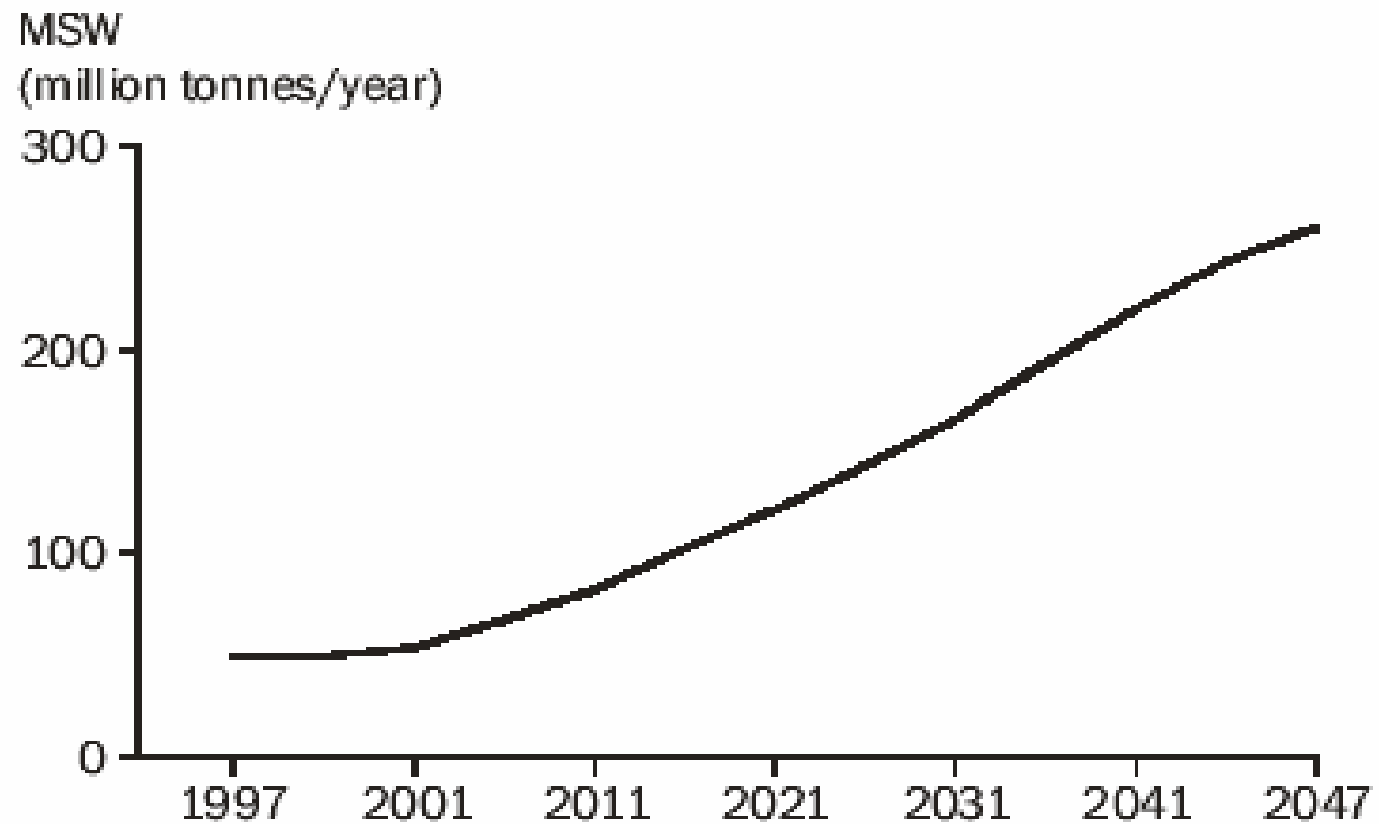
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Some severe problems of solid waste management in India

- Rapid population growth
- Urbanization
- Industrial growth

Projected trends of MSW generation in India



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Waste generation

- Approximately 80,000 tonnes/day
- MSW generation rate is twice of rate of population growth (in the last decade)
- Problem has become more acute in mega cities in India

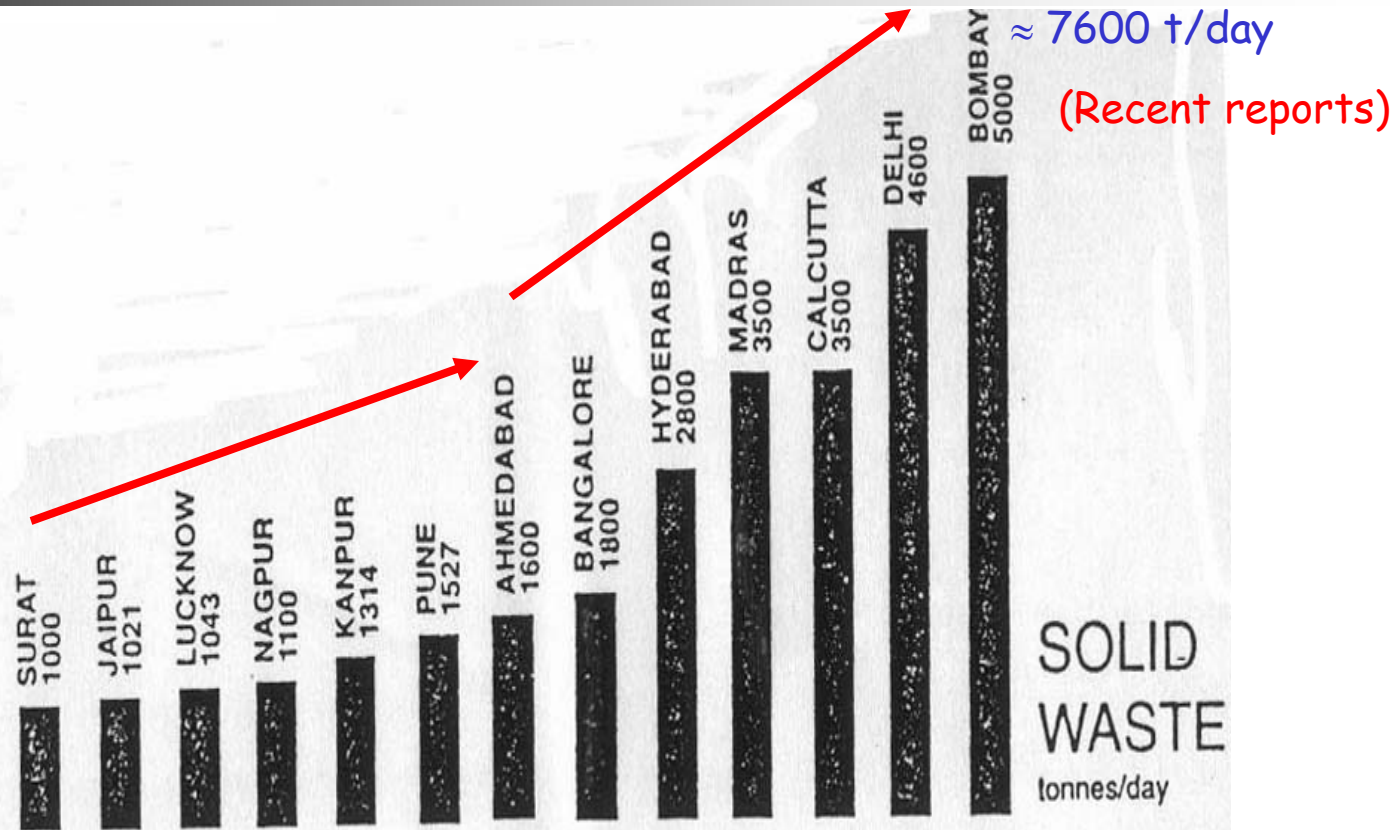
Dire necessity of safe landfilling of MSW

Some worldwide comparisons of waste generation rates

Country	Kg/person/day	Volume/day (litres)	Density (tonnes/cu.m)
India	0.25	1.0	0.25
Ghana	0.25	1.0	0.25
Sri Lanka	0.40	1.6	0.25
Singapore	0.85	4.25	0.2
Malaysia	0.70	3.5	0.2
Europe	1.00	8.0	0.13
USA	1.25	12.0	0.10

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MSW generated in different cities



After Bio-energy news (1996)

