Disposal of Solid Wastes.

Landfills — are physical facilities used for disposal of residual Solid Wastes in the Surface Soils of the earth.

Sanitary landfill — refers to an engineered facility for the disposal of MSW, designed and operated to minimize public health & environmental impacts.

Secure Landfills — for disposal of Hazardous Wastes.

Landfilling — is the process by which residual Solid wastes are placed in a landfill.

- Cell, Daily cover of 6-12 inchs native Soil, lift, bench or terrace, final lift, final cover material or layer, leachate, landfill gas, Landfill liners,

(2)

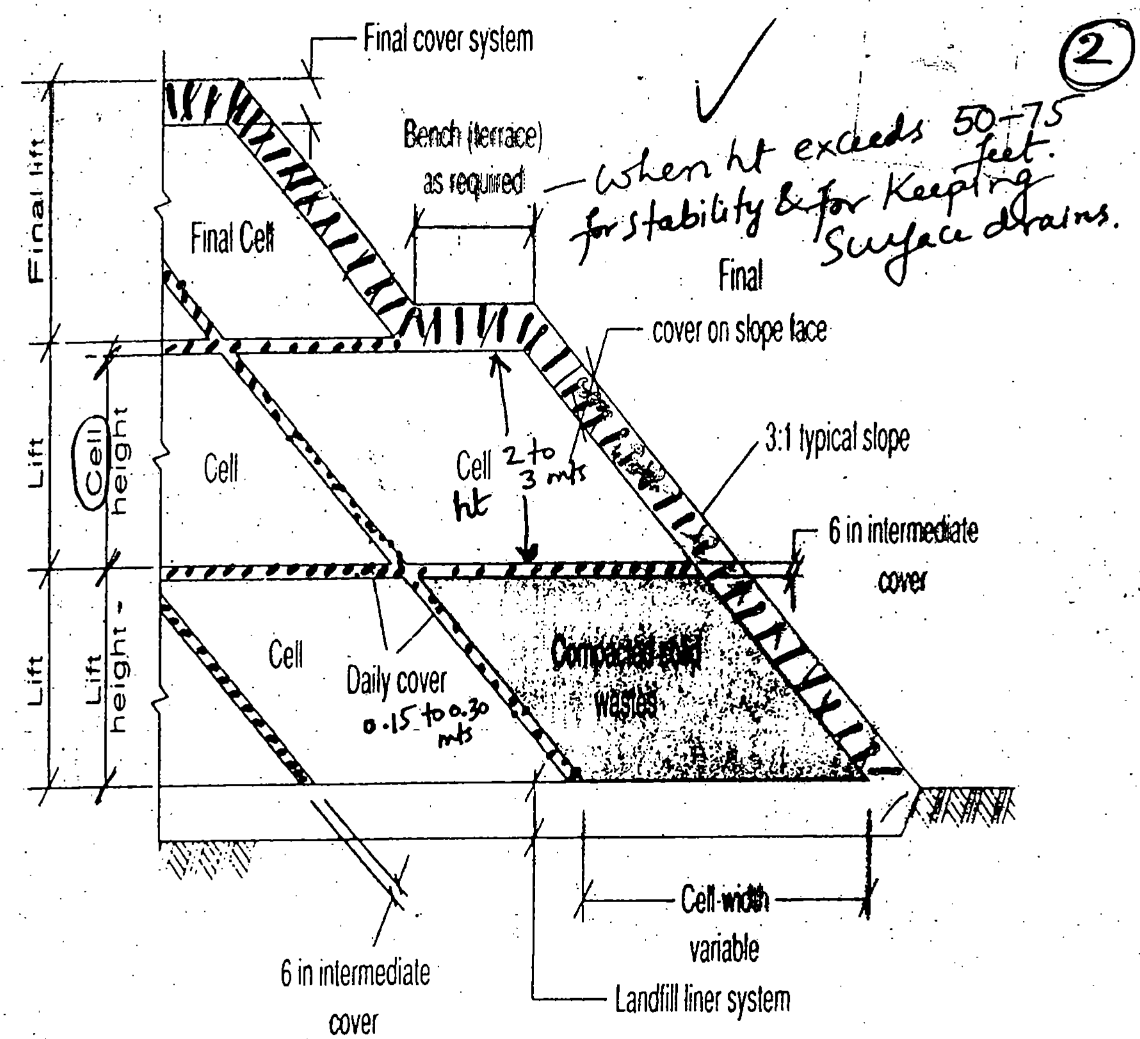


FIGURE 11-2
Sectional view through a sanitary landfill.

Landfill control facilities, landfill monitoring, landfill closure, post closure (typically for 30 – 50 years).

✓ Density of waste varies from 0.4 – 1.25 t/m³.
For Design 0.85 t/m³ for Biodegradable wastes.
1.1 t/m³ for inert waste.

Sanitary landfill – Sanitary landfill (2a) is a technique for the final disposal of Solid waste in the ground that causes no nuisance or danger to public health or safety, neither does it harm the environment during its operation or after its closure.

3 types of Sanitary Landfills are:–

(1) **Mechanized Sanitary landfill:–** For large cities generating more than 40 tonnes/day of SWs requires heavy equipments like track type tractor, backhoe, loader, dump truck, drag liner etc.

(2) **Semi-mechanized Sanitary landfill:–** For cities & towns generating 16–40 tonnes/day of SWs, it is advisable to use heavy machinery to support manual Labour.

(3) **Manual Sanitary landfill:–** For Small towns generating less than 15 tonnes/day of SWs, only manual labours are used.

Landfill Siting Considerations :-

Factors that must be Considered for Siting a new landfill Site are :-

① Haul distance — minimum haul distance are desirable. (To achive economy).

② Location Restrictions — Near Airports, in flood plains, in wetlands, in areas of Know faults, in Seismic Impact zones, unstable areas etc. [▶ away from highway by 50 m, 500m from Habitation, 200m away from Lake, 300m from public parks etc.]

③ Available land area — It is desirable to have sufficient area, including adequate buffer zone, to operate for atleast 5 years, at an aquired site. minimum life of site should be 5 years.

④ Site Access — As far as possible near existing wider roads.

⑤ Climatologic Conditions — Local weather plays an Imp. role. Rainfall, temperature, humidity, wind direction & speed etc.

(6) <u>Surface water hydrology</u> — Natural drainage & runoff characteristics must be considered.

✓ Flooding (e.g., limits of 100 year-flood), must be identified.

(7) <u>Hydrogeologic & Geologic Conditions</u> —

• most imp. factors. Type of soil & ground - water conditions may lead to pollution due to leachate movement & gas movements. (GW table > 2 m)

(8) <u>Local Environmental Conditions</u> —

Very difficult to operate near residential area because of traffic, noise, odor, dust, airborne debris, visual impact, vector control, hazards to health & property values.

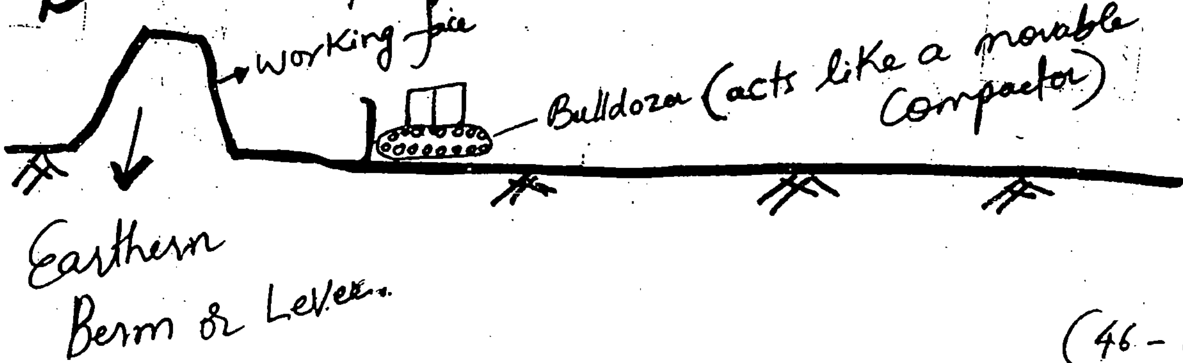
(9) <u>Ultimate use for completed landfills</u> —

For parks, playground, vegetation, parking lots, small sheds, etc.

Preparation of the Site for Landfilling :- (5)

- ✓ Existing drainage must be modified to divert rain water from entering into landfill area.
- ✓ Construction of access roads.
- ✓ Weigh bridge.
- ✓ Fences allaround the area.
- ✓ In Sections preparation of landfill trenche's bottom & Sides by providing liners.
- ✓ Leachate collection & extraction facilities are placed on top or within the liner.
- ✓ pipes are laid for CH_4 gas extraction.
- ✓ monitoring wells are drilled at various points, in and around landfill site.
- ✓ Resting Shed for workers & Garage for parking & Servicing of landfill equipments, medical facilities for Workers etc. Drinking water facilities.

Placement of S.Wastes :-



- ✓ Thickness of each SW layer 18–24 inches (46 – 60 cms)
- ✓ Typical cell height – 8–12 feet. (2.5–3.5m)
- ✓ Width of cell 10–30 feet. (3–9 mt)
- ✓ Each cell is covered with a soil cover of 6–12 inches (15 – 30 cms). [or at the end of each operating period].
- ✓ After completion of filling, a final cover layer has to be provided with adequate slope. (Say 1 in 200).
- ✓ Vertical or horizontal gas extraction wells may be installed & extracted gas may be flared or routed to energy recovery facilities.

Post closure management -

Monitoring & maintenance of completed landfills must continue for (by law) some atleast 30-50 years.

Reactions Occuring in Landfills -

✓ Physical reactions → ✓ Lateral diffusion of landfill gases like CO_2, H_2S, CH_4, NH_3 etc.

✓ movement of leachate.

✓ Settlement caused by compaction & consolidation and decomposition of materials.

✓ Chemical reactions → ✓ Dissolution & suspension of SWs.

✓ Evaporation & vaporization of chemical compounds.

✓ oxidation-reduction reactions within SWs because of org. matter.

✓ Release of gases & acids making SWs in cells acidic in nature.

Biological reactions-

- Initially oxidation of org. matter. (CO_2)
- Once O_2 gets depleted reduction or putrefaction with the release of CO_2, CH_4, trace amounts of H_2S & NH_3 gases. Along with these gases H_2O is also released.

Classification of Land fills-

I ⟶ Hazardous Waste.

II ⟶ Designated waste.

III ⟶ Municipal Solid waste (MSW).

Types of Landfills-

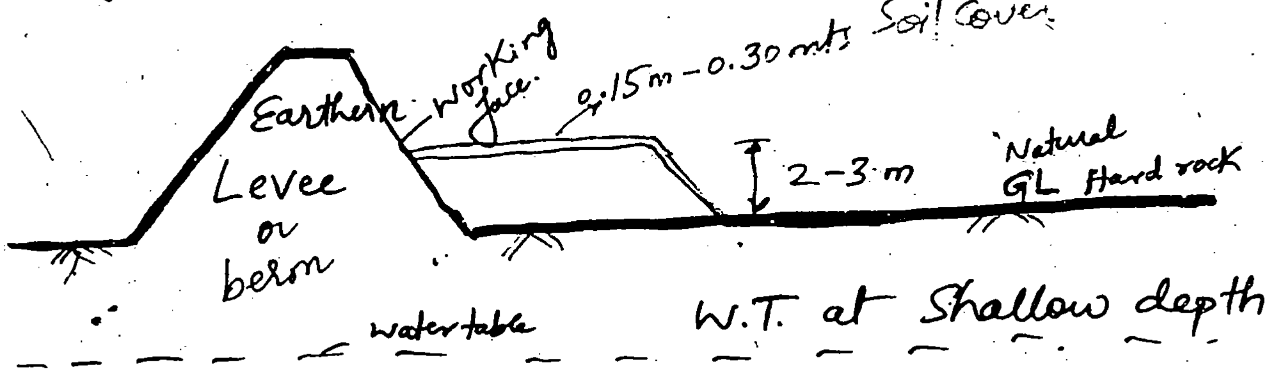
1. Landfills for Commingled MSW.
2. Landfills for Shredded Solid wastes.
3. Landfills for Individual waste Constituents. (monofills) Ex:- Ash, asbestos etc.
4. Landfills designed to maximise gas production. (Methane gas)
5. Landfills as integrated treatment units.

Land filling methods.

(9)

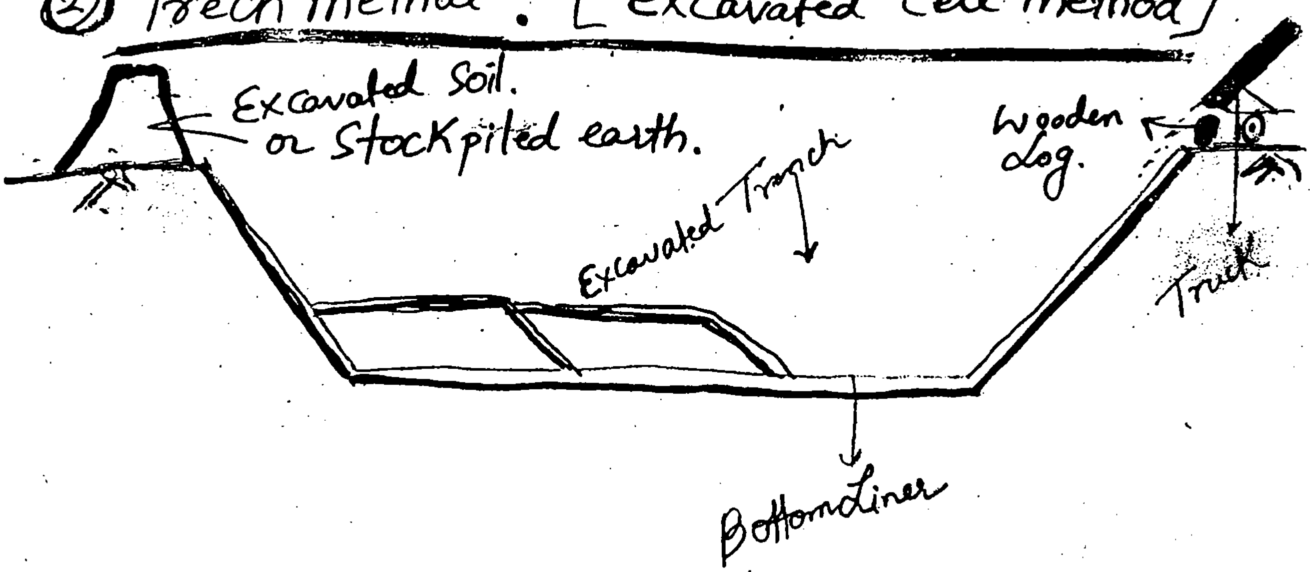
① Area method ÷ when excavation is not possible due to Shallow WT or hard rock beds.

✓ Cover material must be hauled in trucks or earthmoving equipment from adjacent land or from borrow pits.



② Trech method ÷ [Excavated Cell method]

Also called pit method



✓ Water table is at greater depth and soil is soft for easy excavation, to get enough cover material.

✓ Holding capacity of landfill site increases tremoundously.

✓ Liners at sides and at bottom is a must.

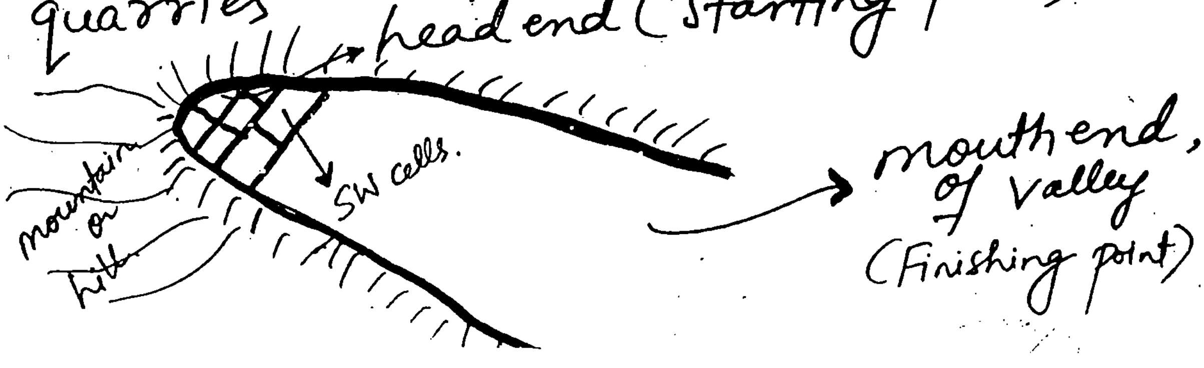
✓ Trenches are typically square 1000 ft width × 1000 ft length. (Even Rect)

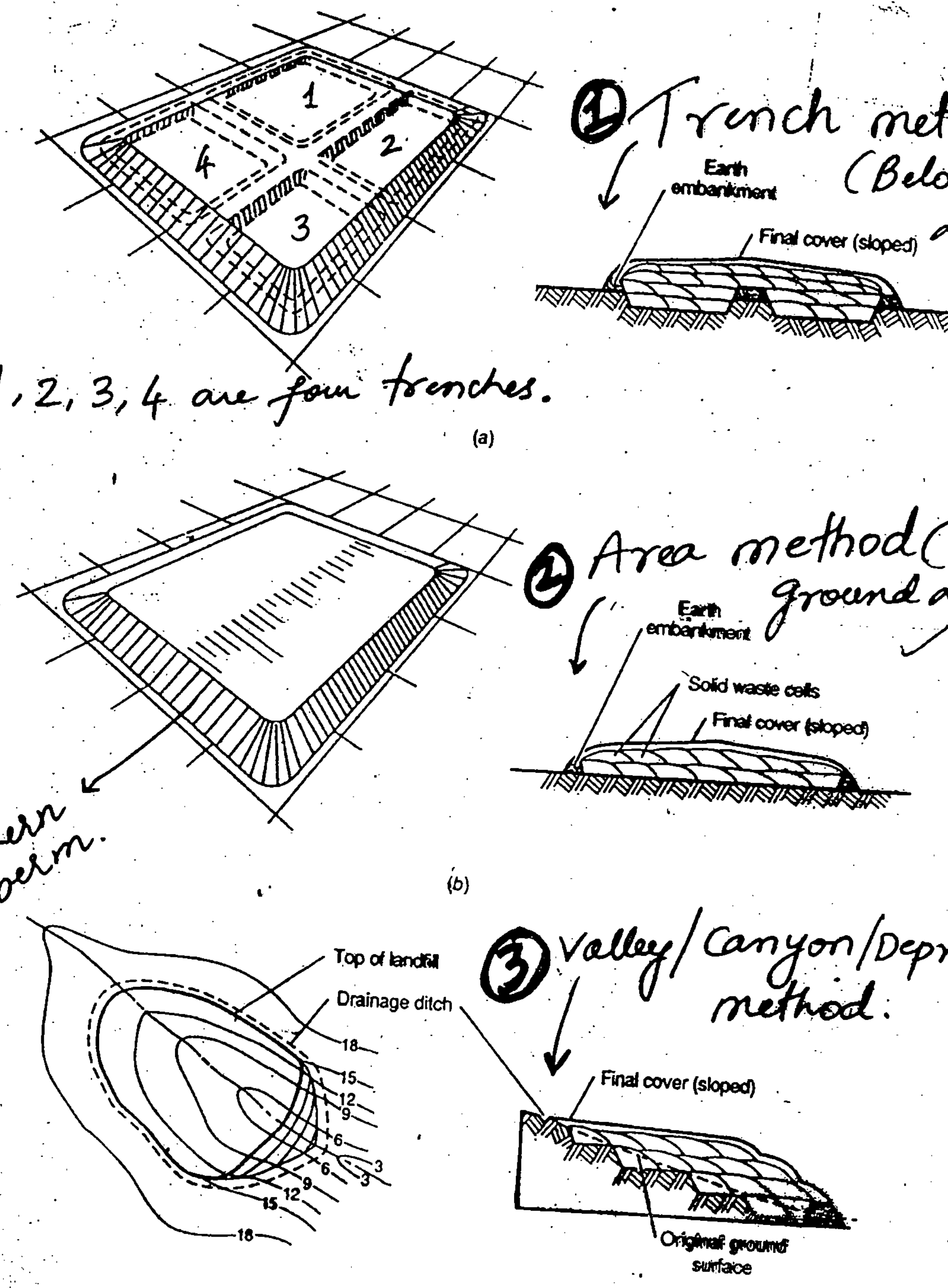
✓ Side slopes of 1.5 : 1 to 2 : 1. [18.4° to 26.5 degrees]

✓ If rectangular → 200 – 1000 ft Length
15 – 50 ft width
3 – 10 ft depth.

③ Canyon / Valley / Depression method :-

✓ Canyons, ravines, dry borrow pits, quarries are used.





① Trench method (Below ground Landfill)

1, 2, 3, 4 are four trenches.

② Area method (Above ground Landfill)

Earthern berm.

③ Valley/Canyon/Depression method.

FIGURE 11-7
Commonly used landfilling methods: (*a*) excavated cell/trench, (*b*) area, and (*c*) canyon/depression.

RIVER OF SORROW - Hwang-Ho (China)
COURCE CHANGE - CHAMBAL (RAVINES)
↓
India.

✓ The availability of cover material is the Key for Successful use of Valley or Canyon or depression method. (11)

✓ Another major problem is diversion of huge quantity Surface runoff, coming down from hills.

Classification of Landfilling.

- Small size Landfill = < 5 hectares area.
- medium Size landfill = 5–20 hectares area.
- Large Size landfill = > 20 hectares.

{Note:- 1 hectare = 10,000 m^2.}

(4) Combination of both Area & trench methods–

- Since these two methods of Constructing Sanitary landfills use Similar operating techniques it is possible to combine them to make full use of site & cover material, and to obtain better results. This method is becoming more popular as it can accomodate more SWs in trenches.

Ramp method:—

- A Combination method is called a progressive Slope or ramp method, where the depositing, Covering, and compacting are performed on slope.
- The covering Soil is excavated infront of the daily cell.

Advantages & disadvantages of the Sanitary Landfill:—

Advantages: ① The initial capital investment is lower than that required to establish incinerator plants or composting facilities for waste treatment.

② It creates employment for unskilled labour, which is available in abundance in developing countries.

③ methane gas is collected and this gas canbe an alternate Source of energy for Some citie.

(4) It has lower operating and maintenance expenses than other treatment methods.

(5) It allows lands considered unproductive to be recuperated, making them useful for constructing parks, playgroun recreational facilities, green areas, etc.

Disadvantages:- (1) The acquisition of the terrain is often a problem due to local inhabitants opposition to the Selected Site. [Known as the NIMBY phenomenon: Not In My Back Yard].

(2) The rapid process of urban growth that limits the amount of land available and makes it more expensive, causing the Sanitary landfill to be located at a distance from the city.

(3) The finished landfills are not recommended for building homes, Schools etc.

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(4) The restriction against building heavy infrastructure because of settling & sinking after the landfill is finished.

(5) Hazardous wastes cannot be dumped in Sanitary landfills. (Ex: Love canal incident in USA)

(6) It can cause a longterm environmental impact if necessary precautions are not taken in the selection of site and if mitigation measures are not applied.

