IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

Welcome to Week-9

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During this week (Week-9)

- Landfill Liner Requirements
- Leachate Collection System
- Gas Collection System
- Professional Engineering Issues

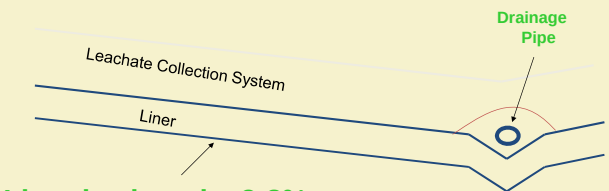
How do you Remove Leachate from the Landfill?

- Drain as much as you can by gravity (liner system and pipes)
- Pump from low points
  - Penetration through the liner
  - Pumps inside landfill

Leachate Collection System

- If leachate flow is intercepted or impeded by a liner, then it should be removed from the landfill by use of a leachate collection system. A leachate collection system is a high-permeability layer designed to transmit leachate from the liner.

How is Leachate Removed



Liner is sloped ~ 2-8%

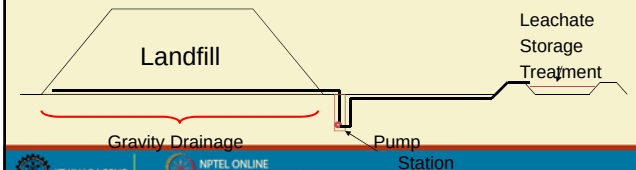
What is a Geonet?

- A synthetic (HDPE) material used for drainage of liquids. It is a has transmissivity in the later direction.

What is a Geotextile?

- A geosynthetic textile that is used in many civil engineering applications. It separates fine granular materials from coarse granular materials, plus it allows water to flow through.

Leachate is then sent to Treatment and/or Storage Facility

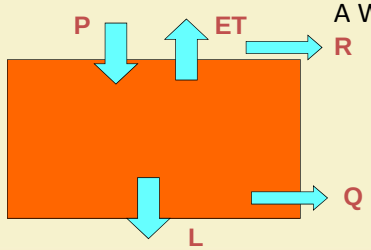


How do you Predict Leachate Generation?

- You must estimate how much leachate is generated to design your landfill.
- HELP --
  Hydrologic Evaluation of Landfill Performance

HELP

A Water Balance Model

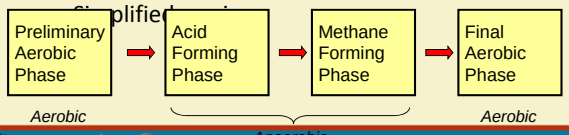


Leachate

- Can contain many compounds. The quality of leachate is dictated by the type waste. For MSW, leachate quality is very much dictated by the phase of landfill stabilization.

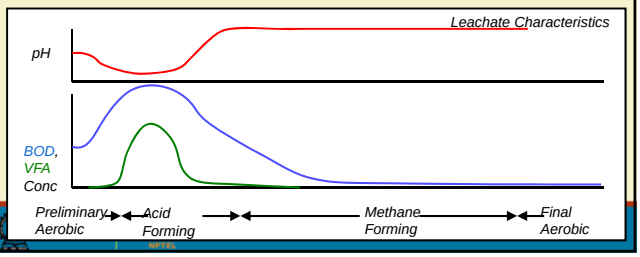
Waste Stabilization

- Phases of Landfill Stabilization
  - Previous investigators have described different phases of landfill stabilization
  - Simplified version



Waste Stabilization

- The phase of stabilization influences leachate and gas characteristics



Waste Stabilization

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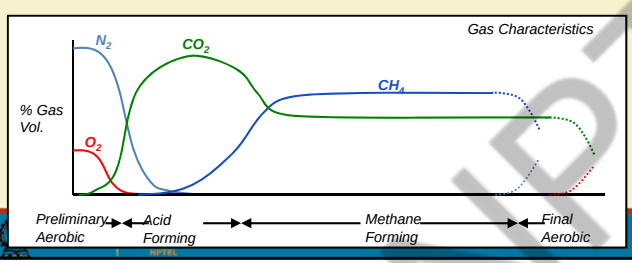


How is Leachate Managed?