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City Landfill, Calcutta, India



www.thescreamonline.com/.../people22.html



**Industrial estate,
Gujarat**

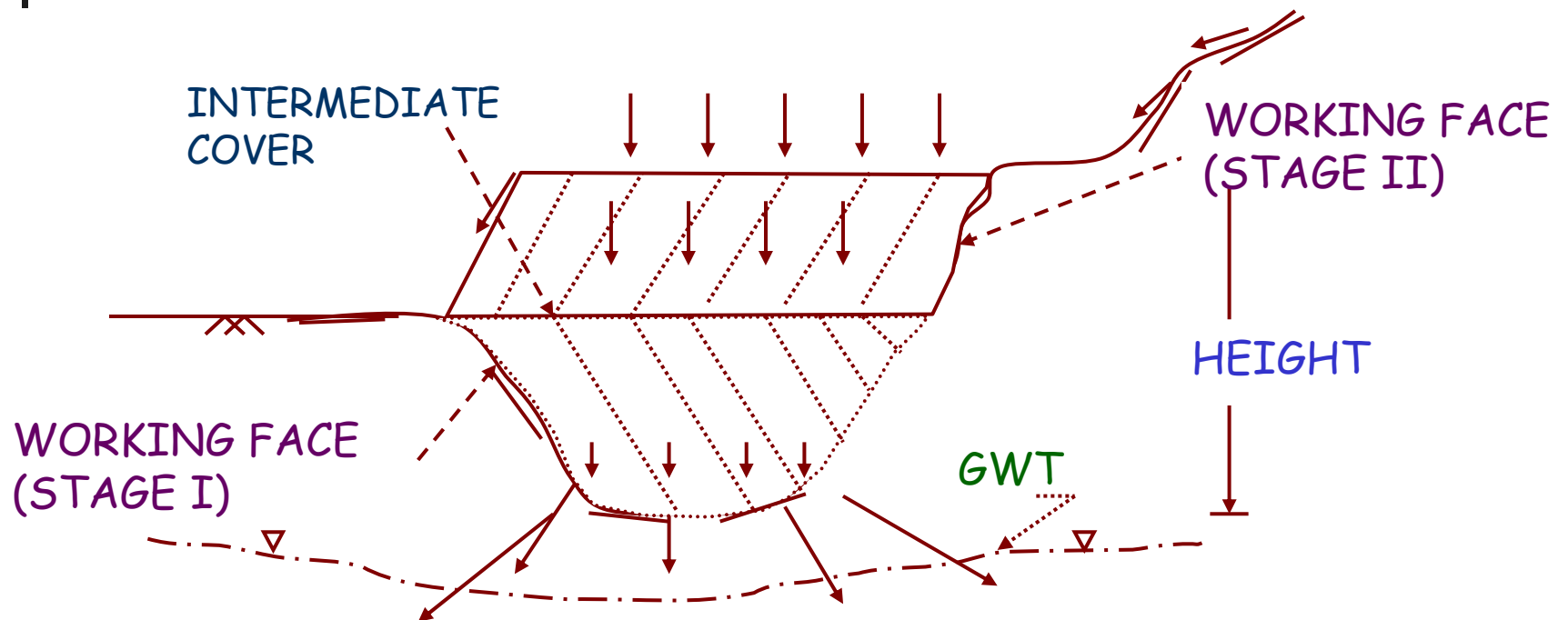


World Scenario



www.edu.dudley.gov.uk/.../holes/index.htm

Typical MSW dumping yard (Valley filling)



Close look at the composition of MSW in Mumbai (in Summer 2002)



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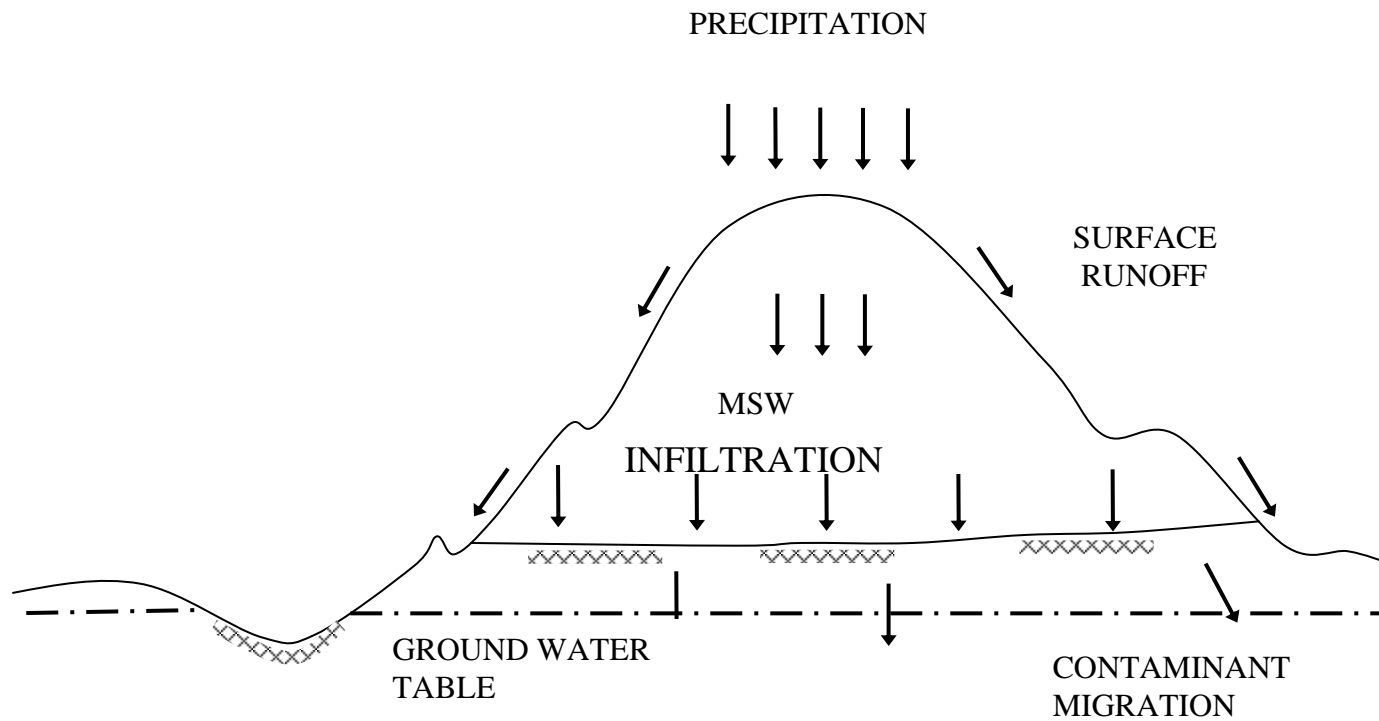
Waste composition from various Asian Countries

Component (% by weight)	China (Shanghai) 1998	India 1995	Indonesia 1993	South Korea 2001	The Philippines 1999	Turkey (Istanbul) 2000	Japan 2000
Organic matter	67.3	41.8	70.2	32.8	49	43	34
Paper and cardboard	8.8	5.7	10.9	23.8	19	7.8	33
Plastics	13.5	3.9	8.7	–	17	14.2	13
Glass	5.2	2.1	1.7	2.8 ^a	–	6.2	5
Metals	0.7	1.9	1.8	–	6	5.8	3
Textile and others	4.5	44.6 (textile 4.3)	6.2	40.6 ^b	9	23.1	12

^aMetals and ceramics are included

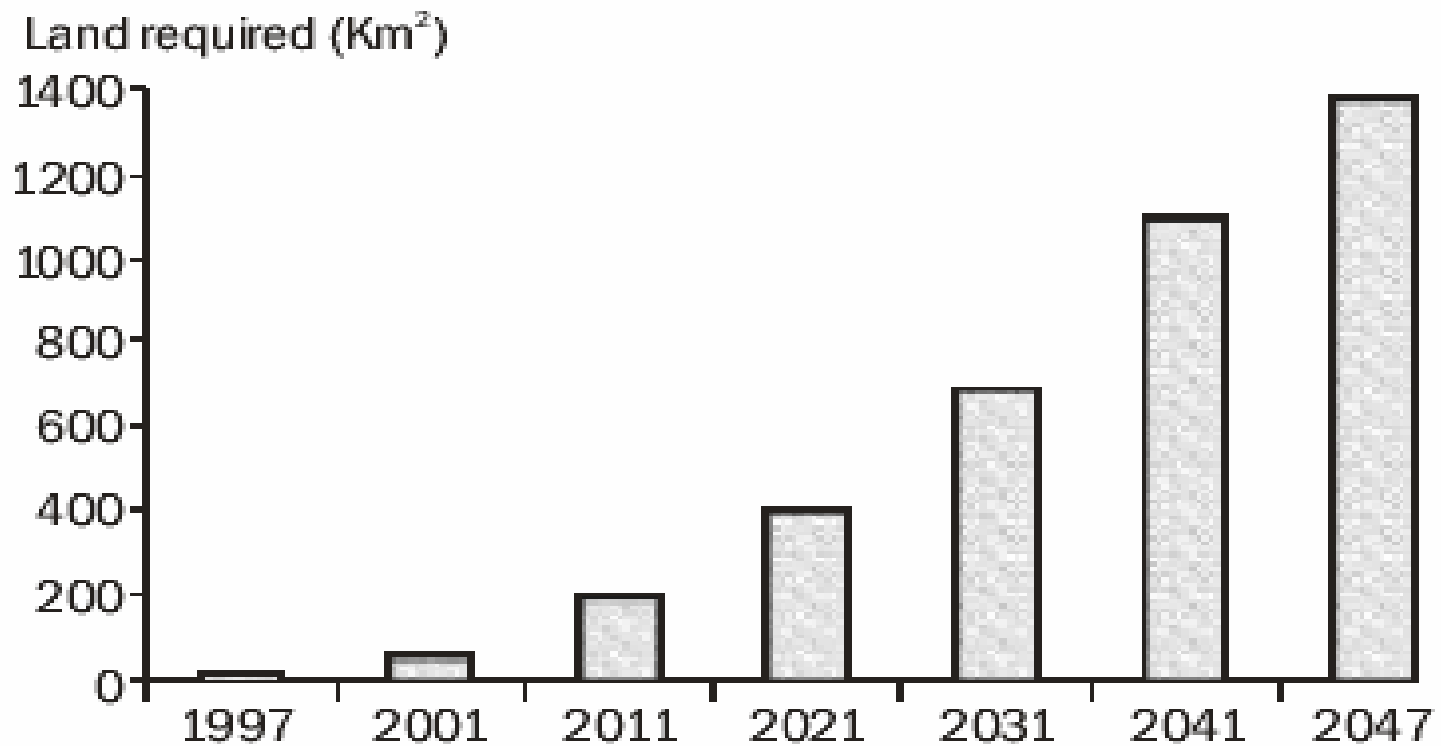
^bAsh is included

Typical MSW Yard



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Cumulative land requirement for MSW disposal