(•) It may cause ground water pollution, release of greenhouse gases, breeding place for flies & rodents, flying debris, bad odors, increase in vehicular traffic on roads, etc.

(7) The properties or lands surrounding the Sanitary landfill may be devalued.

Importance of Soil Cover:-

- 6" or 12" Soil cover at the end of each days operation has following advantages:
- minimize the presence & proliferation of flies.
- Prevent the entry & proliferation of rodents.
- prevents fire & Smoke.
- Reduce bad odors. (H_2S gas).
- Reduce the intake of rainwater into the SW cells.
- Direct gases towords the Vents to evacuate them from the Sanitary landfill.
- Have an aesthetically acceptable appearance
- Allow growth of vegetation.
- The heat released due to anaerobic decomposition is retained within the cell, which further helps in faster decomposition of biodegradable wastes.

Typical equipments used in Landfills:–

 (15)

Note– They are very heavy, hence also they act as movable Compactors.

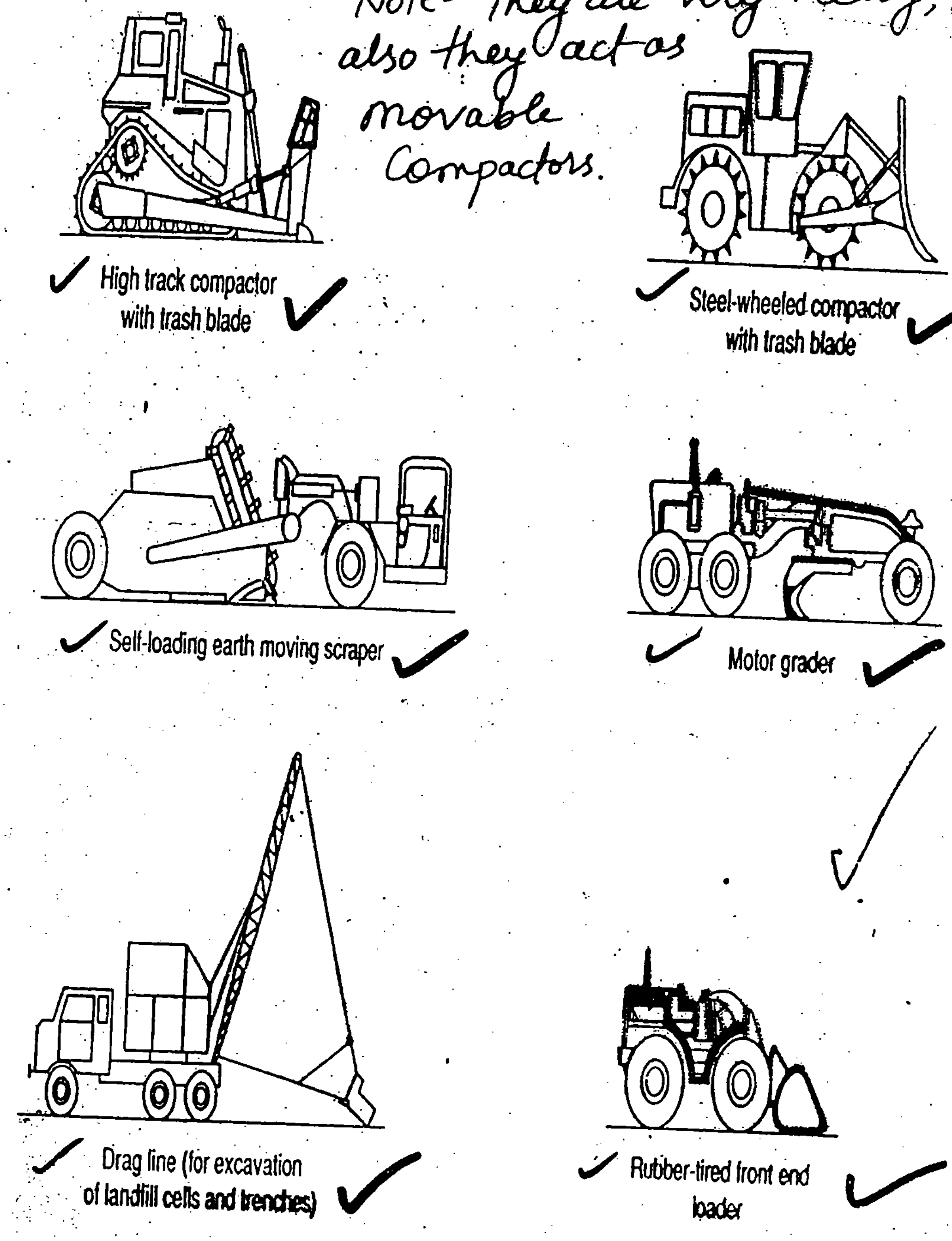

FIGURE 11-68
Typical equipment used at landfills for the placement and covering of solid waste.

Table 11-15 Important factors that must be considered in the design and operation of solid-waste landfills

Factor	Remarks
Design	
Access	Paved all-weather access roads to landfill site; temporary roads to unloading areas.
Cell design and construction	Will vary depending on terrain, landfilling method, and whether gas is to be recovered.
Cover material	Maximize use of on-site earth materials; approximately 1 m^3 of cover material will be required for every 4 to 6 m^3 of solid wastes; mix with sealants to control surface infiltration. In some designs, intermediate cover is not used.
Drainage	Install drainage ditches to divert surface-water runoff; maintain 1 to 2 percent grade on finished fill to prevent ponding.
Equipment requirements	Vary with size of landfills.
Fire prevention	Water on-site; if nonpotable, outlets must be marked clearly; proper cell separation prevents continuous burn-through if combustion occurs.
Groundwater protection	Divert any underground springs; if required, install sealants for leachate control; install wells for gas and groundwater monitoring.
Land area	Area should be large enough to hold all wastes for a minimum of 1 yr but preferably 5 to 10 yr.
Landfilling method	Selection of method will vary with terrain and available cover. & GW.
Litter control	Use movable fences at unloading areas; crews should pick up litter at least once per month or as required.
Operation plan	With or without the codisposal of treatment plant sludges and the recovery of gas.
Spread and compaction	Spread and compact waste in 0.6-m (2-ft) layers.
Unloading area	Keep small, generally under 30 m (100 ft).
Operation	
Communications	Telephone for emergencies.
Days and hours of operation	Usual practice is 5 to 6d/wk and 8 to 10 h/d.
Employee facilities	Restrooms and drinking water should be provided.
Equipment maintenance	A covered shed should be provided for field maintenance of equipment.
Operational records	Tonnage, transactions, and billing if a disposal fee is charged.
Salvage	No scavenging; salvage should occur away from the unloading area; no salvage storage on-site.
Scales	Essential for record keeping.

Source: From Tchobanoglous et al. [11-8]

(17)

TABLE 11-27
Important factors that must be considered in the operation of landfills

Factors	Remarks
Days and hours of operation	Usual practice is 5 to 6 d/wk and 8 to 10 h/d
Communications	Telephone for emergencies
Employee facilities	Restrooms and drinking water should be provided
Equipment maintenance	A covered shed should be provided for field maintenance of equipment
Litter control	Use movable fences at unloading areas; crews should pick up litter at least once per month or as required
Operation plan	With or without the codisposal of treatment plant sludges and the recovery of gas
Operational records	Tonnage, transactions, and billing if a disposal fee is charged
Salvage	No scavenging; salvage should occur away from the unloading area
Scales	Essential for record keeping if collection trucks deliver wastes; capacity to 100,000 lb (45000 Kgs or 45 tonnes)
Security	Provide locked gates and fencing; lighting of sensitive areas
Spread and compaction	Spread and compact waste in layers less than 2 ft thick to achieve optimum compaction
Unloading area	Keep small, generally under 100 ft on a side; operate separate unloading areas for automobiles and commercial trucks

(18)

TABLE 11-23
Important factors to consider in the design of landfills

Factors	Remarks
Access	Paved all-weather access roads to landfill site; temporary roads to unloading areas.
Land area	Area should be large enough to hold all community wastes for a minimum of 5 yr, but preferably 10 to 25 yr; area for buffer strips or zones must also be included.
Landfilling method	Landfilling method will vary with terrain and available cover; most common methods are excavated cell/trench, area, canyon (see Figs. 11-7, 11-8, and 11-9).
Completed landfill characteristics	Finished slopes of landfill, 3 to 1; height to bench, if used, 50 to 75 ft; slope of final landfill cover, 3 to 6%.
Surface drainage	Install drainage ditches to divert surface water runoff; maintain 3 to 6% grade on finished landfill cover to prevent ponding; develop plan to divert stormwater from lined but unused portions of landfill.
Intermediate cover material	Maximize use of onsite soil materials; other materials such as compost produced from yard waste and MSW can also be used to maximize the landfill capacity; typical waste to cover ratios vary from 5 to 1 to 10 to 1.
Final cover	Use multilayer design (see Fig. 11-53); slope of final landfill cover, 3–6%.
Landfill liner	Single clay layer (2 to 4 ft) or multilayer design incorporating the use of a geomembrane (see Figs. 11-36, 11-39, and 11-40). Cross slope for terrace type (see Fig. 11-39) leachate collection systems, 1 to 5%; maximum flow distance over terrace, 100 ft; slope of drainage channels, 0.5 to 1.0%. Slope for piped type (see Fig. 11-40) leachate collection system, 1 to 2%; size of perforated pipe, 4 in; pipe spacing, 20 ft.
Cell design and construction	Each day's wastes should form one cell; cover at end of day with 6 in of earth or other suitable material; typical cell width, 10 to 30 ft; typical lift height including intermediate cover, 10 to 14 ft; slope of working faces, 2:1 to 3:1.
Groundwater protection	Divert any underground springs; if required, install perimeter drains, well point system, or other control measures.
Landfill gas management	Develop landfill gas management plan including extraction wells (see Fig. 11-20), manifold collection system, condensate collection facilities (see Fig 11-25), the vacuum blower facilities, and flaring facilities (see Fig. 11-27) and/or energy production facilities (see Fig. 11-29). Operating vacuum at well head, 10 in of water.
Leachate collection	Determine maximum leachate flow rates and size leachate collection pipe and/or trenches; size leachate pumping facilities; select collection pipe materials to withstand static pressures corresponding to the maximum height of the landfill.
Leachate treatment	Based on expected quantities of leachate and local environmental conditions, select appropriate treatment process (see Table 11-18 and Fig. 11-46).
Environmental requirements	Install vadose zone gas and liquid monitoring facilities; install up- and downgradient groundwater monitoring facilities; locate ambient air monitoring stations.
Equipment requirements	Number and type of equipment will vary with the type of landfill (see Figs. 11-68 and 11-69) and the capacity of the landfill (see Table 11-26).
Fire prevention	Water onsite; if nonpotable, outlets must be marked clearly; proper cell separation prevents continuous burn-through if combustion occurs.

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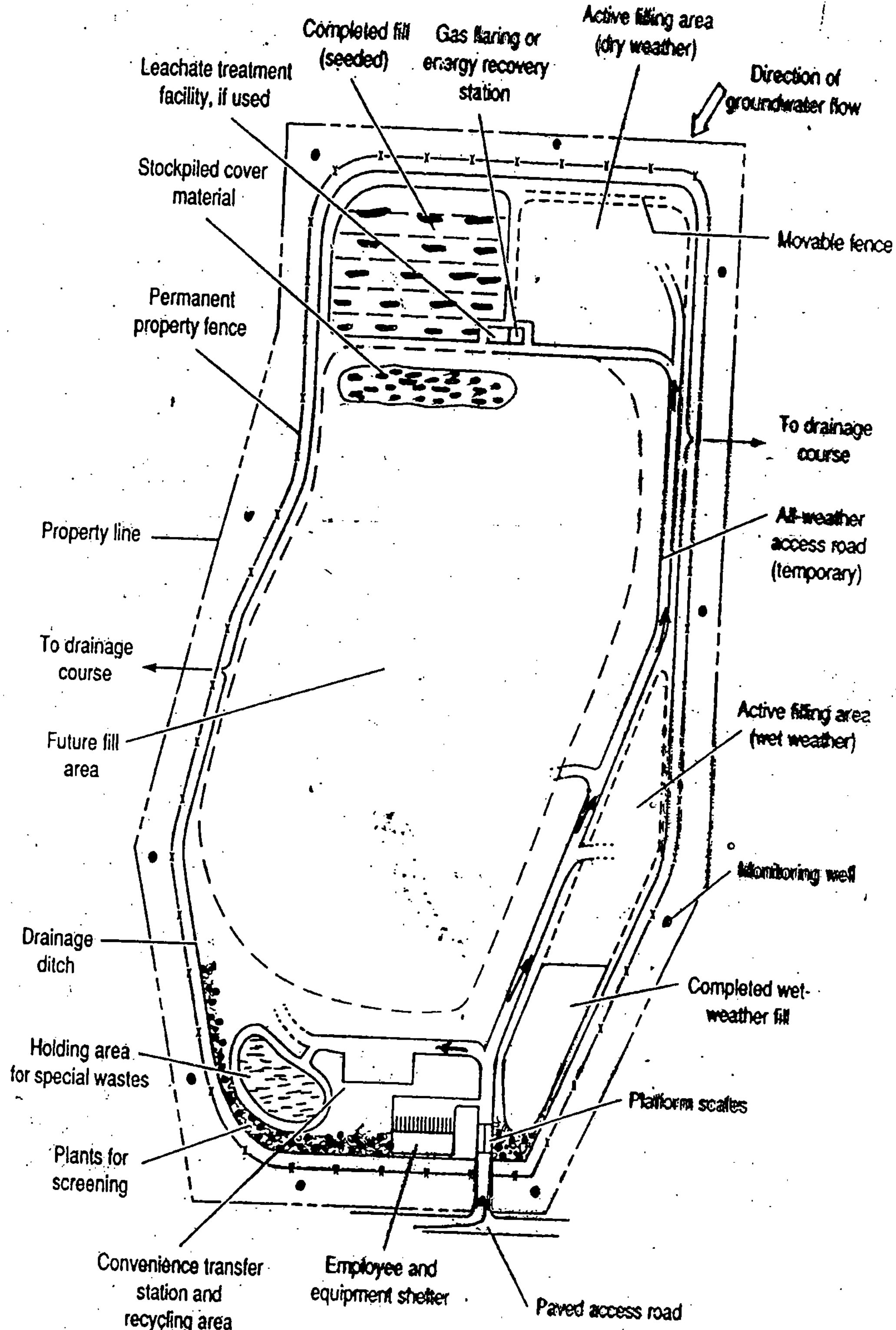

FIGURE 11-63
Typical layout of a landfill site.

Development & Completion of a Solid waste Landfill.

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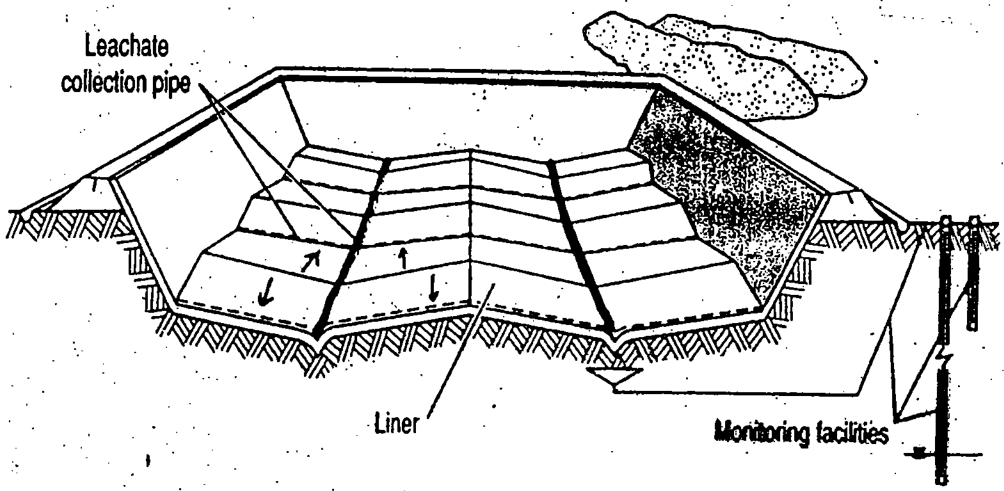
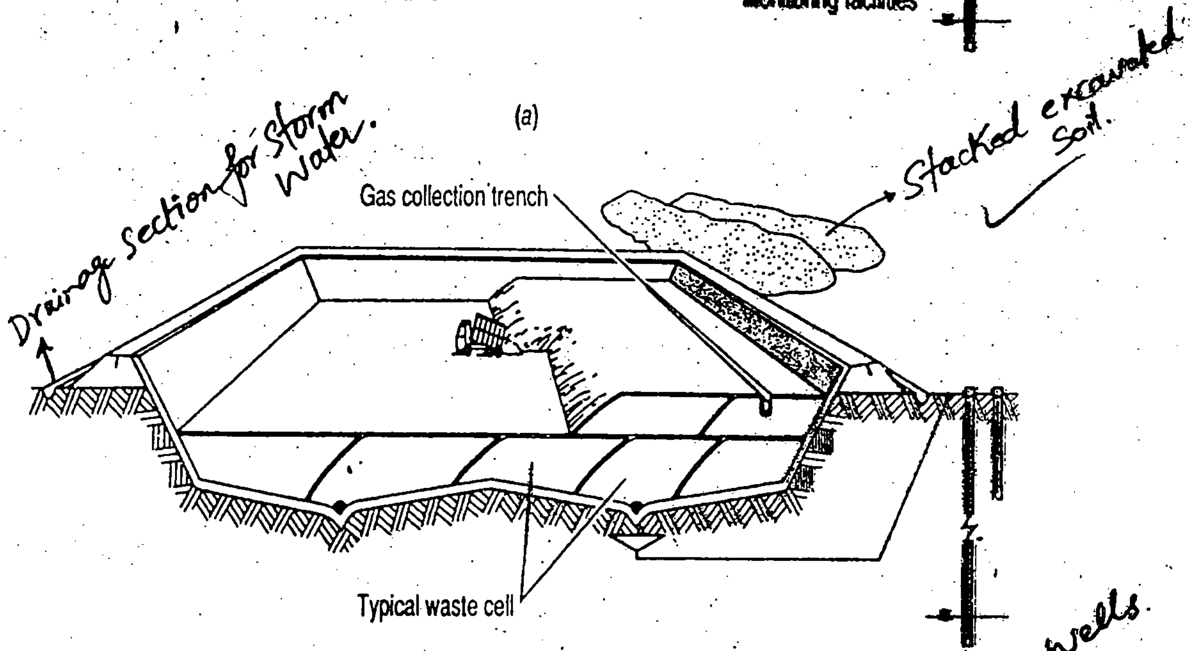


(a)



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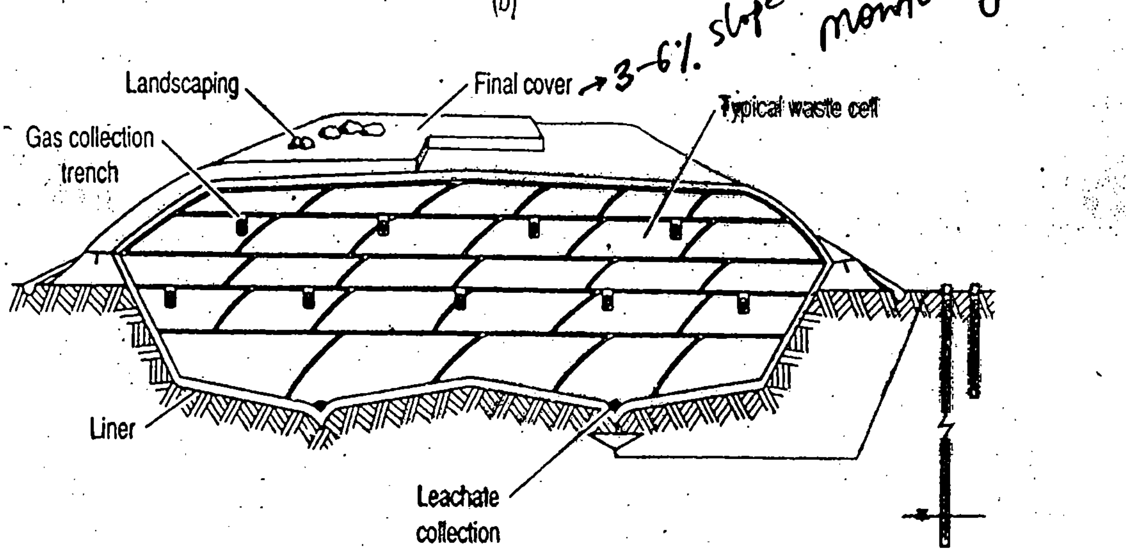

Typical Landfill final cover Configurations.

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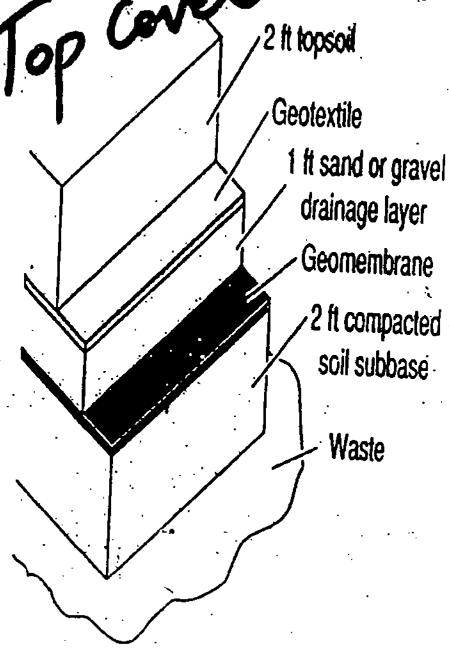
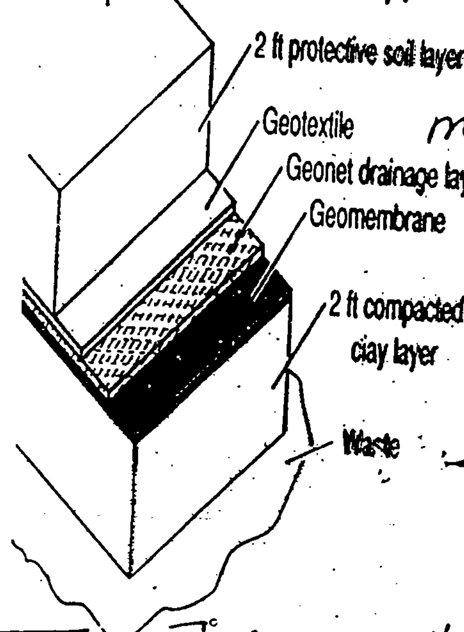
✓ The top Soil has to Support vegetation growth.

Final Cover must enhance Surface drainage, minimize infiltration.