- On-Site WWTP (must discharge effluent)
- Haul to Off-Site POTW
- Pretreat On-Site and Haul Off-Site
- Pipeline
- Evaporate
- Leachate Recirculation

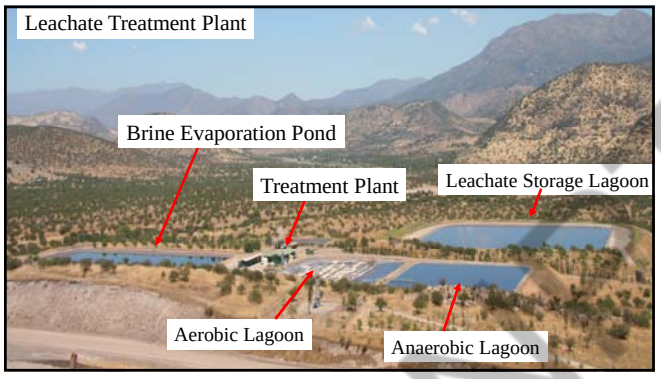
Leachate Treatment Methods

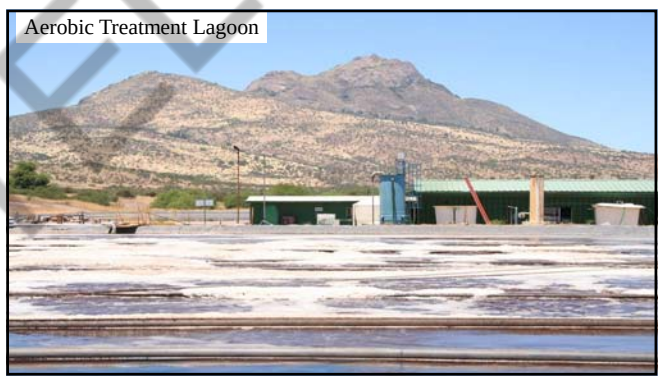
Aerobic treatment processes
- Activated sludge process
- Aerated pond
- Sequencing batch reactor

Anaerobic treatment processes
- Anaerobic digestion
- Up-flow anaerobic sludge blanket (UASB)


Lined Leachate Lagoon

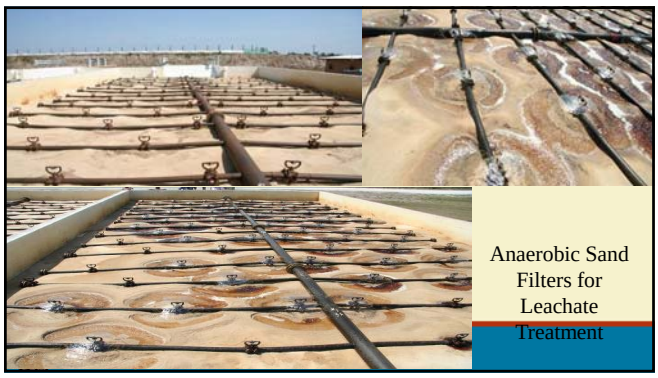

Lined Leachate Lagoon


Leachate Treatment Plant
Brine Evaporation Pond
Treatment Plant
Leachate Storage Lagoon
Aerobic Lagoon
Anaerobic Lagoon


Aerobic Treatment Lagoon


Leachate Treatment Using Wetlands


Aeration Pond
LANDFILL BIOREACTOR SYSTEM



Anaerobic Sand Filters for Leachate Treatment

Irrigation Spray field

Leachate Storage Tank

Leachate Recirculation to Landfill using Spray Irrigation

Leachate Recirculation to Landfill using Horizontal Trenches

Leachate Treatment Methods

Physicochemical Processes

- Adsorption
- Coagulation flocculation
- Chemical oxidation
- Air stripping
- Ion exchange
- Membrane filtration e.g. reverse osmosis, nanofiltration

The processes effectiveness depends on the age of landfill

Treatment Process effectiveness based on landfill age

Landfill age	< 5 years (young)	5-10 years (medium)	>10 years (Old)
Leachate type	Biodegradable	Intermediate	Stabilized
Processes	Treatment efficiency		
Biological treatment	Good	Fair	Poor
Adsorption	Fair-Poor	Good-Fair	Good
Coagulation-floculation	Fair-Poor	Good-Fair	Good
Chemical Oxidation	Fair-Poor	Fair	Fair
Membrane processes (RO)	Fair	Good	Good

Reverse Osmosis Treatment

Landfill Gas

- Gas wells are typically installed after the landfill has been filled up
- A vacuum is pulled on these wells to extract the gas into a pipe system
- The gas is then flared or turned to energy

Landfill Gas

- What is Landfill Gas?

$$C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2$$

Landfill Gas Contains

- Methane
- Carbon Dioxide
- Water Vapor
- Hydrogen Sulfide
- NMOC (nonmethane organic compounds)
- heavy metals??

