SOLID WASTE MANAGEMENT

To determine depth of sanitary landfill:

- **Location of bedrock**
- **Seasonal high groundwater**
- **Finish grade**
- **3–5 ft above groundwater**

- Lower groundwater in landfill with curtain drains.

- **Soil depth flies can emerge from at landfill = 6 in compacted or 5 ft un-compacted.**

Landfill classes:

- **Class I, Municipal solid waste, household, and tires**
- **Class II, Industrial**
- **Class III, Farm landscaping waste**
- **Class IV, Construction/demolition**

- **Final landfill cover = 2 feet.**

- **Paper comprises most of garbage.**

- **Cell**…unit of daily waste**.**

- **Lifts**…vertical layers of cells.

Municipal solid waste (MSW) **EX**cludes:

- Wastes generated from municipal services
- Water and wastewater treatment plants
- Industrial processes
- Agricultural operations

Characteristics:

- Composition
  - Residential and commercial waste make up about 60% of the total municipal waste generated per person in the U.S.
- Quantities
  - Average waste generated per person in U.S. in 2006 was 4.6 lb/person per day.
- Specific weight
  - Varies from about 100 to 175 lb/cubic yard

Special wastes collected separately:

- Medical wastes (infectious and pathological)

        - RCRA defines medical waste as any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals
        - Infectious waste usually comes from a medical care or related facility
        - **Must be segregated at the source and clearly color (red) coded and marked**
        - Must at all times be kept separate from regular trash and other solid waste
        - **Most infectious waste can be treated for disposal by incineration or autoclaving**, and residue can be disposed of in an approved landfill
    - Animal wastes
        - May contain disease organisms causing salmonellosis, leptospirosis, tularemia, foot-and-mouth disease, hog cholera, and other illnesses
        - Manure contaminated with foot-and-mouth disease virus must be buried in a controlled manner or otherwise properly treated
        - Excreta from sick animals should be stored 7–100 days or as long as necessary to ensure destruction of pathogens
        - **Dead animals are best disposed of at an incinerator** or rendering plant or in a separate area of a sanitary landfill
    - Waste oil
        - Lead content of oil is of particular concern
        - Approximately 60% of the waste oil is reprocessed and used for fuel
        - About 25–30% is re-refined and re-used as a lubricant
    - Old tires
        - Old tire dumps can cause major fires and release many hazardous chemicals contributing to air and groundwater pollution
        - Can collect rainwater in which mosquitoes breed and provide harborage for rates and other vermin
        - **Not suitable for disposal by landfill** but may be acceptable if shredded or split
        - Recycling is preferred and may be required

Collection:

- Cost has been estimated to represent about 60–75% of the total cost of solid waste management, depending on the disposal method
- Major application of manual loading collection vehicles is in the collection of residential source-separated and commingled wastes and litter
- **Solid waste collectors have an injury frequency approximately 10x the national average for all industries**
- Workmens' compensation rates account for 9–10% of payroll for all solid waste collectors

Transfer and transport:

- **Direct-haul distance (one-way) of 25–30 miles is about the max economical distance**

- Volume of waste that can be stored temporarily on the unloading platform of a direct-load transfer station is often defined as the **surge capacity** or the **emergency storage capacity** of the station

Waste reduction and materials recovery:

- Proper management should first prevent and reduce generation of solid wastes, reduce hazardous characteristics, and recover and recycle waste to the extent practical and dispose of remaining wastes in a manner that does not endanger public health or the environment
- **Composting is considered a form of recycling**
- Energy recovery…where unsorted solid waste or shredded solid waste (i.e., **refuse derived fuel** (RDF) is burned to produce steam or electricity
- Recycling one ton of newspapers can save 3–3.3 cubic yards of landfill space

Composting:

- Controlled decay of organic matter in a warm, moist environment by action of bacteria, fungi, and other organisms
- Principal applications are for:
  - Yard wastes
  - Organic fraction of MSW
  - Partially processed commingled MSW
  - Co-composting the organic fraction of MSW with wastewater sludge
- Improves soil moisture retention
- **A good soil conditioner, but a poor fertilizer**
- For pathogen-reduction purposes, the **temp of the mixture must be maintained at or above 131 degrees F for at least 3 consecutive days**
- Two weeks to as much as 18 months may be required for complete stabilization and curing of compost
- Key concepts and objectives:
  - Biological process
  - Results in production of biologically stable end product
  - End products free of viable pathogens
  - End product free of viable plant seeds
  - End product can be applied to land beneficially
- Process (three steps):
  - Pre-processing
  - Decomposition and stabilization of organic material
  - Post-processing
  - **Odor control is a major concern in all processes**
  - Aeration and controlled, enclosed processing facilities can be used to minimize the problem
- Essentially all of the organic matter (except cellulose and lignin) are converted during the composting process
- Cellulose and lignin and further decomposed via fungi and actinomycetes
- Technologies:
  - **Windrow**

