Civil 4-2 (Environment)
Jalil Sir.
22F

SOLID WASTE MANAGEMENT

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Syllabus:

Solid Waste Management

- Ultimate disposal methods
- Resources and energy recovery and recycling
- Soil pollution
- Industrial solid waste collection and disposal

Hazardous Waste Management

- Identification, sources and characteristics
- Hospital waste management practices
- Legal aspects
- Auditing and prevention
- Methods of treatment and disposal – physical, chemical, biological and thermal treatment
- Stabilization and solidification, engineering storage, incineration, landfill and deep burial

References

1. Solid Waste Engineering by P. A. Vesilind, W. Worrell & D. Reinhart
2. Hazardous Waste Management by C. A. Wentz
3. Text Book of Solid Wastes Management by I. H. Khan & N. Ahsan
4. Environmental Engineering by A. P. Sincero & G. A. Sincero
5. Environmental Engineering by H. S. Peavy, D. R. Rowe & G. Tchobanoglous
6. Water Supply & Sanitation by M. F. Ahmed & M. M. Rahman

Solid Waste Management

What is Solid Waste?

Solid waste means any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations, and from community activities.

In Simple Words - Solid wastes are any discarded or abandoned materials. Solid wastes can be solid, liquid, semi-solid or containerized gaseous material.

What is Solid Waste Management?

Solid waste management is all the activities and actions required to manage waste from its inception to its final disposal. This includes amongst other things, collection, transport, treatment and disposal of waste together with monitoring and regulation. It also encompasses the legal and regulatory framework that relates to waste management encompassing guidance on recycling etc.

Ultimate Disposal Methods of Solid Wastes

Ultimate disposal

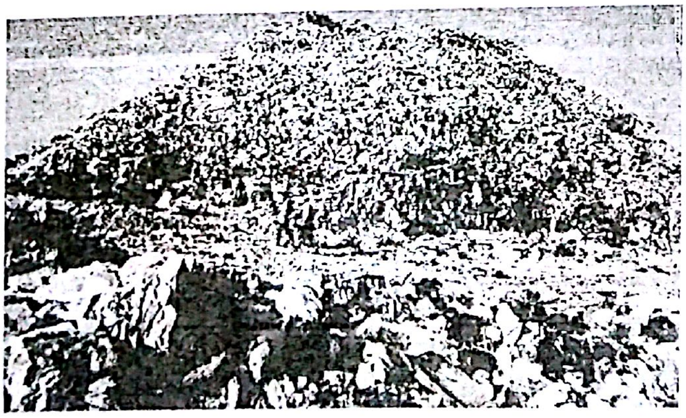
Regardless of how much reuse, recycling and energy recovery is achieved some fraction of the solid wastes must be returned to the environment.

Ultimate disposal methods:

1. Landfilling
2. Landfarming
3. Deep-well injection
4. Land burial
5. Dumping in oceans and other large water bodies.

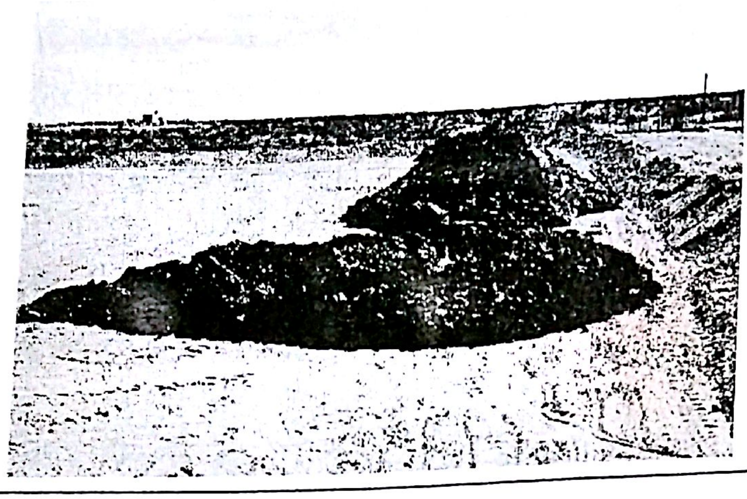
Landfilling

Landfilling is the method of disposal used most commonly for municipal solid wastes. It involves the disposal of solid wastes on or in the upper layer of the earth's mantle.



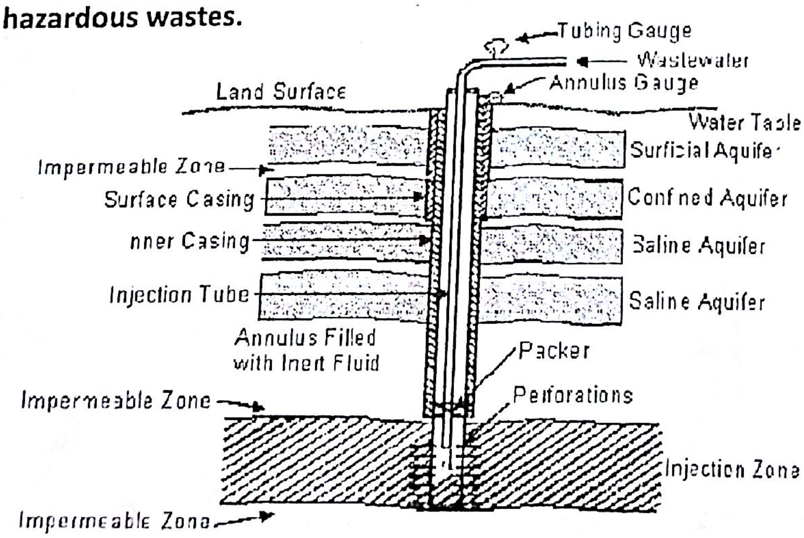
Landfarming

Landfarming is a waste-disposal method to treat biodegradable industrial wastes. The wastes are either applied on top of the land or injected below the surface of the soil.



Deep-well Injection

Deep-well injection for the disposal of liquid and solid wastes involves injecting the wastes deep in the ground into permeable rock formations or underground caverns. It is used principally for liquid wastes that are difficult to treat and dispose of by more conventional methods and for hazardous wastes.



Solid Waste Disposal Practices in Low-Income Countries

Type	Description	Indicators
Waste discarded at source	This is common in cities and towns where no collection system operates. Waste is deposited by households in streets and open spaces as they generate it.	• No primary collection. • No functional institution responsible for solid waste management (SWM). • Scattered waste in streets and open areas. • Waste consumption by animals is common. • Burning of waste piles.