Why Bother with Landfill Gas?

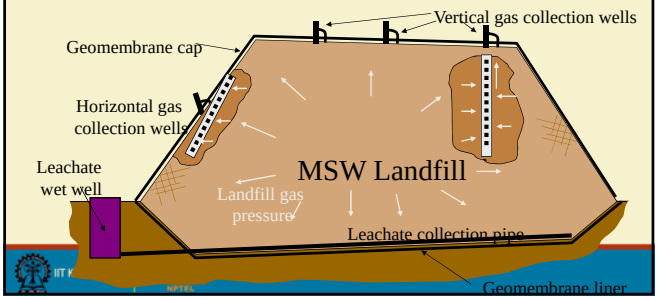
- Odor
- Toxics
- Greenhouse Gas
- Explosive Gas

- Potential Energy Source

How is Gas Collected?

- Typically use vertical wells.
- Installed after landfill has reached final grade.
- Use an auger.

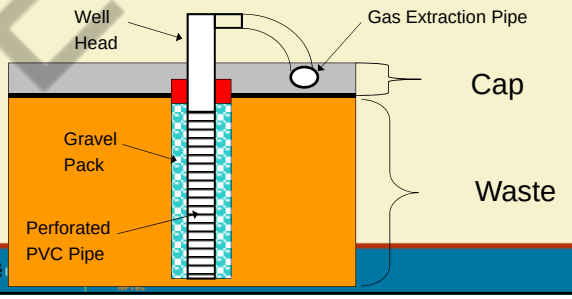
Landfill gas generation and flow



Wells

- Passive Wells (wells open to atmosphere)
- Active Wells (wells connected to a gas extraction system).

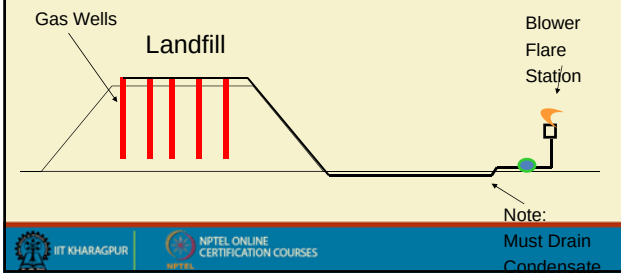
Typical Landfill Gas Well



What is the Driving Force for Gas to Leave the Landfill?

- Pressure
- Without any wells, gas will find way to surface (or bottom)
- Wells provide path of escape (create pressure gradient)

Landfill Gas is Typically Extracted to a Blower-Flare Station



LFG Generation Curves

What is Condensate?

- Moisture that condenses from landfill gas when it cools.

Gas to Energy?

What is a Bioreactor Landfill

- A sanitary landfill that is operated in a fashion to accelerate the decomposition of the solid waste
- Primarily accomplished by getting recirculating leachate to the landfill
- My research program has been heavily involved in bioreactor research

How Are Landfills Operated?

- Trucks come in across a scale and are weighed
  - Note: A tipping fee is charged, normally based on weight (e.g. $25/ton)
- The trucks deposit their waste at the working face
- Landfill operators compact the garbage
- The waste is covered at the end of every day (usually by soil, but possibly other materials)

Landfill Closure and Post Closure

- When a landfill stops accepting waste, it must be "closed" according to the regulations
- An engineered cap must be constructed
- The cap is designed to keep rainwater out and gas in
- The landfill must be maintained during a "post-closure" care period for 30 years (at least)
- The landfill accrues the money to pay for closure and post closure during the life of the landfill

Groundwater Monitoring

- Most landfills require groundwater monitoring
- Frequency is annual or semi-annual
- If pollutants are detected, more frequent monitoring must be undertaken
- If contamination is found, actions must be taken

Cap System

- Very similar to a liner, but designed to keep water out instead of keeping leachate in.

