Water Supply & Sanitary Engineering (DI05006021)

Unit 11: Recycling of wastewater and Solid Waste

Lecture 45: Solid Waste Processing, Treatment, and Disposal

GTU Diploma Engineering

Agenda

- Material Recovery Facilities (MRF) and Recycling
- Biological Processing: Composting
- Anaerobic Digestion (Biomethanation)
- Thermal Processing: Incineration
- Waste-to-Energy (WtE) Concepts
- Final Disposal: Sanitary Landfilling
- Landfill Gas and Leachate Management
- The Waste Management Hierarchy

The Waste Management Hierarchy

- An internationally recognized framework ranking waste management options based on environmental impact.
- 1. Prevention/Reduction (Most Preferred)
- 2. Reuse
- 3. Recycling / Composting
- 4. Energy Recovery (Incineration)
- 5. Disposal (Landfill) (Least Preferred)

Material Recovery Facilities (MRF) and Recycling

- MRF: A specialized plant that receives, separates, and prepares recyclable materials for end-user manufacturers.
- Unit Operations in MRFs:
- Size Reduction: Shredders and crushers.
- Screening: Trommel screens to separate by size.
- Magnetic Separation: Overband magnets for ferrous metals (iron/steel).
- Eddy Current Separators: Repel non-ferrous metals (like aluminum) for collection.
- Air Classifiers: Separate light materials (paper/plastic) from heavy materials (glass/stones).

Biological Processing: Composting

- Composting: The controlled, aerobic, biological decomposition of organic waste into a stable, humus-like product (compost).
- Ideal Conditions:
- C/N Ratio: 25:1 to 30:1. Carbon provides energy; Nitrogen is for microbial cell growth.
- Moisture Content: 50-60%. Too dry halts microbial action; too wet turns the process anaerobic (causing odors).
- Aeration: Regular turning or forced air to maintain oxygen levels.
- Temperature: Rises to 55-65°C (thermophilic phase), which is critical for destroying pathogens and weed seeds.

Composting Methods

Concept 1	Concept 2

Windrow Composting: Organic waste is formed into long, low piles (windrows) and periodically turned by mechanical equipment for aeration.

Aerated Static Pile: Waste is mixed with bulking agents (like wood chips) and placed over perforated pipes. Air is blown or drawn through the pile; no turning is required.

In-vessel Composting: Takes place inside enclosed drums or silos. Highly controlled environment (temperature, moisture, aeration), resulting in faster composting and superior odor control. High capital cost.

Anaerobic Digestion (Biomethanation)

- Biomethanation: The decomposition of organic matter by microorganisms in the absence of oxygen.
- Products: Biogas (primarily Methane CH4 and Carbon Dioxide CO2) and digestate (nutrient-rich sludge).
- Process Stages: Hydrolysis -¿ Acidogenesis -¿ Acetogenesis -¿ Methanogenesis.
- Applications: Ideal for high-moisture organic waste (food waste, sewage sludge, animal manure).
- Energy Recovery: The methane produced is captured and burned to generate electricity or heat.

Thermal Processing: Incineration

- Incineration: Controlled combustion of solid waste in the presence of oxygen at high temperatures (850°C - 1000°C).
- Advantages: Drastically reduces waste volume (by 80-90%) and mass (by 70-80%). Destroys pathogens and toxic organics. Generates steam for electricity (Waste-to-Energy).
- Requirements: Waste must have a high net calorific value and low moisture content.
- Residues: Bottom ash (can sometimes be used in construction) and Fly ash (highly toxic, requires secure landfilling).

Air Pollution Control in Incineration

- A major challenge of incineration is the emission of toxic gases (NOx, SOx, HCl, Dioxins, and Furans) and particulate matter.
- Control Technologies:
- Electrostatic Precipitators (ESP) / Fabric Filters: Capture fly ash and particulate matter.
- Wet or Dry Scrubbers: Inject lime slurry to neutralize acid gases (SO2, HCl).
- Activated Carbon Injection: Adsorbs heavy metals (mercury) and highly toxic dioxins/furans.
- Strict temperature control (¿850°C for 2 seconds) is mandated to prevent the formation of dioxins.

Final Disposal: Sanitary Landfilling

- Sanitary Landfill: An engineered facility for the disposal of MSW, designed to minimize public health and environmental impacts.
- Unlike an 'open dump', a sanitary landfill isolates waste from the surrounding environment using highly engineered liner and cover systems.
- Site Selection Criteria: Adequate land area, hydrogeological isolation (impermeable natural clay), away from fault lines, floodplains, and airports (bird strike hazard).
- Daily Cover: A layer of soil (approx 15 cm) is applied over the compacted waste at the end of each day to prevent odors, fires, and access by vectors (rats, birds).

Landfill Liner and Leachate Management

- Leachate: Highly contaminated liquid generated as water percolates through the decomposing waste, extracting dissolved and suspended materials.
- Bottom Liner System: Prevents leachate from contaminating groundwater.
- Typically consists of a composite liner: a High-Density Polyethylene (HDPE) geomembrane placed over a thick layer of compacted, low-permeability clay.
- Leachate Collection: A network of perforated pipes laid in a gravel drainage layer above the liner collects leachate and pumps it out for wastewater treatment.

Landfill Gas (LFG) Management

- Decomposition of organic waste in the anaerobic depths of the landfill generates Landfill Gas (LFG).
- LFG Composition: Typically 50% Methane (CH4) and 50% Carbon Dioxide (CO2), plus trace volatile organic compounds.
- Hazards: Methane is explosive and a potent greenhouse gas (25x more impactful than CO2).
- Management: LFG must be extracted using vertical wells. It is then either flared (burned safely) or, preferably, conditioned and used to run turbines to generate electricity.

Summary

- Following the waste hierarchy, reduction and recycling (MRFs) are the most preferred management strategies.
- Organic fractions can be processed via composting (aerobic) or biomethanation (anaerobic) to recover nutrients and energy.
- Incineration provides significant volume reduction and energy recovery but requires strict air pollution control.
- Sanitary landfills are highly engineered facilities essential for final disposal, featuring liners, leachate collection, and gas management to protect the environment.