Type	Description	Indicators
Uncontrolled local disposal	There is a primary collection system and waste is taken manually or in carts to a few undesignated disposal points. There is no secondary transportation using vehicles. Such systems are common in small towns.	• There is an institution responsible for SWM. • Waste is removed from streets to nearby open places. • Waste quantities accumulate. • Waste picking starts. • Waste consumption by animals is common.

[illegible]	Description	Indicators
Uncontrolled city disposal	Primary and secondary collection is available. Waste is generally removed from the immediate environment and taken in vehicles to undesignated placed away from residential areas.	• There is an institution responsible for SWM. • Waste is removed in two stages i.e. primary and secondary. • Transfer points are provided. • Often, vehicle drivers decide the disposal point. • Waste picking continues at all stages.

[illegible]	Descriptions	Indicators
Semi-controlled Disposal	Primary and secondary collection is provided. Waste is generally removed from the immediate environment and taken in vehicles to designated places outside the residential area. There is no management or equipment at the disposal site.	• Waste disposal options are in the planning stage. • Vehicle drivers transport the collected waste to designated site. • Waste picking continues at all stages.

Controlled disposal	Primary and secondary collection is provided. Waste is taken outside the residential area to designated sites in vehicles. There is some operational control and equipment/plant available at the site, though disposal is not fully engineered.	• Engineering disposal options are in the planning stage. • Vehicle drivers transport the collected waste to designated sites. • Controls over waste picking at disposal sites begin. • Solid waste authority owns the site. • Waste picking continues.

Type	Description	Indicators
Fully engineered disposal/ sanitary landfill	Waste is disposed of in a fully-controlled manner with maximum protection to the environment. This is quite uncommon in low-income countries.	• Details of planning and records are available. • All facilities for proper land filling and environment protection are available and function satisfactorily. • No waste picking. • There exists a strong landfill management unit.

Landfill Development Levels

Solid waste disposal by landfill should be done in a sanitary manner to protect health and environment. Landfills in developing countries may be categorized into 4 development levels based on the available facilities of the landfills. The main features of these landfill development levels are presented in Table 1.

Table: Sanitary Landfill Levels in Developing Countries.

Facility	Level 1	Level 2	Level 3	Level 4
Description	Controlled tipping	Sanitary Landfill with bund and daily cover	Sanitary Landfill with leachate re-circulation	Sanitary Landfill with Leachate Treatment facilities
(1) Soil cover	√ (Periodic)	√	√	√
(2) Embankment		√	√	√
(3) Drainage facility		√	√	√
(4) Gas venting		√	√	√
(5) Leachate collection			√	√
(6) Leachate recirculation			√	√
(7) Leachate treatment				√
(8) Liner				√

Sanitary Landfill

Sanitary landfill is an engineered method for land disposal of solid and hazardous wastes in a manner that protects the environment and public health. It is the only widely acceptable method of solid waste disposal currently all over the world.

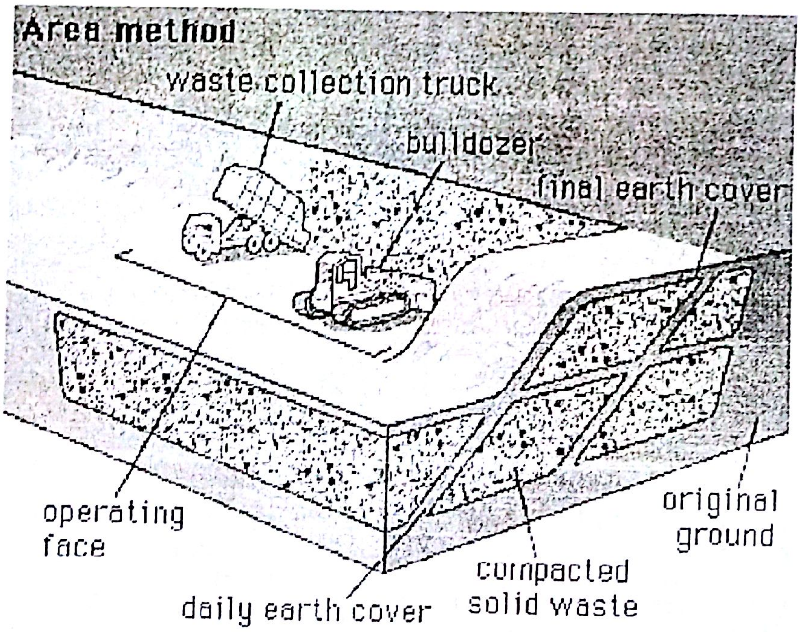
Landfilling Methods

The principal methods for landfilling dry areas can be classified as

- Area method
- Trench method
- Depression method

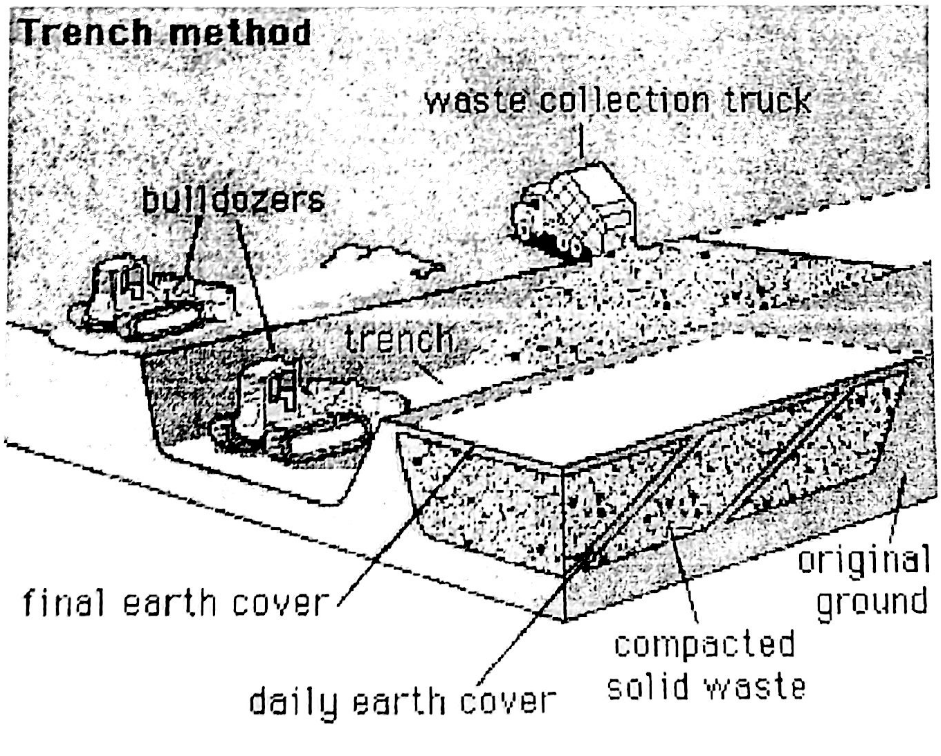
Area Method

- It is used when the terrain is unsuitable for excavation.
- The filling operation is usually started by building an earthen levee against which wastes are placed in thin layers and compacted.
- When the thickness of the compacted wastes reached a height of 2~3m at the end of each day's operation, a layer of cover material is placed over the completed fill.
- Successive lifts are placed on top of one another until the final design shape is reached.
- A final layer of cover material is applied on the final shape.