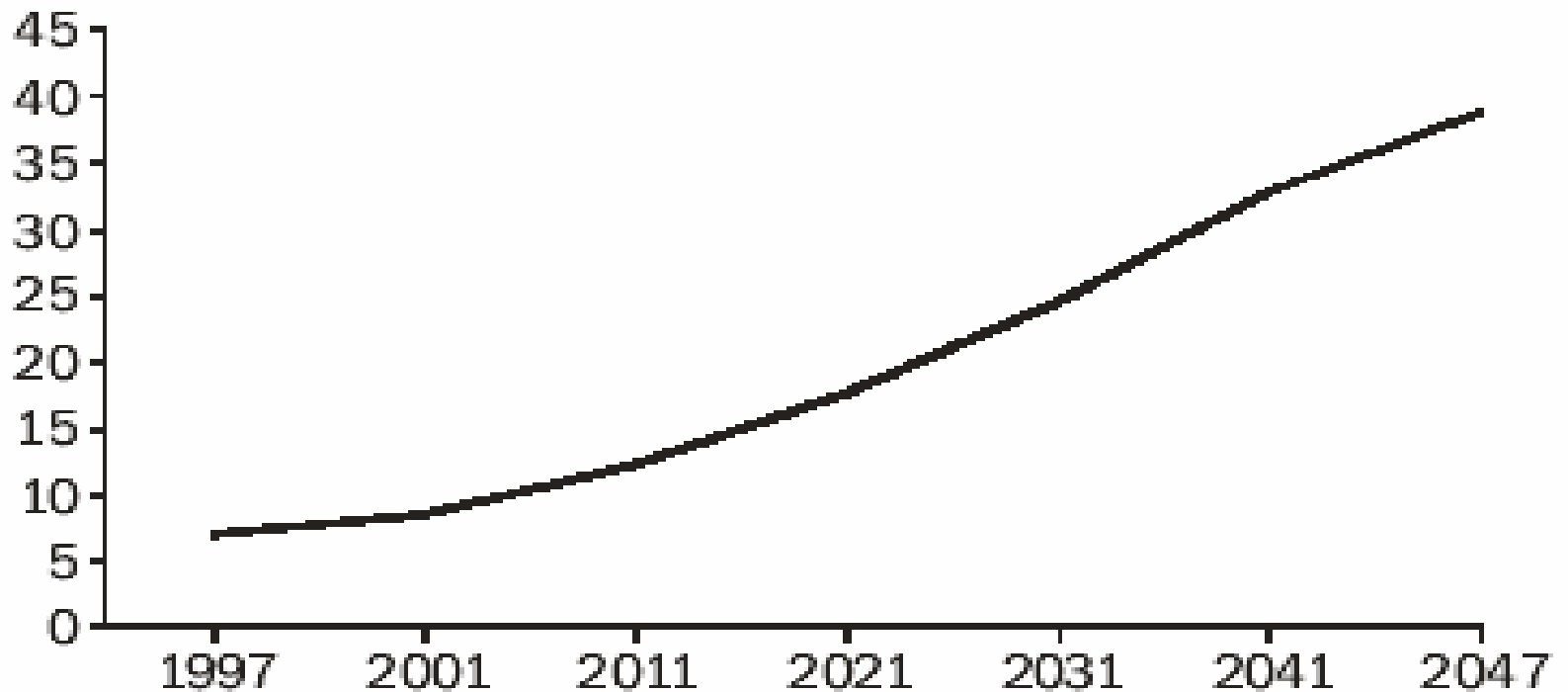


After Singhal and Pandey (2001)

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Emissions of methane from landfills

Methane emissions
(million tonnes/year)



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Effect of rain on Leachate production

-In Delhi, maximum leachate produced during the rainy period;

-In August, the Leachate production is estimated to be about 8,14,800 cu.m

→ The MSW landfills must have liners and Leachate and treatment system

After Dinesh kumar et al. (2001)

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Waste composition in four mega cities in India [Delhi -1; Mumbai - 2; Chennai -3 and Kolkata -4

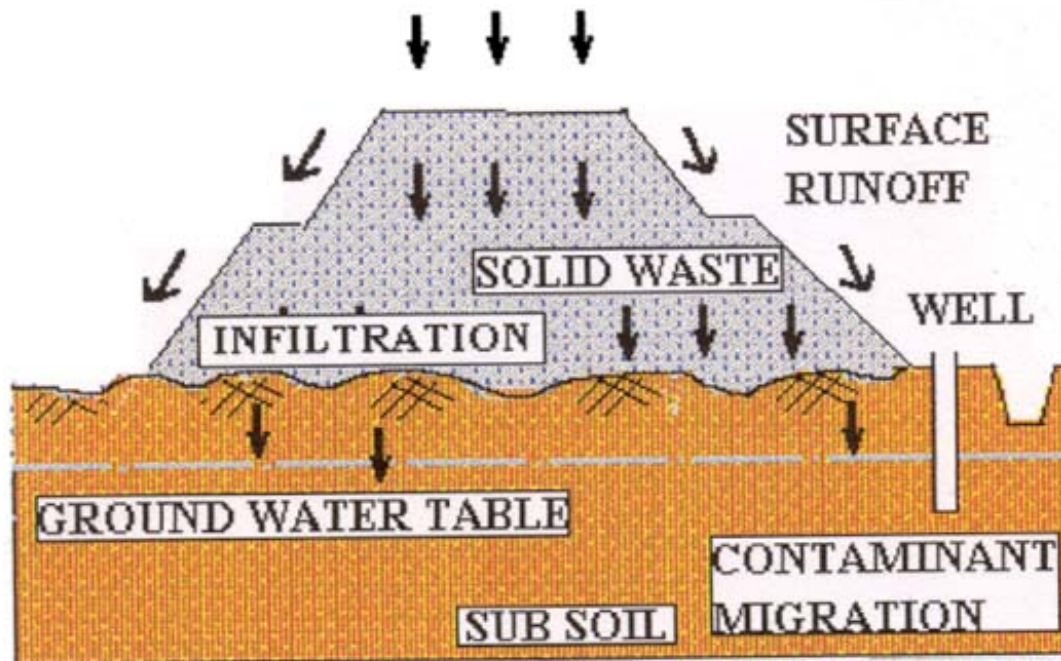
Description	1	2	3	4
#Population [Million]	10	13.8	5.8	12
MSW [tons/day]	+5000	+7600	+4000	+4000
Waste Composition [↓]				
Paper [%]	5.57	7.70	4.84	3.18
Plastic* + Metal + Glass & Crockery [%]	7.25	7.67	5.54	5.23
Biodegradable [%]	38.60	39.09	57.24	41.24
Bioresistant^ [%]	13.87	9.24	10.90	16.77
Inert material [%]	34.71	39.09	57.24	41.24
*Textiles/Polyethene bags; ^Leather, Rubber, Synthetic material, etc.,				

Waste composition in other countries

Description	1	2	3	4	5	6	7	8
#Population [Million]	--	--	--	6	--	--	--	--
MSW [tons/day]	--	--	--	8000	--	--	--	--
Waste Composition [↓]								
Paper [%]	31	37	50	25	16	30	12	17.1
Plastic* + Metal + Glass & Crockery [%]	26	23	18	14	25	20.5	12	22.1
Biodegradable [%]	28	28	13	44	58	32	74	29.2
Bioresistant^ [%]	4	12	8	7	7.5	--	--	7.5
Inert material [%]	11	--	11	19	24.1	17.5	2	24.1
Geneva - 1; UK -2; USA -3; Bangkok - 4; Australia - 5; China - 6; Nairobi -7; Berlin -8								

