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REDEFINING URBAN LANDFILLS – TRANSFORMATION OF SANITARY LANDFILL THROUGH LANDSCAPE DESIGN

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AIM: To study the various landscape design strategies that can be adopted in restoration of a landfill site and various issues caused by Sanitary landfills.

OBJECTIVES:

- To study the ecological and environmental degradation prevention methods.
- To identify and compare various techniques in remediation.
- To study the issues in landfill site in India and analyse challenges, scope and opportunities
- To explore various landscape strategies for various issues and develop guidelines.

SCOPE AND LIMITATIONS:

The understanding on function of landfills, with respect to solid waste, and landscaping is included in this study. The policy making and guidelines have been considered as guidelines for strategic design.

Only landscaping design factors were focused in landfill design guidelines and policies mentioned. Issues and impacts specific to Indian context were taken into consideration.

CENTRAL RESEARCH QUESTIONS:

1. What are the landscape strategies that can be used to convert the Sanitary landfill site into Usable/ vegetative land and prevent impacts that arise due to landfills?

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OUTCOME: Identifying techniques suitable for the current scenario for Indian context, the challenges in the adopted methods, and derive guidelines for designing a functional sanitary landfill site.

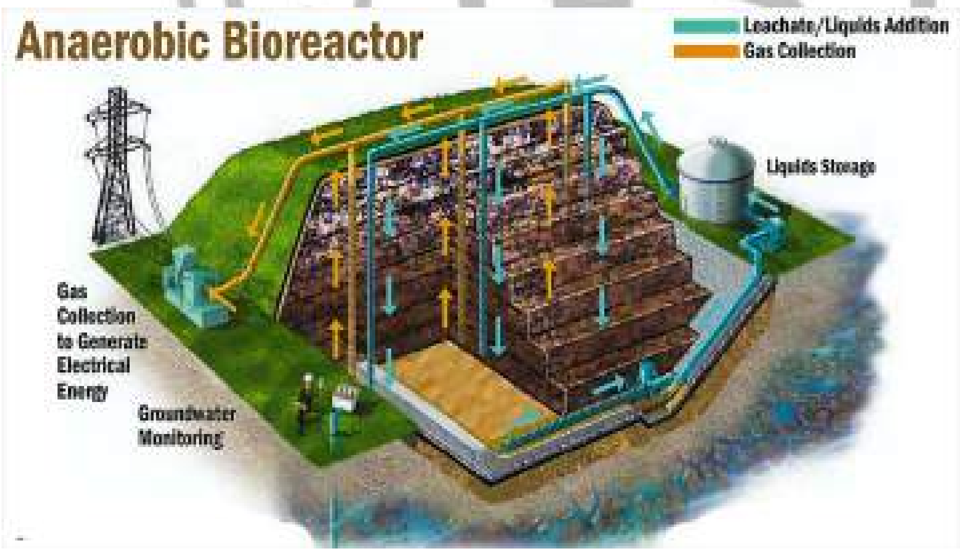
1. INTRODUCTION :

1.1 What is a SANITARY LANDFILL?

It is a method of disposing Municipal solid waste by isolating it from the environment and humans by covering the MSW after collecting it for a stipulated period of time (eg:10-15 years) with a layer of Earth and Geo synthetic membrane Known as vegetative capping and blending it with the surroundings so that the collected waste in-turn doesn't cause ecological and environmental pollution due to exposure to air and contact with ground.

An **environmentally sustainable landfill** should be functional in two phases:1 Operational phase i.e. landfill phase,2. Post-operational phase- final use created after capping of deposited and compacted wastes.

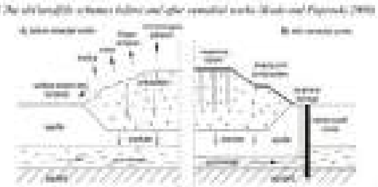
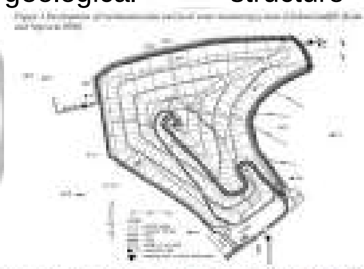
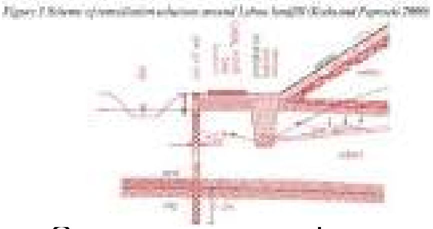
Fig-1:Sectional view of a typical sanitary landfill



Source: Kaszubska, M. and Wzorek, M., 2017. The Bioreactor–an Innovative Method of Disposal of Solid Waste. Economic and Environmental Studies.

2. LITERATURE REVIEW:

S.no	Type of the research paper-Authors-Year	Summary-Design strategies- illustrations	Implementable aspects/Takeaways

1	**Experimentational investigation of strategies' effectivity** - *Julita Dworak, Eugeniusz Koda, Magdalena Daria Vaverkova- 2018*	The paper presents- concept of landscaping of the **MSW landfill Lubna, Warsaw**. Area- 22 ha . • Restoration on this landfill is based on 1. weather, topography, ecosystem, slope of landfill 2. The compost from waste- used as subsoil for planting. • landfill slope stability –1.filling the berms with waste -2. reinforcement-cohesive soil + compost +constructed berms for steep  slopes. • Groundwater protection- bentonite cut – off wall - 0.6 m thickness 5.5–17 m depth. • Degassing wells-biogas source/methane gas  collection. • Leachate collection- "finger" pipe drainage to- Peripheral leachate drainage-based on hydro-geological structure of site   • Covering- mineral cover system(with permeability coefficient less than 10-9 m/s)for the body waste- allows moisture and oxygen penetration -oxygen fermentation. • vegetation cover-appropriate plant species.	Slope stability - constructed berms. Barrier/ cut-off wall can be given - g round water protection. Degassing wells - Methane gas collection. Finger pipe drain - leachate collection. Covering material-should allow fermentation. Composting- onsite.

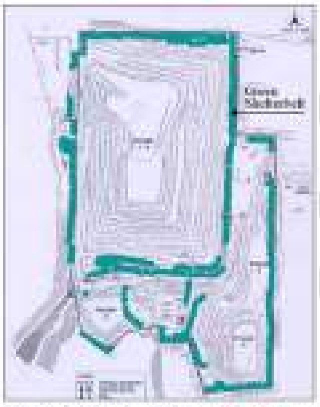
<table>
<tr>
<td>2</td>
<td>comprehensive investigation
-Ashkan Nochian, Osman Mohd Tahir, Suhardi Mualan and Ding Rui, 2019</td>
<td>The study emphasizes that landscape can play a significant role along with landfill from site selection stage unlike commonly used only in Post closure stage. The landscape work on landfill site has been divided into 4 stages listed as below.
Significant landscape work based on each landfill life cycle
<table>
<tr><th></th><th colspan="4">Significant landscape work</th></tr>
<tr><td>Siting and planning stage</td><td>After-use consideration</td><td>Buffer distance</td><td>Flora and fauna analysis</td><td></td></tr>
<tr><td>Designing stage</td><td>Enforcement of buffer zone (shelterbelt)</td><td>Blocking eyesore view</td><td>Design criteria association with after-use plan</td><td></td></tr>
<tr><td>Construction stage</td><td>Building any amenities in accordance with after-use plan</td><td>Implementing buffer zone (shelterbelt)</td><td>Preserving in-situ natural vegetation</td><td>Transplanting existing plants</td></tr>
<tr><td>Operation stage</td><td>Landscape maintenance/ management program</td><td>Separation and storage of useful stuff to be reusing</td><td>Initial establishment of landfill cover greening</td><td>Transplanting existing plants</td></tr>
<tr><td>Closure and post-closure stage</td><td>Completing of vegetation's establishment</td><td>Association to final after-use</td><td>Surveillance on existing soft and hard landscaping</td><td></td></tr>
</table>
All the listed works done stage wise helps to achieve a resource efficiency and increase recycling capacity while also addressing few environmental issues by integrated approach of landscaping and waste management techniques like reusing waste, composting, etc.