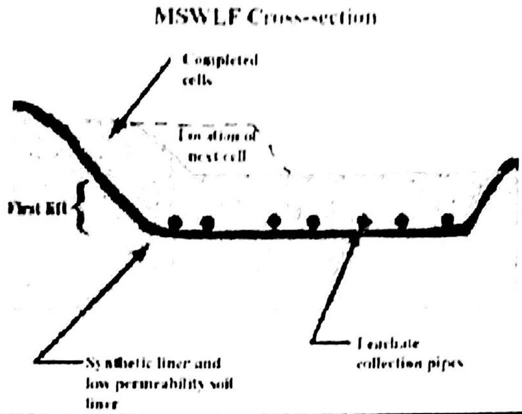
Trench Method

- It is the most widely used method of landfilling.
- It is suitable where the water table is well below the soil surface and excavation is not difficult.
- The sides and base of the trench which is to be filled with solid wastes are lined with impermeable materials if natural clay layer is non-existent.
- An earthen embankment is constructed at the boundary of the landfill site to prevent entry of surface runoff and flood water.
- The filling of waste starts from the bed and is the same as in the case of area method of landfilling.
- The excavated soil is used as cover material.



Depression Method

- It is used where natural or artificial depressions exist.
- Canyons, ravines, dry borrow pits, and quarried have all been used for this purpose.
- The techniques to place and compact solid wastes vary with the geometry of the site, the characteristics of the cover materials, the hydrology and geology of the site, and the access to the site.



Advantages and disadvantages of sanitary landfill

Advantages	Disadvantages
1. Where land is available, a sanitary landfill is the most economic method of solid waste disposal.	1. In highly populated areas, suitable land may not be available within the economical haul distances.
2. The initial investment is low compared with other disposal methods.	2. Proper sanitary landfill practices must be adhered to; otherwise it will turn into an open dump.
3. A sanitary landfill is the final or complete disposal method as compared to other method that need subsequent operations.	3. Sanitary landfills located in residential area cause nuisance and provoke public opposition.
4. A sanitary landfill can receive almost all types of solid wastes, eliminating the necessary for separate collection.	4. A completed landfill will settle and require periodic maintenance.
5. A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment.	5. Buildings constructed on completed sanitary landfills require special considerations for design.
6. Low-land can be reclaimed and used for many purposes.	6. Methane and other gases generated in landfills may become a hazards and nuisance and interfere with the use of completed landfills.

Planning and Design of a Sanitary Landfill

A sanitary landfill needs careful planning and design for its successful implementation. Important considerations in the planning and design of a sanitary landfill are presented in the following Table.

Table: Important considerations in the planning and design of a sanitary landfill

Waste quantities and characteristics	*(i)* Existing *(ii)* Projected
Environmental Impact Assessment	*(i)* Selection of different possible sites *(ii)* Preparation of Environmental Impact Assessment (EIA) Report *(iii)* Selection of the best site based on EIA
Design of filling area	i. Selection of landfilling method based on site topography, subsurface strata, etc. ii. Design dimensions (cell width and length, lift, fill depth, daily cover thickness, intermediate cover thickness, thickness of liner and final cover) iii. Specification of operational features (method of compaction, leveling, and grading, transportation of cover material, equipment requirement, staff requirement)

Design of Landfill Components	(i) Access roads (ii) Leachate control (iii) Gas control (iv) Surface water diversion (v) Special working area (vi) Site office (vii) Weigh bridge (viii) Workshop for equipment (ix) Vehicle and equipment parking area (x) Support utilities (xi) Fencing (xii) Car wash pool (xiii) Monitoring facilities/probes (xiv) Plantation and landscaping

Design Documents	(i) Development of preliminary site plan of fill areas (ii) Development of landfill contour plan, excavation plan, sequential fill plans, completed fill plans, fire prevention, litter, vector, odor, and noise control, surface water diversion (iii)Computation of solid waste storage volumes, quantity of cover material, and life of landfill (iv)Development of final site plan including normal fill areas, special working areas during rains, leachate control system, gas control system, access roads, site office, weigh bridge and other structures e.g. workshop and garage, monitoring wells/probes/stations, fencing etc. (v) Preparation of elevation plans with cross-sections of excavated fill, completed fill, and phase development fill at various stages (vi)Preparation of construction details for fencing, access roads, liners, leachate collection and disposal system, gas collection and energy recovery or flaring facilities, surface water diversion channels, workshop, garage, site office, weigh bridge etc. (vii)Preparation of final land use plan after closure of landfill (viii)Preparation of environmental monitoring plan (ix)Preparation of cost estimates (x) Preparation of design report (xi)Application along with EIA report for obtaining approval of the regulating authority

Operational Manual

A sanitary landfill should have an operational manual for proper operation of the site, which should contain the following items:

(1) Waste receiving control;
(2) Recording the amount of type of wastes received;
(3) Rates and rating system for receiving wastes;
(4) Regulation of traffic and behavior at the site;
(5) Instruction for deposit of first layer of waste;
(6) Routes for deposit of different types of wastes, including daily cover;
(7) Hauling and compaction of deposited wastes;
(8) Occupational safety of the workers and other working within the site;
(9) Regulation and routine for work with leachate,
(10) Routine for cleaning the roads and site including collection of littering paper;
(11) Routine to avoid dust and smoke;
(12) Routine for fire control.

Planning of a sanitary landfill

- The design period should be 10-30 years
- The landfill site must provide sufficient landfill capacity for the selected design period
- The site must support ancillary solid waste functions
  - leachate collection and treatment
  - storm water collection
  - landfill gas management
  - landfill control area
  - special waste services
  - material recovery facilities
- Calculate the required landfill capacity with data of population projection, per capita waste generation rate, diversion rate, compacted density of solid wastes and soil cover.
- The following factors could affect the volume requirement of the landfill
  - new regulations for waste diversion/recycling
  - existence or closure of competing facilities
  - different cover options
  - non-residential waste changes

Problem 1: A refuse has the following components and bulk densities:

Component	Percentage by weight	Uncompacted bulk density (lb/ft^3)
Miscellaneous paper	50	3.81
Garden waste	25	4.45
Glass	25	18.45

Assume that the compaction in the landfill is 44.4 lb/ft^3. Estimate the % volume reduction achieved during compaction of the waste. Estimate the overall uncompacted bulk density if the miscellaneous paper is removed.