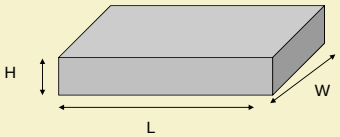
What do you do the the landfill after closure?

- Watch forever?
- Golf course, park?
- Mine?

Landfill Sizing and volume calculations

- Sizing your landfill
- Equations for volume:

Simple Estimate



Volume = L x W x H

- Example:
- The foot print area of a landfill is 1000 ft by 750 ft. The anticipated depth is 30 ft. What is the volume in yd^3?

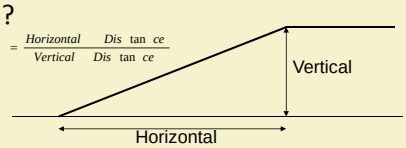
Volume = 1,000 ft x 750 ft x 30 ft

Volume = 22,500,000 ft^3

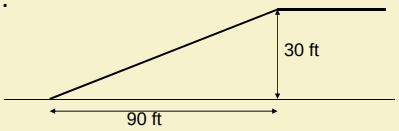
Volume = 833,000 yd^3

- This analysis did not consider side slope
- How are the side slopes described at a landfill?

$$Slope = \frac{Horizontal\ \ Dis\ \tan\ ce}{Vertical\ \ Dis\ \tan\ ce}$$



- Example:



$$Slope = \frac{90\ ft}{30\ ft} = 3:1\ slope$$

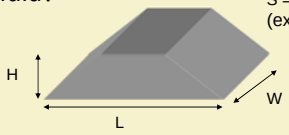
- Note: Slopes are sometimes referred to in %, which would correspond to

$$Slope = \frac{Vertical\ \ Dis\ tan\ ce}{Horizontal\ \ Dis\ tan\ ce}$$

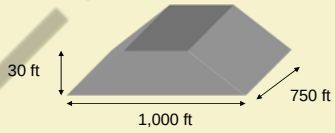
- In the case of the previous example, a 3:1 slope would be expressed as 33%. A 4:1 slope would be 25%.
- More common when describing shallow slopes

- How do you factor side slopes into volume formula?

S = Slope
(example, for a 3:1 slope, S = 3)



$$V = L\,xWxH - (L + W)SH^2 + \frac{4}{3}S^2H^3$$



S = 3

$$V = 1000\ x\,750\ x\,30 - (1000 + 750)\,3\,x\,30^2 + \left(\frac{4}{3}\right)3^2\ x\ 30^3$$

Volume = 17,800,000 ft^3

Volume = 660,000 yd^3

- Landfill capacity refers to the time that the landfill can receive waste at a given waste filling rate

$$Capacity\ (yr) = \frac{Landfill\ \ Volume\ (yd^3)\ x\ Waste\ \ Density\ (\frac{ton}{yd^3})}{Waste\ \ Filling\ \ Rate\ (\frac{tons}{year})}$$

- Example: For the previous landfill volume of 660,000 yd^3, what would be the capacity (years) of the landfill if C&D debris waste accepted at 500 tons per day and the landfill debris density was 1500 pcy?

$$Capacity\ (yr) = \frac{660,000\ yd^3\ x\ 1500\ (\frac{lb}{yd^3})\ x\ \frac{1\ ton}{2000\ lb}}{500\ (\frac{tons}{day})\ x\ 365\ \frac{day}{year}}$$

Capacity = 2.7 years

Facility Siting

- Selecting the location of a solid waste management facility
- Must balance several issues
  - regulatory
  - environmental
  - economic
  - social
  - political

Regulatory Issues

- Some regulations place restrictions on where a facility might be located
  - Airports
  - Floodplains
  - Wetlands
  - Fault Areas
  - Seismic Impact Zones
  - Unstable Areas

Environmental Issues

- Contamination of water
  - Groundwater, surface water
- Contamination of air
- Contamination of soil
- Destruction of sensitive lands
  - Wetlands, unique habitats
- Impact of wildlife
  - Dust
  - Noise
  - Odor

Economic Issues

- Location of facility relative to source of waste
- Land prices
- Distance to markets
- Labor costs
- Need for infrastructure upgrade
- Site capacity

Social Issues

- Disruption of "quality of life"
- Reduction in property values
- Environmental justice
- Presence of historical, cultural and archeological significant areas

Political Issues

- For good or bad, politics often plays a role
- It is often common to site a solid waste facility in locations near the fewest number for voters (e.g. locating a landfill at the boundary of two cities)