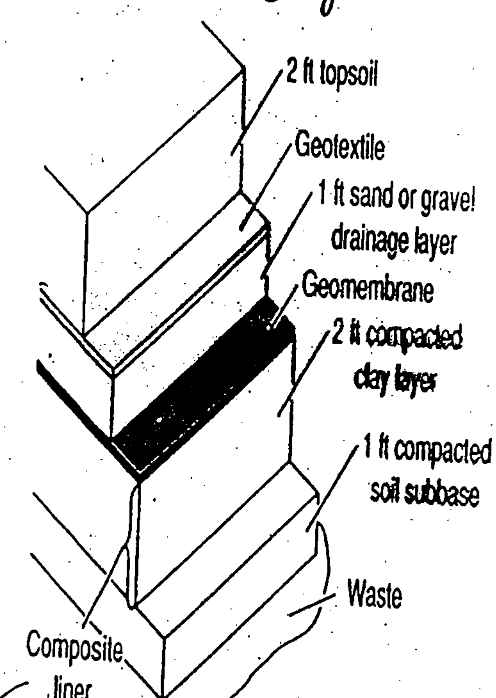
Top Cover

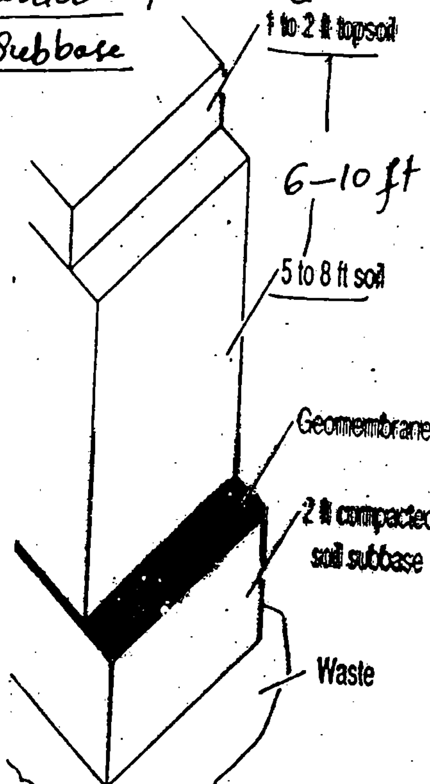




Typical Components (a) of landfill Cover.

- Surface layer] Locally available soil.
- Protective layer]
- Drainage layer] (b) Sand, gravel
- Barrier layer → Geomembrane.
- Subbase ← Compacted clay.





6–10 ft soil cover.

✓ In place of geomembrane, Astro-turn can also be used.

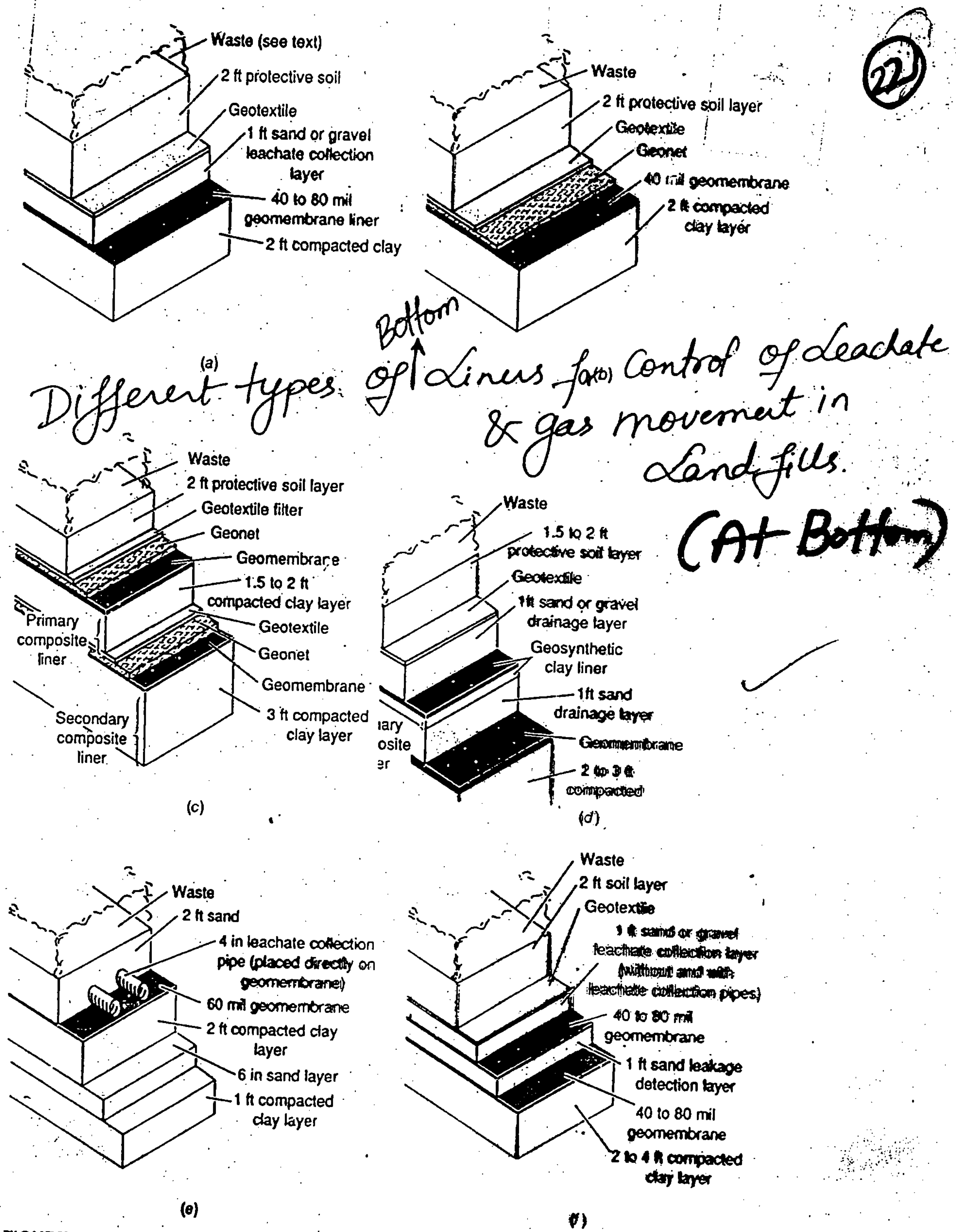
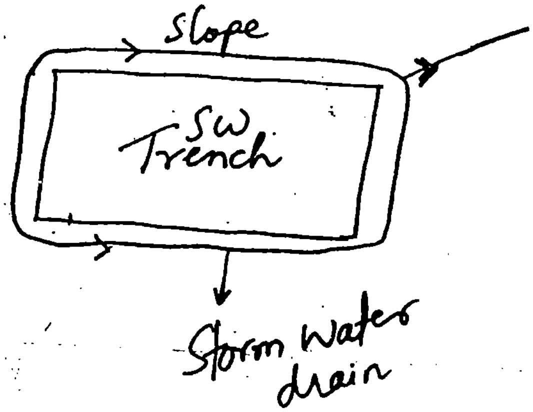
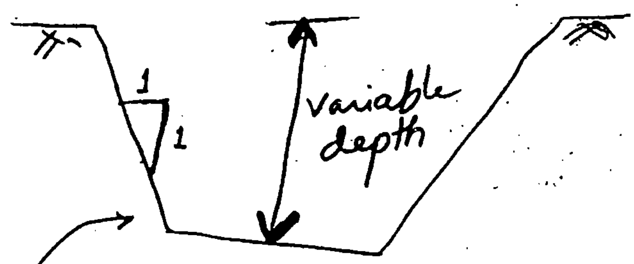


FIGURE 11-36
Typical landfill liners: (*a*, *b*) single-composite barrier types and (*c*–*f*) double-composite barrier types. Note in the double-liner systems the first composite liner is often identified as the primary liner or as the leachate collection system, while the second composite liner is identified as the leachate detection layer. Leachate detection probes are normally placed between the first and second liners.

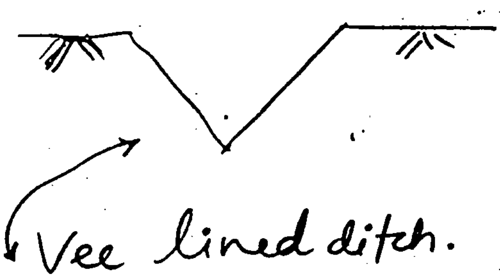
Surface water management.

✓ Rainfall, Stormwater runoff, intermittent streams or artesian Springs.





Trapezoidal lined ditch.



Vee lined ditch.

Shaped vee lined ditch.

Landfill closure & postclosure care -

closed landfills have to be maintained for 30-50 years into the future from the date stopping landfilling in that site.

Composition & Characteristics, generation, movement & Control of Landfill gases.

✔ The principal gases — CO_2, CH_4, (under anaerobic reduction or putrefaction)
Trace gases — NH_3, H_2S, N_2, O_2, CO, H_2, etc.

✔ When CH_4 is present in air in Conc between 5–15%, it is explosive.

Generation of principal landfill gases & Leachate in different phases.

phase I = Initial Adustment phase, in which (Org) biodegradable components in MSW gets oxidized under aerobic Conditions.

phase II = Transition phase, oxygen gets depleted & anaerobic Conditions begin to develop.

phase III = Acidphase → First Step – Enzyme mediated transformation (hydrolysis) of

higher molecular mass Compounds (2)
(eg. lipids, polysaccharides, proteins, & nucleic acids) into Compounds suitable for use by micro-organisms. (Acidogens or acid former bacterias).

<u>Second Step is</u> acidogenesis, the acidogens (bacterias) convert the complex acids into simpler lower molecular mass acids like acetic acid [CH_3COOH] and small concentrations of fulvic acid.

✓ CO_2 is the principal gas, with H_2 gas produce.

✓ The pH of leachate will drop below 5 or lower. There is an increase in the BOD_5, COD & conductivity of Leachate.

✓ Due to low pH heavy metals will be solubalized.

✓ many essential nutrients also gets mixed up with Leachate.

phase 4 – methane fermentation ③

phase, methenogens or methane formers Convert acetic acid & H_2 gas in CH_4 & CO_2.

✓ Due to Conversion of acids pH will again, rise to above 6.5.

✓ The BOD_5, COD & Sp. Conductivity of leachate will reduce significantly.

phase 5 – maturation phase, occurs after all the readily available BO have been Converted to CH_4 & CO_2.

✓ The gas generation diminishes slowly.

✓ The leachate will contain fulvic & humic acids, which are complex for decomposition, by anaerobic bacterias.

(30)

Generalized phases in generation of Landfill gases.

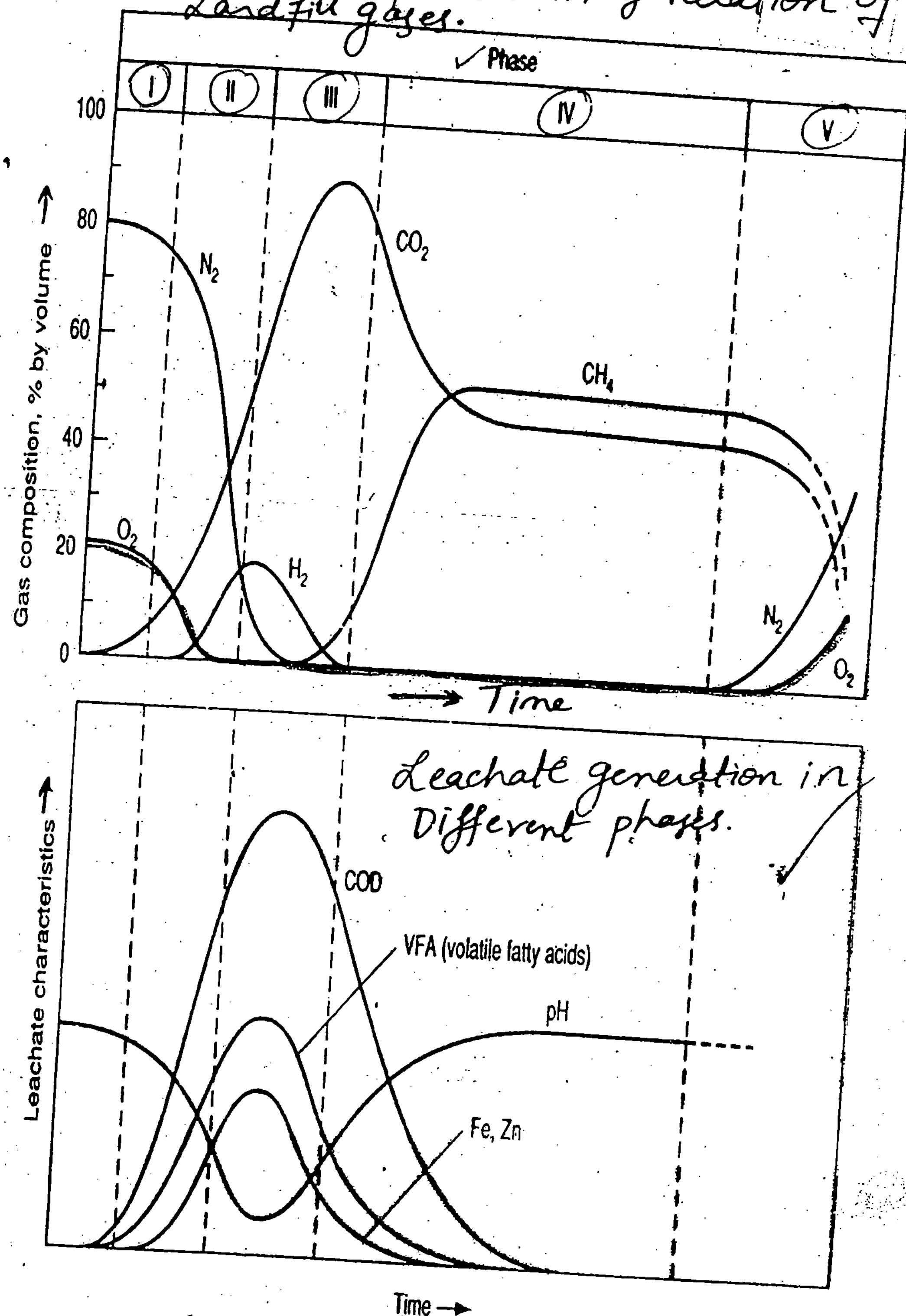


FIGURE 11-11 phase I – Initial adjustment.
phase II – Transition phase.
phase III – Acid phase.
phase IV methane fermentation, phase V – maturation

(·) Injection into a gas distribution grid.

The potential volume of landfill gas generation can be estimated to be 200–300 m^3/tonne msw.

(CPHEEO) Typical Constituents of MSW gas.

:: Major Constituents	Range
Methane (CH_4)	30–60% ← major
CO_2 Carbon dioxide	34–60% gases
Nitrogen (N_2)	1–21%
O_2	0.1–2%
H_2S Hydrogen Sulphide	0 to 1%
Co Carbon monoxide	0–0.2%
Hydrogen (H_2)	0–0.2%
Ammonia (NH_3)	0.1–1%
:: Trace Constituents	0–240 ppm.
Acetone	0–39 ppm.
Benzene	0– 12 ppm.
chloroform	

Time duration of phases :- It varies and depends upon :

(1) Distribution of org. components.
(2) Availability of nutrients. (%)
(3) Moisture Content.
(4) Degree of initial compaction.

[varies from 1 day to 5 years]

Volume of Gas Produced :-

✓ Org matter + H_2O $\xrightarrow{\text{bacteria}}$ biodegraded org. matter + CH_4 + CO_2 + heat + water + other gases.

• If Generalized formula for org. matter found in MSW → $C_aH_bO_cN_d$, then volume of gas produced = ↓

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c-3d}{4}\right)H_2O \longrightarrow \left(\frac{4a-b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b+2c+3d}{8}\right)CO_2 + dNH_3.$$

✓ In general org. matter present in SWs can be divided into 2 groups :-

(1) Materials that decompose within 3 mon.

(2) materials that will decompose upto 50 years. (5)

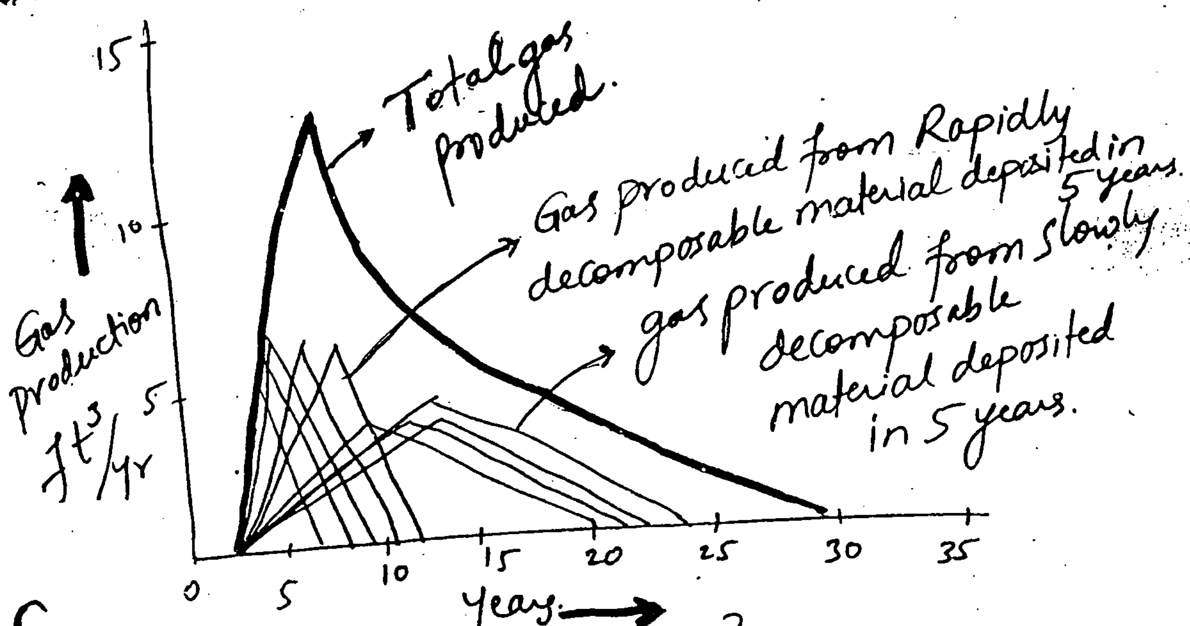
✓ Foodwastes, Newspaper, Cardboard, yard wastes, (leaves & grass trimmings) are example for **readily biodegradable** OM.

✓ Textiles, rubber, leather, wood, misc organic are **slowly biodegradable** OM.

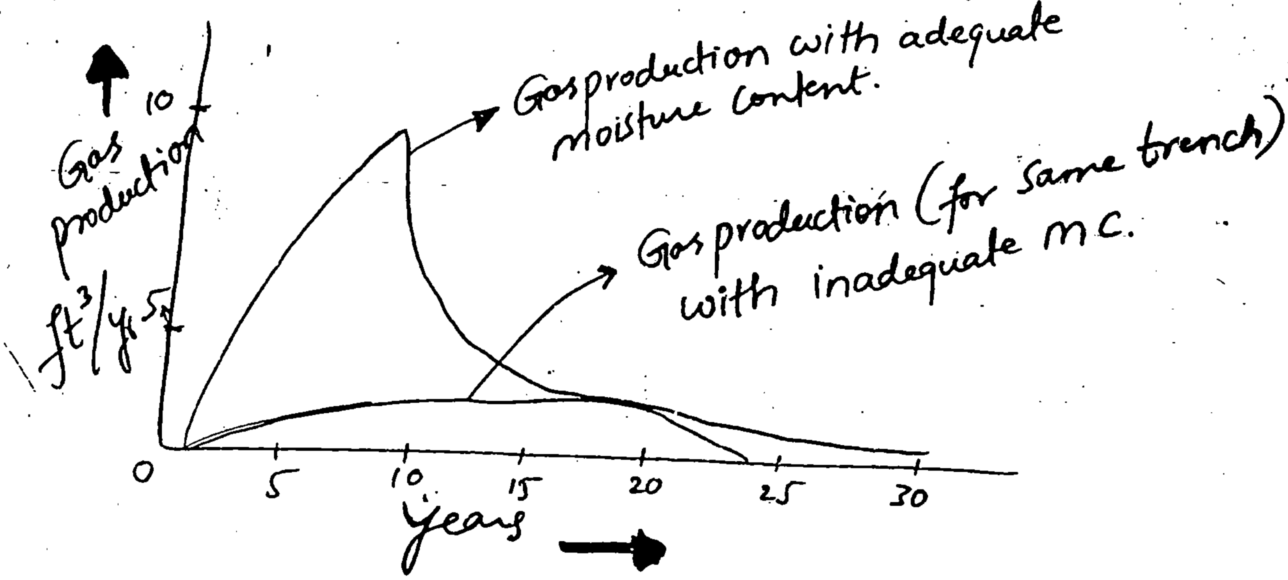
✓ plastics are non-biodegradable.

✓ Gas outputs of 10-20 m^3/hr corresponds to 50-100 KW of Electric Energy.

Variation of gas Production with time.



- The gas production reaches peak within first 2 years then slowly tapers off, continuing for upto 25 years or beyond it. (maxi of 50 years).
- optimum moisture content → 50–60%.



Movement of Landfill gases :-

- Usually under normal conditions the gas produced are released to the atmosphere by means of molecular diffusion.
- Both CO_2 & CH_4 have been found at a conc. of 40% at lateral distances of 400 ft from edges of unlined landfills.

- Both CH_4 & CO_2 are green house gases, [GhGs], causing green house effect (GHE). (7)

- CO_2 is 1.5 times denser than air & 2.8 times denser than CH_4, hence it moves towords the bottom of landfills.

- Some qty. of these gases also move upword & escape into the atmosphere by convection & diffusion.

- ordinary clay liners cannot prevent the downword movement of CO_2, only geomembrane liner can stop its movement.

- CO_2 is readily soluble in water & can react with it forming Carbonic acid, making water acidic.

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

This reaction lowers the pH.