Solution: The overall bulk density prior to compaction is
$(50 + 25 + 25)/ [(50/3.81) + (25/4.45) + (25/18.45)] = 4.98\ lb/ft^3$.

$\therefore$ The fraction remaining of initial volume during compaction = 4.98 / 44.4 = 0.11

$\therefore$ The % volume reduction = $(1 - 0.11) \times 100 = 89$

If the mixed paper is removed, the overall bulk density is

$(25 + 25)/ [(25/4.45) + (25/18.45)] = 7.18\ lb/ft^3$.

Problem 2: Calculate the required landfill capacity for a community for the year 2040 from the following data:
Projected population = 12,00,000
Per capita generation rate = 6.4 lb/cap/d
Diversion fraction = 0.25
Compacted waste density = 44.4 lb/ ft^3
Assume a soil daily cover is used that accounts for 20% of the landfill volume.

Solution: Compacted waste volume for the year 2040 is

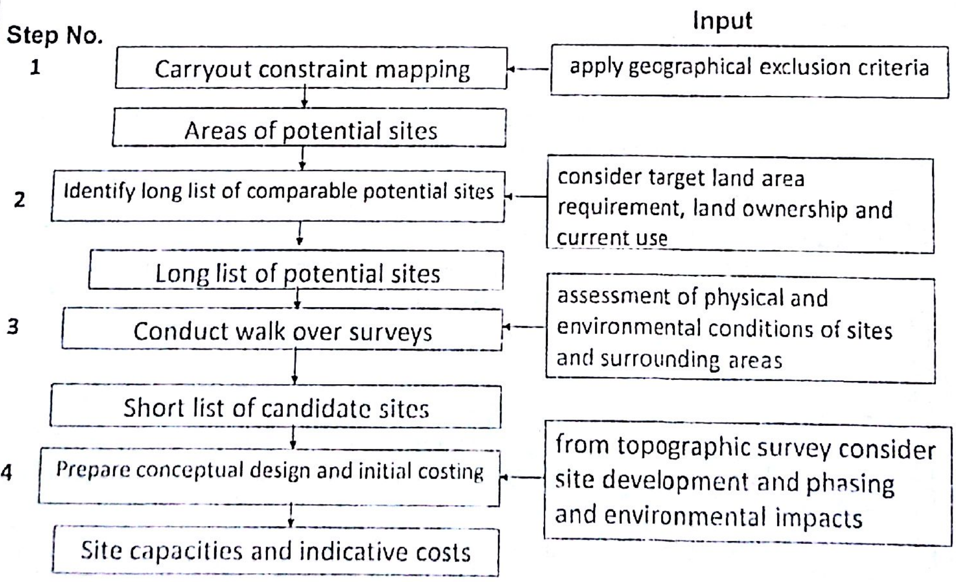
[(Population) x (Per cap. gen. rate) x (1- DF) x 365 d/y] / (Compacted waste density)
= [1200000 x 6.4 x (1- 0.25) x 365] / 44.4 = 4.74×10^7 ft^3

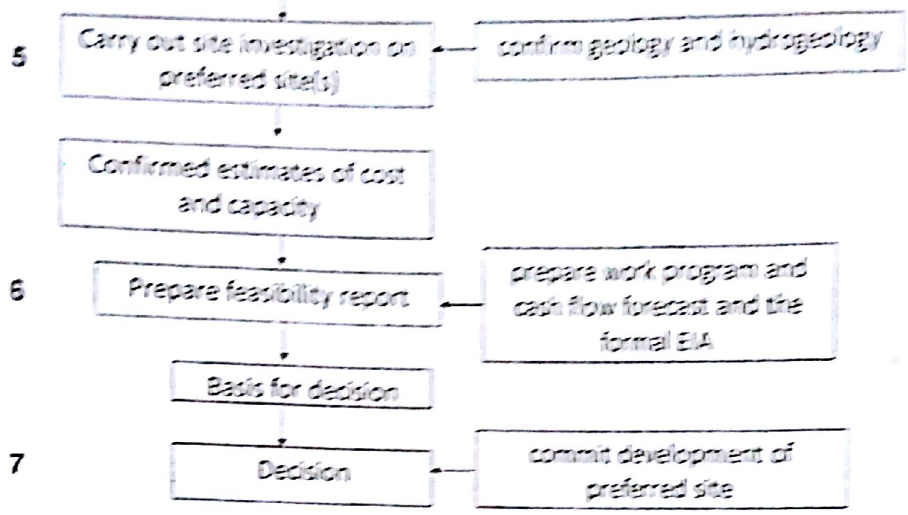
To account for the volume requirement for the cover soil:
$0.20 (V) + 4.74 \times 10^7 = V$
$\therefore V = 5.92 \times 10^7 ft^3$

Landfilling with an average depth of 25 ft would have a footprint of 54.4 acres.

Site Selection

The general process of site selection is likely to follow the step-by-step sequence illustrated in the following Figure.