Figure 3. Conceptual green shelterbelt for Air Hitam Sanitary Landfill in Malaysia as a demonstration (Hatfield, 2009)

Figure 4. [illegible]</td>
<td>Stages of landscape development from landfill to landscape restoration are to be noted. The after use of the landfill must be consciously planned during the siting stage itself while gathering the necessary material required form the waste received at the facility along the operational stage.</td>
</tr>
</table>

3	**Comparative study-**Sam *Tarrant,Jeff Ollerton, Md Lutfor Rahman, Joanna Tarrant, and Duncan McCollin-2012*	Location: United Kingdom. Nine pairs of sites have been documented for comparative analysis. Two types among the nine sites are: 1. restored landfill sites 2. Reference sites Comparison parameters: 1.Floral characteristics, 2.species richness, 3.abundance of flower- visiting insects. Method- Standardized Field survey over two seasons.  Table 2. Species richness for the main taxa of flower-visiting insects recorded on restored landfill sites and reference sites. (2007: Restored landfill / Reference site; 2008: Restored landfill) Bees (except Bombus) – Hymenoptera: Apoidea – 2 – 3 – 6 Bumblebees – Hymenoptera: Bombus – 5 – 4 – 4 Beetles – Coleoptera – 2 – 3 – 5 Butterflies – Lepidoptera – 1 – 6 – 6 Flies – Diptera – 6 – 8 – 4 Hoverflies – Diptera: Syrphidae – 11 – 10 – 16 Other – — – 3 – 1 – 2 Total – — – 30 – 37 – 41 The restored landfill sites are noted to have being able to support the pollinator population when floral resources are provided. Seen evidently in the season where they may be absent elsewhere.	Sowing suitable flowering plants before the end of pollinator visiting season helps in propagation of grasslands. **Observations-no difference** between the **restored landfill and reference sites** in terms of species richness or abundance of plants.
4	**Comprehensive study-** *Sam Tarrant,Jeff Ollerton,Md Lutfor Rahman,Joanna Tarrant,and Duncan McCollin-2012*	The study strives to emphasize the fact that, - “Biodiversity conservation through restoring degraded habitats or creating new habitats” act advocated in the UK Biodiversity Action Plan, can be achieved through restoration of landfill caps using appropriate species mixes. Key points: Restoration of landfill caps-problematic because of poor soil -high concentration of landfill gas. Study on suitable Plant communities of these sites is important as they may have a bigger role in restoration of landfill caps and could get recognition in the broader biodiversity conservation framework. • Huge area of landfill sites are potential conservation by creating opportunities to restore biodiversity and ecosystem functions.	Restored landfill sites- show various environmental characteristics- hence regenerative plant species are ideal for landfill caps. Proper management of landfill sites to support appropriate species mixes can help meet conservation target.
5	**Experimentational study-** *Reyhan Erdogan , Zeynep Zaimoglu, M. Yavuz Sucu, Fuat Budak and Secil Kekec-2007*	• Study aims at identifying applicability of the tested plant species to be used in rehabilitation and recreational arrangement of landfill sites-sample groups of perennial grass and shrubs plants. • Leachate stabilization strategy used-phytoremediation. • Nitrogen(vital component of chlorophyll) accumulation ratios and the effects of landfill leachate in diluted proportions on growth and development of few plant species are studied. • Tested species-1.*Cynodon dactylon* *2. Nerium oleander* *3. Pelargonium pellatum* *4.Stenotaphrum secundatum* *5. Paspalum notatum* *6. Pennisetum clandestinum*	There are natural alternatives for Leachate management Phytoremediation techniques- some species can be utilized for phytoremediation. Presence of Nitrogen in leachate is very useful for the plant growth when leachate irrigation is done. Leachate tolerant

		7. Mentha piperita. • *survival rate* of 100%- seen in *S. secundatum, K. scoparia and N. oleander*,- being irrigated with pure leachate • *Survival rate of* 0 to 35%- Other species under the same conditions.	species compared are- evergreen grasses and shrubs in nature

3. LANDFILL WORKING AND COMPREHERNSIVE DESIGN GUIDELINES:

3.1. SITE CHARACTERISTICS:

3.1.1 Type of soil: loamy coarse sand, predominantly clayey loam-Preferable, sandy silty soils (predominantly sandy)-not-preferable because they are very permeable.

Soil permeability: ease with which water seeps through a soil.

Permeability coefficient k (cm/s)
(Logarithmic Scale)

k (cm/s)	10^2	10^1	1.0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10
Drainage	Good						Bad		Practically impermeable			
Sanitary landfill	Extremely bad									Good		
Type of soil	Coarse gravel		Clean sand, sand mixed with gravel		Very fine sand, organic and inorganic soils, mix of sandy silt and clay / Impermeable soil, for example: homogeneous clay under the weathering area					Impermeable soil, for example: homogeneous clay under the weathering area		

Source. Adapted from CETESB. Industrial solid wastes. 2nd enlarged edition. São Paulo, 1993, p. 91.

3.1.2 **Availability of cover material:** Undulated land can be good sources of cover material.

3.1.3 **Depth of the water table**: Preference- well drained land- water table is more 1m deep the whole year round. water table less than 1m deep - rejected

d)The direction of groundwater flow: If a plume occurs, wells in that plume will be contaminated. Barrier wall/cut-off wall along the landfill periphery -depth = bottom of the aquifer, is to be given to restrict contamination.

3.2.CLIMATE CONDITIONS:

Wind direction: Preferable location- In the direction of wind from the urban area, or trees and thick vegetation should be planted all around the landfill.

Rainfall: perimeter drains and the leachate collection and disposal system depends on the amount of rainfall.

3.3.LANDFILL PLANNING AND DESIGN :

3.3.1.Design Life: 'active' period -'closure' and post-closure'

Table-1: Table showing landfill capacity

Landfill Capacity	Area occupied by waste
Small size landfill	less than 5hectare
Medium size landfill	5 to 20hectare area
Large size landfill	greater than 20hectare area

Source: CPHEEO

Typical range -10 to 25 years

Maximum allowed height-30 meters (but varies depending on site conditions).

3.3.2Buffer area and protection: 5 to 20 m strip - between the site border and the area of waste embankments or trenches- plant a hedge of shrubs and trees - berm for visual screening. Fast growing species suggested- pine, eucalyptus, laurel, bamboo, etc.

3.4.SITE PREPARATION:

3.4.1Leveling:

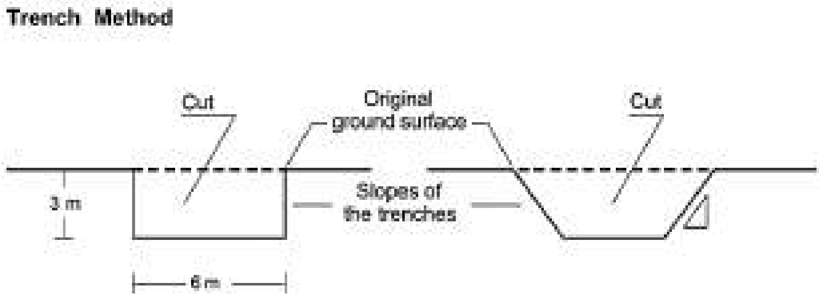
1. base surface gradient of 2 or 3% after clearing the land.

2.Top soil to be collected and stored.

3.4.2.Landfill Methods:

a) Trench method: used when the water table is deep and the gradients of the terrain are gentle**. Desirable for Cohesive soils, such as glacial till or clayey silt soil types. Trenches are aligned perpendicularly to the prevailing wind,** to reduce the amount of blowing litter

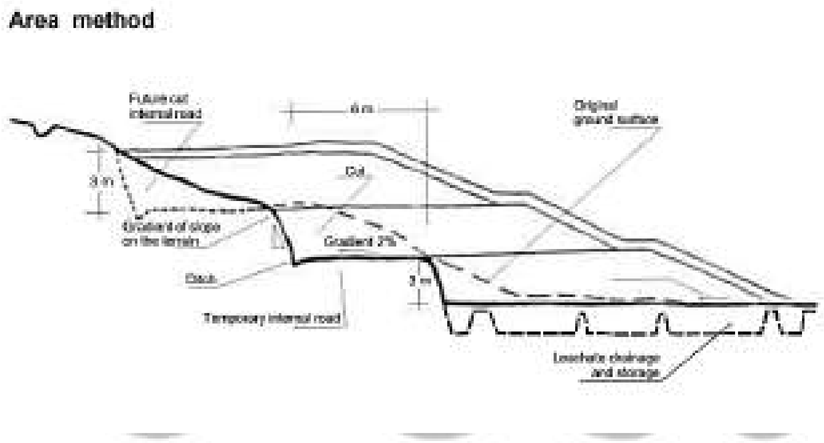
Fig-2: Landfill methods



Source: Jaramillo, J., 2003.

b) Area method: waste is placed on **the natural surface of the ground**. used on flat terrain, abandoned quarries, strip mines, depressions, and low parts of ravines.