✓ This lower pH in turn increases hardness & mineral content of the groundwater through Solubilization.

passive Control of Landfill gases:-

The movement of gases has to be Controlled to: (i) reduce atmospheric emissions,

(ii) to reduce release of odourous emissions

(iii) to minimise Subsurface gas migration,

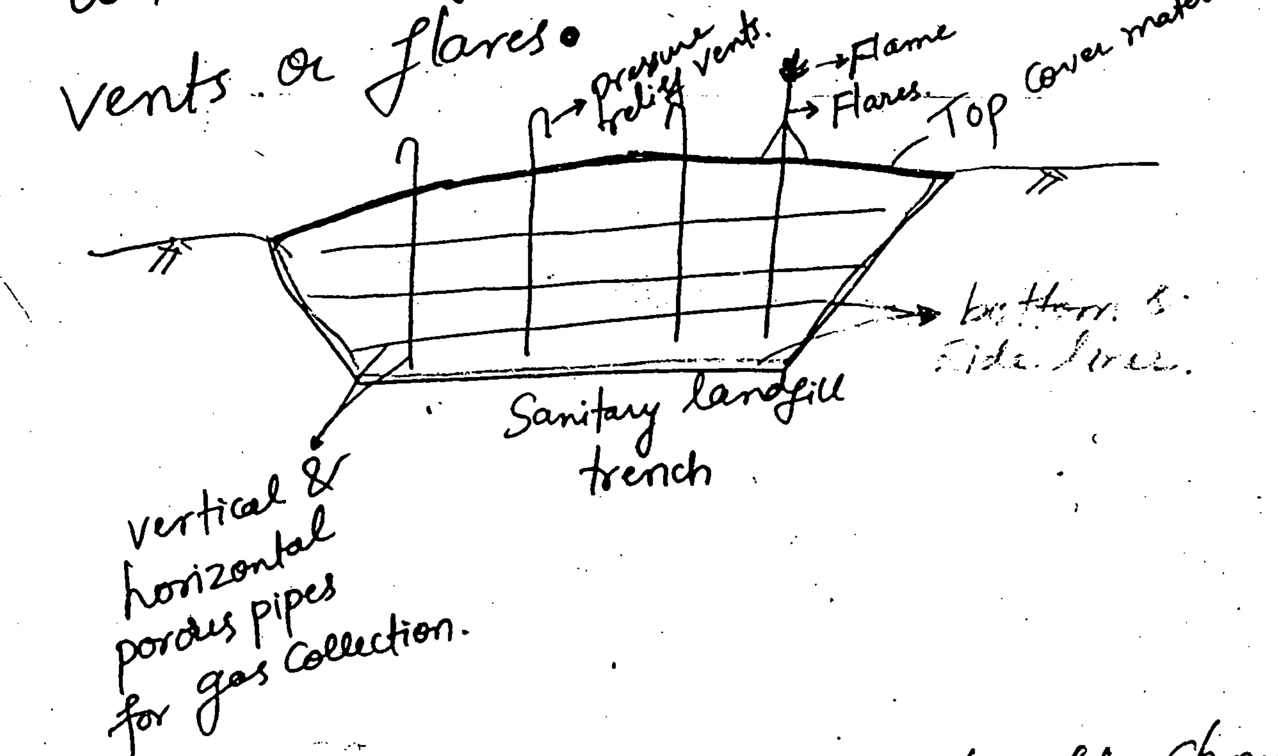
(iv) to allow recovery of energy from CH_4.

- **In passive Control Systems**, the pressure of the gas that is generated within the landfill serves as a driving force for the movement of gases produced.
- **In active gas Control Systems**, energy in the form of an induced Vacuum is used to Control the flow of gas.

Note- When The gas production is maximum in the first 5 years passive Control Systems are adopted & later on active gas Control Systems are adopted.

Pressure relief Vents / Flares in Landfill cover :-

✓ Most common passive method of mitigation of lateral movement of gases & also to relieving gas pressure within landfill is either pressure relief vents or flares.



✓ In case of burners, their height should be 10-20 feet above the completed fill.

→ The burner can be ignited by hand or by a continuous pilot flame.
↑ more advantageous

(a) Perimeter Interceptor Trenches :-

(9a)

- ✓ Gravel filled perimeter trenches (vertical
- ✓ perimeter trenches contain horizontal perforated PVC or PE pipes.
- ✓ These perforated horizontal pipes are connected to vertical risers through which the collected gases are vented into atmosphere.
- ✓ Usually in such systems no side liners are provided. [fig (a) in P No 10].

(b) Perimeter Barrier trench or Slurry wall :-

(fig (b) in P No 10)

- ✓ perimeter barrier trenches are filled with relatively impermeable materials such as bentonite or clay slurries.
- ✓ Slurry filled trenches acts like a barrier for lateral movement of landfill gases.
- ✓ The gases are removed & vented into the atmosphere by gas extraction wells or gravel filled trenches.

- No Side liners are needed.
- The longterm effectiveness of barrier trenches is uncertain.

Impermeable barriers within Landfills:-

[Fig © in PNo 10]

- Before dumping of SWs starts, the bottom & Sides are provided with impermeable liners.
- Gas may pass through compacted clay hence now-a-days most of Landfills use geomembranes.

Some of Landfill Sealants to Control movement of gases & Leachate.

- Compacted clays like bentonites, illites, Kaolinites.
- Synthetic Chemicals like polymers, rubber latex.
- Synthetic membrane liners like PVC, butyl rubber, hypalon, PE, nylon reinforced liners.

passive facilities used for control of landfill gas (9C)

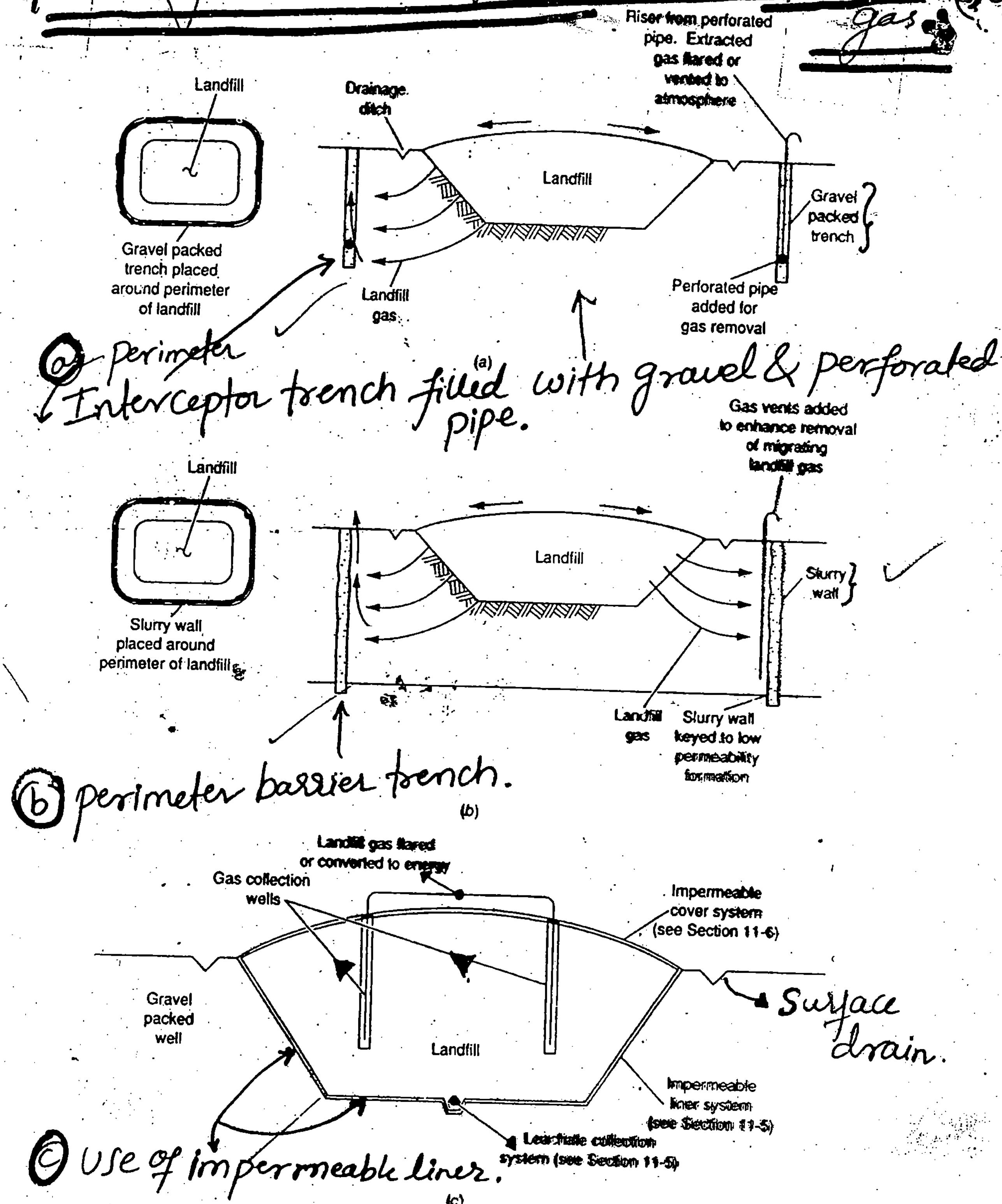
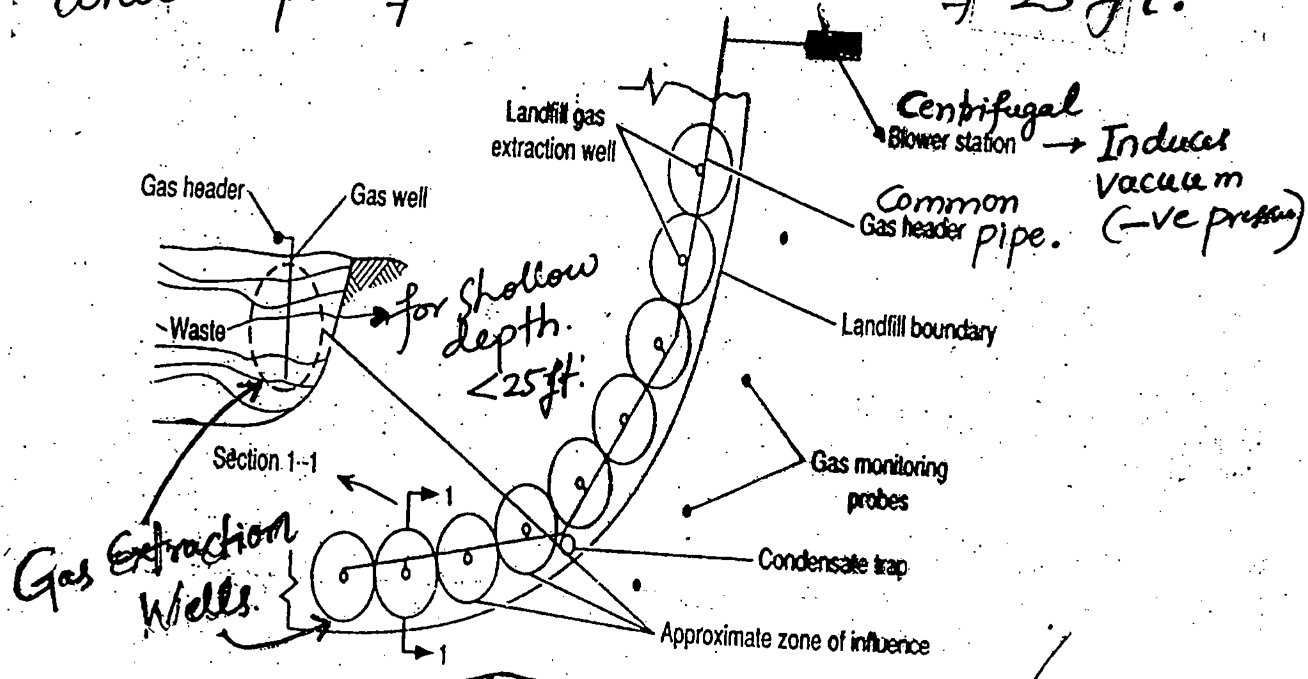


FIGURE 11-18
Passive facilities used for the control of landfill gas: (*a*) interceptor trench filled with gravel and perforated pipe, (*b*) perimeter barrier trench, and (*c*) use of impermeable liner in landfill. Note interceptor barrier perimeter trenches are used to control the off-site migration of landfill gas from existing unlined landfills.

Perimeter Gas extraction and odor Control Wells (9d)

where depth of the well is minimum of 25 ft.



Active Control of gases.
where the depth of the trench > 25 ft.

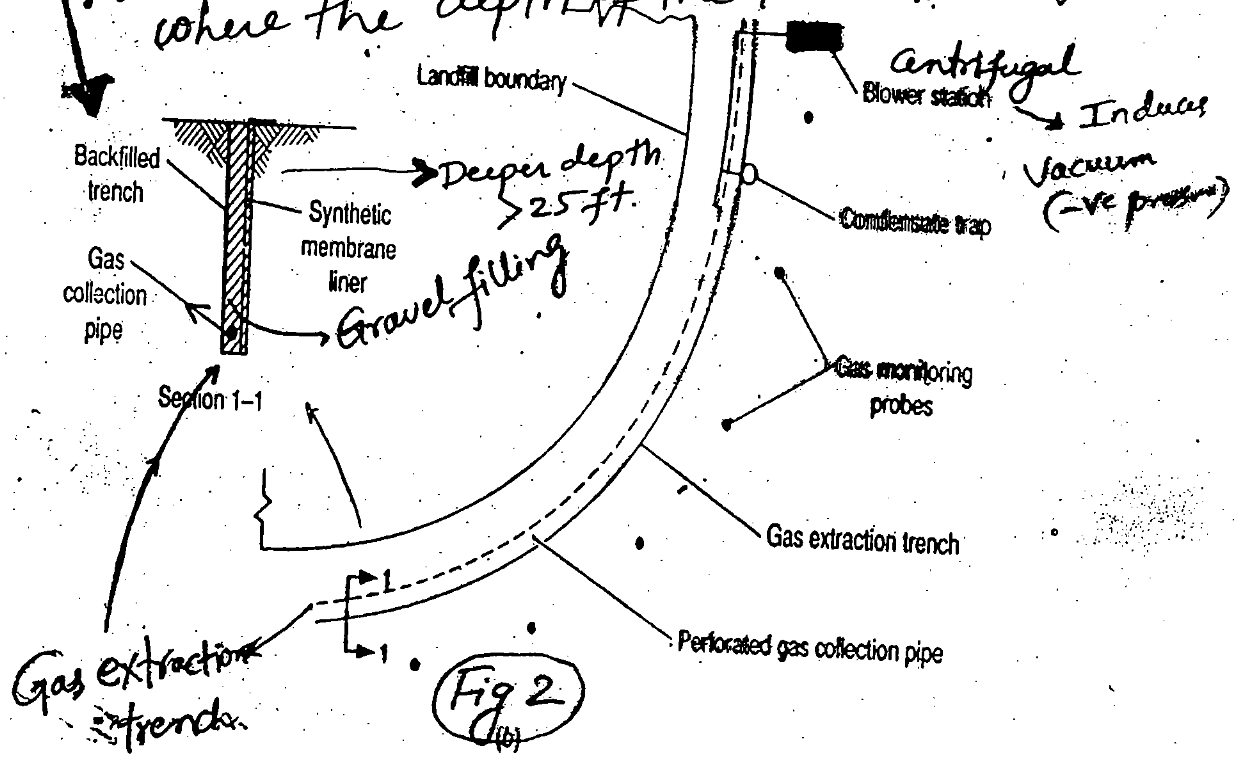


FIGURE 11-19
Active facilities used for the subsurface control of landfill gas migration: (*a*) perimeter landfill gas extraction wells and (*b*) perimeter landfill gas extraction trench.

Active Control of Landfill gas with perimeter facilities.

(9e)

✓ The horizontal lateral movement can be controlled by using perimeter gas extraction wells & trenches & by creating a partial vacuum, which induces a pressure gradient towards the extraction well.

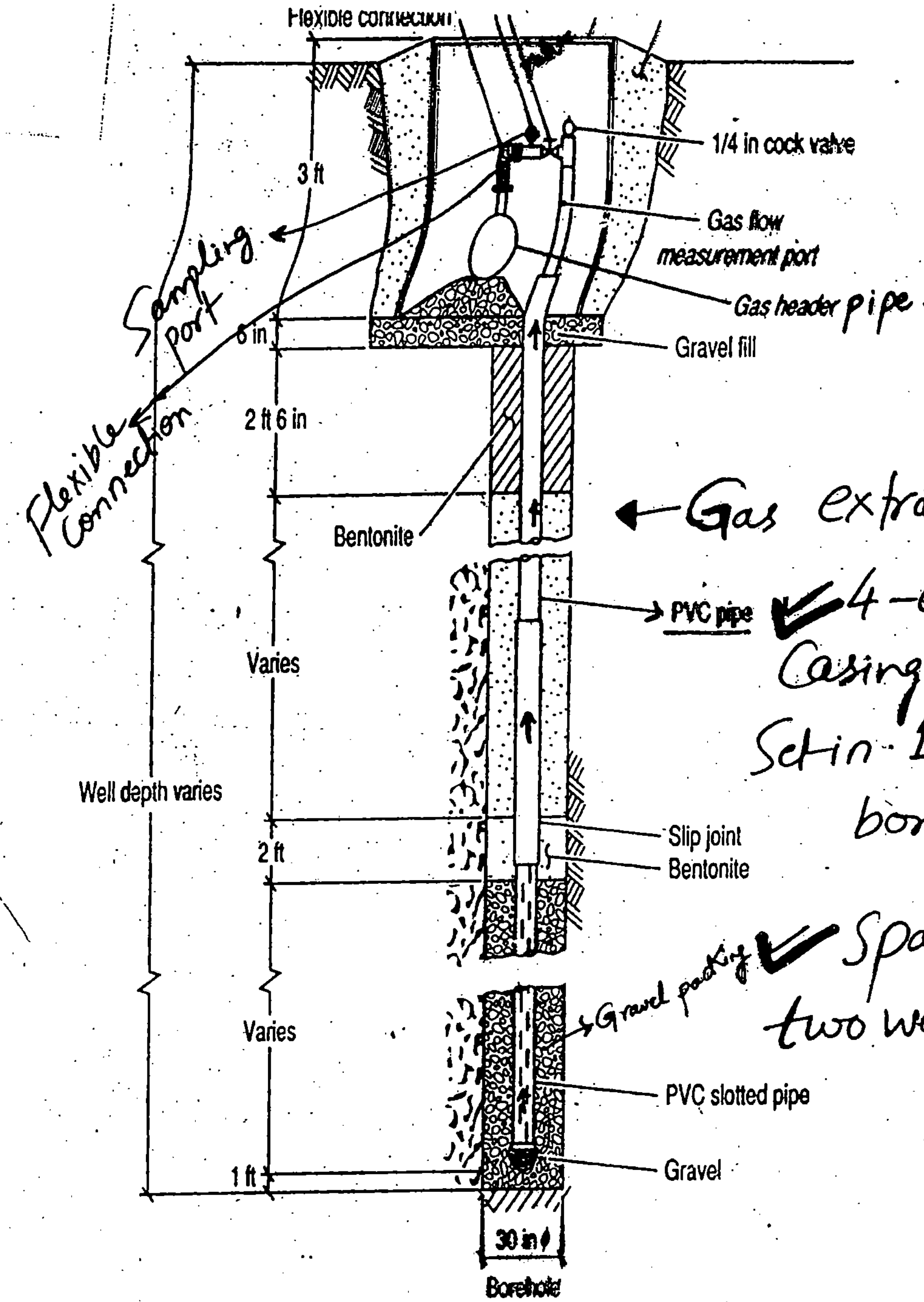
(See p No. 2 fig 1 & 2)

Active Control of Landfill gases with vertical & horizontal gas extraction wells.

(i) **Vertical gas extraction wells** – (See p No 4 fig-a). The wells are spaced so that their radii of influence overlap. (Fig b).

✓ Vertical wells are installed after landfilling is completed.

9f

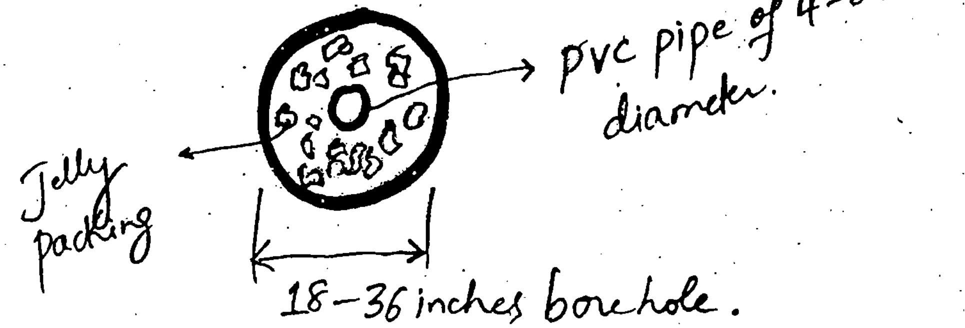


← Gas extraction well.

✓ 4–6 inch pipe
Casing of PVC or PE.
Set in 18–36 inches borehole.

✓ Spacing between two wells – 25–50 ft.

FIGURE 11-20 (Tch p No 408)
Representative detail of a landfill gas extraction well. (Courtesy of California Integrated Waste Management Board.)



✓ 4-6 inch pipe, 18-36 inche borehole. (9A)

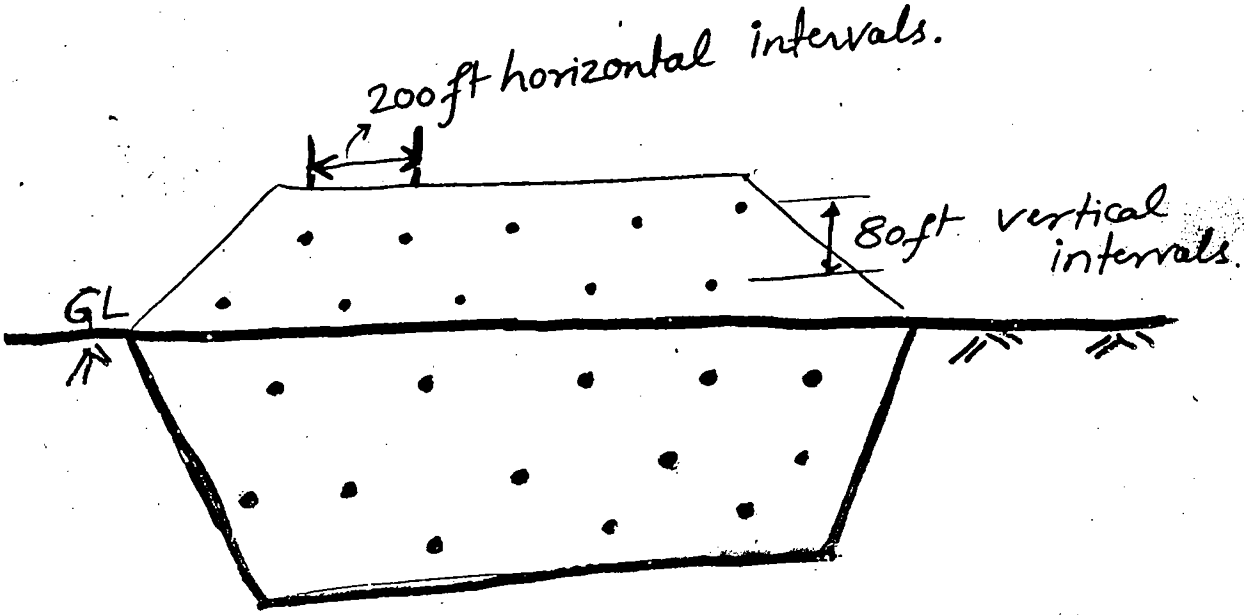
✓ 2/3 rd of length is provided with perforated PVC or PE pipe. Remaining 1/3 rd is towords the top without perforations.

✓ Landfill gas recovery wells are typically designed to penetrate to 80% of the waste depth in Landfill.

② Horizontal gas extraction wells — (PNo5)

✓ Horizontal extraction pipes are laid after 2 or more lifts have been completed.

✓ Excavated by using a backhoe.