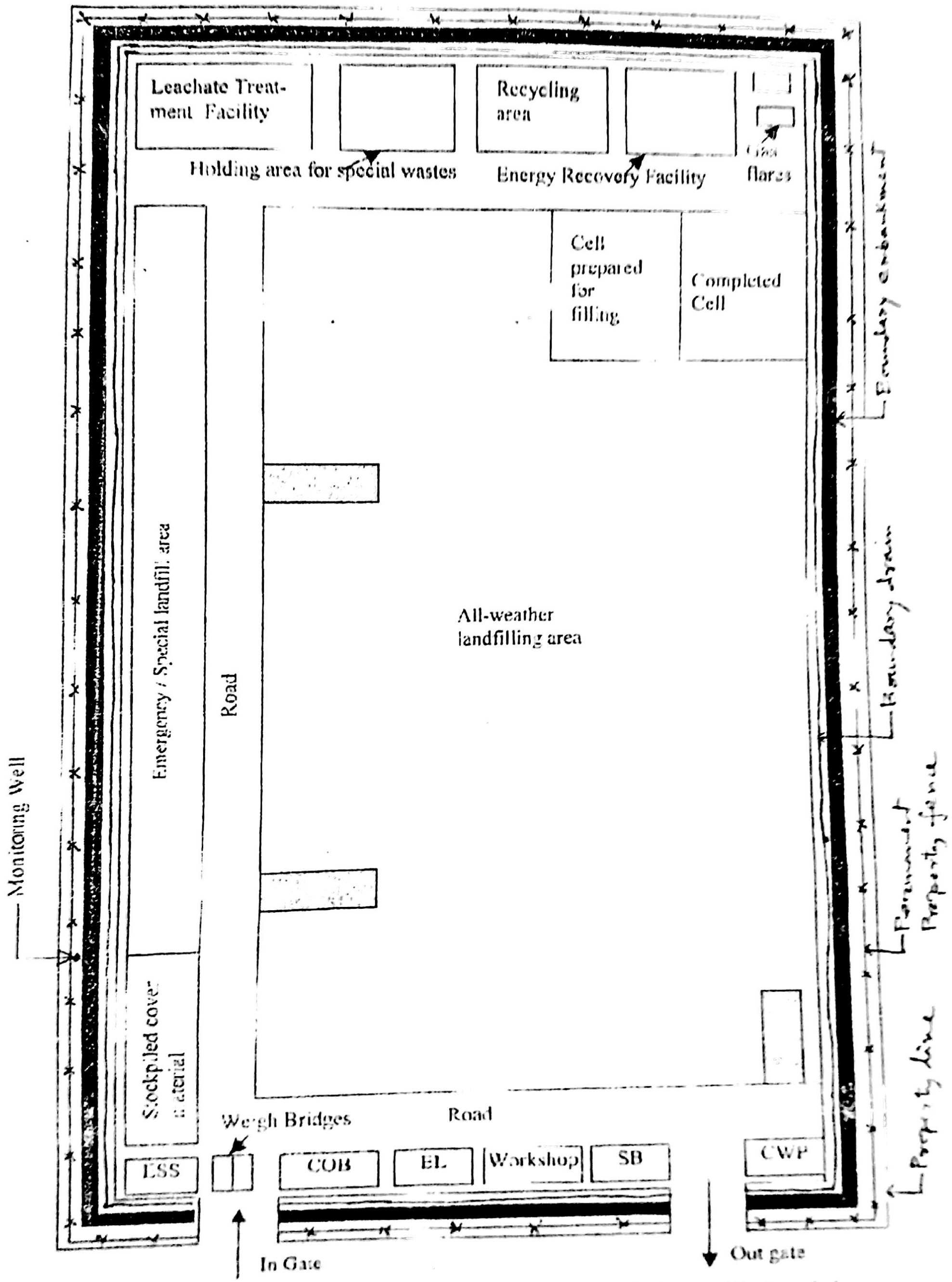
Constraint Mapping

The list of area exclusion criteria is given in the following Table.

Aspect	Criteria
Transport	T1. More than 2 km from a suitable main road T2. More than an economic travel distance from points of origin of waste generation
Natural conditions	N1. Flood plain or other area liable to flooding N2. Extreme morphology N3. High or seasonably high water table N4. Geologically faulted area N5. Wetlands or other areas of ecological significance
Land use	L1. Designated groundwater recharge, sole source aquifer or surface water catchment areas for water supply schemes. L2. Incompatible future land use designations on or adjacent to the site L3. Within a military exclusion zone

Aspect	Criteria
Public acceptability	P1. Within 200 m of existing residential area P2. Within an acceptable distance from historical, religious or other important cultural site or heritage P3. Areas with high population density
Safety	S1. Within 5 km of an airport runway S2. Within a microwave transmitter exclusion zone S3. Within a safe buffer distance from an existing of planned quarry S4. Area of former military activity S5. Areas known to contain collapsing soil

Layout Plan of a Landfill Site



ESS: Electrical Sub-Station COB: Control Office Building EL: Env. Lab

SB: Security Barrack CWP: Car Wash Pool

Decomposition of Solid Wastes in Landfills

Solid wastes that is disposed off in a landfill decomposes by physical, chemical and biological processes, and the landfill can be considered as a natural biochemical reactor.

Three stages of waste decomposition:

i. Aerobic decomposition
ii. Facultative decomposition
iii. Anaerobic decomposition

Aerobic decomposition:

- First stage of decomposition by aerobic microorganisms due to presence of oxygen in the small amount of air trapped during waste disposal.
- It is dominant near the surface of landfills as more oxygen is available until covered by soil.
- It comes to an end when all the available oxygen is exhausted.
- The general reaction is:

Biodegradable waste + O_2 + *Aerobic microbes* = CO_2 + H_2O + *biomass +heat + partially degraded waste*

- The materials released in the process contribute to the formation of leachate. An acidic environment is created.

Facultative decomposition:

- Second phase of decomposition by facultative microbes as oxygen is depleted within the waste.
- The general reaction is:

  Biodegradable waste+ Facultative microbes = CO_2+ H_2O + NH_3+ H_2 + VFA + biomass + partially degraded waste
- Highly acidic leachate (pH = 5.5-6.5) is generated

Anaerobic decomposition:

- Anaerobic (methanogenic) bacterial become active and produce methane, carbon dioxide and water
- The process continues for many years.
- The general reactions are :

  $H_2 + CO_2 = CH_4 + H_2O$

  $VFA = CH_4 + CO_2$
- The dominant gas produced is methane. Other gases produced include N_2 and H_2S.
- The pH of leachate increase to 7-9 and becomes less chemically aggressive
- The methane has high calorific value and is therefore suitable for energy recovery.
- If the methane escapes the landfill, it contributes to green house effect.

Leachate Management

Leachate can be defined as liquid that is produced from decomposition of wastes and from percolation of external water through the wastes extracting dissolved and suspended matters from it including the products of its decomposition.

Characteristics of Leachate

The characteristics of leachate may vary with the type of waste deposited in the landfill. It also changes with time depending on the physical, chemical and biological reactions that take place in the landfill. A generalized variation in the concentration of leachate constituents with time is shown in the following Figure.