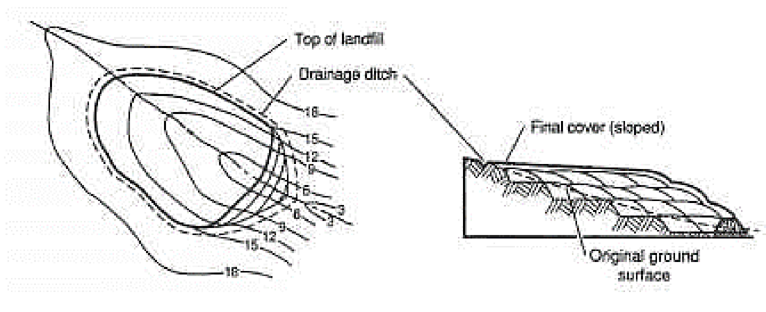
Fig-2: Landfill methods



Source: Jaramillo, J., 2003.

c) Valley or combination method: **used in valleys and ravines,** solid waste is **placed in "lifts"** from the bottom up with a **depth of 8 to 10 feet**.

Fig-2: Landfill methods



Source: Jaramillo, J., 2003.

3.5.3. Earthworks: For stability of the earth slopes -1.construction of embankments or containment dikes,2. construction of berms,3. excavation of trenches,4. excavation of drainage canals, 5. construction of dirt roads, 5. layers of compacted soil for waterproofing or protection to be done in required areas.

Fig-3: Ratio of Landfill slopes

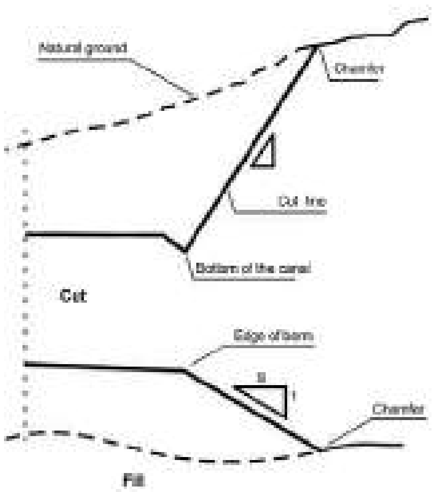


Figure 5.3
Designation of slopes

Source: Jaramillo, J., 2003.

3.6. DESIGN OF SLOPES:

- Preferable terrain - relatively impermeable material (fine sand mixed with silt, clay) .
- Preferable maximum height of a slope-5 m.

3.6.1 Slope Stability Aspects: In preliminary design of a landfill section, the following slopes may be adopted:

(a) Excavated soil slopes (2.5 Hor : 1 Vertical)

(b) Temporary waste slopes (3.0 Hor : 1 Vertical)

(c) Final cover slopes (4.0 Hor : 1 Vertical)

Slopes recommended in cut

Type of material	Recommendable slope S height of the cut H (m) up to 5 m	Observations
1. Silty sands and compact silts	1/2	$k = 10^{-7}$ cm/s. Level 1:1 the more weathered upper part. In the case of easily eroded materials, the slope should be 1:1
2. Silty sands and non-compact silts	1/4	$k = 10^{-7}$ cm/s impermeable counterdrain (intercepting ditch at the top of a slope). Level to 1.5:1 in the most weathered part.
3. Silty sands and very compact silts	1/4	$k = 10^{-7}$ cm/s. Level the loose upper part.
4. Not very sandy clays, firm and homogeneous	1/2	$k = 10^{-8}$ cm/s. Level 1:1 the weathered part. If there is a flow of water, build subdrainage.
5. Bland, expansive clays	1	$k = 10^{-8}$ cm/s

Source. Taken and adapted from Secretariat of Public Works, Department of Antioquia, Colombia.

3.6.2 Slopes of embankments: common value in embankment slopes= 1.5 : 1 .

Recommended slopes of waste for forming embankments in the landfill =2:1 or 3:1.

Fig-4: Ratios of landfill waste embankments

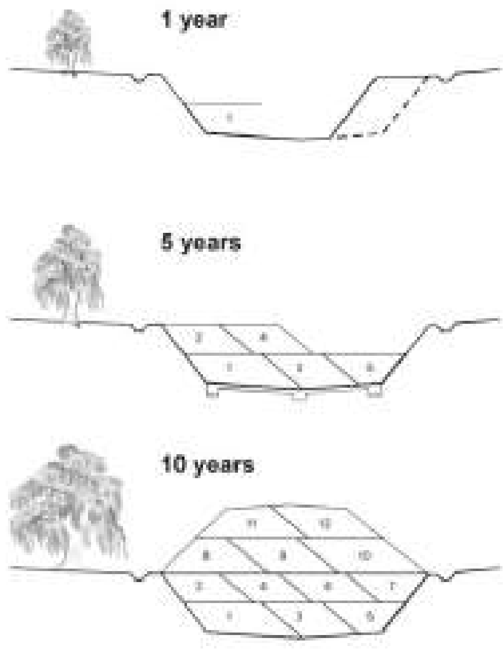
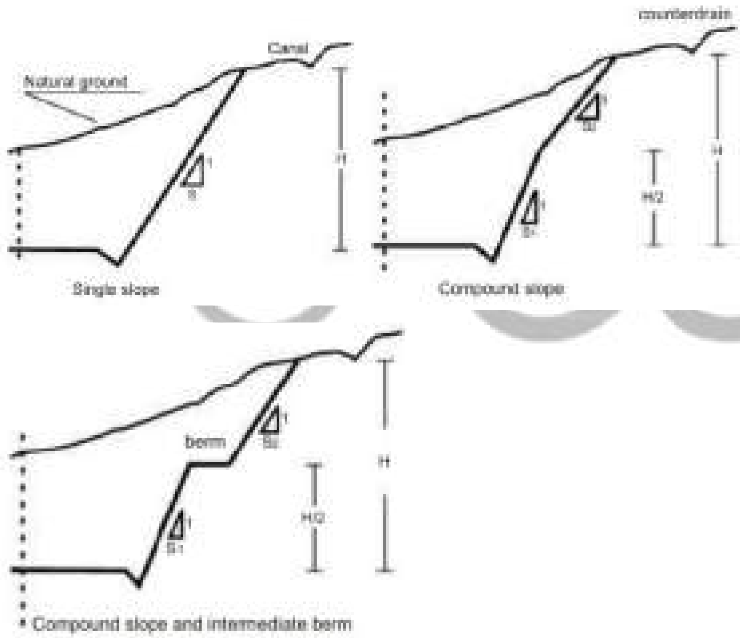


Figure 7.9
Sequence of the construction of embankments for filling the site



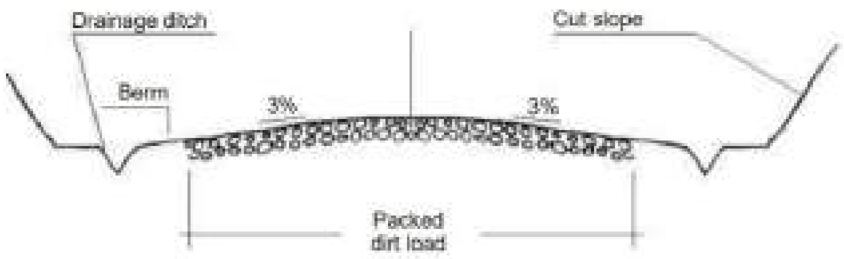
Source: Jaramillo, J., 2003.

<u>3.7. PERIPHERAL INFRASTRUCTURE</u>:

3.7.1Access road: The maximum gradient of uphill road can be 7%, and 10% downhill.

3.7.2Peripheral drainage of rainwater: Even the smallest of the water sources existing in the landfill area should be diverted and channeled before the operation starts.