        - **Windrows are 3–6 ft high and 6–15 ft wide at the base**
        - Normally conducted in uncovered pads and **relies on natural ventilation**
        - **Frequent mechanical mixing of piles**
        - Accelerated if turned over every 4 or 5 days
        - Typical conditions…turned over every other day
        - To meet EPA requirements, **must be turned over 5 times in 15 days** maintaining a temp of 55 degrees C
        - Complete process may take 2–6 months
    - **Aerated static pile**
        - Material placed in a pile and oxygen is provided by mechanical aeration systems
        - **Pile is built up 8–12 feet** using front-end loader
        - **Oxygen is provided by pulling air up through the pile** with an exhaust fan
    - **In-vessel methods**
        - Accomplished inside an enclosed container/vessel
        - Designed to **minimize odors and process time by controlling environmental factors such as air flow, temp, and oxygen concentration**
        - **Detention time varies from 1–2 weeks**
        - Virtually all systems employ a **4–12 week curing period after active composing**
- Pathogen control:
    - **EPA requires 131 degrees F for 3 days (but this does *not* kill all pathogens)**
    - Microbial activity is greatest when mean municipal compost temp is 114–140 degrees F.
    - Temp above 140 degrees F tend to slow the process as many organisms dies off at and above this temp
- Causes of odors:
    - Poor temp control
    - Low C/N ratios
    - Excessive moisture
    - Poor mixing
- Health hazards:
    - Pathogens may be spread by leachate, air, insects, rodents, and poor housekeeping and personal hygiene
    - Possible leachate contamination of groundwater and surface water
    - Toxic chemicals may remain in finished compost
    - Insect and rodent breeding

Landfills:

- Site must be geologically, hydrologically, and environmentally suitable
- NOT an open dump
- Larger landfills usually are more efficient and result in lower unit costs
- Governed by Subtitle D of RCRA and EPA (CFR)

- **Plan for 20–40 years in the future and by acquiring adequate sites at least 5 years prior to anticipated needs and use**
- Methods:
  - **Trench**
    - **Primarily used on level ground**, though suitable for moderately sloping ground
    - **20–25 ft wide** and at least twice as wide as any compacting equipment
  - **Area/Ramp**
    - Used on **fairly flat and rolling terrain…can utilize natural slope of land**
    - **Side slopes are 20–30%**
    - Cover material hauled from nearby stockpile or other source
    - Base is established by elevation of bedrock, groundwater, and bottom liners and leachate collection and removal systems
  - **Valley/Ravine fill**
    - Where ravine is deep, solid waste should be **placed in lifts from the bottom up with a depth of 8–10 ft**
    - Cover material obtained from the sides of the ravine
- Site prep requires **map drawn at scale of not less than 200 ft to the inch with contours at 2-ft intervals**
- Location:
  - **Normal economic hauling distance to a solid waste disposal site is 10-15 miles**
  - Disposal site may be as far as 40–80 miles away if a transfer station is used
- Accessibility:
  - Should be located **near major highways** to facilitate use of the existing arterial roads and lessen hauling time to the site
  - Disposal area itself should normally be **located at least 500 ft from habitation**
  - Allow vehicular traffic to utilize site throughout the year
  - Provide good access roads
- Leachate generation:
  - Precipitation less runoff, transpiration, and evaporation will determine amount of infiltration
  - Soil cover should have low permeability with low swell and shrink tendency upon wetting and drying
  - **Surface slope 4% and no greater than 30% for side slopes**
  - Evapotranspiration during the growing season for grasses and grains may be 20–50 inches
- Leachate control:
  - Bacterial activity will generally cease when the moisture content drops below 14–16%
  - Multi-layer landfill liner method ensures each layer has specific function
  - Composite liner designs employing geometric membrane and clay liner provide more protection and are hydraulically more effective than either type of liner alone
  - If leachate becomes problematic the following can be used:

    - A cap on the surface (clay liner or liner regarded with topsoil seeded to grass) can be used to effectively shed precipitation
    - Cutoff walls/dams
    - Pressure treatment and sealing of bottom and sides of the fill
    - Surface water drains up-gradient around landfill area
    - Curtain drains/wells
- Gas generation:
  - Monitoring probes must be installed
  - **Monthly monitoring is required (methane)**
  - Gases created include ammonia, carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide, methane, nitrogen, and oxygen
  - **Methane and carbon dioxide are the principal gases produced from anaerobic decomposition of biodegradable organic waste in MSW**
  - Phases of **gas generation**:
    - **Phase I…Initial adjustment**
      - Begins undergoing bacterial decomposition under aerobic conditions
    - **Phase II…Transition phase**
      - Anaerobic conditions begin to develop
    - **Phase III…Acid phase**
      - Bacterial activity initiated in Phase 2 accelerates
      - Hydrolysis of higher molecular mass compounds
      - Acidogenesis of higher molecular mass compounds into lower molecular mass compounds
      - Carbon dioxide is principal gas generated in this phase
    - **Phase IV…Methane fermentation**
      - Acetic acid and hydrogen are converted to methane
      - Carbon dioxide becomes more predominant
      - pH value within landfill will rise to more neutral levels (6.8–8)
    - **Phase V…Maturation phase**
- Control of gas migration:
  - **When methane is present in the air in concentration between 5 and 15%, it is explosive**
  - Lateral migration can be controlled by impermeable cutoff walls/barriers or via ventilation system (i.e., gravel-filled trenches) around the perimeter
- Methane recovery and utilization:
  - Methane is produced in a landfill when anaerobic methane-producing bacteria are active
  - **Acidic conditions inhibit growth of methane-producing bacteria**
  - Alkaline conditions have opposite effect
  - **Presence of oxygen and nitrogen with methane gas would indicate entrance of air into the landfill due to methane being withdrawn too rapidly**
  - Methane, as it comes from a landfill, is often very corrosive
  - Deep landfills (30 ft or deeper) are better methane producers
  - Extracted gas may be used for heating and generating electricity
- Management of surface waters:

    - Design basis should be max 25-year, 24-hour precipitation
    - Major source of water is precipitation-infiltration during operation before final cap is put in place
        - Can be minimized by temporary use of impervious geomembrane sheets
        - Small amounts if infiltration desirable for support of biological decomposition
- Cover material:
    - Stockpile final cover and other soil for cold-weather operation and access road maintenance
    - **Final cover grade should be 4% slope and slope maintained at 1:30**
    - **Daily 6-inch cover**
    - Groundwater protection is driving force
- Fire protection:
    - **Limit solid waste cells to about 200 tons with depth of 8 ft and 2 ft of compacted earth between cells** to minimize spread of underground fires
    - **Daily 6-in cover** also minimizes start/spread of underground fires
- Equipment:
    - **One piece of compaction and earth-moving equipment needed per 80 loads per day received**
    - Life of a tractor is about 10,000 hours
    - Community of population less than 10,000 requires 1 1/8 cubic yd bucket on a suitable tractor
    - Communities w/population between 10,000 and 30,000 should have a 2 1/4 cubic yard bucket
    - Populations of 30,000 to 50,000 should have at least a 3-cubic yd bucket
- Operation control:
    - **Direction of operation should be with the prevailing wind**
    - Snow fencing or some other means of containing papers should be provided
    - Screen from public line of sight
    - Noise levels **between 7 a.m. and 10 p.m.** are generally required **to be kept below 60dBA in rural areas, 65 in suburban areas, and 70 in urban areas**
    - Tires are generally not acceptable in landfills
    - Should be **minimum of one man at a site and 6 men per 1,000 cubic yards dumped per day** that the site is open
    - Length of open face should be controlled
    - Should be **spread and compacted from the bottom up into a 12–18 inch layer (24 max)** with a tractor
    - **Three to five passes** should give compaction of 1,000–1,250 lb/cubic yd
    - **Passing over** the waste **should be done continually throughout the day** to ensure good compaction and vermin and fire control
    - At **end of day, should be covered with 6 inches of earth** or a suitable form
    - **Final cover of waste** should be **at least 2 feet**
- Maintenance:
    - Settlement will vary 20–30%
    - **90% of settlement can be expected within first 5 years**
    - Settlement maintenance is required for 20–30 yrs