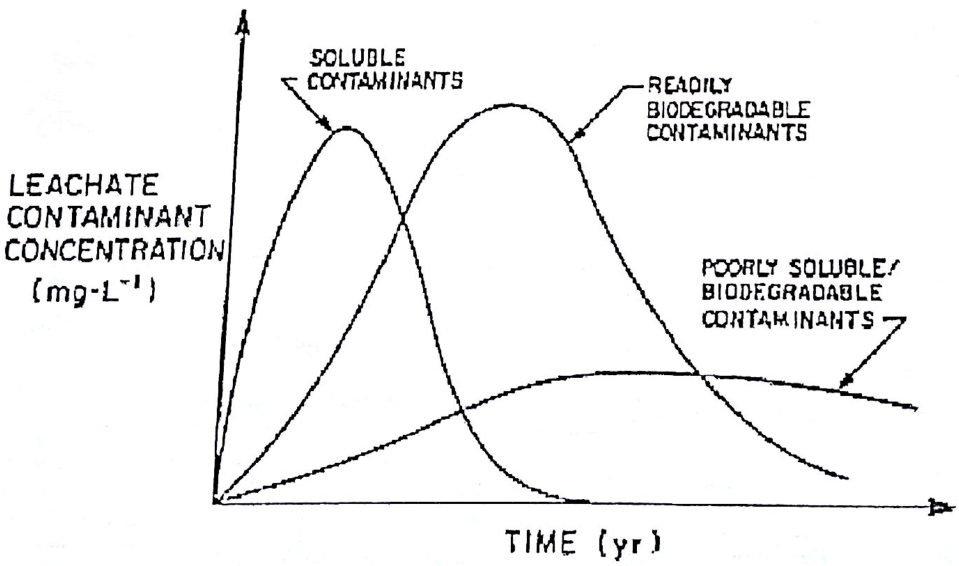


Fig. Typical concentration profile of leachate constituents.

- The concentration level of a constituent first increases to a peak value and later over a period of time is starts decreasing, the time to attain the peak value depends on the type of pollutant – readily soluble pollutants reach the peak value quickly, easily biodegradable pollutants attain the peak value later, and poorly soluble/biodegradable pollutants reach the peak value after a long time from the start of decomposition of the wastes. Representative data on the characteristics of leachate are given in the Table of the next page.

- After about 25 to 30 years of closure of a landfill, the waste is fully stabilized. The concentration of pollutants in the leachate is then significantly low and may not be harmful.

Table : Data on the composition of leachate from landfills.

Parameter	Concentration mg/L*	
	Range	Typical
BOD_5	2000-30000	10000
TOC	1500-20000	6000
COD	3000-45000	18000
TSS	200-1000	500
Organic nitrogen	10-600	200
Ammonia nitrogen	10-800	200
Nitrate	5-40	25
Total phosphorus	1-70	30
Ortho-phosphorus	1-50	20
Alkalinity as $CaCO_3$	1000-10000	3000
pH	5.3-9.6	6
Total hardness as $CaCO_3$	300-10000	3500
Calcium	200-3000	1000
Magnesium	50-1500	250
Potassium	200-2000	300
Sodium	200-2000	500
Chloride	100-3000	500
Sulfate	100-1500	300
Total iron	50-600	60

*Except pH

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Leachate Migration

In most cases, it is impossible to predict accurately the movement of escaped leachate, but the main controlling factors are the surrounding geology and hydrogeology. Escape to surface waters may be relatively easy to control whereas escape to groundwater can be much more difficult both to control and to clean up.

The degree of groundwater contamination will be affected by physical, chemical and biological actions taking place in the sub-surface region as the leachate moves from the landfill to the sub-surface region.

In case of verticle migration difficult to detect the position of contamination of GW

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Leachate Management System

Key components are:

- Leachate minimization
- Leachate containment
- Leachate collection
- Leachate recirculation
- Leachate treatment
- Final disposal of leachate
- Monitoring of leachate leakage

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Leachate Quantities

In order to design a suitable landfill liner and an effective leachate collection system, it is necessary to estimate the quantity of leachate that will be generated in the landfill. The common methods are:

1. Water Balance Method (WBM)
2. Hydrologic Evaluation of Landfill Performance (HELP) model

WBM : It is the most widely approach for estimating the quantities of leachate and can be expressed as

$$L = P - ET - RO - \Delta S$$

Where,

L = the leachate volume

P = the volume of precipitation

ET = the volume lost through evapotranspiration

RO = the volume of surface runoff

ΔS = the volume of moisture storage available in soils and waste in excess of the initial moisture content.

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ΔS = Retained by soil cover

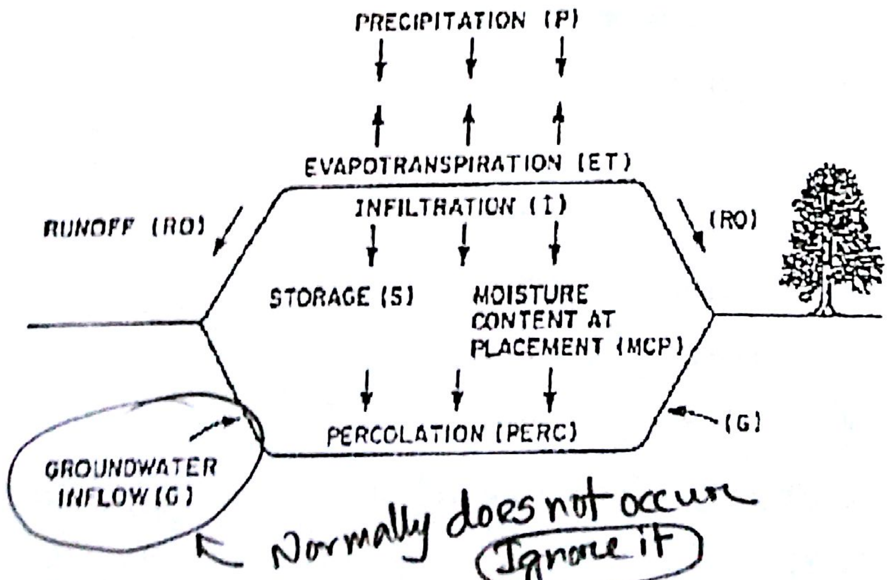

Fig. Schematic of components of water balance with a landfill

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Problem 3: Estimate the percolation of leachate through a landfill 10m deep, with a 1m cover of silty clay for the following data.

P = 2500 mm/year

R = 0.35 (Runoff coefficient)

ET = 780 mm/year

Silty clay field capacity = 400 mm/m → 40%

Refuse field capacity = 300 mm/m → 30%

Assume further that the soil cover is at field capacity when applied, and that the incoming waste has a moisture content of 150mm/m.

field capacity ↙ max amount of water can be retained by material

Solution :

Percolation through the soil cover is

$L = P(1 - R) - ET - \Delta S$

$= 2500\,(1 - 0.35) - 780 - (400 - 400)$

$= 845$ mm/y

field capacity ← soil can't retain any moisture

The refuse has a net absorption capacity of (300-150) mm/m i.e. 150mm/m.

The leachate front will move (845 mm/y) / (150 mm/m) = 5.63 m/y

So, it will take

10 m / (5.63 m/y) = 1.78 y

to produce a leachate that will be collected at a rate of (845mm×area of landfill) per year.