Fig-5: Drainage on berms made as access roads on waste landfill



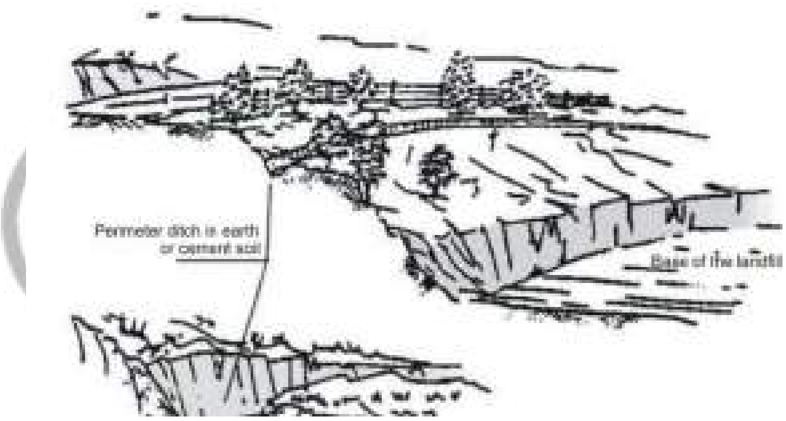
Source: Jaramillo, J., 2003.

3.8.LEACHATE:

3.8.1Leachate management: The high nitrogen content in leachate makes it harmful. This nitrogen content can be reduced using Phytoremediation ponds with synthetic bottom liners.

3.8.2 Perimeter drainage for runoff waters and leachate:

Fig-6: Detail of Perimeter drain

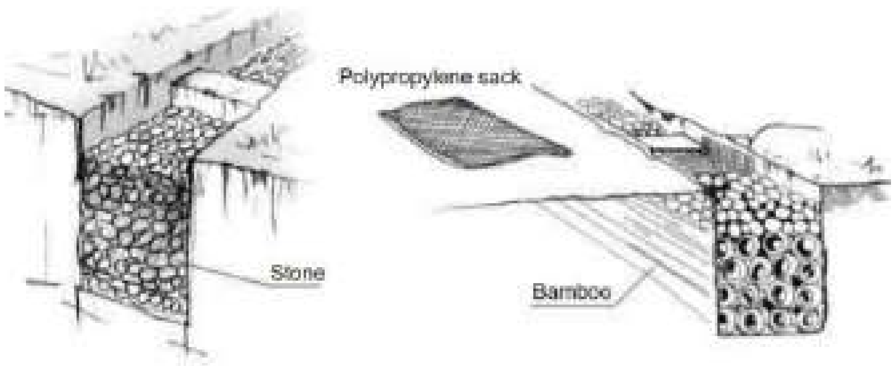


Source: Jaramillo, J., 2003.

3.8.3. Leachate drainage:

1. granular soil layer-30 cm thk
2. protection layer -20 cm to 30 cm thick- silty soil.
3. Geomembrane thickness -1.5 mm or more.
4. compacted clay barrier -1 m thick, permeability (K) - less than 10-7 cm/sec.
5. earthen screens are installations- intervals of five or ten meters, width - 0.20 to 0.30 m.,
6. For more storage capacity for the ditches -1. filling with stones of 4 to 6 inches (not gravel) , 2.infiltration of the liquids and retain fine particles that might cause silting 3.polypropylene sacks– or dry ferns, and even grass.

Fig-7: Detail of leachate storage

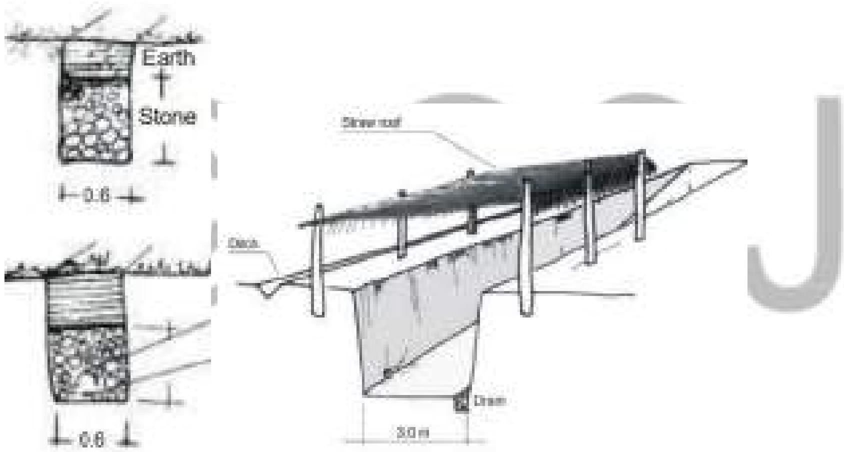


Details of the leachate storage ditches

Source: Jaramillo, J., 2003.

7. Minimization of leachate in rainy regions:
    1. cover the whole surface area of the trenches
    2. fill banks with a light roof made of palm, straw, or plastic

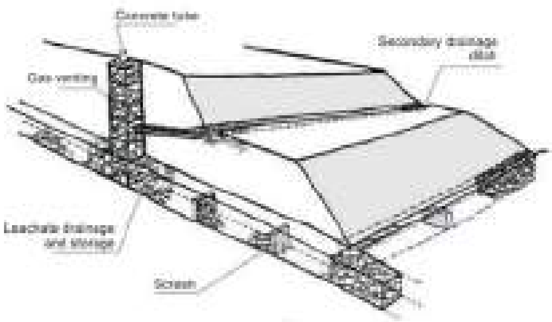
Fig-8: cover detail for rainy season



Source: Jaramillo, J., 2003.

3.9. Landfill gas collection and venting: Controlled collection and treatment/use to be adopted. Gas vents placement spacing- 30 m to 75 m on the landfill.

Fig-9: Figure showing interconnected drainage and gas system inside the filled landfills

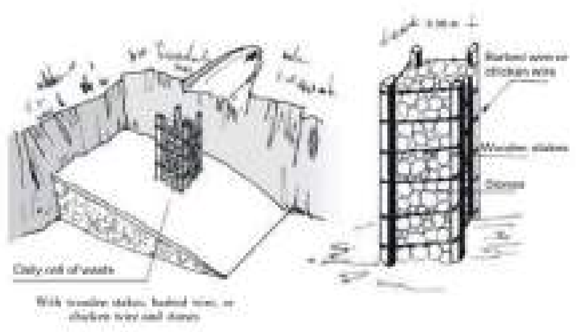


Interconnection of the systems for drainage of gases and leachate

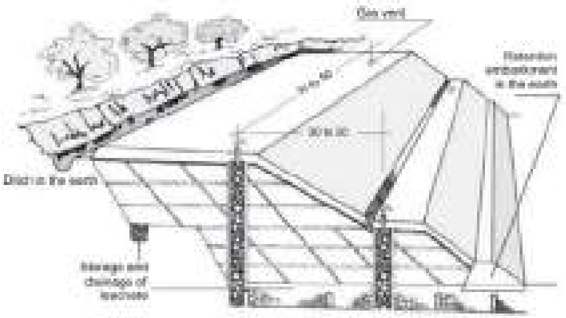
Source: Jaramillo, J., 2003.

3.9.1. Vents :are built vertically. It is recommended that each vent have a diameter of 0.30 to 0.50 m. and they be installed at 20 or 50 m. intervals.

Fig-10: Figure showing layout and construction detail of vents in landfill



Construction of gas drains or vents



Layout of vents in the landfill

Source: Jaramillo, J., 2003.

3.10.Drainage:

Surface Water Drainage System: perimeter ditch - for the collection and diversion of rainwater runoff. .

Design of perimeter ditch: preferable shape- trapezoidal, preferable material- earth or cement-soil .

Fig-11: Figure showing various cross-sections of landfill drains

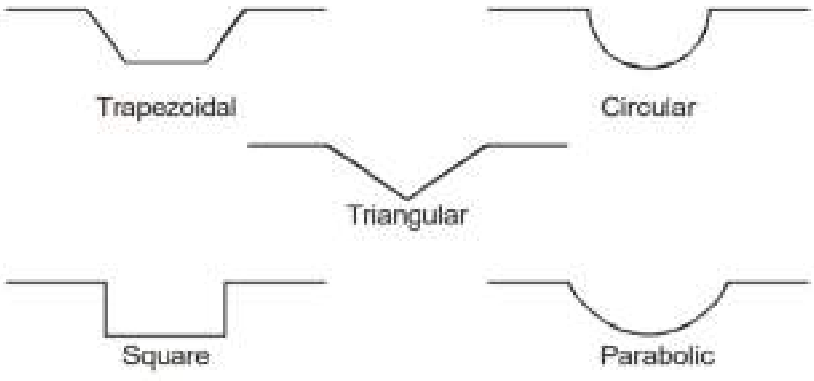


Figure 5.14
Cross-sections of drainage ditches for runoff waters

Source: Jaramillo, J., 2003.