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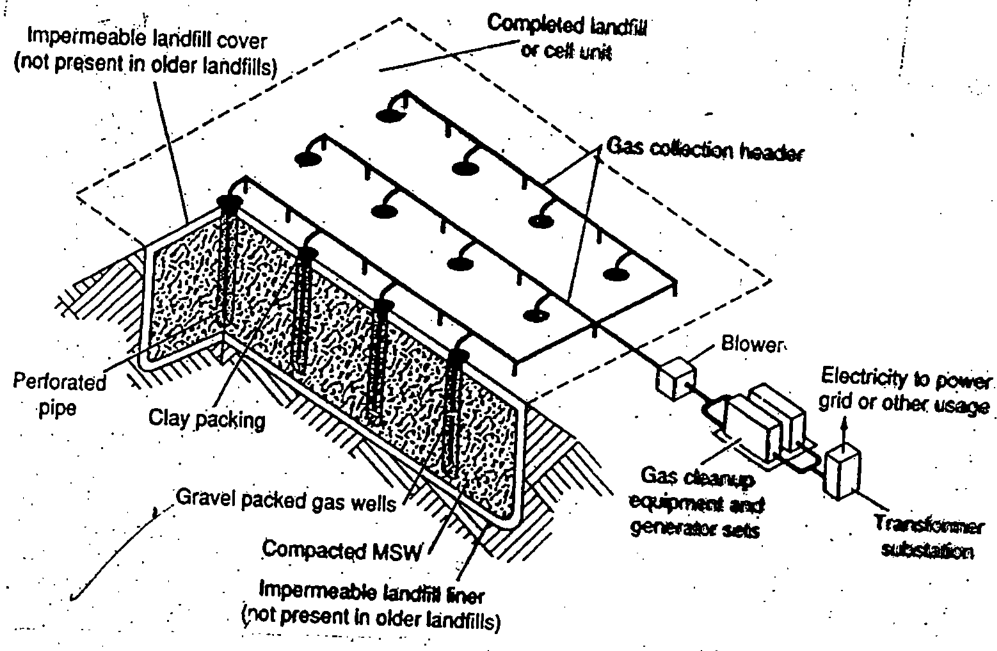


FIGURE 11-21
Landfill gas recovery system using vertical wells.

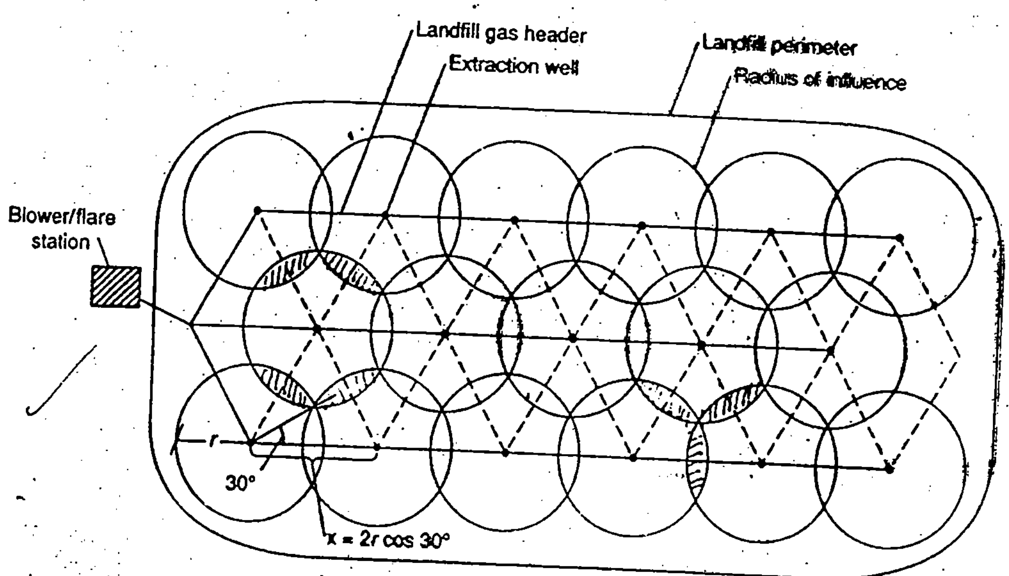


FIGURE 11-22
Equilateral triangular distribution for vertical gas extraction wells. (Courtesy of California Integrated Waste Management Board.)

Horizontal gas extraction wells :-

(9i)

✓ The reason for gravel filling & open joints is to allow differential settling which occurs with passage of time.

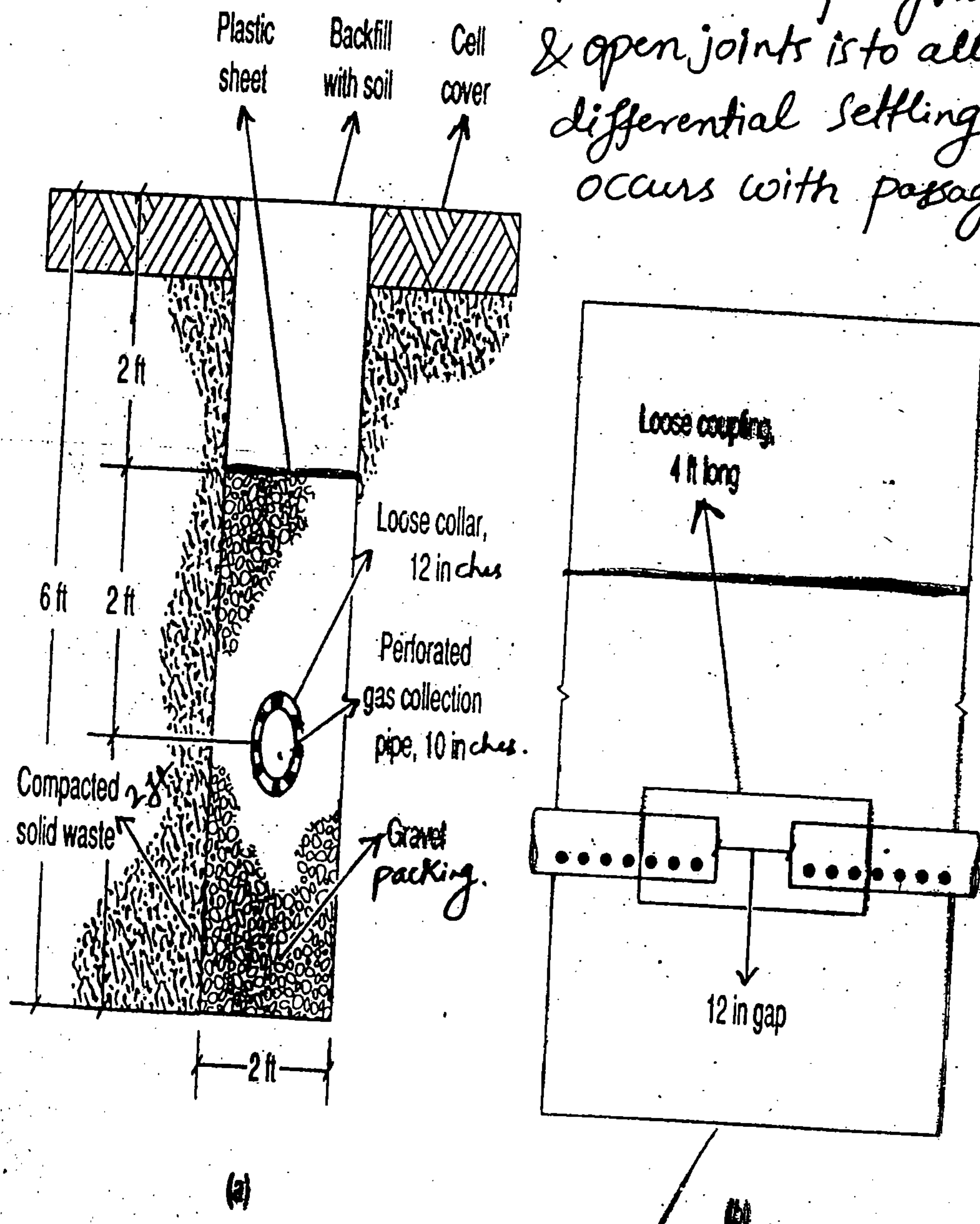


FIGURE 11-25
Details of horizontal gas extraction trench: (*a*) section through trench and (*b*) side view. (Courtesy of County Sanitation Districts of Los Angeles County.)

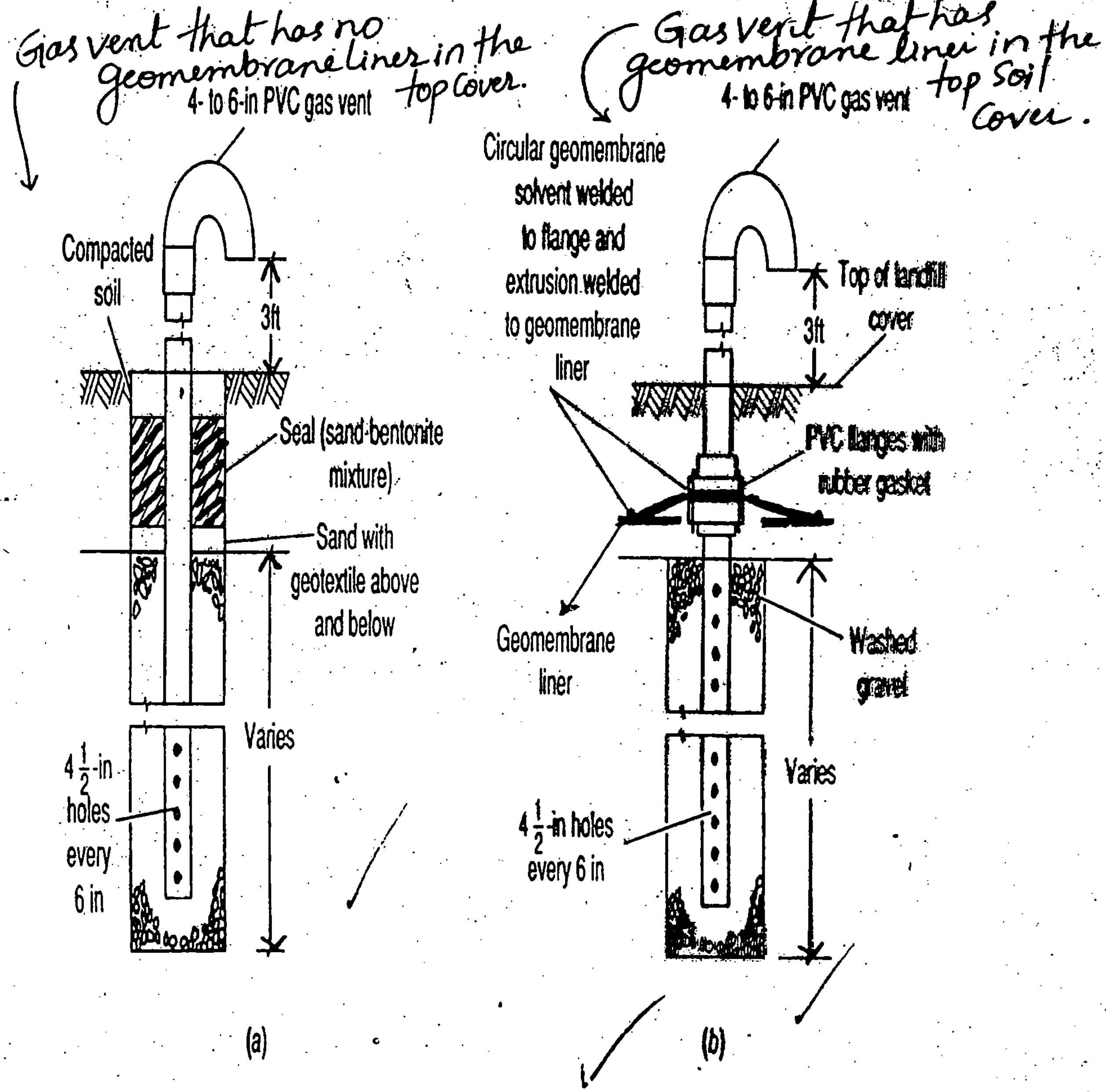


FIGURE 11-16
Typical gas vents used in the surface of a landfill for the passive control of landfill gas: (*a*) gas vent for landfill with a cover that does not contain a geomembrane liner and (*b*) gas vent for a landfill with a cover that contains a synthetic membrane liner.

(11)

Candle stick type waste gas burner to flare landfill gases.

(a) without pilot flame.

(b) with pilot flame.

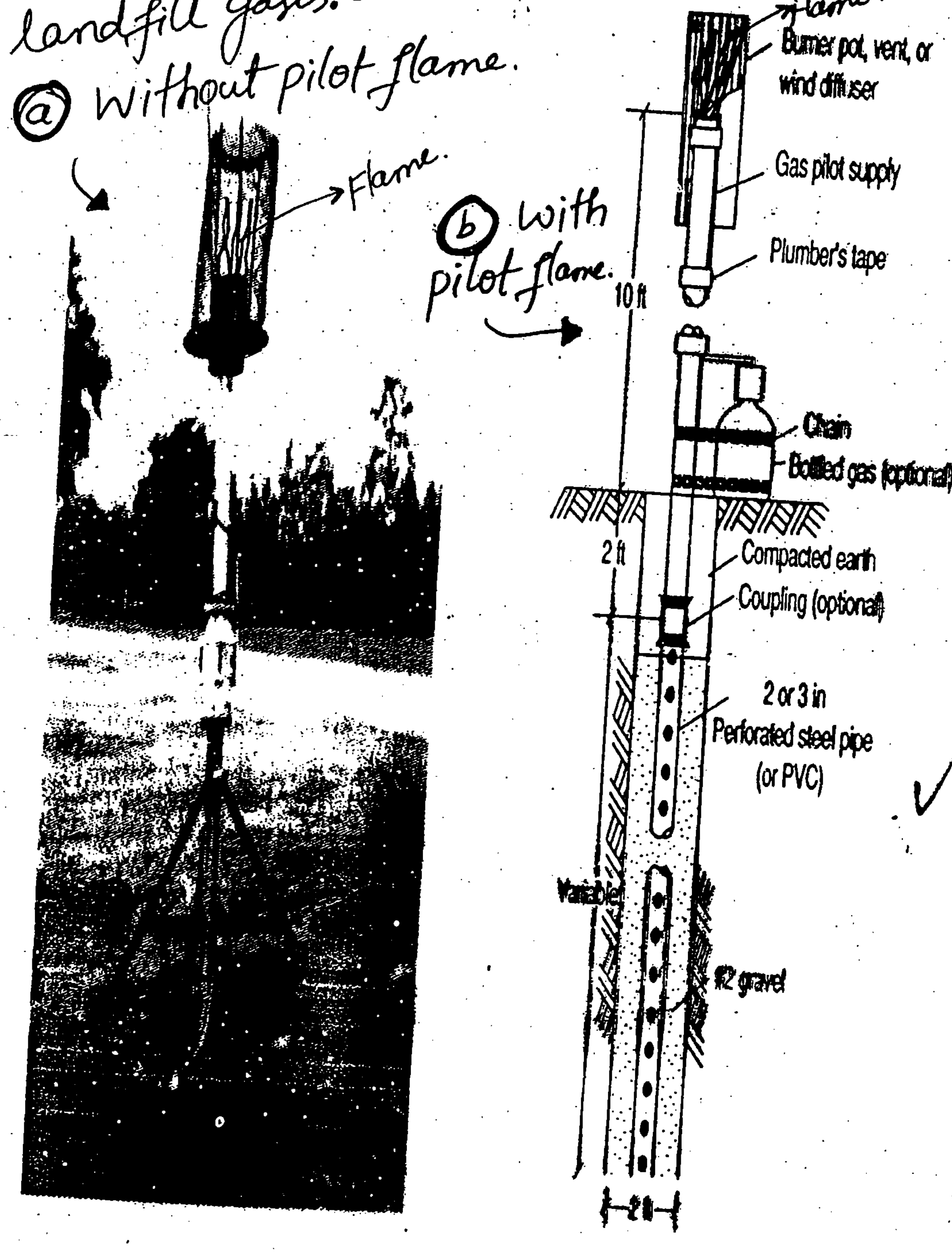


FIGURE 11-17

Typical candlestick type waste gas burner used to flare landfill gas from a well vent or several interconnected well vents: (*a*) without pilot flame and (*b*) with pilot flame.

Lechate. (1)

✓ Leachate may be defined as liquid that has percolated through Solid waste & has extracted dissolved & suspended materials from Solid waste.

✓ liquid → Entered through rain.
→ produced from decomposition.

Composition of Leachate :-

✓ Biological & chemical constituents are leached into Solution.

✓ Constituent	✓ New Landfill ((Less than 2 years)) Range (mg/L)	Typical	✓ Mature Landfill ((>10 years))
✓ BOD_5	2000-30,000	10,000	100-200
✓ TOC	1500-20,000	6000	80-160
✓ COD	3000-60,000	18000	100-50
✓ TSS	200-2000	500	100-40
✓ pH	4.5-7.5	6.0	6.6-7.

Movement of leachate in unlined Landfills :-

- ✓ The main movement is downwords.
- ✓ many of the chemical & biological constituents are removed by filtering & adsorptive action of soil strata.
- ✓ Liners usually consist of combination of geomembrane & clay liners, to prevent down word as well as lateral movement of Landfill gases & Leachate.

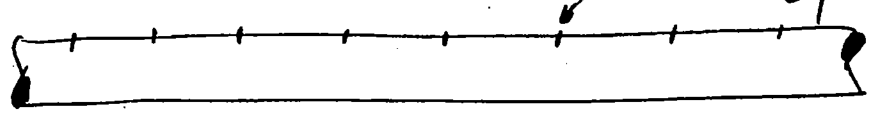
Ex:- Synthetic flexible membrane Liners (FMLs), bottom seals, artificial earthen liners, Subsurface barriers.

Design of leachate collection facilities.

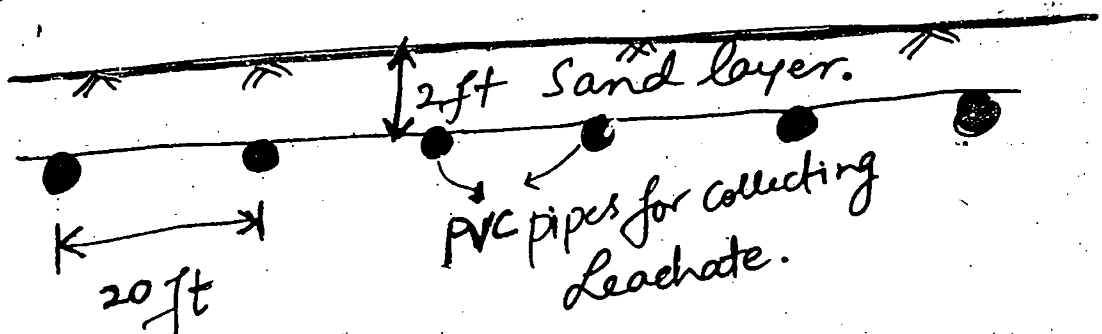
(1) • Sloped terraces – Cross slope of terrace → 1–5 %.

• Slope of drainage channel – 0.5 – 1 %.

(2) Piped bottom → 4 inch pvc pipes with perforations.



✓ Bottom Slope of 1.2–1.8%.



✓ Leachate holding tanks are provided to hold 1–3 days of leachate produced.

Leachate management options:

✓ (1) leachate Recycling.
✓ (2) leachate Evaporation.
✓ (3) Treatment & disposal.
✓ (4) Discharge to municipal STP.

Leachate treatment :-

- **Biological process** — ① Activated Sludge process. (ASP)
② Aerated Stabilization basins.
③ Trickling filters. (TF).
④ Rotating Biological contractors. (RBC).
⑤ Anaelobic lagoons & contractors.
⑥ Nitrification / denitrification.

- **chemical processes** → ① Neutralization.
② precipitation. ③ oxidation. ④ Wet air oxidation.

- **physical operations** — ① Sedimentation / flotatio
② Filtration. ③ Air Stripping (Rem. of volatile organics)
④ Adsorption. ⑤ Evaporation. ⑥ Ion exchange. ⑦ Ultra filtration. ⑧ R.O.
⑨ Steam Stripping.

5

TABLE 11-18
Representative biological, chemical, and physical processes and operations used for the treatment of leachate[a]

Treatment process	Application	Comments
Biological processes		
Activated sludge	Removal of organics	Defoaming additives may be necessary; separate clarifier needed
Sequencing batch reactors	Removal of organics	Similar to activated sludge, but no separate clarifier needed; only applicable to relatively low flow rates
Aerated stabilization basins	Removal of organics	Requires large land area
Fixed film processes (trickling filters, rotating biological contactors)	Removal of organics	Commonly used on industrial effluents similar to leachates, but untested on actual landfill leachates
Anaerobic lagoons and contactors	Removal of organics	Lower power requirements and sludge production than aerobic systems; requires heating; greater potential for process instability; slower than aerobic systems
Nitrification/denitrification	Removal of nitrogen	Nitrification/denitrification can be accomplished simultaneously with the removal of organics
Chemical processes		
Neutralization	pH control	Of limited applicability to most leachates
Precipitation	Removal of metals and some anions	Produces a sludge, possibly requiring disposal as a hazardous waste
Oxidation	Removal of organics; detoxification of some inorganic species	Works best on dilute waste streams; use of chlorine can result in formation of chlorinated hydrocarbons
Wet air oxidation	Removal of organics	Costly; works well on refractory organics
Physical operations		
Sedimentation/flotation	Removal of suspended matter	Of limited applicability alone; may be used in conjunction with other treatment processes
Filtration	Removal of suspended matter	Useful only as a polishing step
Air stripping	Removal of ammonia or volatile organics	May require air pollution control equipment
Steam stripping	Removal of volatile organics	High energy costs; condensate steam requires further treatment
Adsorption	Removal of organics	Proven technology; variable costs depending on leachate
Ion exchange	Removal of dissolved inorganics	Useful only as a polishing step
Ultrafiltration	Removal of bacteria and high molecular weight organics	Subject to fouling; of limited applicability to leachate
Reverse osmosis	Dilute solutions of inorganics	Costly; extensive pretreatment necessary
Evaporation	Where leachate discharge is not permissible	Resulting sludge may be hazardous; can be costly except in arid regions

[a] Adapted from Ref. 43.

6

TABLE 11-16

Guidelines for leachate control facilities

Item	Comments
Synthetic flexible membrane liners (FMLs)	Liners must be designed and constructed to contain fluids, which include wastes and leachates. For MSW waste management units, synthetic liners are not required. However, if this alternative is selected, synthetic liners must have a minimum thickness of 40 mils. These liners must be installed to cover all natural geologic materials that are likely to be in contact with waste or leachate at a waste management unit.
Bottom seals	No specific regulations exist governing the application of bottom seals at MSW waste management units. Design, construction, and installation of bottom seals are subject to the approval of the local enforcement agencies.
Artificial earthen liners	Clay liners are optional for MSW landfills. If required by site conditions, clay liners for MSW waste management units must be a minimum of 1 ft thick and must be installed at a relative compaction of at least 90 percent. A clay liner must exhibit a maximum permeability of 1×10^{-6} cm/s. Clay liners, if installed, must cover all natural geologic materials that are likely to be in contact with waste or leachate at a waste management unit.
Subsurface barriers	A subsurface barrier is intended to be used in conjunction with natural geologic materials to assure that lateral permeability standards are satisfied. Barriers may be required by regional agencies at MSW waste management units where there is potential for lateral movement of fluid, including waste and leachate, and the permeability of natural geologic materials is used for waste containment in lieu of a liner. Barriers must be a minimum of 2 ft thick for clay material or a minimum of 40 mils for synthetic materials. These structures are required to be keyed a minimum of 5 ft into natural geologic materials that satisfy permeability requirements of 1×10^{-6} to 1×10^{-7} cm/s. If cutoff walls are used, excavations for waste management units must also be keyed into natural geologic materials exhibiting permeabilities of no greater than 1×10^{-6} cm/s. Barriers are required to have fluid collection systems upgradient of the structure. The systems must be designed, constructed, operated, and maintained to prevent the buildup of hydraulic head against the structure. The collection system must be inspected regularly and accumulated fluid removed.