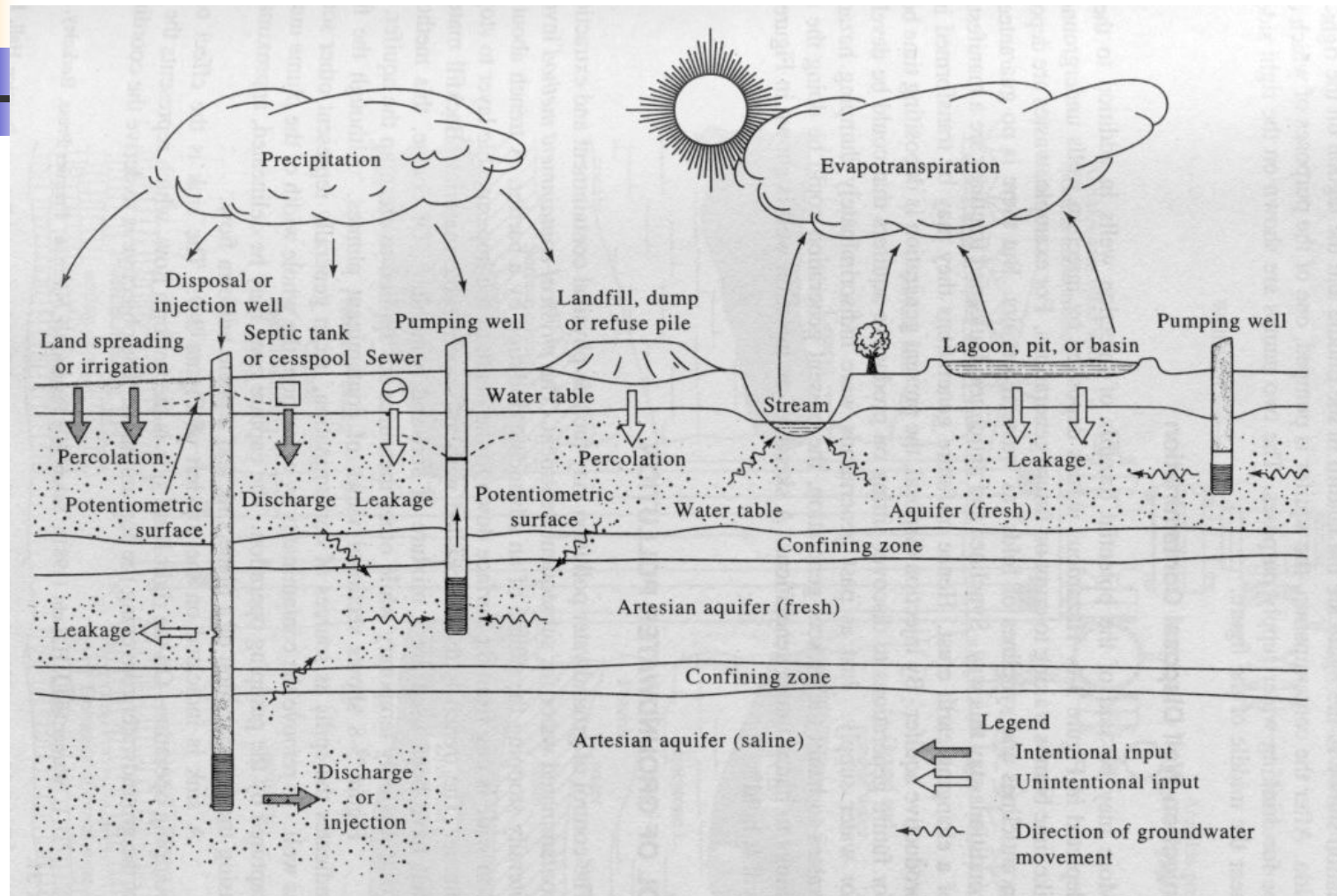
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Un-regulated landfill



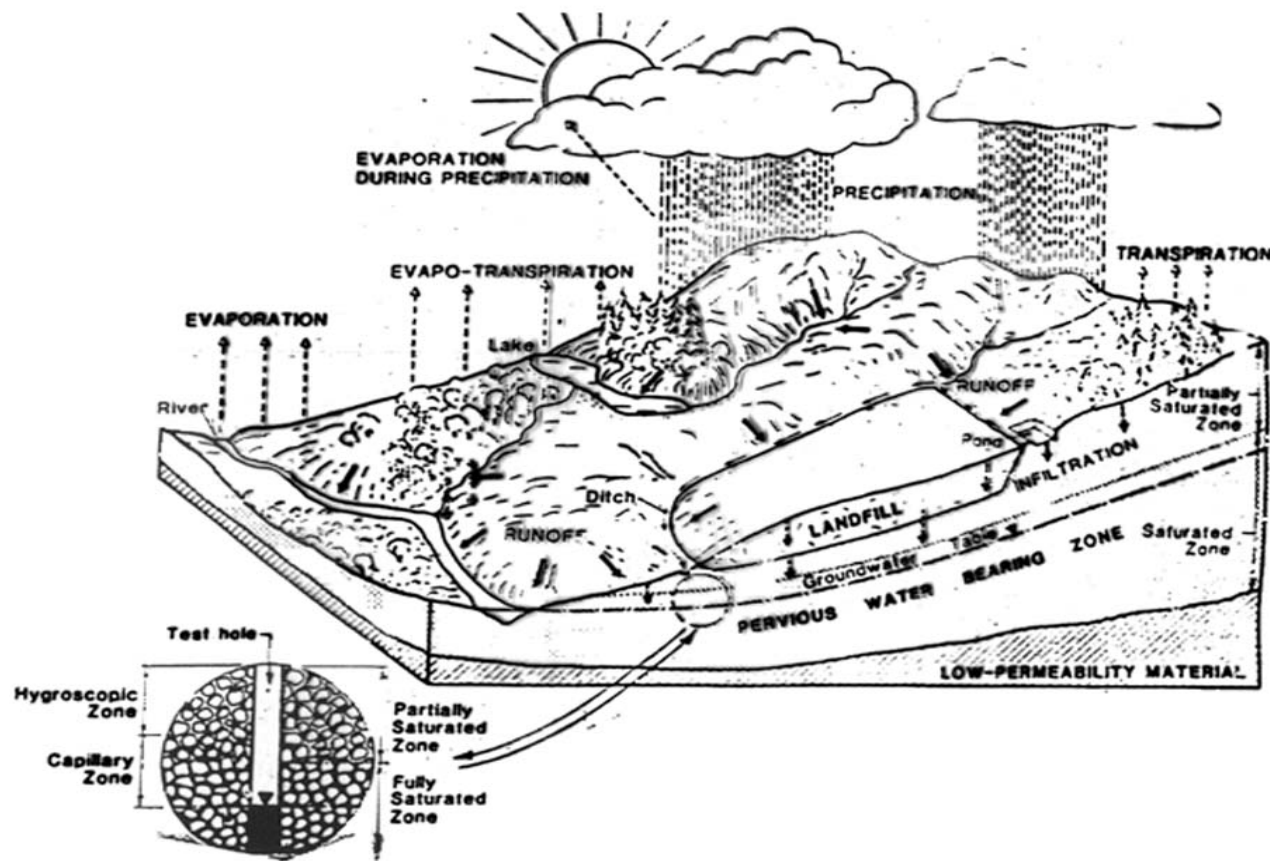
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Ill effects due to unregulated



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Hydrologic cycle as applied to landfill containment system



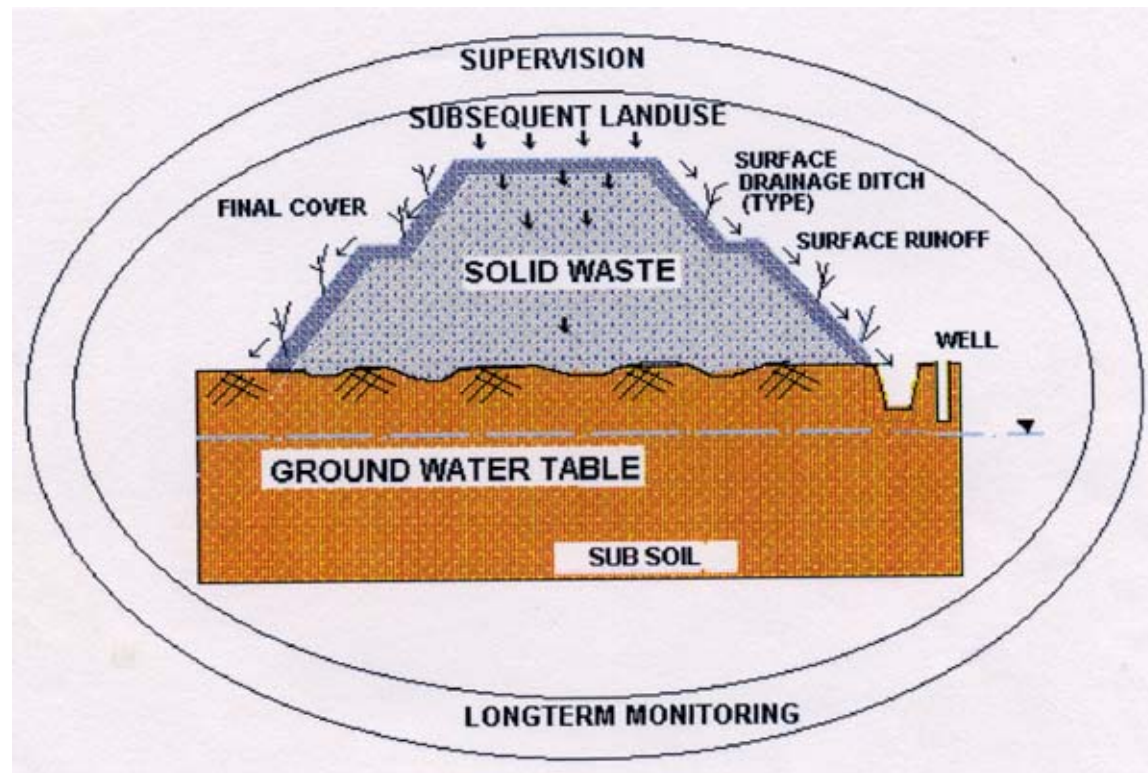
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Dangers due to un-regulated dumping yards