3.11. When waterlogged land is allotted for landfill:

1.Drainage ditches in the lowest part of the land.

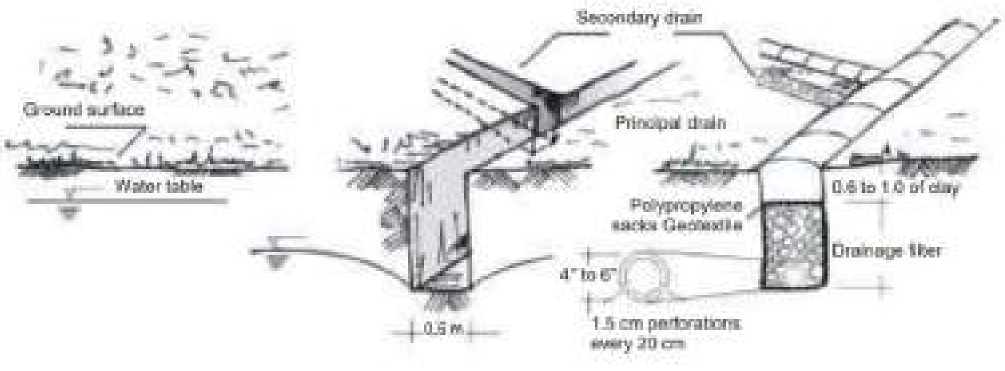
2.first levels of waste at the base of the site - at least 1.0 m. above the highest water level.

3.Set perforated concrete pipes in place - fill the ditches with stones and gravel, to act as a filter.

4.Cover the stone and gravel drain with geotextile fabric to prevent silting up.

5. layer of compacted clayey matter - 0.3 to 0.6 m thk -to isolate upper surface of the drainage and the MSW.

Fig-12: Figure showing drain cross-sections in a water-logged landfill site

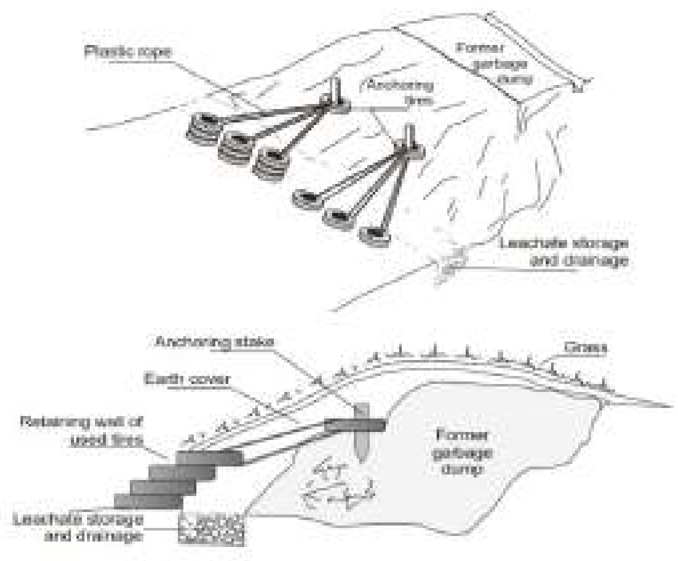


Drainage for land with a high water table

Source: Jaramillo, J., 2003.

3.12. Control of slope stability: wall of gabions can be used, or old tires tied together with plastic ropes, and also plants can be sown.

Fig-13: Figure showing methods to achieve landfill slope stability



Controlling slope stability with car tires

Source: Jaramillo, J., 2003.

3.13.Site Infrastructure:

Table-2:Table showing infrastructure facilities that are to be provided for functioning of a Sanitary landfill

Aspect	Infrastructure/equipment	Usefulness
1. Control of water pollution	? Ditches for collection and diversion of surface runoff water.	Prevent surface water from penetrating into the site of the sanitary landfill, thereby reducing the generation of leachates[2].
	? Drains for collection and evacuation of leachates.	Limit infiltration of leachates to groundwater and reduce the risk of surface discharge of leachates.
	? Leachate treatment plant or pumping station[1].	Reduces the contaminating power of the leachate to dispose of it in a collection system.
	? Monitoring well.	Facilitates monitoring of the quality of groundwater to detect possible failures in the system.
2. Control of odors and gases	? Gas vents.	Permits the controlled evacuation of gases, preventing risks of fires, explosions, or release of gas in neighboring areas.
	? Spreading and compacting with appropriate machinery (com-pactor, tractor, etc.) or in the case of manual operations, roller and tampers.	This is the essence of the sanitary landfill method, which makes it possible to confine solid waste (Figure 7.3).
3. Reduction of impact on the landscape	? Perimeter fence, preferably using native vegetation.	Isolates and delimits the site; reduces spreading of odors; catches MSW blown by the wind.
4. Labor safety and hygiene	? Control building.	Helps to control the quantity and type of residues entering the site.
	? Storehouse, changing rooms, and washrooms.	Facilitates the hygiene of the workers and the storage of their working clothes, equipment, and tools.
	? Occupational safety and hygiene equipment (gloves, mask, etc.).	Protects the personnel from diseases and minimizes impacts of work accidents.

Source: CPHEEO

3.14. Design And Construction Of Landfill Liners:

- Compacted Clays and Amended Soils: thickness about 25 cm
  (a) Natural clay =mineral component of a liner system
  .(b) If clay is un- available-bentonite enhanced soil/amended soil to be used.

- Geomembranes: High Density Poly ethylene geomembrane =minimum thickness of 1.5 mm.
- Drainage Blanket: clean coarse sand or gravel is preferable- permeability greater than 10-2 cm/sec.
- Operational phase: 15 to 30 cm of native soil -for the working faces of the landfill.

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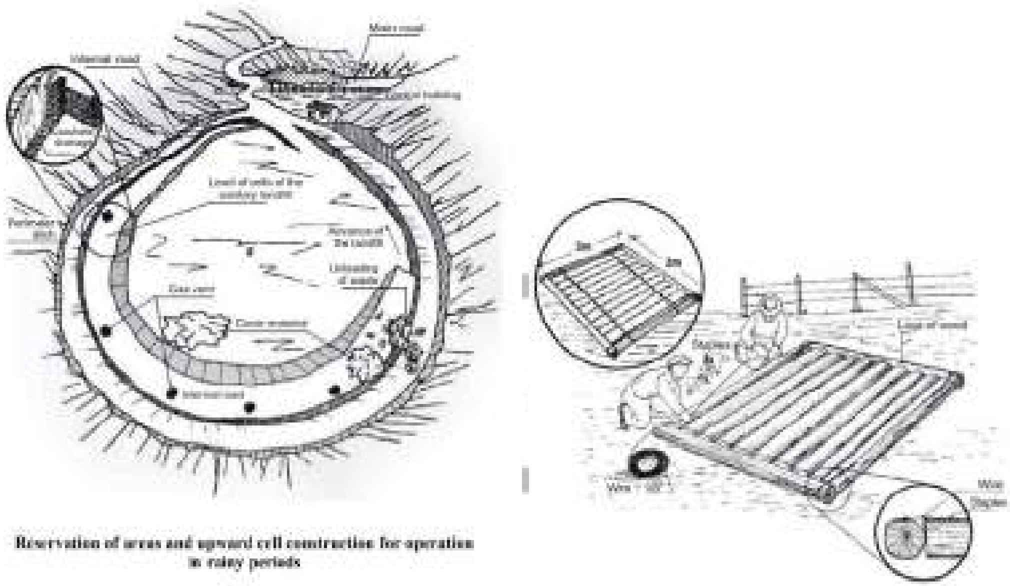
At the operational stage-Ideally, 150 mm thk layer of soil is to be added for every 2 m layer of waste.

3.15. Operation in the rainy season: harder to form the cells in wet weather. Below listed are necessary precautions:

a) Partially cover the landfill surface with a roof of palm leaves, plastic, or other local material.
b) Least affected areas -to be reserved for access roads, so that operations can continue in bad weather.
c) Construction of artificial road - with wooden logs or small-sized rubble

Fig-14: Figure showing access road and construction detail



Source: Jaramillo, J., 2003.

Construction of the artificial road:

- Timber road using 3-meter trunks tied together with a 1/8"-diameter wire. Modules of 3 m long by 3 m wide size as per site conditions.
- Later covered with gravel to prevent the vehicles from slipping on it.
- Rubble from the demolition of old buildings can be used to build and maintain some provisional internal roads in the landfill.