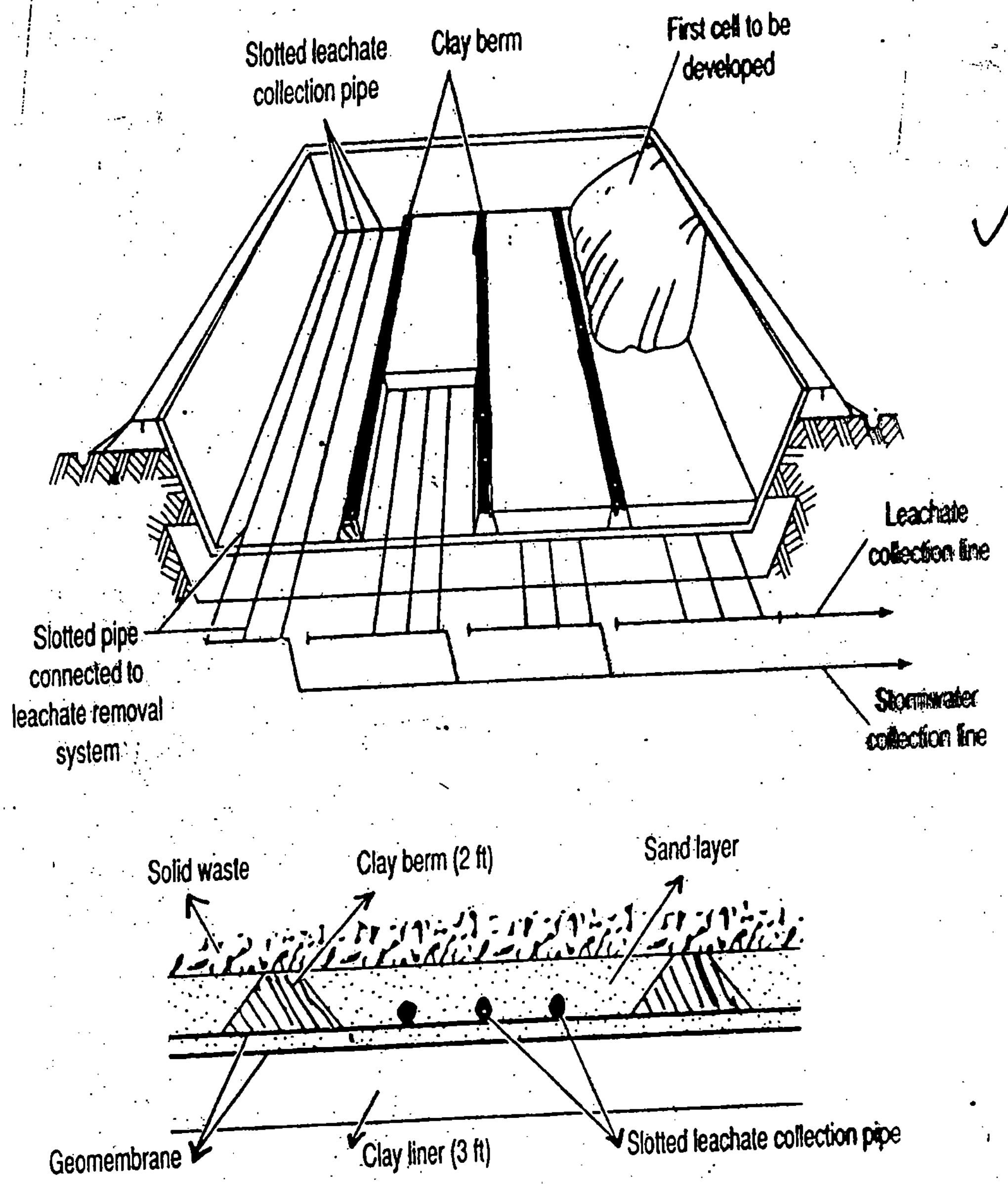
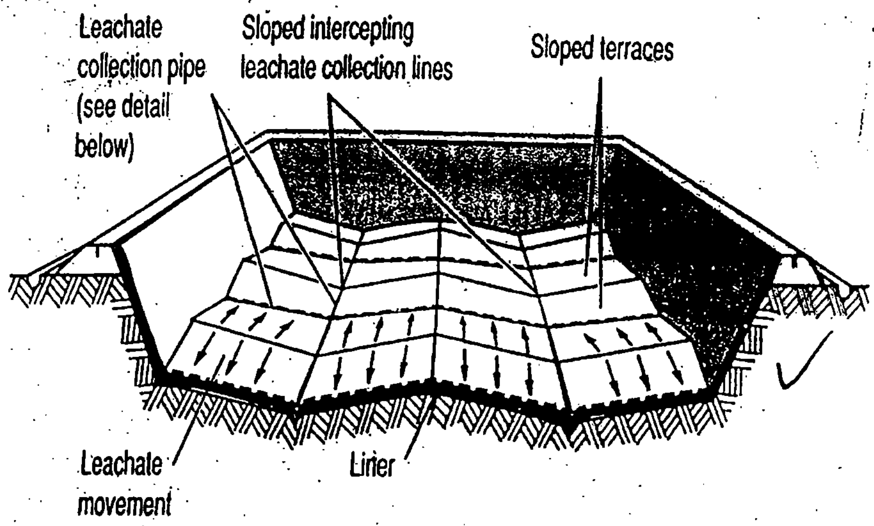
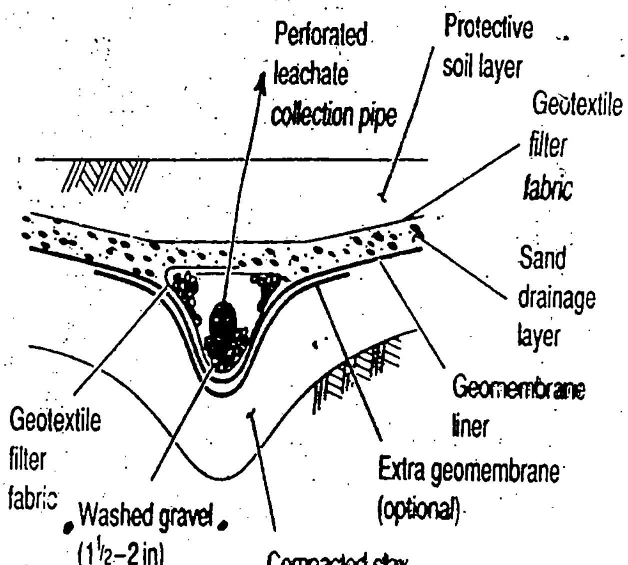


FIGURE 11-40
Typical leachate collection system using multiple leachate collection pipes: (*a*) pictorial view and (*b*) detail of typical leachate collection pipes (adapted from Ref. 33).



(a)



(b)

FIGURE 11-39
Leachate collection system with graded terraces: (a) pictorial view and (b) detail of typical leachate collection pipe.

Note :- Generally the disposal sites considered ① suitable for recovery of energy having more than 1 million tonnes of wastes in place, a majority of which should be less than 10 years. [i.e., 5–40 lit/kg of SW/year].

methods of gas production potential :-

The 03 methods used for estimating the gas production :-

ⓐ **Test Wells** – ✓ most reliable method.

Individual tests are performed at each well to measure gas flow & quality.

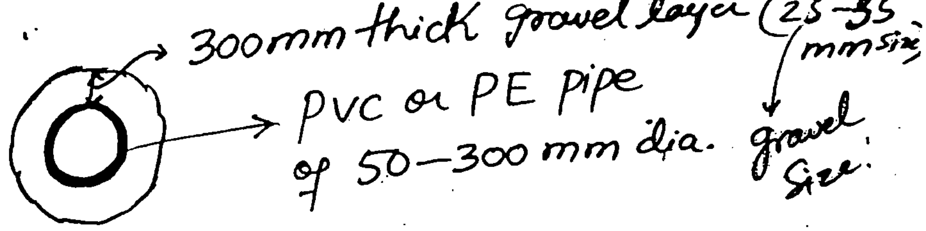
✓ A general rule applied is to reduce the amount of gas collected by test wells by 50%.

ⓑ **Rough approximation** – The easiest method of assuming 1 tonne of SW will produce $6\ m^3$ of landfill gas per year. (The waste tonnage should be less than 10 years)

✓ There may be a variation of 50% in gas production.

(c) <u>model estimates</u>– models of gas production predicts gas generation during the Site filling period & after closure. "<u>First order</u> Decay model" & "<u>Waste</u> in place <u>model</u>" are the 2 main models used for estimation.

✓ Calorific value of biogas = 4500 Kcal/m^3 to 5000 Kcal/m^3.



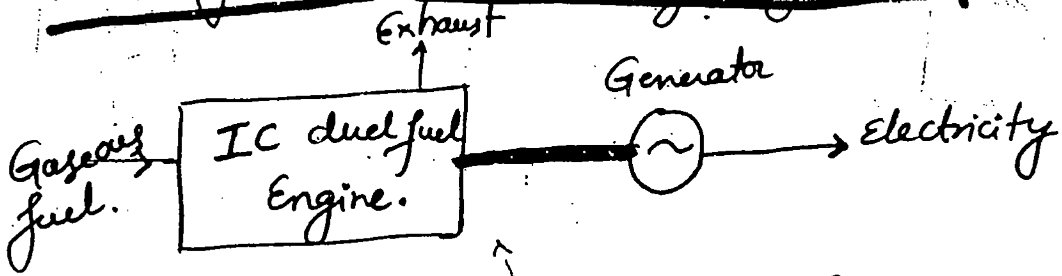
✓ The depth of gas well is 80% of height of landfill.

✓ The **3** primary approaches to using the landfill gas:

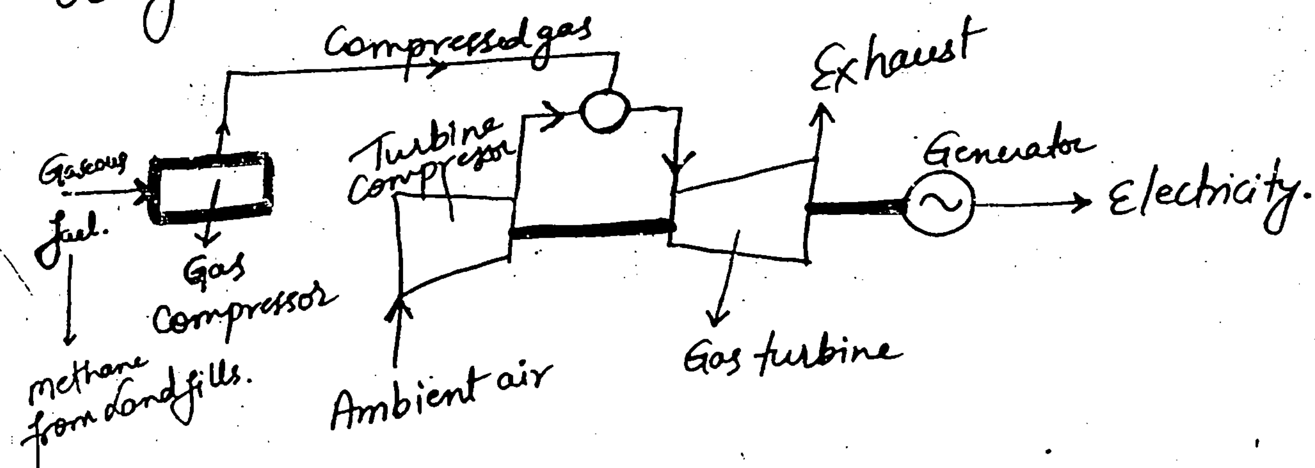
✓ (a) Direct use of gas locally (on site or nearby)

✓ (b) generation of electricity & distribution through grid.

Landfill Gas Recovery Systems:



✓ In smaller installations (upto 5 MW) it is common to use IC duel fuel engine or gas turbines.



In larger installations, the use of steam turbines is common.

Gas Purification & Recovery: using physical adsorption, chemical adsorption & by membrane seperation CO_2 & CH_4 are seperated

✓ Semipermeable membranes allow CO_2, H_2S, H_2O to pass while CH_4 is retained.

Medium quality gas – • 50% CH_4 gas.
The gas has to be processed to remove impurities & made dry to make it non-corrosive especially chlorinated hydrocarbons & H_2S gas.

High quality gas – ✓100% CH_4 gas. ✓Very very difficult & costly, hence rarely adopted.

① **Role of IC Engines** – ✓Internal Combustion engines are most commonly used.

✓ They are similar to automobile engines

✓ IC engine capacity varies from 30 – 2000 KW. ✓Medium quality gas is used.

② **Gas turbines** – ✓use medium quality gas.
✓They require more gas hence are adopted at larger landfills.

✓ Their capacity varies from 500 KW to 10 MW.

(1 MW = 1000 KW)

③ **Steam turbines** – ✓In cases where extremely large gas flows are available, steam turbines can be used for power generation. ⑧

④ **Fuel Cells** – ✓A new emerging technology.

✓ 1 – 2 MW capacity.

✓ They convert chemical energy into usable electric & heat energy.

10^6 – mega (M)	10^{-12} – pico (p)
10^3 – Kilo (K)	10^{-9} – nano (n)
	10^{-6} – micro (μ)
	10^{-3} milli (m)
	10^{-2} centi (c)

↑ Standard prefixes. →

(Dec, 2010) Ex:- Determine the amount of air required to oxidize one tonne of waste having the chemical equation - $C_{50}H_{100}O_{40}N$.

use $C_aH_bO_cN_d + \left(\frac{4a+b-2c-3d}{4}\right)O_2$

$\longrightarrow aCO_2 + \left(\frac{b-3d}{2}\right)H_2O + dNH_3$.

(8 marks)

Soln:- The reqd coefficients are:

$a = 50$
$H = 100$
$O = 40$
$d = 1$

Using these coefficients the resulting eqn will be

(2)

$$C_{50}H_{100}O_{40}N + 54.25O_2 \rightarrow 50CO_2 + 48.5H_2O + NH_3$$

(1354) (1736) (2200) (873) (17)

Note:- Atomic wts of
C = 12
H = 1
O = 16.
N = 14

Oxygen reqd per tonne of $C_{50}H_{100}O_{40}N$

will be $= O_2 = \frac{1736}{1354} \times 1000$

$= 1282$ Kgs/tonne.

use eqn $NH_3 + 2O_2 \rightarrow H_2O + HNO_3$

to determine the O_2 reqd to Stabilize the NH_3 i.e. ammonia gas.

$$NH_3 + 2O_2 \longrightarrow H_2O + HNO_3$$

(17) (64) (18) (63)

The O_2 reqd per tonne of waste. (3)

is:

$$O_2 = \frac{17}{1354} \times \frac{64}{17} \times 1000 = 47.3 \text{ Kg/tonne.}$$

Now Determine the amount of air required. Assume air contains 23.15 % O_2 by weight and density of air is 1.2928 Kg/m^3

$$O_{2\,(total)} = 1282 + 47.3 = 1329.3 \text{ Kg/tonne.}$$

The mass air reqd is

$$A_{maxi} = \frac{1329.3 \text{ Kg/tonne}}{0.2315} = 5742 \text{ Kg/tonne}$$

The volume of air reqd is

$$V_{air} = \frac{5742 \text{ Kg/tonne}}{1.2928 \text{ Kg/m}^3} = \underline{4442} \text{ m}^3\text{/tonne.}$$

(Jan 10) ①

Ex:- From the following data estimate the waste generation rate per day for a residential area consisting of 1200 houses. The observation location is a local transfer station that receives all the waste collected for disposal. The observation period is one week. Also estimate per capita generation rate assuming 4 persons per house.

Vehicle type	Number of Loads.	Volume of vehicle m^3	Sp. wt of SWs (Kg/m^3)
Compactor truck	10	15.30	296.5
Flat bed load	08	1.53	133.4
Private cars/trucks	25	0.23	88.9

(10 marks)

(P.T.O)

Soln: ✓Number of houses = 1200. (2)

✓Number of persons per house = 4

✓Collection frequency = once in 7 days

Compactor truck $= \dfrac{10 \times 15.30\,m^3 \times 1000\,kg}{296.5\,kg/m^3}$ (Numbers)

$= 516$ Kgs

Illy for flat bed load $= \dfrac{08 \times 1.53 \times 1000}{133.4}$

$= 91.75 \simeq 92$ Kgs.

Illy for private cars/trucks $= \dfrac{25 \times 0.23 \times 1000}{88.9}$

$= 64.67 \simeq 65$ Kgs.

Total SW produced per one

Week $= 516 + 92 + 65 = 673$ Kgs/wk

SW generation per person/day.

$$= \frac{1200 \text{ houses} \times 4 \text{ persons/house}}{673 \text{ Kgs} \times 7 \text{ days}}$$

$= 1.02$ Kg/person/day.

Dec 2010

Ex:- An area consisting of 400 houses contributes SWs. Estimate the SW generation rate, if the observation location is a transfer station (TS) and period of generation is one week. The waste is carried out in 2 types of vehicles viz, compactor trucks and flat bed trucks.

Number of compactor truck load – 10

Volume of each compactor truck – $15 m^3$.

Density of Waste of Compactor ④.
= 295 Kg/m^3.

Number of flat bed truck load = 20.

Volume of each flat bed truck - 1.25 m^3.

Density of Waste of flat bed truck
= 110 Kg/m^3

Number of persons in each house
= 6 (6 marks)

Soln:- SWs carried by Compactor

trucks = $\frac{10 \text{ Numbers} \times 15 m^3 \times 1000 \text{ Kgs}}{295 \text{ Kg/m}^3}$

= 508.47 ≃ 509 Kgs.

Illy SWs carried by flat bed trucks

= $\frac{20 \text{ numbers} \times 1.25 m^3 \times 1000 \text{ Kgs}}{110 \text{ Kg/m}^3}$ = 227.27 ≃ 228 Kgs

Total Waste produced or carried (5)
by 2 types of vehicles is (509 + 228) kgs
i.e. 737 Kgs.

SW generation/person/day = $\frac{400 \text{ houses} \times 6}{737 \times 7 \text{ days}}$

= 0.465 Kgs or 465 gms.

(July 2011)
Ex:- Estimate the quantity of SW generation per annum in a municipal area having one lakh dwellings. Assume each person produces 350 gms of Solid Waste per day. Also workout the number of collectors required per day, if a

Collector Collects 12 Kgs/hour and works for 8 hours per day. (6)

Assume mean population of 5 residents per dwelling. (10 marks)

Soln: SWs generated per day

$= 1,00,000 \times 5 \times 0.350$

$= 1,75,000$ Kgs

per annum $= 1,75,000 \times 365$ days

$= 6,38,75000$ Kgs or 63,875 tonnes.

1 collector collects 12 Kgs/hour & works for 8 hours.

i.e. per day he collects $= 12 \times 8$

$= 96$ Kgs/day.

∴ Number of collectors required (7)

$$= \frac{1,75,000 \text{ Kgs}}{96 \text{ hours}} = 1822.92$$

$\simeq$ 1823 Collectors

are required.

(Dec, 2010) Ex:- Determine the area and size of land fill required for a municipality with a population of 50,000 given

Solid Waste generation — 1500 gm/per/day

Compacted density of SW in Land fill = 500 Kg/m³

Average Compacted depth of Solid Waste = 3 mts. (6 marks)

Soln:- SW generated by a ~~town~~ per day $= 50{,}000 \times \frac{1500\,gms}{1000}$ (8)

$= 75{,}000$ Kgs.

Density or Sp. wt of SW $= \frac{75000\,kgs}{500\,kg/m^3}$

$= 150\ m^3/day.$ = Quantity of SW.

Now $150\ m^3/day = L \times B \times D$

Assume $L = 2B$.

$\therefore 150\ m^3/day = 2B \times B \times 3\ mts$ (given)

$150\ m^3/day = 2B^2 \times 3\ mts$

$\therefore B^2 = \frac{150}{6}$ i.e. $B = \sqrt{\frac{150}{6}}$

$= \sqrt{25}$

$B = 5\ mts$

$L = 2B = 2 \times 5 = 10\ mts$

Size of each trench for burying (9)

One days waste is $10\,m\,(L) \times 5\,m\,(B) \times 3\,m\,(D)$

Assume life of landfill size as 5 years.

i.e. $150\,m^3/day \times 1825$ days $\left\{ \because 365 \times 5\,years = 1825 \right\}$

$= 2{,}73{,}750\,m^3$ of SWs to be buried in trenches.

i.e. 1825 trenches of size $10 \times 5 \times 3\,m$ are needed.

Area needed $= 1825 \times (10 \times 5)\,m^2$

$= 91{,}250\,m^2$ ($\because$ 1 Acre $= 4047\,m^2$)

$= \dfrac{91{,}250\,m^2}{4047\,m^2} = 22.54$ Acres.

$\simeq 23$ Acres.

Additional area for shed for workers & equipment reqd = 3 Acres.

Total area reqd = 26 Acres

INTRODUCTION TO 3R (REUSE, REDUCE, RECYCLE) ☺

Between 1960 and 2008 the amount of waste each person creates has almost doubled from 1.2 to 02 kgs per day. The most effective way to stop this trend is by preventing waste production in the first place.

Waste prevention; also known as "source reduction," is the practice of designing, manufacturing, purchasing, or using materials (such as products and packaging) in ways that reduce the amount or toxicity of trash created. Reusing items is another way to stop waste at the source because it delays or avoids that item's entry in the waste collection and disposal system.

Source reduction, including reuse, can help reduce waste disposal and handling costs, because it avoids the costs of recycling, municipal composting, land filling, and combustion. Source reduction also conserves resources and reduces pollution, including greenhouse gases that contribute to global warming.

Source Reduction refers to any change in the design, manufacture, purchase, or use of materials or products (including packaging) to reduce their amount or toxicity before they become municipal solid waste. Source reduction also refers to the **reuse** of products or materials.

Benefits of Reduction:

- **Saves natural resources:**

  Waste is not just created when consumers throw items away. Throughout the life cycle of a product from extraction of raw materials to transportation to processing and manufacturing facilities to manufacture and use waste is generated. Reusing items or making them with less material decreases waste dramatically. Ultimately, fewer materials will need to be recycled or sent to landfills or waste combustion facilities.

- **Reduces toxicity of waste:**

  Selecting non-hazardous or less hazardous items is another important component of source reduction. Using less hazardous alternatives for certain items (e.g., cleaning products and pesticides), sharing products that contain hazardous chemicals instead of throwing out leftovers, reading label directions carefully, and using the smallest amount necessary are ways to reduce waste toxicity.

- **Reduces costs:**

The benefits of preventing waste go beyond reducing reliance on other forms of waste disposal. Preventing waste also can mean economic savings for communities, businesses, schools, and individual consumers.