- Ground water contamination
- Loss of useful gases into surrounding environment
- Environmental and health hazards

Regulated landfill



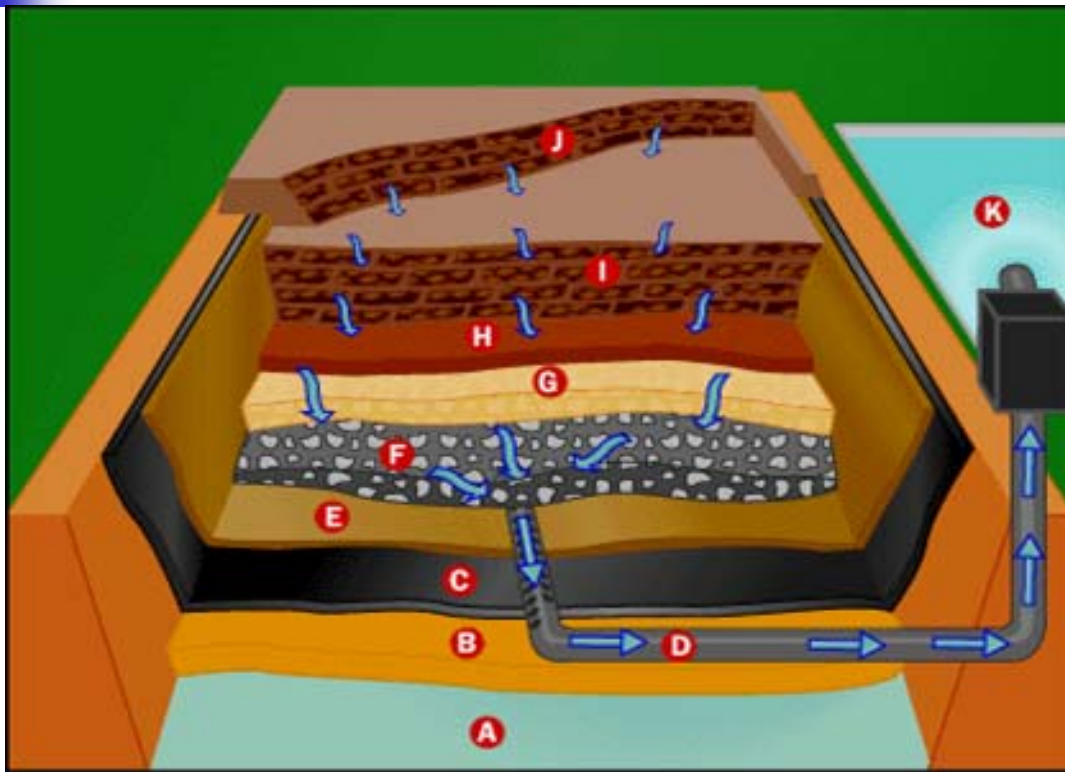
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Merits of regulated landfills

- Environmental protection
- Prevention of groundwater contamination
- Minimization of leachate generation
- Gas/power generation
- Land use for subsequent applications

Parts of a landfill



©2000 How Stuff Works

- A - Ground water
- B - Compacted clay
- C - Geomembrane
- D - Leachate collection pipe
- E - Protection layer
- F - Gravel
- G - Drainage layer
- H - Soil layer
- I - Old cells
- J - New cells
- K - Leachate pond



Key elements of a landfill

- **Bottom liner system** - separates MSW and subsequent leachate from groundwater
- **Cells (old and new)** - where the MSW is stored within the landfill
- **Storm water drainage system** - collects rain water that falls on the landfill
- **Leachate collection system** - collects water that has percolated through the landfill itself and contains contaminating substances (**leachate**)
- **Methane collection system** - collects methane gas that is formed during the breakdown of MSW
- **Covering or cap** - seals off the top of the landfill



Site selection for MSW landfills

- A. Large enough to accommodate the SW needs of the area it serves (lifetime, 10 yrs)
- B. Compatible with the local SW management programs
- C. Site must protect public health, safety, welfare, & environment
- D. Minimize adverse impacts on surrounding area
- E. Minimize adverse impacts on property value
- F. Minimize impacts on traffic flow
- G. Minimize potential for fire, spill, accidents
- H. Outside the 100 year flood plain
- I. Far from airports (birds) - 5 km from jet ports, 3 km from other airports
- J. Provide emergency response plan including notification, evacuation, & containment procedures



Typical Waste categorization in Europe

- Belgium - Class I Industrial waste
Class II Municipal waste
Class III Inert waste
- Germany - Class I Inert wastes
Class II Wastes with higher pollutants
Class III Hazardous wastes



Typical Waste categorization in Europe

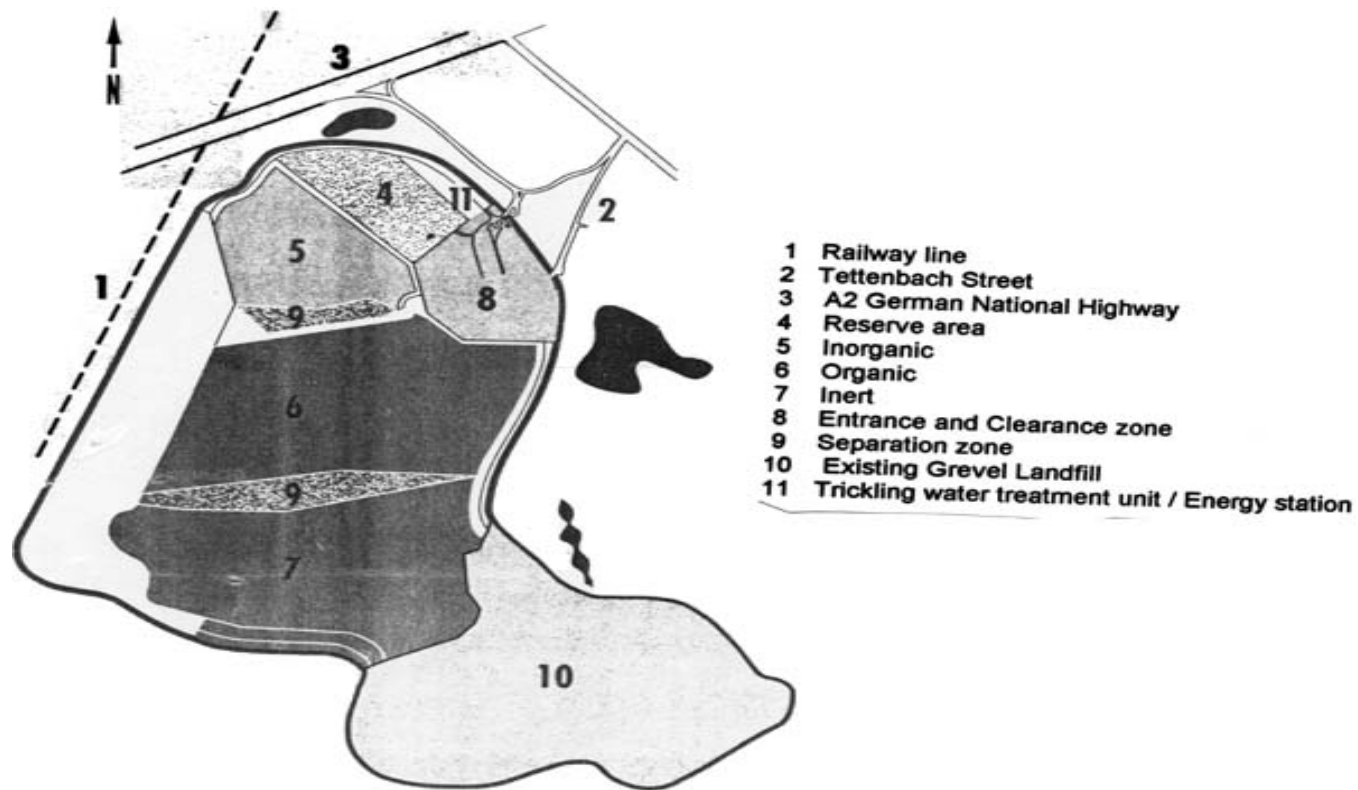
- UK - 1 Household, municipal waste
 - 2 Commercial wastes
 - 3 Industrial wastes
 - 4 Inert wastes
- France – Class A (Special Industrial wastes)
 - Class B -- do --
 - Class C -- do --
 - Class D Municipal and putrescible waste
 - Class E Inert and construction industry wastes