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HELP Model:
- It is the most frequently used computer model for leachate generation.
- It requires detailed on-site morphology and extensive hydrologic data to perform the water balance.
- It is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a landfill.
- Site specific information is needed for precipitation, evapotranspiration, temperature, wind speed, infiltration rates, and watershed parameters, such as, area, imperviousness, slope and depression storage.
- The model accepts weather, soil and design data and uses solution techniques that accounts for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane, or composite liners.
- The HELP model is most useful for long-term prediction of leachate quantity and comparison of various design alternatives; however, it is not suitable for prediction of daily leachate production.

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Leachate Control
- Because of the potential risk involved in allowing leachate to percolate to the groundwater, best practice calls for its elimination or containment. Ultimately it may be necessary to collect and treat the leachate.
- The use of clay has been favored method of reducing or eliminating the percolation of leachate. Membrane liners have also been used, but they are expensive and require care so that they will not be damaged during the filling operations.
- The liner system in a landfill should be designed to satisfy the following requirements:
  1. It should prevent migration of leachate or landfill gas to the subsurface soil or groundwater.
  2. Liner material should have adequate resistance to damage due to vehicular movement, climatic conditions, or chemical reactions with the waste or leachate
  3. It should be installed both at the base and around sides of the landfill.

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- Landfills may be designed with single, composite, or double liners.
- Equally important in controlling the movement of leachate is the elimination of surface-water infiltration, which is the major contributor to the total volume of leachate. With the use of an impermeable clay layer, and appropriate surface slope (1 to 2 percent) and adequate drainage, surface infiltration can be controlled effectively.

Leachate Collection System

- Leachate collection system is designed to avoid accumulation of leachate in the landfills.
- It includes sloped terrace and a pipe network for leachate collection.
- It is provided at the bottom of landfills but above the liner system in a drainage layer filled with granular materials.
- Completely wrapping the fill is a nonwoven geotextile to filter out any fines to protect the granular fill.

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A leachate collection system is shown here

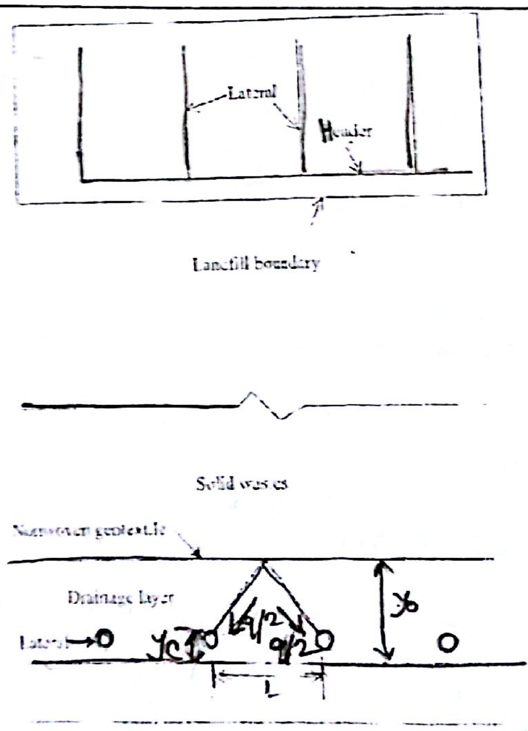

Fig. Leachate collection system

Nonwoven geotextile

$q = \frac{\text{flow}}{\text{length}}$

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The spacing of laterals can be deduced as follows:

q = rate of flow per unit length of the lateral.
y_c = elevation of the lateral's top surface above the liner
y_o = thickness of the drainage layer
L = spacing of the lateral
K = hydraulic conductivity of the drainage layer.

According to the Figure in the previous slide,

Area → hydraulic gradient

$$q/2 = [(y_o + y_c) / 2] K [(y_o - y_c)/(L/2)]$$

→ velocity

or, $q = 2K (y_o^2 - y_c^2) / L$

$\therefore L = 2K(y_o^2 - y_c^2)/q$

L-05

Problem 4:
Design the spacing of laterals for an uncapped landfill for a required maximum leachate head of 30.5cm (y_o), if the top surface of the laterals is 10 cm (y_c) above the bottom liner. Assume that the hydraulic conductivity of the drainage layer is 100 m/d (K) and the overall vertical hydraulic conductivity through the waste is 10^{-3}cm/s. Also, determine the flow rate through each lateral.

Solution :
Downward percolating water, $q_v = K_v = 10^{-3}$ cm/s = 10^{-5} m/s = 10^{-5} m³/ m²-s

$\therefore q = q_v L = 10^{-5} L$ m³/ m-s

$L = 2K(y_o^2 - y_c^2)/q = [2 \times 100 \times (0.305^2 - 0.10^2)] / [10^{-5} L \times (60 \times 60 \times 24)]$
$\therefore L = 4.38$ m

$q = q_v L = 10^{-5} \times 4.38 = 4.38 \times 10^{-5}$ m³/ m-s

verticle velocity
→ $V = Ki$
↑ verticle permeability

$i = \frac{\text{head diff}}{\text{path of travel}}$

for this type of flow $i = 1$

L-05

Problem 5:
The following three soils layers are lying between the base of a landfill and the underlying aquifer. How long will it take for leachate to migrate to the aquifer? Also, calculate the amount of leachate flowing down if the landfill area is 50 hectare

	Depth (m)	Porosity (%)	Permeability (m/s)
Soil A	2.0	42	3.0×10^{-9}
Soil B	2.5	44	2.0×10^{-8}
Soil C	3.0	43	5.8×10^{-7}

L-05

pore velocity / interstitial velocity

Solution:
Average interstitial velocity, $\upsilon_p = \frac{k}{\alpha}$ ← porosity

$(v_p)_A = (3.0 \times 10^{-9}) / 0.42$ m/s
$(v_p)_B = (2.0 \times 10^{-8}) / 0.44$ m/s
$(v_p)_C = (5.8 \times 10^{-7}) / 0.43$ m/s

$$\therefore \textit{Total travel time} = \left[\frac{2.0}{(3.0\times10^{-9})/0.42} + \frac{2.5}{(2.0\times10^{-8})/0.44} + \frac{3.0}{(5.8\times10^{-7})/0.43}\right]$$

$$\times \frac{1}{60\times60\times24\times365} = 10.69 \text{ years}$$

Equivalent permeability. $K_e = \dfrac{\sum d_i}{\sum \frac{d_i}{k_i}}$

$$= \frac{2.0+2.5+3.0}{\frac{2.0}{3.0\times10^{-9}} + \frac{2.5}{2.0\times10^{-8}} + \frac{3.0}{5.8\times10^{-7}}} = 9.41\times10^{-9} m/s$$

Flow Rate, $Q = vA = K_e A = 9.41 \times 10^{-9} \times (50 \times 10^4) \times (60 \times 60) = 16.94$ m^3/h

End of lec-05
05/11/16

Lec-06
12/11/16

Leachate Treatment

Due to a variety of physical, chemical and biological constituents in leachate, no single treatment method can be recommended.