Siting Process

- Might involve some groups of public/private officials, or might involve advisory committees from the community
- Most new siting activities (for publically owned facilities) involve an active effort to engage the public in the siting process

Example Siting Process

1. Research, identify and exclude any locations that are eliminated because of regulations
   - Some areas are automatically excluded
   - e.g. airports near MSW landfills
2. Identify and exclude other locations that where siting is considered a near impossibility
   - Don't waste you time if you know there is no way a facility could be sited there
   - e.g. in areas with high-population densities

Example Siting Process

3. Develop a map showing all potential areas where a site might be located
   - It is often common to break the locations into to a grid, so uniform areas of land can be "scored"
4. For remaining areas, identify those issues which are important
   - In some cases you will rank these issues. For example, a community might view contamination of groundwater as being more important than location to center of waste generation. This

Example Siting Process

5. Find measures of those issues
   - Example: For the issue of contamination of groundwater, it might be depth to groundwater (m)
   - Example: For issue of endangered species, it might be # of species per hectare
6. Develop a scale that measurements can be applied to
   - For example, 0 = terrible site, 5 = great site
   - Depth to groundwater:
     - *0-2 m = 0*
     - *2-4 m = 1*
     - *6-8 m = 4*

Example Siting Process

7. Collect measurements
   - Go out and collect the measurements identified. This might involve reviewing existing compiled data, or going out and collecting new data. There is a limit to how much new data can be collected.
8. "Score" the locations
   - Develop a score for each location that considers how well it meets each measure, and how each issue is rank relative to each other
9. Examine top locations and try to select the best site
   - While the site with the top score might be best, there are always other issues that might come into play that you did not pick up in ranking process

Facility Permitting

- Just because you have agreed to a site and you are ready to go, that does not mean you can start construction
- You have to get a permit (in most cases)
  - The permit process can be lengthy
  - Public input is allowed
  - Permit is rarely granted after first submittal

Permit Process

1. For large facilities, the facility owner normally hires an engineering consulting firm.
2. The owner meets with consultant and describes what they want.
   - In some cases, the owner might have a very good understanding of what they want out of a facility.
   - In other cases, not.
3. It is a good idea to meet with the regulatory agency (the permit granting engineer) to discuss the proposed facility and the issues that are of concern

Permit Process

4. The engineering firm sets to work to begin a conceptual design of the facility.
   - The permit application package will include:
     - The permit application (the form)
     - A set of engineering drawings
     - Supporting engineering calculation
5. The engineer presents the conceptual design at various levels of completion
   - The submittals will normally be in the form of engineering drawings
   - E.g. 30% completion, 60% completion, 90% completion
6. The engineer signs and submits the permit application
   - The permit reviewer has a certain period of time to grant the permit or to ask more questions

Permit Process

7. The permit reviewer usually submits one or more request for additional information (RAI)
   - The engineer has a defined period of time to respond
8. Once the permit reviewer is satisfied, they will issue a notice of intent to issue the permit
   - At this point, the project has to be advertised. The public is allowed to comment. The public can file to have hearings in court, …
9. If it is not held up, the permitting engineer will issue the permit, along with specific permit conditions

Professional Practice Issues

- The permitting design process
- The design process
- The construction process

The Design Process

- A bulk of the design process for a solid waste management facility must be accomplished during the permitting process
- The engineering firm will normally be hired to do both permitting and design
  - Different milestones are reached at different times during the design of the project
  - Examples of milestones:
    - Completion levels during the design (e.g. 30% complete, 60% complete, …)
    - Permit-level design

Deliverables

- Permit-level design deliverables
  - Permit Application
  - Engineering Drawings
  - Engineer's Report
  - At this point, the engineers drawings may not be at the level required for construction
- Construction-ready design deliverables
  - Construction ready drawings
  - Contract specifications

A Note on Engineering Drawings

- There are many different sets of engineering drawings that are prepared along the way
  - Pre-permit application drawings (30%, 60%, … For internal and client review only)
  - Final permit application drawings
  - Construction-ready drawings
  - As-built drawings

Design Process

- Once you have your permit in hand (or a notice of intent (NOI) to issue permit), the engineers brings the permit-level drawings to construction-ready.
- In addition to this, the construction specifications are compiled