Landfill ready for receiving waste

Existing old landfill

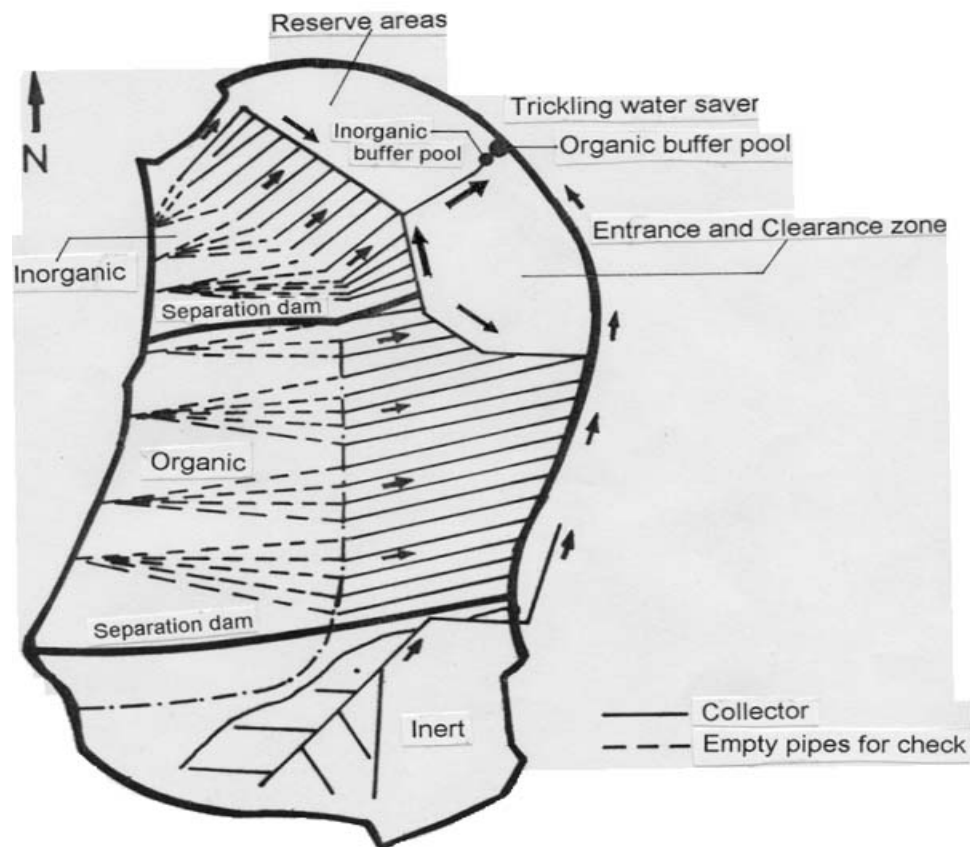


Deposition areas in Dortmund landfill



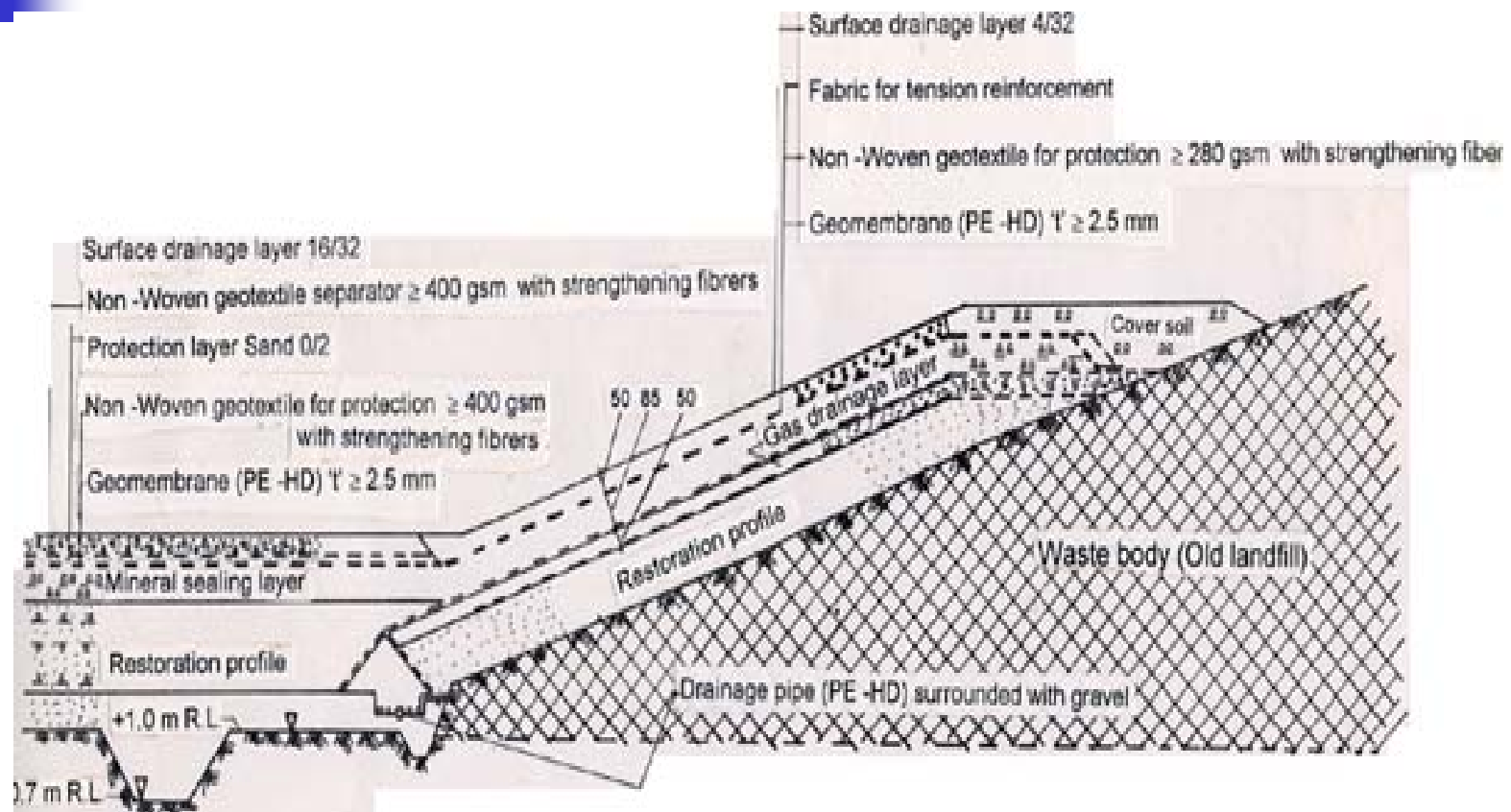
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Drainage system at Dortmund landfill



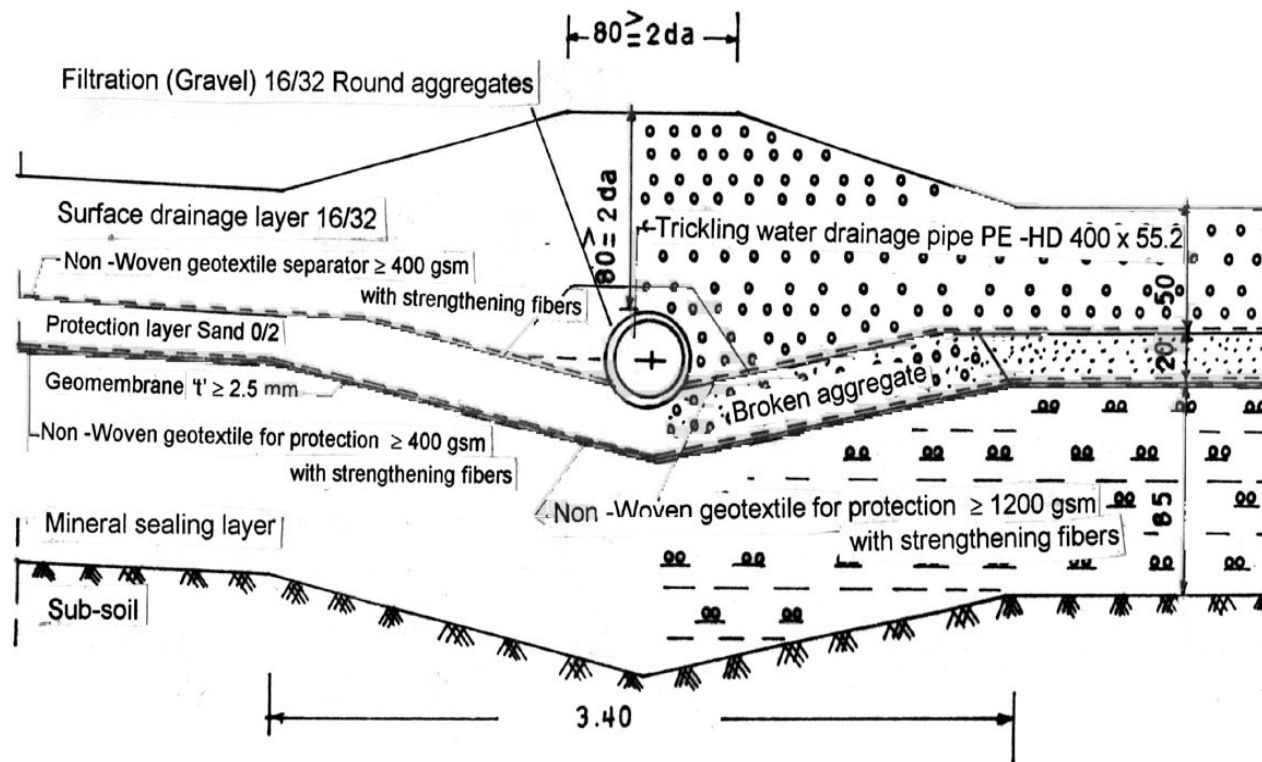
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Typical cross-section of Friesland/Wittmund landfill