Following are the important factors in the design of a leachate treatment system:

1. Quantity or rate of flow of leachate generated
2. Concentration of various contaminants
3. Available treatment and disposal options

Leachate treatment options are summarised in the following Table.

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Table: Summary of leachate treatment options

Treatment option	Removal objective	Comments
Biological		Best used on "young" leachate
Activated sludge	BOD/COD	Flexible, shock resistant, proven, minimum SRT increases with increasing organic strength, >90 % BOD_5 removal possible.
Aerated lagoons	BOD/COD	Good application to small flows, >90 % BOD_5 removal possible.
Anaerobic	BOD/COD	Aerobic polishing necessary to achieve high-quality effluent
Powered activated carbon	BOD/COD	>95 % COD removal >99 % BOD removal
Physical/chemical		Useful as polishing step or for treatment of "old" leachate
Coagulation/ precipitation	Heavy metals	High removal of Fe, Zn, moderate removal of Cr, Cu, Mn, little removal of Cd, Pb, Ni
Chemical oxidation	COD	Raw leachate treatment requires high chemical doses, better used as polishing step.
Ion exchange	COD	10-70 % removal, slight metal removal
Adsorption	BOD/COD	30-70 % COD removal after biological or chemical treatment
Reverse osmosis	TDS	90-96 % TDS removal

Needs further process → Not the final process

Physical chemical method

Very expensive method

CT

L-06

Leachate Recirculation

- Most sanitary landfills are traditionally constructed that the leachate is collected and treated prior to final discharge. The rate of stabilization in "dry" landfills may require many years, often preventing commercial recovery of methane gas and delaying closure and possible future use of the landfill site.

- In contrast, leachate recirculation option that requires the containment, collection and recirculation of leachate back through the landfilled waste offers more rapid stabilization within 2-3 years instead of the usual 15-20 years. This acclerated stabilization is enhanced by the routine and uniform exposure of microorganisms to constituents in the leachate, thereby providing the necessary contact time, nutrients, substrate for efficient conversion and degradation. The landfill becomes a dynamic anaerobic bioreactor.

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- Lechate can be recirculated to the landfill by
  - wetting of waste as it is placed
  - spraying of leachate over the landfill surface
  - injection of leachate into vertical columns or horizontal trenches installed within the landfill.

- Leachate recirculation increases the base flow of leachate from the landfill. The additional flow must be considered during design, especially following rain events. It is very important to have contingency plan when leachate generation exceeds on-site storage capacity.

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Final Disposal of Leachate

- Leachate may be disposed off through evaporation, recirculation back to the landfill, or on land, into sewers or waterbodies.
- Leachate evaporationis is carried out in evapration ponds with a suitable clay or geomembrane lining at the base and sides of the ponds. It is suitable for dry weather conditions and for low volume of leachate.
- Leachate recirculation is achieved by pumping the treated leachate to "dry" landfills and distributing the leachate into the landfills.
- The final disposal of the leachate in sewers, land or waterbodies should conform to the prescribed guidelines/standards laid down by the relevant authority.

** Only applicable for ... ??

L-06

Stormwater Management

- Stormwater management is very important for a landfill site.
- Surface runon into a landfill increases the volume of leachate generated and is usually controlled by constructing dikes at the periphery of the landfill site.
- Surface runoff from a landfill is to be maximized by applying soil cover maintaining suitable slope in order to reduce infiltration of stormwater into the landfill resulting in production of less amount of leachate. Surface runoff is to be properly drained out to prevent the erosion of the soil cover and the flooding of access roads. Improper drainage of stormwater may totally disrupt the movement of waste dump vehicles/trucks during heavy rainfall.
- Roadside drains are constructed to collect the stormwater runoff from all types of surfaces within the landfill and discharge it into the surrounding natural drainage channels. To prevent erosion of the top cover soil, saucer drains at the berms and top surface are constructed and connected to covered pipes which discharge the collected stormwater into the road side drains as shown in the following Figure.
- The dimensions of a drain/pipe depend on design rainfall, size and geometry of the catchment area, and slope and type of the drainage surfaces.

1-06

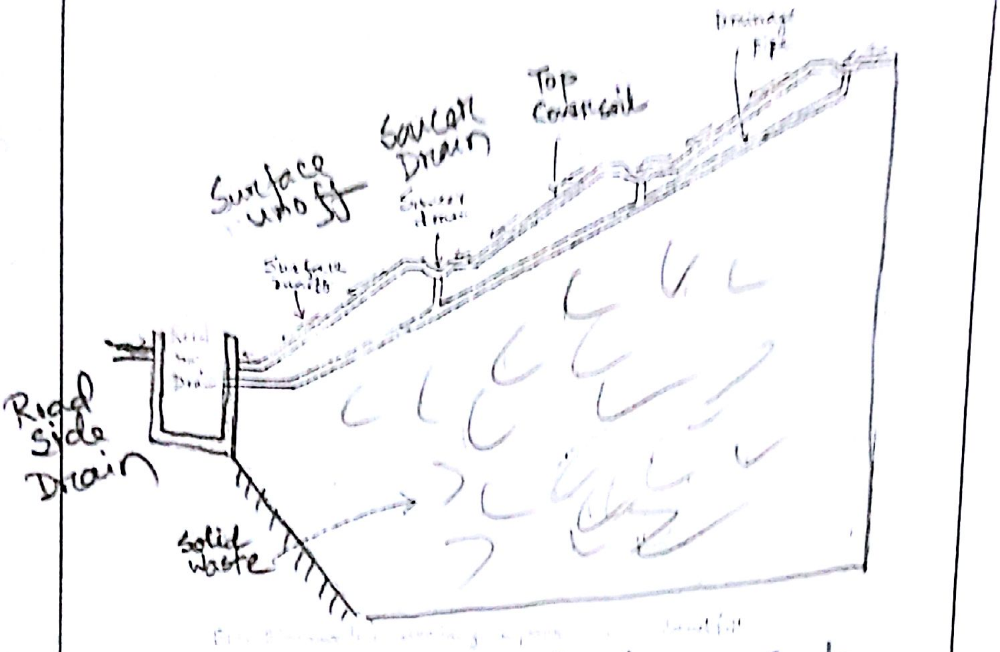

Fig: stormwater drainage system in a landfill

Design considerations for Designing Road side Drain — Total amount of flow coming from landfill side