- **Communities.** More than 7,000 communities have instituted "pay-as-you-throw" programs where citizens pay for each can or bag of trash they set out for disposal rather than through the tax base or a flat fee. When these households reduce waste at the source, they dispose of less trash and pay lower trash bills.

- **Businesses.** Industry also has an economic incentive to practice source reduction. When businesses manufacture their products with less packaging, they are buying fewer raw materials. A decrease in manufacturing costs can mean a larger profit margin, with savings that can be passed on to the consumer.

- **Consumers.** Consumers also can share in the economic benefits of source reduction. Buying products in bulk, with less packaging, or that are reusable (not single-use) frequently means a cost savings. What is good for the environment can be good for the pocketbook as well.

REDUCE:

One of the easiest ways to be a good environmental citizen is to reduce, or cut back, in key areas of your life. Three of the most important resources you can reduce your consumption of are:

- Energy
- Water
- Solid waste

Here's a quick breakdown of how reducing affects these areas:

- **Energy**—Energy is generated and consumed with most activities, and it often results in releasing carbon into the environment. In addition, there is a finite amount of energy available from traditional (non-renewable) methods such as coal and oil. Developing alternative, renewable energies (such as solar, wind and geothermal) helps to reduce our dependence on non-renewable resources to power our lives.
- **Water**—Water covers 71% of the Earth's surface, but relatively little is suitable for consumption. In many parts of the world, drinkable water is in very short supply. Every time a drop of water goes down the drain, it becomes unsuitable for consumption unless properly treated.
- **Solid Waste**—There is only so much room available for solid waste disposal, and because landfills are so tightly packed, it takes a great deal of time for material to decompose. The easiest way to reduce solid waste is to reduce your consumption of daily products. Be cautious of what you buy, and whether anything you are going to put in a trash can really belongs there.

Communities as well as individuals are always looking for new ways to address the concern of reduction in the above areas. The most common form is found in household waste and recycling. For example, a new type of waste reduction program is being explored known as a Pay-as-You-Throw (PAYT) trash collection program. Residents will pay a fee per bag of garbage instead of a lump sum for the service. In turn, the curbside recycling program component is offered at no charge or a reduced fee.

The ideal outcome of PAYT is that residents will start recycling more in an effort to save money. According to the EPA, about 75 percent of what is found in the average garbage can is recyclable, so a PAYT program rewards people who choose alternative forms of disposal for this content, such as curbside recycling or composting.

There are several ways to reduce waste:

* Decrease the quantity and toxicity of trash you throw away and reuse containers and products.
* Recycle as much as you can and purchase products with recycled content.
* Practice composting to decompose organic waste, such as food scraps and yard waste.

The concept of reduce, reuse, and recycle is just as vital for household hazardous waste and industrial materials.

* Household Hazardous Waste: Improper disposal of household products containing corrosive, toxic, ignitable, or reactive ingredients can pollute the environment and endanger human health.
* Industrial Materials: Industrial non-hazardous wastes that can be recycled and reused are essential to a successful resource conservation program.

REUSE:

Reuse is simply the act of finding a second (or third, or tenth or hundredth) use for a product to prolong its life. Reuse is an important step after you've already reduced, but before you are ready to recycle.

Reuse is a process that many of us already implement in our everyday lives without realizing it. Any time you buy or sell a product second-hand, such as from Craig list, eBay or Goodwill, you are providing an additional use for this product, while at the same time, not requiring another one to be created.

The important thing to consider when you want to reuse is that "creativity is king" in the process. The creativity also provides the opportunity to be thrifty, by reusing what you already have for new, innovative purposes.

Benefits of Reuse.

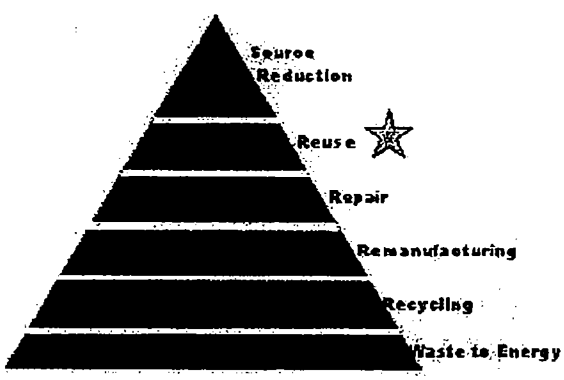
It is important to recognize that the sustained growth in reuse efforts, as well as the sustained interest of the reuse industry, derives in large measure from the solid waste reduction hierarchy: Reduce, Reuse, and then Recycle. It is best to reduce first, reuse as a second option, then to resort to recycling. Reuse is recognized as being distinct from recycling, both in doctrine, and in the handling of the materials this unique industry diverts from the waste stream. Recyclers have successfully kept materials out of the landfill by collecting, segregating, processing and manufacturing their collected goods into new products. Reusers, on the other hand, with little or no processing, keep materials out the waste stream by passing the goods they collect on to others.

There are also forms of managing materials that are not quite reuse and not quite recycling.

§ **Repair** is a method of taking an item, which may appear to have lived its useful life, and fixing it so that it can still be productive.

§ **Remanufacturing** and **refurbishing** are ways of taking some used components and some new components to "rebuild" an item. For instance, toner cartridges are often used, then sent to a manufacturer to be broken down and rebuilt using some of the original parts that are reusable, and some new parts. Other items commonly repaired or rebuilt include engines, "single-use" cameras, appliances and electronic equipment.

Reuse is a means to prevent solid waste from entering the landfill, improve our communities, and increase the material, educational and occupational wellbeing of our citizens by taking useful products discarded by those who no longer want them and providing them to those who do. In many cases, reuse supports local community and social programs while providing donating businesses with tax benefits and reduced disposal fees.



Environmental Benefits:

Many reuse programs have evolved from local solid waste reduction goals because reuse requires fewer resources, less energy, and less labor, compared to recycling, disposal, or the manufacture of new products from virgin materials. Reuse provides an excellent, environmentally-preferred alternative to other waste management methods, because it reduces air, water and land pollution, limits the need for new natural resources, such as timber, petroleum, fibers and other materials. The US Environmental Protection Agency has recently identified waste reduction as an important method of reducing greenhouse gas emissions, a contributing factor to global warming.

Community Benefits

For many years, reuse has been used as a critical way of getting needed materials to the many disadvantaged populations that exist. Reuse continues to provide an excellent way in which to get people the food, clothing, building materials, business equipment, medical supplies and other items that they desperately need. There are other ways, however, that reuse benefits the community.

Economic Benefits

When reusing materials, instead of creating new products from virgin materials, there are fewer burdens on the economy. Reuse is an economical way for people of all socio-economic circles to acquire the items they need. From business furniture to household items, from cars to appliances, and just about anything else you could think of it is less expensive to buy used than new.

Reuse is the Solution.

While manufacturing new products drains our limited natural resources, and disposing of unwanted materials pollutes our environment, our communities face difficulties getting the affordable goods they need. One way to prevent waste, improve our communities, and increase the material well-being of our citizens is to take useful products discarded by those who no longer want or need them and provide them to those who do.

Every community has some existing form of reuse – and, every community needs more reuse now! Volunteer efforts, for-profit businesses and charities are all making reuse happen, including:

- thrift stores and charitable drop-off centers;
- reuse centers, equipment and materials;
- "drop & swap" stations at landfills;
- used equipment stores and salvage yards;

- local and regional material exchanges.

Reuse Supports Solid Waste Management Goals.

Buying and using items that are reusable supports a method of waste management that has been identified by the U.S. Environmental Protection Agency and others, as a priority method of handling materials. In many cases an item can be reused several times, then sent to the recycling center for processing. The list of reused items is virtually unlimited, and reuse centers can be found in nearly every community.

Building Materials – Lumber, tools, windows, doors, light fixtures, paint, plumbing supplies and fixtures, architectural pieces, fencing, hardware, and many other items needed for constructing or refurbishing a building can be found used.

Office Furniture and Supplies – Desks, tables, chairs, filing cabinets, credenzas, shelving units, stacking trays, tape dispensers, notebook binders and other equipment and supplies can be reused in offices, schools, hospitals, non-profit organizations and others.

Computers and Electronics – Personal computers, printers, fax machines, televisions, video cassette recorders can be reused in business, personal, and non-profit environments.

Art Materials – Fabric, paint, lumber, stage props, and a wide variety of other items can be used for school or cultural organization creative projects.

Medical Equipment and Supplies – Equipment and supplies that are obsolete to one hospital, clinic or organization may find a home in another facility, especially those in less-industrialized nations.

Surplus Food Items and Equipment – Boxed, bagged, canned and even prepared food from grocery stores, warehouses, manufacturers' over-runs and discontinued items, catered events, restaurants can be reuse by homeless shelters, soup kitchens, and other organizations serving disadvantaged people. Stoves, refrigerators, freezers, and other items can also be found used.

Household Items – Appliances, clothing, furniture, dishes, vehicles, paint, and virtually anything else for the home can be found by shopping reused instead of brand new. And in most cases, at a significantly lower price. Another form of reuse is shopping specialty stores that sell antiques or vintage items. Shopping and holding

[redacted]

garage and yard sales are other popular forms of reuse.

Reuse Means Value-Added!

Reusing an item means that it continues to be a valuable, useful, productive item, and replaces new items that would utilize more water, energy, timber, petroleum, and other limited natural resources in their manufacture. Businesses can save significant dollars in disposal by reselling or donating items that are no longer needed. Many chemicals and solvents that are no longer useful to one organization, can be used in other applications by other organizations. This method of "materials exchange" results in disposal savings by the generating company, and saving in the purchase of the material by the recipient organization. Reuse adds value!

Reuse Supports Community Development Goals

In addition to making a positive contribution to the reduction of solid waste, many reuse programs in a community are operated by charitable organizations as a means of providing items to low-income or disadvantage people. Donating your surplus items can also

RECYCLE:

Recycling is the process of taking a product at the end of its useful life and using all or part of it to make another product. The internationally recognized symbol for recycling includes three arrows moving in a triangle. Each arrow represents a different part of the recycling process, from collection to re-manufacture to resale. Recycling reduces our waste sent to landfills, and making new products out of recycled ones reduces the amount of energy needed in production.

The U.S. EPA estimates that 75 percent of our waste is recyclable, which goes well beyond what you toss in your recycling bin at home or at school. Recycling serves two key purposes:

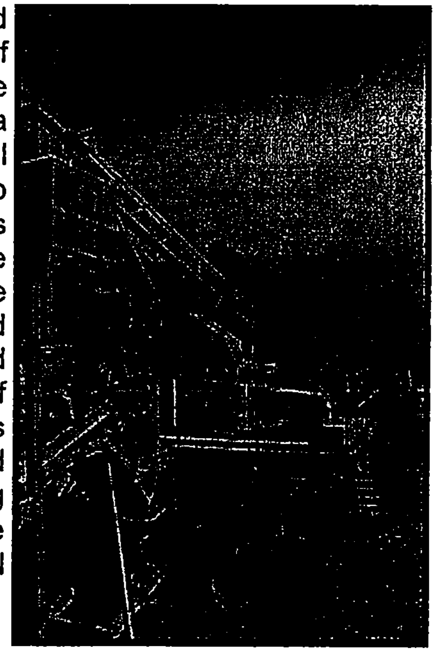
1. It keeps valuable material such as aluminum and paper **out of landfills**, so this material can be reused in other forms and not wasted.
2. It **prevents hazardous materials** and chemicals such as lead and mercury from ending up in landfills, which can contaminate soil and leach into our drinking water

Because of the second purpose, it's important to recycle lots of products, including those that you might not initially think of recycling. This includes batteries, electronics, motor oil, paint and any product that has "Caution" or "Warning" on the label.

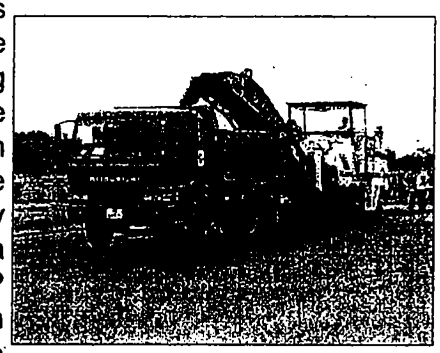
[redacted]

1. Recycled Concrete Aggregate (RCA)

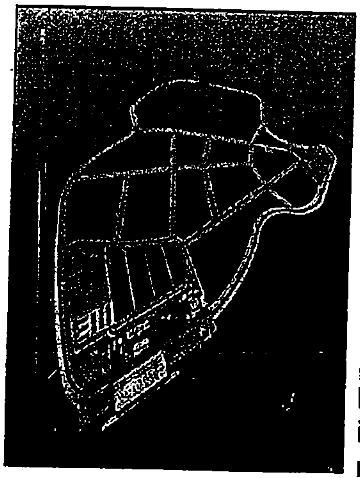
Recycled concrete aggregate (RCA) is derived from the construction and demolition (C&D) of civil and building structures. The disposal of the C&D waste is a problem due to limited land area in Singapore. Moreover, the lack of natural aggregates available in Singapore has also posed a need to source for alternative materials for construction. To address these problems, we have set up a plant to process the C&D waste into RCA which contain mainly aggregate and cementitious materials. We have been awarded a research grant to study the effective usage of RCA for construction. The project was completed successfully and RCA has been used in road construction and civil engineering precast concrete components. At present, we are also studying the use of RCA in structural concrete.



2. Reclaimed asphalt pavement (RAP) is derived from asphalt pavement wastes which are generated from the resurfacing and reconstruction of asphalt pavement. The waste can be processed into RAP which contains mainly aggregate and asphalt. The use of RAP has been practiced worldwide for many years and the technologies and technical data are well documented. At present, the use of RAP in still Singapore is very limited. We have been awarded a research grant from NEA to study the effective usage of RAP in road construction. This offers an important opportunity to save the use of virgin materials, conserve energy, divert materials from landfills and save cost.



3. MSW Incinerator ASH (MSW ASH)



Singapore faces a unique challenge due to our limited land area and high rate of waste generation. In 2006, about 7000 tonnes of **municipal solid waste** (MSW) is generated every day and most of the waste is incinerated. The incineration produces about 1700 tonnes of MSW ash per day which is currently disposed at Pulau Semakau landfill. Due to limited land area in Singapore, there is a need to recycle the MSW ash. A project has been carried out to process the MSW ash into an Engineered Aggregate to be used for construction applications. The process involves physical and chemical treatment using a patented technology. The engineered aggregate has been tested to be non-hazardous and is safe for usage in diverse applications such as base and sub base for road construction, land reclamation, backfill for trench, structural landfill, artificial reefs, concrete blocks, shore protection etc.

BIOMEDICAL WASTE MANAGEMENT (BMW)

Biomedical waste consists of solids, liquids, sharps, and laboratory waste that are potentially infectious or dangerous. It must be properly managed to protect the general public, specifically healthcare and sanitation workers who are regularly exposed to biomedical waste as an occupational hazard.

Biomedical waste poses hazard due to two principal reasons – the first is *infectivity* and other *toxicity*

Bio-medical waste means "any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals.

Biomedical waste differs from other types of hazardous waste, such as industrial waste, in that it comes from biological sources or is used in the diagnosis, prevention, or treatment of diseases. Common producers of biomedical waste include hospitals, health clinics, nursing homes, medical research laboratories, offices of physicians, dentists, and veterinarians, home health care, and funeral homes.

There was no legislation on Medical waste till the Ministry of Environment and Forest (MoEF) proposed the first draft rules in 1995. The rules recommended on-site incinerators for all hospitals with more than 50 beds. At the same time, in a public interest case, the Supreme Court of India, in March 1996, ordered the inclusion of alternate technologies and their standards in the Rules.
The second draft rules were notified in 1997. The final rules were notified on 20th July 1998 and were called Bio-Medical Waste (Management & Handling) or BMW Rules 1998 (see website at: http://dpcc.delhigovt.nic.in/act_bmw.htm).

Two other amendments have come through since. The first amendment notified on March 6th 2000, is referred to as Bio-Medical Waste (Management & Handling) (Amendment) Rules 2000. This amendment only changed Schedule VI of the rules, concerning having waste management facilities for treatment of waste. Even when the first deadline for eight cities with a population of more than 3 million was over, these cites had not been able to achieve anything significant in this direction. This amendment thus extended the deadline for implementation for the first phase. The second amendment to the rules was notified on 2nd June 2000 (called BMW Rules, 2000). Some of the major changes made included defining the role of the municipal body of the particular area, nominating Pollution Control Boards/ Committees as Prescribed Authorities, addition of forms for seeking authorization to operate a facility and for filing an appeal against order passed by the prescribed authority.

The entire country now comes under the umbrella of the rules as 31st December 2002 was the deadline for the last phase of implementation of the rules covering all the health care institutions, cities, towns and villages nationally. Initially, the states were given the option to decide the Prescribed Authority. Most of the states either nominated State Pollution Control Boards or the department of health as the prescribed authority. However, since the work involved a lot of technical intervention like monitoring the air emission from the incinerators, monitoring of the waste water effluent etc. eventually it was felt that pollution control departments would be appropriate as the prescribed authority and an amendment (Second Amendments to the Rules, June 2000) was made to this effect.

The fact that the Ministry of Family Health and Welfare was not as actively involved in determining the BMW Rules, as was the Ministry of Environment, explains, to some extent, some of the difficulties in implementing the Rules at the level of health care facilities.

Salient features of the Bio-Medical Waste (Management and Handling) Rules, 1998:

• The rules apply to all persons who generate, collect, receive, transport, treat, dispose, store, or handle bio-medical waste in any form.

• It is the duty of the occupier, where required to set up requisite bio-medical waste treatment facilities like incinerator, autoclave, microwave for treatment of waste, or ensure requisite treatment of waste at a common waste treatment facility.

• Bio-medical waste is to be treated and disposed in accordance with schedule I.

• Bio-medical waste has to be segregated at the point of generation in accordance with schedule II before its storage, transportation, treatment and disposal. The containers are to be labeled as per Schedule III.

• No untreated bio-medical waste can be kept beyond a period of 48 hours.

• **Prescribed Authority**: The State Pollution Control Boards have been nominated as the Prescribed Authority for granting authorization and implementing the rules. (As per the 2nd amendment, June 2000).

• **Authorization**: Every occupier, except those providing treatment /service to less than1000 patients a month, and every operator of a bio-medical waste facility, needs to take authorization from a prescribed authority.

• **Advisory Committee**: The Government of every State/Union territory has to constitute an advisory committee. The committee will include experts from medical and health fields, from the municipal department and other related departments.

• **Annual Report**: Every occupier /operator has to submit an annual report to the prescribed authority in Form II by January 31st every year. The report will include information about the categories and quantities of bio-medical waste handled during the preceding year.

• **Maintenance of Records**: Every authorized person shall maintain records related to the generation, collection, reception, storage, transportation, treatment, disposal and/or any form of handling of bio-medical waste in accordance with the Rules and any guidelines issued.

• **Accident Reporting**: When any accident occurs at any institution or facility or at any other site where bio-medical waste is handled or during transportation of such waste, the authorized person has to report the accident in Form III to the prescribed authority.

• **Appeal:** Any person aggrieved by an order made by the Prescribed Authority under these rules may, within 30 days from the date on which the order is communicated to him appeal to the Government of State/ Union territory

COMPONENTS:

The following is a list of materials that are generally considered biomedical waste:

Solids

- Catheters and tubes
- Disposable gowns, masks and scrubs
- Disposable tools, such as some scalpels and surgical staplers
- Medical gloves
- Surgical sutures and staples
- Wound dressings

Liquids

- Blood
- Body fluids and tissues
- Cell, organ, and tissue cultures

Sharps

- Blades, such as razor or scalpel blades
- Lancets
- Materials made of glass, such as cuvettes and slides
- Metal stylets
- Needles
- Plastic pipettes and tips
- Syringes

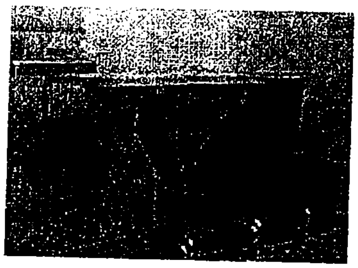
Laboratory waste

- Animal carcasses
- Hazardous chemicals with biological components
- Media
- Medicinal plants
- Radioactive material with biological components
- Supernatants

Exceptions

Cadavers, urine, feces, and cytotoxic drugs are not considered biomedical waste.

MANAGEMENT:



Sorting of medical wastes in hospital

At the site where it is generated, biomedical waste is placed in specially-labelled bags and containers for removal by biomedical waste transporters. Other forms of waste should not be mixed with biomedical waste as different rules apply to the treatment of different types of waste. Biomedical waste is treated by any or a combination of the following methods: incineration; discharge through a sewer or septic system; and steam, chemical, or microwave sterilisation. Any tools or equipment that come into contact with potentially infectious material and are not disposable or designed for single-use are sterilised in an autoclave.

Household biomedical waste usually consists of needles and syringes from drugs administered at home (such as insulin), soiled wound dressings, disposable gloves, and bed sheets or other cloths that have come into contact with bodily fluids. Disposing of these materials with regular household garbage puts waste collectors at risk for injury and infection, especially from sharps as they can easily puncture a standard household garbage bag. Many communities have programs in place for the disposal of household biomedical waste. Some waste treatment facilities also have mail-in disposal programs.

Biomedical waste treatment facilities are licensed by the local governing body which maintains laws regarding the operation of these facilities. The laws ensure that the general public is protected from contamination of air, soil, groundwater, or municipal water supply.

Applicability of BMW Rules, 1998:

The BMW Rules are applicable to every occupier of an institution generating biomedical waste which includes a hospital, nursing homes, clinic, dispensary, veterinary institutions, animal houses, pathological lab, blood bank by whatever name called, the rules are applicable to even handlers.

CATEGORIES OF BIOMEDICAL WASTE SCHEDULE – I

WASTE CATEGORY	TYPE OF WASTE	TREATMENT AND DISPOSAL OPTION
Category No. 1	**Human Anatomical Waste** (Human tissues, organs, body parts)	Incineration/deep burial
Category No. 2	**Animal Waste** (Animal tissues, organs, body parts, carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by veterinary hospitals and colleges, discharge from hospitals, animal houses)	Incineration/deep burial
Category No. 3	**Microbiology & Biotechnology Waste** (Wastes from laboratory cultures, stocks or specimen of live micro organisms or attenuated vaccines, human and animal cell cultures used in research	Local autoclaving/ microwaving / incineration
Category No. 4	**Waste Sharps** (Needles, syringes, scalpels, blades, glass, etc. that may cause puncture and cuts. This includes both used and unused sharps)	Disinfecting (chemical treatment/ autoclaving / microwaving and mutilation / shredding
Category No. 5	**Discarded Medicine and Cytotoxic drugs** (Wastes comprising of outdated, contaminated and discarded medicines)	Incineration / destruction and drugs disposal in secured landfills
Category No. 6	**Soiled Waste** (Items contaminated with body fluids including cotton, dressings, soiled plaster casts, lines, bedding and other materials contaminated with blood.)	Incineration / autoclaving / microwaving
Category No. 7	**Solid Waste** (Waste generated from disposable items other than the waste sharps such as tubing, catheters, intravenous sets, etc.)	Disinfecting by chemical treatment / autoclaving / microwaving and mutilation / shredding
Category No. 8	**Liquid Waste** (Waste generated from the laboratory and washing, cleaning, house keeping and disinfecting activities)	Disinfecting by chemical treatment and discharge into drains
Category No. 9	**Incineration Ash** (Ash from incineration of any biomedical waste)	Disposal in municipal landfill
CategoryNo.10	**Chemical Waste** (Chemicals used in production of biological, chemicals used in disinfecting, as insecticides, etc.)	Chemical treatment and discharge into drains for liquids and secured landfill for solids.