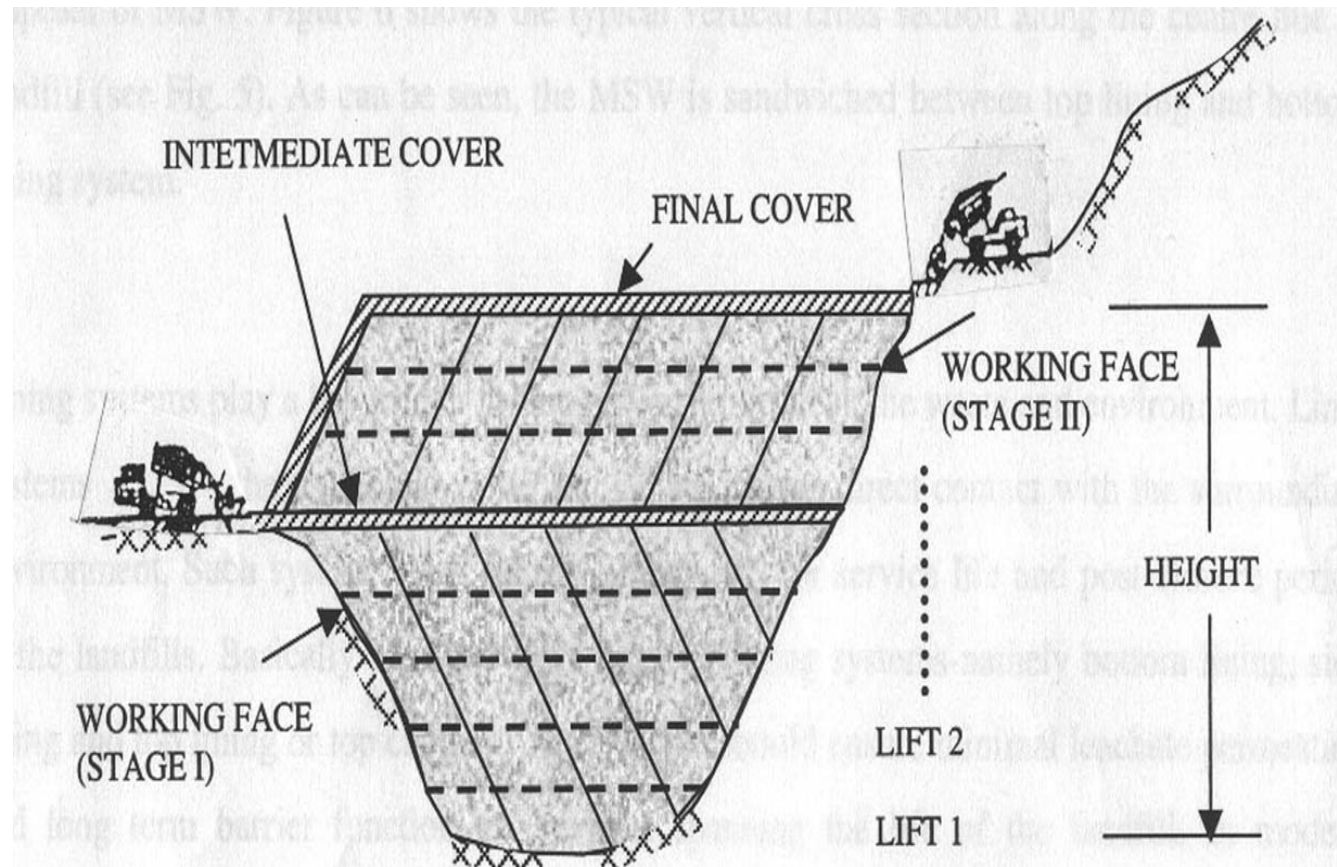
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Typical cross-section of bottom lining system at Freisland/Wittmund landfill



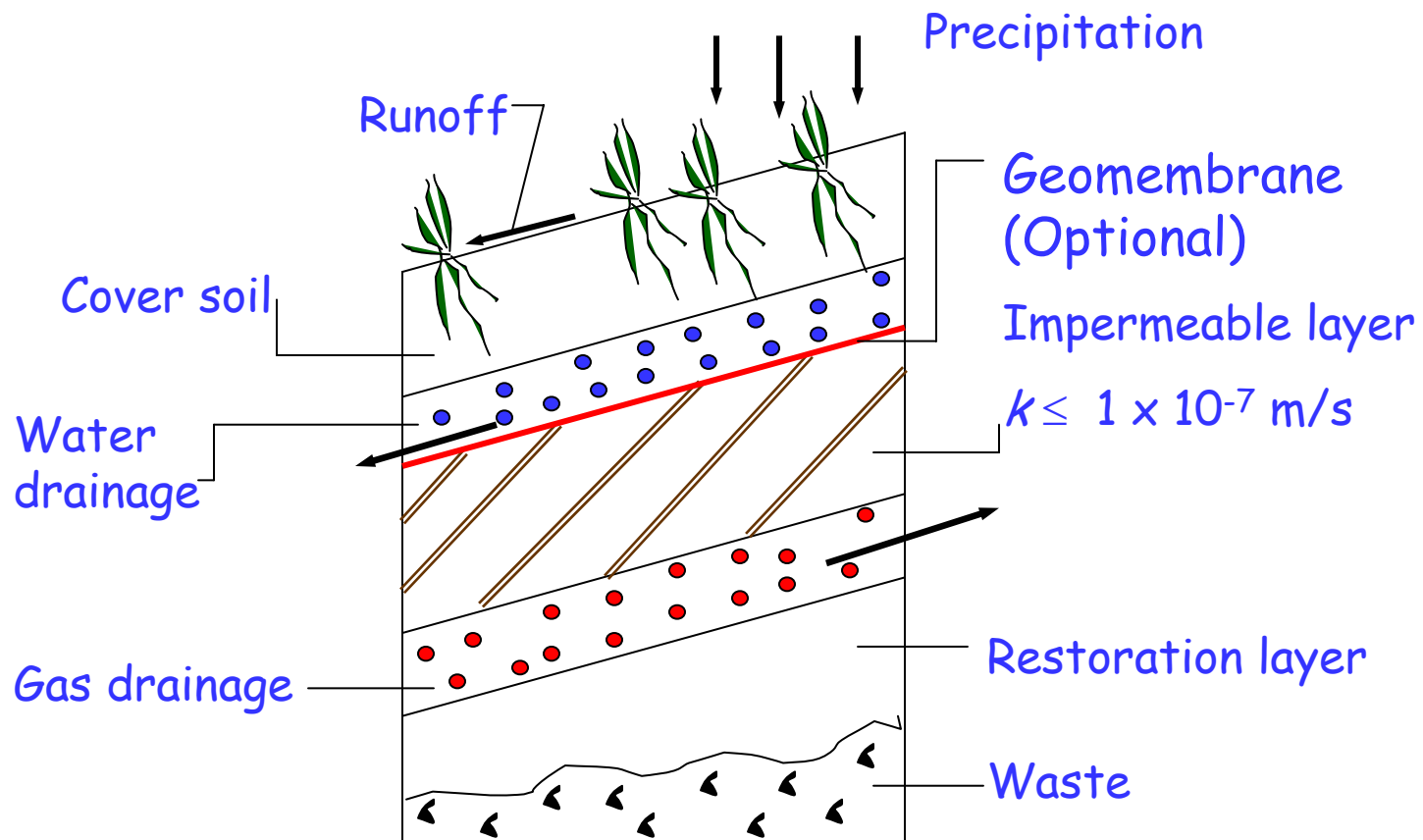
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Possible disposal options for MSW in India



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Capping system for sealing MSW