3.16. Pollution Prevention During Operation:

Traffic:

(a) routing must be done to avoid residential areas

(b) using one-way routes to avoid traffic conflict in narrow roads

(c) carrying out road improvements, Eg: strengthening or widening roads, improved provision of footpaths, etc.

Plantations preferable for clearing dust coming from the trucks.

Noise: Peripheral noise abatement - dense vegetation.

Evergreens - best noise blocker.

Odour: can prevented through

- adequate compaction
- effective use of appropriate types of daily cover
- consideration of prevailing wind direction for:1. leachate treatment plants,2. gas flares, and 3. direction of Piling.
- Plantation of fragrant trees along wind direction.

Litter:

(a)filling direction and sequence should be based on prevailing wind direction and strength

(b) Strategically placed mobile screen close to the tipping area or on the nearest downwind crest

(c) Temporary banks and bunds immediately adjacent to the tipping area (d) to trap windblown litter-

1.Litter screens, fences, nets

2. Perimeter ditches should be given and maintained free of litter

3. screening using tree buffer

Bird Control: Birds get attracted to food wastes. Large birds such as eagles, gulls are regarded as a nuisance to be considered. Control methods:

1.use of bird scaring techniques

2.Bird netting- effective option for preventing birds from landing on waste.

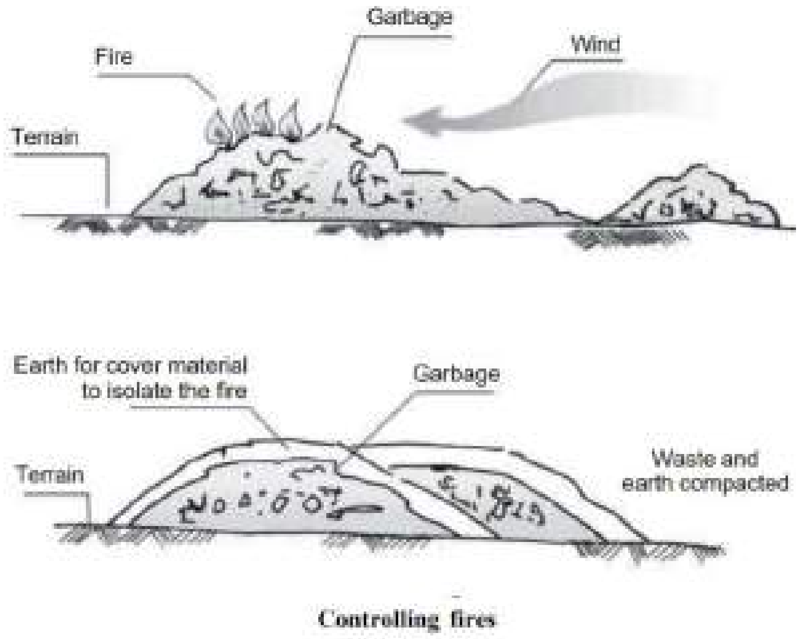
Vermin and Other Pests: well defined cells- prevent rodents and insects infestation.

Mosquito repellant Plantation species can be planted.

3.17.Landfill Fire Management

Fires: caused by landfill gas, volatile substances in leachate. should be extinguished with earth.

Fig-15: Figure showing fire mitigation technique



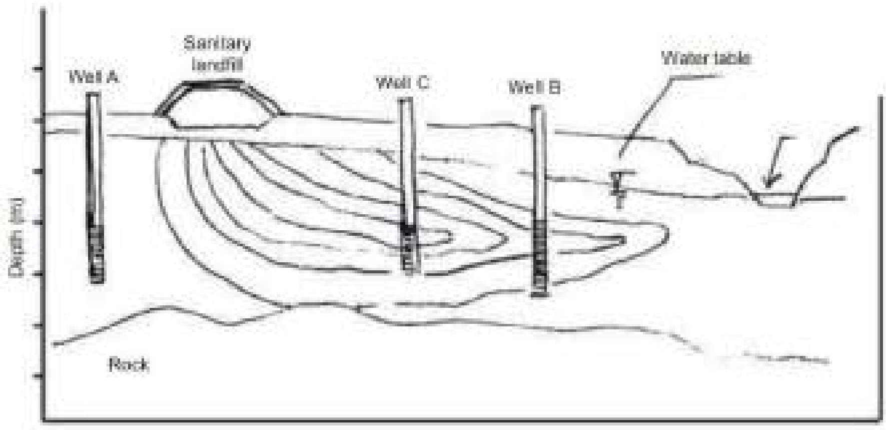
Source: Jaramillo, J., 2003.

3.18.Landfill Safety Aspects: (a) moving vehicles (b) steep slopes(c) bodies of standing water (d) contaminated, toxic, flammable or infective material and (e) flammable, toxic or hazardous gas. Emergency plans to be laid down.

3.18.1Monitoring wells: Finding the water table- granular material placed bottom-8" diameter pipe is installed- for the collection of water samples.

3.18.2. Location of the monitoring wells: at least 10, 20 and 50 m from the landfill area and from the exterior drainage of leachate, 3-4 wells will be sufficient.

Fig-17: Figure showing Plume and deteriorated wells in the plume precinct



Location and characteristics of the water monitoring wells

Source: Jaramillo, J., 2003.

3.19. Closure Phase:

1. compact slopes of the dumps -0.20 to 0.40 m thick layer of Earth for 8 to 15 days,

2. An access road- on the landfill cover to enable easy approach.

3.Vegetation species planted should be able to survive without irrigation.

4. Lined ditches or channels are constructed on the final cover to intercept and carry surface water off the cover to the storm water drain/basin.

3.20..Post-Closure Stabilisation, Operation And Care:

Long-Term Vegetative Stabilization:

(a) 1.Seedbed Preparation: grading, furrowing, grouping of species and addition of nutrients and soil amendments to be done.
2. Short-Term Vegetation: assisted by irrigation- initial seeding mixture to increases bio-diversity -reduces the chance of plant community failure.
3.Long-Term :self-generation and minimum management are desirable characteristics.
Factors that limit the growth of plants on landfills: toxicity of landfill generated gases (methane and carbon dioxide) to root systems, low soil oxygen.

(b) Active gas extraction of gas barriers with venting system : to prevent migration to the root zone.

(c) Waste to be removed – to create patches/islands of trees.

(d) Separation of biodegradable waste and non-biodegradable- create zones free of toxic gases.

3.22. End use of the site: plans to integrate it into the natural environment, transforming it into a green area, sports area, garden, nursery or forest.

ponds and engineering controls at landfill facility is a must.

4. LANDSCAPE DESIGN STRATEGIES:

4.1**Landscape architecture design strategies for a landfill site:**

4.1.1 **Hide-Make waste invisible:**

- **capping and planting** is the typical pattern of waste site design.
- **distance from the public** from dumps and waste places
- **screening of dump yards** and landfills when new construction occurs
- **buffered with massive living plants**
- **preventing people** from conceiving of the existence of waste.

4.1.2 **Removal waste**

- **Restore and return** the waste by moving waste out of the site.
- removing extreme **toxic materials, polluted water, and leakages**
- **Excavating polluted soil**, disposing of harmful substances in qualified landfills and **pumping out waste water**.
- Relatively **expensive and disruptive** to the site environment
- Depends on the **volume and characteristics of the waste** involved.

4.1.3 **Neutralize waste**

- to achieve **an inner-site digestion/assimilation** of waste harmful impacts.
- "Clean-and-Green" design approach, using **ecological restoration, bioremediation and scientific** clean-up plans to wait for **natural purification**.
- **contaminants are converted** to nontoxic and nonreactive substances.
- more **environmentally and economically friendly**

- slow by nature.
- persistent **need for supervision and control**, and the **added time needed to** buffer the area from the public.

4.1.4. Frame waste and celebrate it

- **contact with waste** without safety and health concerns.
- encourages **more meaningful action at waste sites**, such as cultural, educational and social participation.
- provide on-site education and tours.
- Inviting people to experience the real matter of waste and its processes, awareness of waste
- encourage public participation.

4.1.5Using waste as a medium

- Making urban products and artifacts out of waste
- Creating a recognizable and consistent pattern of elements for landscape using waste

Table- 3 : Table showing various approaches towards a landfill site

Table 5.1 Eight approaches for designing contemporary waste sites (Summarized from Engler 1995).