[redacted]

COLOUR CODING AND TYPE OF CONTAINER SCHEDULE - II

Color Coding	Type of Container	Waste Category	Treatment options as per Schedule I
Yellow	Plastic bag	Cat.1,Cat.2, Cat.3 and Cat.6	Incineration/ deep burial
Red	Disinfected container/ plastic bag	Cat.3, Cat.6, and Cat.7	Autoclaving/Micro waving/ Chemical Treatment
Blue/ White Translucent	Plastic Bag/ puncture proof container	Cat.4 and Cat.7	Autoclaving/Micro waving/ Chemical Treatment and destruction/ shredding
Black	Plastic bag	Cat.5, Cat.9, and Cat.10 (solid)	Disposal in secured landfill

Different Types of BMW according to WHO:

The World Health Organization (WHO) has classified medical wastes their according to weight, density and constituents into different categories. These are:

- **Infectious**: material-containing pathogens in sufficient concentrations or quantities that, if exposed, can cause diseases. This includes waste from surgery and autopsies on patients with infectious diseases, sharps, disposable needles, syringes, saws, blades, broken glasses, nails or any other item that could cause a cut;

- **Pathological**: tissues, organs, body parts, human flesh, foetuse, blood and body fluids, drugs and chemicals that are returned from wards, spilled, outdated, contaminated, or are no longer required;

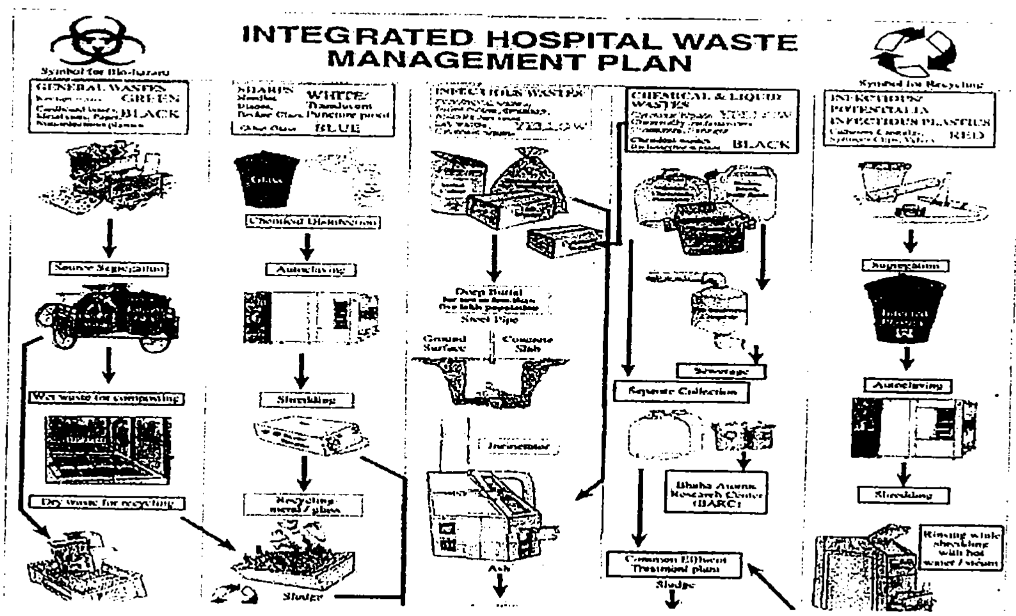
- **Radioactive**: solids, liquids and gaseous waste contaminated with radioactive substances used in diagnosis and treatment of diseases like toxic goiter; and

- **Others**: waste from the offices, kitchens, rooms, including bed linen, utensils.

[redacted]

Estimates of medical waste generation in South Asia

Country	Waste generation (kg/bed/day)	Total waste generation (tons/year)
Bangladesh	0.8 - 1.67	93,075 (255 ton/day) (only in Dhaka)
Bhutan	0.27	73
India	1 - 2	330,000
Maldives	NA	146
Nepal	NA	365
Pakistan	1.06	250,000
Sri Lanka	0.36	6600 (only in Colombo)



SEGREGATION:

Segregation refers to the basic separation of different categories of waste generated at source and thereby reducing the risks as well as cost of handling and disposal. Segregation is the most crucial step in bio-medical waste management. Effective segregation alone can ensure effective bio-medical waste management. The BMWs must be segregated in accordance to guidelines laid down under schedule 1 of BMW Rules, 1998.

[redacted]

How does segregation help?

- Segregation reduces the amount of waste needs special handling and treatment
- •Effective segregation process prevents the mixture of medical waste like sharps with the general municipal waste. •Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics. Provides an opportunity for recycling certain components of medical waste like plastics after proper and thorough disinfection.
- Recycled plastic material can be used for non-food grade applications.
- Of the general waste, the biodegradable waste can be composted within the hospital premises and can be used for gardening purposes.
- Recycling is a good environmental practice, which can also double as a revenue generating activity.
- Reduces the cost of treatment and disposal (80 per cent of a hospital's waste is general waste, which does not require special treatment, provided it is not contaminated with other infectious waste)

Proper labeling of bins

The bins and bags should carry the biohazard symbol indicating the nature of waste to the patients and public.

Schedule III (Rule 6) of Bio-medical Waste (Management and Handling) Rules, 1998 specifies the Label for Bio-Medical Waste Containers / Bags as:

Cytotoxic Biohazard

Label shall be non-washable and prominently visible.

COLLECTION: The collection of biomedical waste involves use of different types of container from various sources of biomedical wastes like Operation Theatre, laboratory, wards, kitchen, corridor etc. The containers/ bins should be placed in such a way that 100 % collection is achieved. Sharps must always be kept in puncture-proof containers to avoid injuries and infection to the workers handling them.

STORAGE: Once collection occurs then biomedical waste is stored in a proper place. Segregated wastes of different categories need to be collected in identifiable containers. The duration of storage should not exceed for 8-10 hrs in big hospitals (more than 250 bedded) and 24 hrs in nursing homes. Each container may be clearly labelled to show the ward or room where it is kept. The reason for this labelling is that it may be necessary to trace the waste back to its source. Besides this, storage area should be marked with a caution sign.

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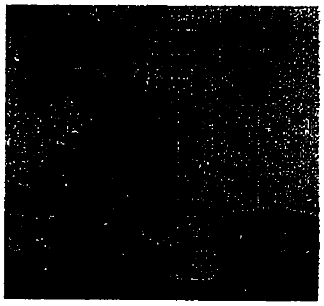


TRANSPORTATION: The waste should be transported for treatment either in trolleys or in covered wheelbarrow. Manual loading should be avoided as far as for as possible. The bags / Container containing BMWs should be tied/ lidded before transportation. Before transporting the bag containing BMWs, it should be accompanied with a signed document by Nurse/ Doctor mentioning date, shift, quantity and destination.

☞Special vehicles must be used so as to prevent access to, and direct contact with, the waste by the transportation operators, the scavengers and the public. The transport containers should be properly enclosed. The effects of traffic accidents should be considered in the design, and the driver must be trained in the procedures he must follow in case of an accidental spillage. It should also be possible to wash the interior of the containers thoroughly.

Personnel safety devices:

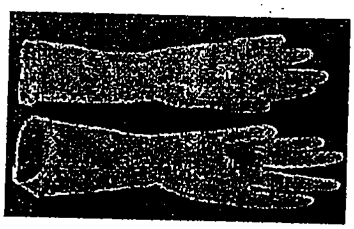
The use of protective gears should be made mandatory for all the personnel handling waste.

✚ **Gloves:** Heavy-duty rubber gloves should be used for waste handling by the waste retrievers. This should be bright yellow in color. After handling the waste, the gloves should be washed twice. The gloves should be washed after every use with carbolic soap and a disinfectant. The size should fit the operator.

✚ **Aprons, gowns, suits or other apparels:** Apparel is worn to prevent contamination of clothing and protect skin. It could be made of cloth or impermeable material such as plastic. People working in incinerator chambers should have gowns or suits made of non-inflammable material.

✚ **Masks:** Various types of masks, goggles, and face shields are worn alone or in combination, to provide a protective barrier. It is mandatory for personnel working in the incinerator chamber to wear a mask covering both nose and mouth, preferably a gas mask with filters.

✚ **Boots:** Leg coverings, boots or shoe-covers provide greater protection to the skin when splashes or large quantities of infected waste have to be handled. The boots should be rubber-soled and anti-skid type. They should cover the leg up to the ankle.



Gloves

Aprons, gowns, suits or other apparels

Masks

Boots

Cleaning devices:

- **Brooms:** The broom shall be a minimum of 1.2 m long, such that the worker need not stoop to sweep. The diameter of the broom should be convenient to handle. The brush of the broom shall be soft or hard depending on the type of flooring.
- **Dustpans:** The dustpans should be used to collect the dust from the sweeping operations. They may be either of plastic or enamelled metal. They should be free of ribs and should have smooth contours, to prevent dust from sticking to the surface. They should be washed with disinfectants and dried before every use.
- **Mops:** Mops with long handles must be used for swabbing the floor. They shall be of either the cloth or the rubber variety. The mop has to be replaced depending on the wear and tear. The mechanical-screw type of mop is convenient for squeezing out the water.
- **Vacuum cleaners:** Domestic vacuum cleaners or industrial vacuum cleaners can be used depending on the size of the rooms.

Storage devices:

✦Dustbins:
It is very important to assess the quantity of waste generated at each point. Dustbins should be of such capacity that they do not overflow between each cycle of waste collection. Dustbins should be cleaned after every cycle of clearance of waste with disinfectants. Dustbins can be lined with plastic bags, which are chlorine-free, and color coded as per the law.

✦Temporary sheds or storage chambers:
Rooms or sheds to house the collected waste from the institution should be located away from functional areas. It should be located preferably in the northeast direction to minimize the effect of wind carrying the pollutants. It should also be located away from chimneys, diesel generator sets, oil storage, gas storage chambers and other potential sources of fire, to prevent fire hazards.
Untreated waste should not be stored for more than 48 hours in this chamber. The chamber should be far away from drinking water tanks. The area should be cordoned off with barbed wire fencing and netting to prevent access to animals and birds. Security should be provided to strictly prohibit unauthorized access of human beings. This will prevent the unauthorized sale of waste material.

Handling devices:

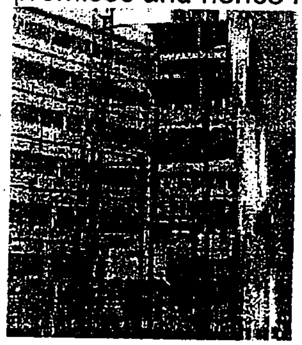
➡Trolleys
The use of trolleys will facilitate the removal of infectious waste at the source itself, instead of adding a new category of waste.
➡Wheelbarrows:

Wheelbarrows are used to transfer the waste from the point source to the collection centers. There are two types of wheelbarrow – covered and open. Wheelbarrows are made of steel and provided with two wheels and a handle. Care should be taken not to directly dump waste into it. Only packed waste (in plastic bags) should be carried. Care should also be taken not to allow liquid waste from spilling into the wheelbarrow, as it will corrode. These are ideal for transferring debris within the institution. Wheelbarrows also come in various sizes depending on the utility.

➡Chutes:

Chutes are vertical conduits provided for easy transportation of refuse vertically in case of institutions with more than two floors. Chutes should be fabricated from stainless steel. It should have a self-closing lid. These chutes should be fumigated everyday with formaldehyde vapors. The contaminated linen (contaminated with blood and or other body fluids) from each floor should be bundled in soiled linen or in plastic bags before ejecting into the chute.

Alternately, elevators with mechanical winches or electrical winches can be provided to bring down waste containers from each floor. Chutes are necessary to avoid horizontal transport of waste thereby minimizing the routing of the waste within the premises and hence reducing the risk of secondary contamination



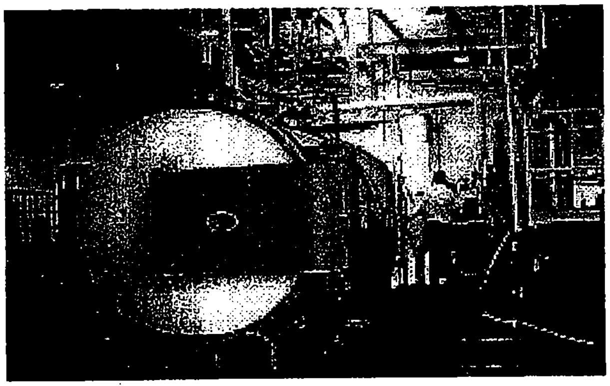
TREATMENT: Technology options for 'treatment'

There are mainly **five** technology options available for the treatment of Bio-Medical Waste or still under research can be grouped as:

1. Chemical processes
2. Thermal processes
3. Mechanical processes
4. Irradiation processes
5. Biological processes

1. Chemical processes.

These processes use chemical that act as disinfectants. Sodium hypochlorit, dissolved chlorine dioxide, peracetic acid, hydrogen peroxide, dry inorganic chemical and ozone are examples of such chemical. Most chemical processes are water-intensive and require neutralising agents.



2. Thermal processes.

These processes utilize heat to disinfect. Depending on the temperature they operate it is been grouped into two categories, which are Low-heat systems and High-heat systems

Low-heat systems (operates between 93 -177°C) use steam, hot water, or electromagnetic radiation to heat and decontaminate the waste.

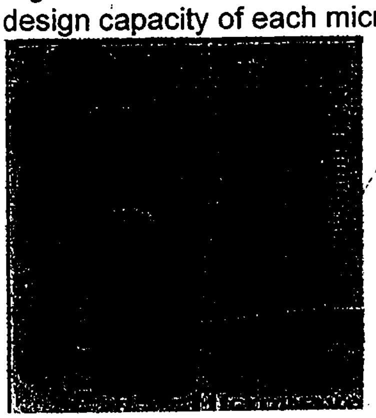
<u>Autoclave & Microwave are low heat systems.</u>

✦ Autoclaving is a low heat thermal process and it uses steam for disinfection of waste. Autoclaves are of two types depending on the method they use for removal of air pockets are gravity flow autoclave and vacuum autoclave. The autoclave should be dedicated for the purpose of disinfecting and treating biomedical waste.

✦ Microwaving is a process which disinfects the waste by moist heat and steam generated by microwave energy. Microwave treatment shall not be used for cytotoxic, hazardous or radioactive wastes contaminated animal carcasses, body parts and large metal items.

The microwave system shall comply with the efficacy tests/routine tests

The microwave should completely and consistently kill bacteria and other pathogenic organism that is ensured by the approved biological indicator at the maximum design capacity of each microwave unit.



High-heat systems (operates between 540 - 8,300°C) employ combustion and high temperature plasma to decontaminate and destroy the waste.
Ex: Incinerator & Hydroclaving are high heat systems.

Hydroclaving - is steam treatment with fragmentation and drying of waste.
Incineration - is a burn technology using incinerators.

- ✓Incinerators should be suitably designed to achieve the emission limits.
- ✓Wastes to be incinerated shall not be chemically treated with any chlorinated disinfectants.
- ✓Toxic metals in the incineration ash shall be limited within the regulatory quantities
- ✓Only low sulphur fuel like Diesel shall be used as fuel in the incinerator

3. Mechanical processes.
These processes are used to change the physical form or characteristics of the waste either to facilitate waste handling or to process the waste in conjunction with other treatment steps. The two primary mechanical processes are
a) Compaction - used to reduce the volume of the waste
b) Shredding - used to destroy plastic and paper waste to prevent their reuse. Only the disinfected waste can be used in a shredder.

4. Irradiation processes.
Exposes wastes to ultraviolet or ionizing radiation in an enclosed chamber. These systems require post shredding to render the waste unrecognizable.

5. Biological processes.
- Using biological enzymes for treating medical waste.
- It is claimed that biological reactions will not only decontaminate the waste but also cause the destruction of all the organic constituents so that only plastics, glass, and other inert will remain in the residues.

Treatment Technologies: Comparison

	Treatment Technologies				
	Incineration	Autoclave	Microwave	Chemical Disinfection	Plasma Pyrolysis
Investment/ Operating cost	High	Moderate	High	Low	High
Suitability Of the waste	Not for radioactive	All except Pathological	All except cytotoxic, radioactive	Liquid waste	All
Ease of Operation	No	Yes	Yes	Yes	No
Waste Volume reduction	Significant	Less	Significant		Significant
Odour Problems	Yes	Slight	Slight	Slight	-
Environmental friendly	No	Yes	Yes	No	Yes

What you can do?

- Use only disposable syringes. After use throw the syringes after breaking them.
- Bandages, cotton and other blood stained materials should not be thrown with general garbage.
- Use black plastic bags to dispose biomedical wastes.
- Keep trash out of reach of small children and infants.
- Diapers, Sanitary napkins etc. should also be disposed separately.
- Drugs that are past date of expiry must never be used.
- Use protective gear when handling waste.
- Avoid needle stick injuries.
- Collect waste when the bin is 3/4th full.
- Avoid using common lift to move waste.
- Avoid spillage, clean spills with disinfectant.
- Use trolleys & do not drag waste bags.

Dos and Don'ts:

Ensure

1. That the used product is mutilated.
2. That the used product is treated prior to disposal.
3. That the used product is segregated.

Do not:
1. Reuse plastic equipment.
2. Mix plastic equipment with other wastes.
3. Burn plastic waste.

We need to avoid:

- Lack of segregation practices, mixing of wastes with general waste makes whole waste stream hazardous;
- Mushrooming of clinics often unregistered aggravating the problem; How to cover them in the existing legislation;
- Open burning by clinics, dispensaries some hospitals;
- Incinerators are old and poorly maintained;
- Poor legislative measures/standards, poor implementation;
- Public ignorance of the law (if any).

ROLE OF NGOs.

During the recent years, NGOs (non-governmental organizations) have taken up initiatives to work with local residents to improve sanitation. They have been playing an active role in organizing surveys and studies in specified disciplines of social and technological sciences. In the field of garbage management, such studies are useful in identifying areas of commercial potentials to attract private entrepreneurs. They can play an important role in segregation of waste, its collection and handling over to local authorities.

A large number of NGOs are working in the field of solid waste management such as Clean Ahmedabad Abhiyan, Ahmedabad, Waste-Wise, Bangalore, Exnora, Chennai, Mumbai Environmental Action Group, Mumbai, and Vatavaran and Srishti in Delhi. They are all successfully creating awareness among the citizens about their rights and responsibilities towards solid waste and the cleanliness of their city. These organizations promote environmental education and awareness in schools and involve communities in the management of solid waste.

THE NGO PROGRAMMES:

- ►Create mass awareness, ensuring public participation in segregation of recyclable material and storage of waste at source.
- ►Provide employment through organizing door-to-door collection of waste.
- ►Ensure public participation in community based primary collection system.
- ►Encourage minimization of waste through in-house backyard composting, vermi-composting and biogas generation.

Urban poverty is inextricably linked with waste. In India alone, over a million people find livelihood opportunities in the area of waste; they are engaged in waste collection (popularly known as rag picking) and recycling through well-organized systems. Substantial populations of urban poor in other developing countries also earn their livelihood through waste. It is important to understand issues of waste in this context. The informal sector dealing with waste is engaged in various types of work like waste picking, sorting, and recycling at the organized level, door-to-door collection, composting and recycling recovery.

THE ROLE OF RAG PICKERS.

Rag pickers are the people who are actually going through the garbage bins, dumping sites to pick out the 'rags'. These rag pickers: women, children, and men from the lowest rung in the society, are a common sight in most cities and towns around the country. Rag picking is considered the most menial of all activities and it is people who have no other alternative that are generally driven to it. Rag pickers contribute a great deal towards waste management as they scavenge the recyclable matter thereby saving the municipality of the cost and time of collecting and transporting this to the dumps.

They are one of the focal points for the recycling of waste. They are the persons who, in spite of all the dangers that they faces, goes on relentlessly picking through the garbage bin, looking for waste that could be useful to them. They sell all the material they picked to the whole sellers and retailers who in turn sell it to the industry that uses this waste matter as raw material. The main items of collection are plastics, paper, bottles, and cans.

While picking through waste, the rag pickers puts themselves at a great risk and is always prone to disease as the waste that they rummages through can be infected. We can indirectly help the rag pickers by carefully segregating the waste that is generated at our homes, thereby facilitating their search for materials that are useful to them. They will not have to scavenge in the bins/yards for long hours.

Occupational hazards associated with waste handling Infections.

- Skin and blood infections resulting from direct contact with waste, and from infected wounds.
- Eye and respiratory infections resulting from exposure to infected dust.
- Different diseases that results from the bites of animals feeding on the waste.
- Intestinal infections that are transmitted by flies feeding on the waste.

[redacted]

ROLE OF POLLUTION CONTROL BOARDS.

Since the disposal of municipal solid wastes poses problems of the pollution and health hazards, the Pollution Control Boards are expected to take action for persuading the civic authorities in proper management of municipal solid wastes. Though, direct responsibility of management of solid wastes is on the local municipal authorities, the Pollution Control Boards need to have close linkage with local authorities in rendering assistance in terms of carrying out necessary surveys and providing technological back-up. The Central Pollution Control Board and the State Pollution Control Boards at the national and state levels are to disseminate information and create awareness among the concerned authorities and public at large.

Action Taken.

The Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs) within the given powers to them under relevant Acts and Rules have been attempting to persuade local bodies to take appropriate measures for the treatment and disposal of domestic sewage and municipal solid waste.

Directions.

In order to initiate a systematic approach on proper management of municipal waste (sewage and solid), CPCB issued directions to all SPCBS under section 18 of the Water (Prevention and Control of Pollution) Act, 1974. Follow-ups on Directions

In compliance to the directions of the CPCB and through initiatives of SPCBs some actions have been taken. Also SPCBs have issued notices to local bodies in the states/ UTs and impressed upon them to take proper measures.

[redacted]

WHAT CAN YOU DO TO REDUCE SOLID WASTES?

- Carry your own cloth or jute bag when you go shopping.
- Say no to all plastic bags as far as possible.
- Reduce the use of paper bags also.
- Reuse the soft drinks poly bottles for storing water.
- Segregate the waste in the house – keep two garbage bins and see to it that the biodegradable and the non-biodegradable is put into separate bins and dispose off separately.
- Dig a compost pit in your garden and put all the bio degradable into it.
- See to it that all garbage is thrown into the municipal bin as the collection is generally done from there.
- When you go out do not throw paper and other wrappings or even leftover food here and there, make sure that it is put in the correct place that is into a dustbin.
- Not to throw the waste/litter on the streets, drains, open spaces, water bodies etc.
- Storage of organic/bio-degradable and recyclable waste separately at source
- Community storage/collection of waste in flats, multi-storied buildings, societies, commercial complexes, etc.
- Managing excreta of pet dogs and cats appropriately.
- Waste processing/disposal at a community level (optional).
- Pay adequately for the services provided.
- Public education.