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Waste landfilling in France

Compacted waste



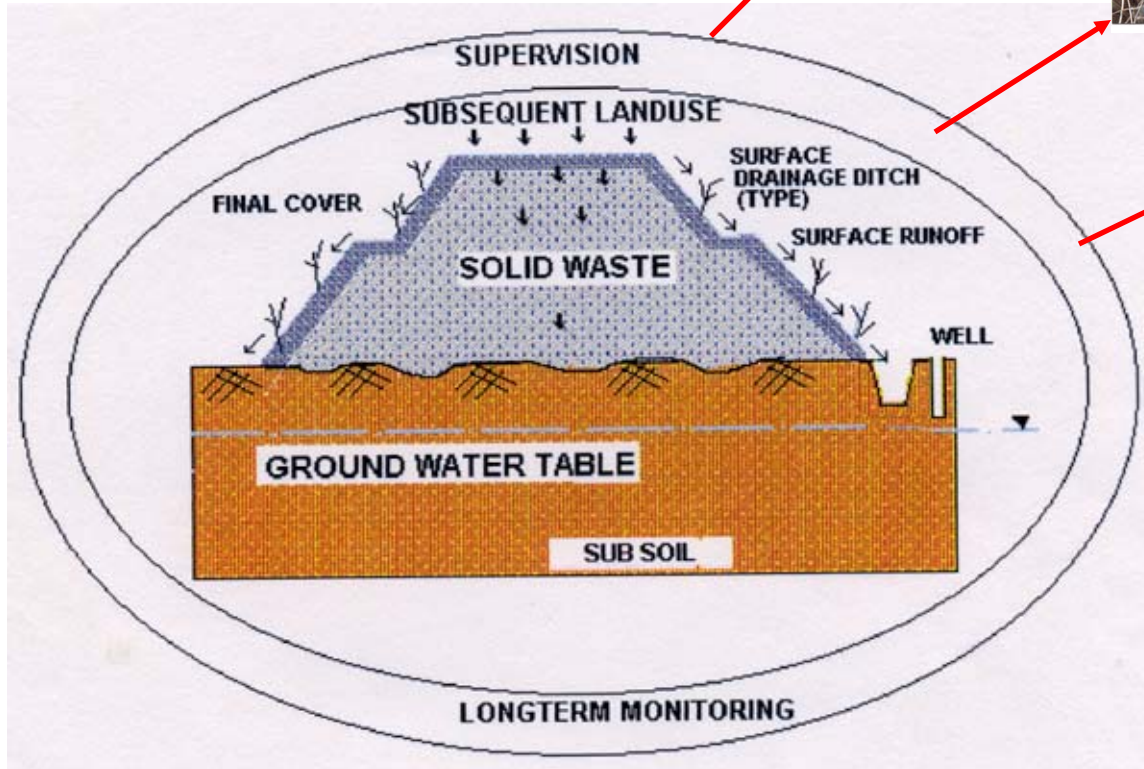
After Gourc (2005)

Condition and Proposition



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Regulated landfills

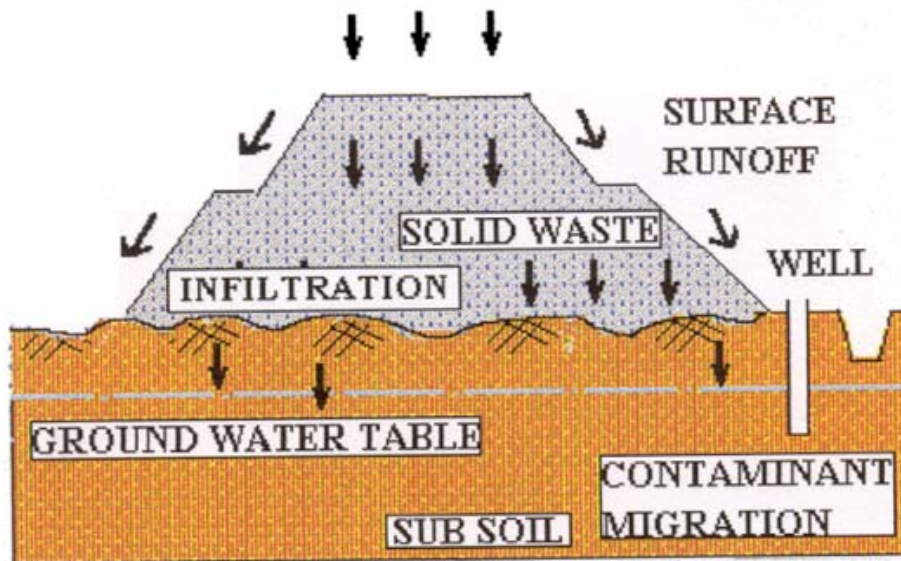


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Unregulated landfills



After The Hindu (1995)

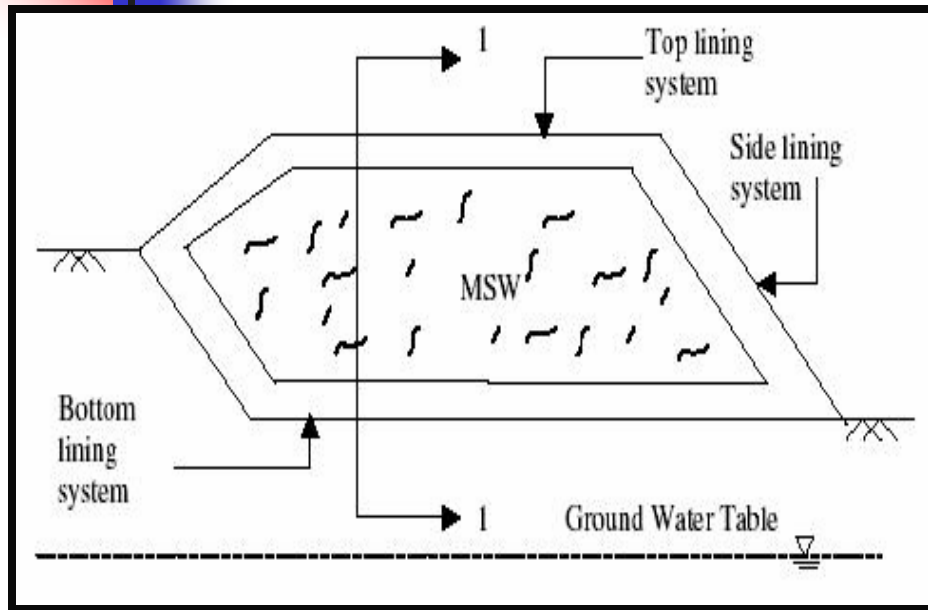


-Ground water contamination

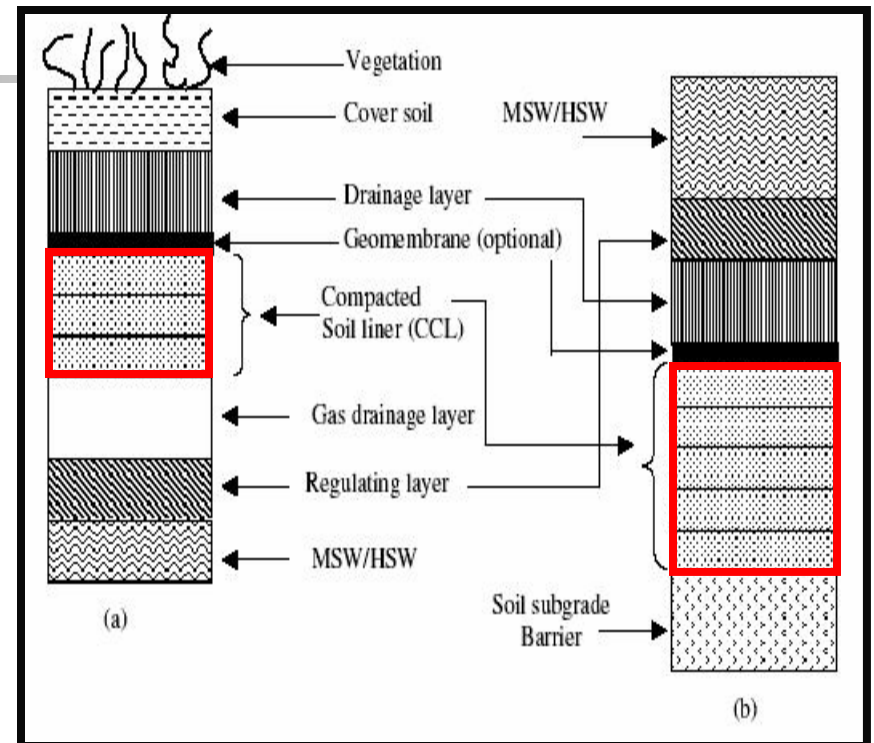
-Loss of useful gases into surrounding environment

-Environmental and health hazards

How do they look like ??



Cross Section of a landfill



Cross Section of liner



Types of Liner Materials

- **Compacted clay liners**
- **Synthetic membrane liners**
- **Amended soil liners**

Present study – Compacted clay liners



Choice of soil liner material

➤ Usually suitable material is:

- naturally available soil of low permeability
(such as clay, silty clay)

➤ When suitable natural liner material is not available:

mixture of sand and bentonite or permeable soil
and bentonite can be used as liner material.



Factors affecting hydraulic conductivity of soil liners

- Pre construction factors
 - **Material Selection**
- Construction factors
 - **Moulding water content and compactive effort**
 - **Liner thickness**
- Post construction factors
 - **Desiccation Cracking**
 - **Cracks due to non-uniform settlements**
 - **Chemical permeants**



Concluding remarks

- Increasing concern for waste management in India and other developing countries.
- Enormous quantities of generation of MSW!!!
- Requirement for designing and constructing engineered landfills.
- Requirement for waste categorization, compaction and covering intermediately.
- Containment of MSW enhances the performance of landfill and prevents environmental contamination.