Design Approach	Waste Facility Status	Site seen as Public Amenity	Waste Site History Recognized	Creates New Kind of Landscape	Rehabilitates Ecological Function	Encourages New Attitudes About Waste Sites	Overall Characteristics Of Design Approach
CAMOUFLAGE	Active or Stopped	No	No	No	No	No	-disguises waste site facility -appeases community fears about waste facility yet it continues to inhibit public perceptions and restrain public care for waste problems.
RESTORATION	Stopped	No	No	Yes	Yes	No	-seeks to rehabilitate site by returning it to its previous conditions. -creates a new, visible landscape for wildlife and reconstructs "nature" for people, but it simply masks the waste.
RECYCLING	Stopped	Yes	No	Yes	No	No	-treats the waste site as a public amenity for recreational, agricultural or private land development.
MITIGATION	Active or Stopped	Sometimes	No	Yes	Yes	No	-weakens the impact or reduces the severity of polluted land or water. -scientific solutions drive the design. It is based on understanding how nature works yet often results in implementing restorative processes that are obscured from the visitor. -sometimes it results in a visible landscape that can be used by wildlife or people.
SUSTAINABLE	Active or Stopped	Yes	Yes	Sometimes	Yes	No	-concerned with the economics, conservation and self-sufficiency of the site. -employs a diverse program that often includes elements of production or reuse of waste resources. -considers waste a valued resource.
EDUCATIVE	Active or Stopped	Yes	Yes	Yes	No	Yes	-emphasizes public awareness and change of attitudes toward waste. -invites people to experience the realities of waste sites and nourishes a more open relationship toward refuse.
CELEBRATIVE	Active or Stopped	Yes	Yes	Yes	No	Yes	-promotes and dramatizes waste sites and facilities through works of art, special design features and unique experiences. -garbage becomes a metaphor of refuse, excess and resources mismanagement. -focuses on reducing the distance between people and their waste and revealing the multiplicity and interconnectedness of waste systems.
INTEGRATIVE	Active or Stopped	Yes	Yes	Yes	Yes	Yes	-combines elements of the celebrative, with the other strategies. -integrates principles of ecology with art. -changes an abused site while at the same time amplifies its reality. -expresses fresh spatial conditions and aesthetic possibilities.

Source: Engler 1995

5. DESKTOP STUDIES:

5.1 Hiriya Garbage Dump in Tel Aviv Transformed Into World's Largest Recycling Facility:


Before


After

Location: Tel Aviv, Israel.

Land use type: World's Largest Recycling Facility

Climate: Mediterranian

Temp: 17-26 Deg C

Annual Rainfall:585mm

Soil type: Self mulching, Dark brown soil seen in prairies.

- **Present land use:800-hectare public park**
- Total of **25 million tons** of waste
- 79 mtrs above sea level
- **Surroundings:** Densely populated metropolitan area.
- **Topography:** table mountain in the middle of dense urban fabric.

Currently- Made into a City park

Reclamation starting year-2011

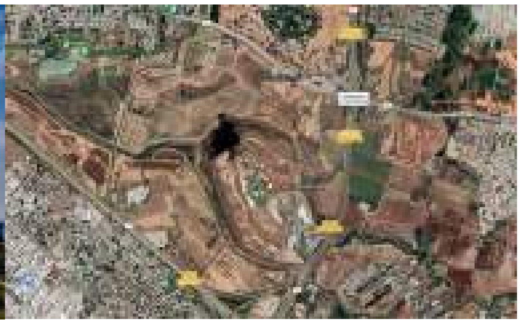
- **Design strategies:**
- Thin heavy crushed concrete capping prevents erosion and takes rain water from above to ground.
- Shallow ramp –serves as access to the topography.
- grinding building waste into gravel
  - mechanical biological treatment
  - materials recovery facility
  - up flow anaerobic sludge blanket digesters
- Hiriya carpentry shop
- Separation technology: separates recyclable materials using water technology
- Water collects in a system of ditches during the short rainy season.
- Low fragrant scrub and herbs along the wide open area help in taking rain water , to underground gravel depots.

- Recycled demolition materials are used for construction of Dry-stone walls, which adjust to the constant settlement of waste.
- The visitors route is a shallow ramp fitted into topography serves as a visitor centre which informs about the methods and opportunities of recycling and landfill reclamation.

Observations:

- Phyto remediation techniques could have been Implemented instead of leachate management.
- Clay liner instead of concrete will be more environment friendly.

Crushed concrete liner allows many activities to take place on the landfill in turn allowing other species to thrive .

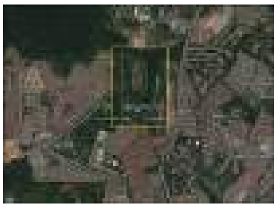


Flood plains are planted with large trees in a park with a retention system will act as flood protection measure.

A retention basin for periodic floods will be excavated, where ramps and bridges connect to the plain

The shading structure on the edge of the plateau act as view points to Tel Aviv's skyline

5.2 Air Hitam sanitary landfills:



Development around the site

- **Located at :Air Hitam Forest Reserve, District of Petaling, Selangor Darul Ehsan, Thailand.**
- Climate: tropical
- Temp: 30 Deg C (Hard winds and high solar radiation)
- Annual Rainfall:1600mm
- Soil type: Sandy and acidic with High drainage.
- **Area:100 acres**
- Receives 3000 ton/day of solid waste.
- **In operation since: November 1995**
- **Topography: valley area.**
- **Total capacity :5.2 million tons**
- **Land Typology: Brownfield site Regeneration :Affected by previous use-abandoned**
- Have contamination problems

Design strategies

- equipped with proper leachate and gas collection systems.
- Equipped with: Heavy duty textile liner, Ground water drainage system Leachate collection and management.
- Several types of development such as i) Recreational area

ii)Golf course, Bio gas powerplant

iii)Agricultural area with fertigation system

iV)Jogging track with permeable pavement, Playground, Street lights, Gazebos, etc.

- First to use landfill gas to generate power in trapping and burning the by productive methane gas.

Vegetation Type:

Exotic species were dominant- resulting in slower growth rate.

Observations:

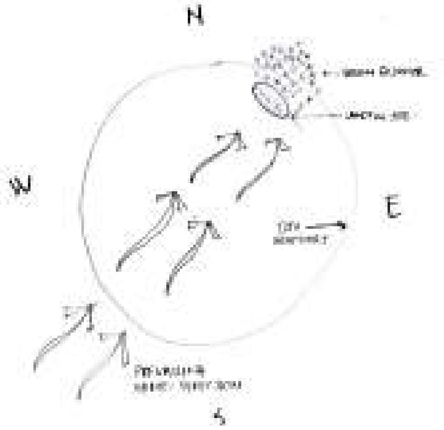
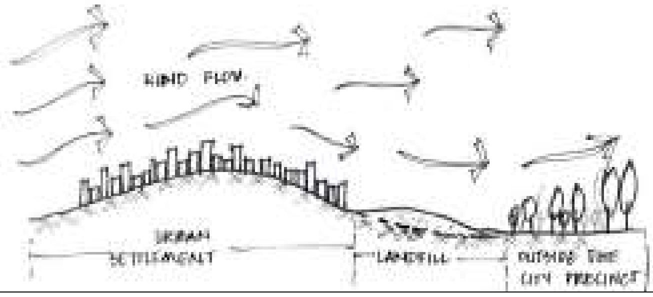
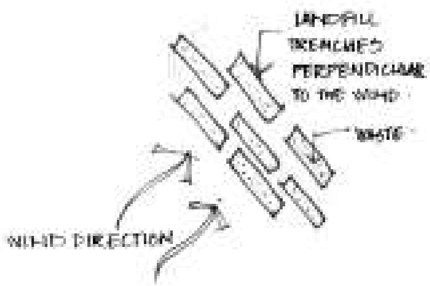
- The landfill served as a landmark of development. Residential areas were developed around landfill site.
- Historical approach is negligible.
- Native species could have been Imparted in feasible areas

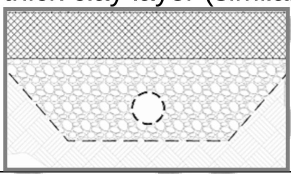
5.3. Desktop studies Comparative analysis:

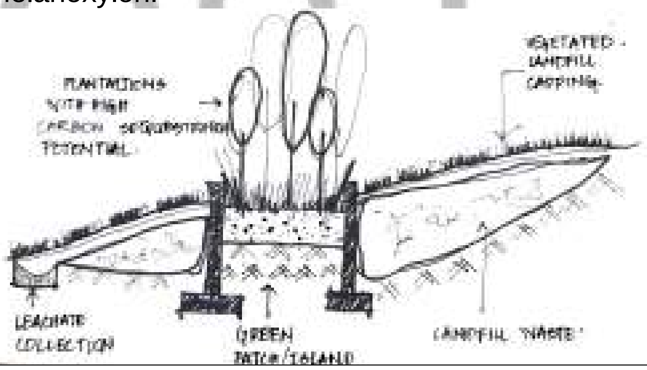
Parameters	Hiriya Garbage Dump in Tel Aviv	Air Hitam sanitary landfills	Inferences
Climate	Mediterranean	tropical	Dry climates allow more waste to get deposited whereas humid climates tend to get capped earlier
Post-closure Land use type	City park	Recreational	Landfills in Indian context also need to allow public access for landfills
Topography	Plateau of the table mountain	valley area	Hilly landforms are more preferred as they are rocky on the bottom
Previous land use		Brownfield site	Most of the landfill sites are previously degraded lands.
Surrounding context	metropolitan area	Residential development	Most of the landfills are surrounded by residential context and dense urban fabric
Area	800-hectare	100acres	Humid regions have smaller landfill area. Implies that the landfills in humid areas become quickly unbearable.
Soil type	(self mulching) Dark brown soil	Sandy and acidic with High drainage	All the soil types are not favourable for a landfill due to high soil permeability
Design Strategies/facilities	•Thin heavy crushed concrete capping •grinding building waste into gravel • mechanical biological treatment • materials recovery facility • upflow anaerobic sludge blanket digesters •Hiriya carpentry shop •Waste Separation with water technology •Water collection ditches •Low fragrant scrub and herbs near open area. •Dry-stone walls, constructed from recycled demolition materials •A shallow access ramp is fitted into the topography being used as information centre.	•leachate and gas collection systems. •textile liner, Ground water drainage system Leachate collection and management. •Bio gas powerplant, Agricultural area with fertigation system, Jogging track with permeable pavement, Playground, Street lights, Gazebos, etc.	Technological advancements in landfill management allow more waste to energy conversion
Vegetation type	Park in the flood plain. Low fragrant scrub and herbs along the wide open area help in taking rain water , to underground gravel deposits	Exotic species are dominant as native trees are not suitable for the salty soil.	Grass cover for capping does not present much opportunity for bio-diversity and ecological functions.

6. Proposed Landfill Landscape Design Guidelines:

Design stage	Parameter	Guidelines
Site	land	Site with Clayey, im-permeable soil, with slight undulations

Characteristics		for collection of cover material, with minimum water depth of more than 1m must be taken.
	climate	Landfill needs to be aligned to the direction of winds along with thick vegetation buffer.  
	Landfill life	Optimum 15-18 Years
Site preparation	Buffer	Minimum 15m to 20m of Vegetative buffer with hedges of shrubs and trees and berm to prevent visual and smell buffer. species suggested- pine, eucalyptus, laurel, bamboo, etc to be planted at siting stage itself to be functional along operational stage.
	Base surface gradient	Minimum of 5% slope for effective drainage
	Landfill method	Area method is most desirable as it has more scope for rejuvenation of degraded land and less risk of groundwater pollution. In case of trench method, it is preferable to position the trenches perpendicular to wind direction to avoid odour. 
	Excavated soil slope	Less than 2.5 (hor) : 1(vertical) is considered safe.
Planning stage	Waste segregation	Allotted area for waste segregation and storage of useful waste must be provided.
	Separate landfills	Separate bio-degradable and non-biodegradable wastes, as bio-degradable and landscaping waste(like brush clippings) can be used as compost in- 45 to 60 days for bio-degrading or used for researching on vermi-composting effectively reducing the landfill volume.

	Peripheral access road	Slope gradient of 5%-7% is considered safe.
	Peripheral Fence	Use fast growing native vegetation in order to prevent the view of ongoing works in the site.
Leachate management	Phytoremediation	Evergreen grasses and shrubs are tolerant to leachate irrigation. Neutralizing leachate and makes it useful for irrigation. Species used: *Eucalyptus tereticornis, Populus deltoids, Terminalia arjuna, Acacia auriculiformis, Syzigium cumini, Albizia lebbek, Dalbergia sissoo, and Pongamia pinnata) and grasses (para grass, cord grass, lemon grass, and Setaria grass.*
	Drainage and minimization	Peripheral drain and finger drain system partially filled with earth layer of 200mm stones or dry fern to let the liquid infiltrate leaving fine particles to avoid siltation. Cover the drains to avoid over flooding in rainy season
	Ground water protection	Bentonite cut-off wall to prevent along landfill periphery extending up to bottom of the aquifer.
Rain water harvesting	Collection and drainage	Water collection channels must be given to collect and divert the water to the drain on the foot of the capping. Whereas bioswales can be given in buffer area to reduce the dependency on drip irrigation.
	For water logged sites	Using perforated pipes with gravel and covered with 0.5m thick clay layer (similar to bio-swales). 
Operation in rainy season	For access roads	Brush waste, Rubble from construction waste, furniture waste can be made use of.
	to cover existing dump	on-site landscape waste like palm leaves roof or thatched roof can help reduce damping of waste in operational stage which makes it difficult for a healthy compost.
Operational phase	Traffic prevention	Rerouting routes to avoid residential areas. Desirable species for prevention of dust coming from truck: Tamarind, *Madhuca longifolia, Butea monosperma, Spanish cherry Flower, Neolamarckia cadamba, Elantha Pazham and Aegle marmelos* .
	Noise prevention	Preferable species- Evergreens- Saraca asoca, Tamarindus indica*, Millingtonia hortensis, Thespesia populnea, Couroupita guianensis, Pterospermum acerifolium, Calophyllum inophyllum, Ficus benjamina, Shrub species- Duranta plumieri, Nerium odorum, Bougainvillea, Clerodedron inermi, Ligustrum ovalifolium, Duranta, Euphorbia neriifolia*
	Visual buffer	Enforcement of shelterbelt to block not just the eyesore view but also dust, noise and litter
	Odour prevention	Fragrant trees species alon wind direction- *Cassia fistula, Lagerstroemia speciosa,Bauhinia, Bombax ceiba, Butea monosperma, Erythrina variegate, Saraca asoca*
	Litter prevention	Trellises, Green walls around the tipping area. Preferable species: *tecoma stans, Albesia lebec, hibiscus tiliaceus,*

		bauhinia variegate, soapnut (Sapindus mukorossi) and cordia obliqua can also absorb suspended particulate matter.
	Vermin and Other Pests	Mosquito repellant species -Marigolds, Pelargonium, garlic, basil, lemongrass, mint and Mulching
	Fire prevention	Trees like *jamun (naaval)*- remove sulphur dioxide *neem, soapnut (Sapindus mukorossi) and Bauhinia variegata* - remove lead from atmosphere and act as green barrier which makes the landfill les prone to fire.
Closure phase	Cover vegetation	Planting Flowering plants and appropriate species mixes help in propagation, regeneration and increase biodiversity of grasslands and sustainability on vegetated capping. Suitable non-edible species- combination of grass and short-rooted shrubs capable of surviving without irrigation water.eg: *S. secundatum, K. scoparia and N. oleander.*
	Cover slope	4Horizontal:1vertical or less can be considered safe for Final cover slope. Plants can be sown for slope stability.
POST-CLOSURE phase	Vegetative Stabilization	As methane and carbon dioxide are present in large quantities in site due to gas emissions, plants and trees with high carbon sequestration are desirable on the Vegetative cover to sustain in long term. Suitable species: red spinach, Thunbergia electa.
		Creating Patches of trees by clearing waste in a particular area, can neutralize the gaseous effect on environment. Suitable species: Eucalyptus, Tectona grandis, Diospyros melanoxylon. 
End Use	Function of site post closure	Should aim at Integrating into surrounding landscape, Self -sustaining, awareness generating, recreational for the public, Universally accessible, should reflect the character of the waste in the landfill and history of the site if any.

Conclusion:

Leachate liquid, methane gas and Green house gases released from the landfills are major issues related to landfills, which cause ground and surface water pollution, release of poisonous gas into the atmosphere and climate change respectively. The sustainable way of treating landfill waste is to neutralize it using, ecological restoration, natural purification, bioremediation, Vermi-composting and scientific landfill techniques but will require constant monitoring and maintenance .

Generating awareness on waste, using waste is one of the ideal practices to educate the public on ideal waste management practices.

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