- **Final 4% grade** w/culverts and lined ditches, as needed, is essential

Summary of Recommended Operating Practices:

- All solid waste should be spread as dumped and **compacted into 12–18 inch thick layers** as it is hauled in
- **Operate tractor up- and down-slope (3:1) of fill to get good compaction (3–5 passes)**
- **All exposed solid waste should be covered with 6 inches of earth at the end of each day**
- **Final earth covering** for surface and side slopes should minimize infiltration, be compacted, and be maintained at a **depth of at least 24 inches**
- **Final** level of fill should provide **4% slope**
- **Depth of solid waste** should usually not exceed an average depth of **8–10 ft after compaction**
- At least **annually an evaluation should be made of the weight of solid waste received and volume of solid waste in place** as a check on compaction and rate at which the site is being used

Site closure or conversion:

- Rat poisoning program (baiting) should be started at least 2 weeks before proposed closing of site that has not been operated as sanitary landfill…and continued until the site has been completely closed
- **Should be covered w/at least 2 feet of compacted earth on top and all exposed sides**
- Side slopes should be no more than 3:1

Incineration:

- **Capacity of storage pit is usually equal to the volume of waste for 2–4 days**
- Process:
  - Unloading
  - Into storage pit
  - Overhead crane loads waste
  - Into feed (charging) chute
  - Directs waste to furnace
  - Fall onto grates
  - Gases and small organic particles rise into combustion chamber (burn at temps in excess of 1600 degrees F)
  - Heat is recovered using water-filled tubes in walls and with a boiler
  - Converts steam to electricity by turbine generator
  - Air pollution control may include ammonia injection for nitrogen oxide control
  - Dry scrubber for SO and acid gas control
  - Bag house (fabric filter) for particulate removal
  - Induced-draft fan to supply air to combustor
  - Cleaned gases discharged to stack
  - Ashes and unburned materials from grates fall into hopper
  - Fly ash mixed with furnace ash and conveyed to ash-treatment facilities

- **Combustion** products and residues:
  - **Three essentials:**
    - **Time** (to drive out moisture)
    - **Temperature** (raised to ignition point, 1,500–1,800 degrees F)
    - **Turbulence** (including sufficient oxygen to ensure mixture of gases formed w/enough air to burn completely the volatile combustible matter and suspended particulates)
  - **Hospital wastes require incineration at temp of 1,800–2,000 degrees F**
  - Results in production of:
    - Combustion gases
    - Particulates
    - Bottom (heavy) and fly (light) ash
  - **Types of furnaces:**
    - **Rectangular refractory lined**
      - 2 or more grates are arranged in tiers
    - **Rotary kiln**
      - Incorporates drying grate ahead of rotary drum where burning is completed
    - **Rectangular furnace with waterwalls**
      - Substitute water-cooled tubes for the exposed furnace walls and arches
  - Modern furnace walls are usually lines with tile or have waterwalls
  - RDF vs mass-fired systems:
    - RDF-fired systems can be controlled more effectively than mass-fired system because of the more homogeneous nature of RDF
    - Because of higher energy content, RDF systems can be physically smaller than mass-fired systems
- When possible, a large municipal incinerator should be used in preference to a small on-site incinerator
- On-site incinerators are used in hospitals, schools, and commercial and industrial establishments
- Incinerators are rated in terms of tons of burnable/incinerable waste per day
- Capacity and stack heights:
  - **High** stacks
    - At least150–200 ft above ground level
    - Constructed to provide natural draft and air supply for combustion
    - **Discharge of gases at these heights also facilitates diffusion and dispersal**
- Odor control:
  - Requires complete combustion of hydrocarbons
  - Excess air and a retention time of 1 sec at 1,500 degrees F
  - Adequate dilution of gases leaving the stack by an effective stack height
- Noise control:
  - **Not greater than 60 dBA (rural), 65 (suburban), and 70 (urban) between 7 a.m. and 10 p.m.**

    - **Between 10 p.m. and 7 a.m. not greater than 50 dBA, 55, and 70, respectively**

RCRA:

- **1976**
- Cradle-to-grave concept
- Extension of Solid Waste Disposal Act of 1965
- Defined hazardous waste
- Protects groundwater
- Controls generation, treatment, landfill, transport, underground tanks disposal of hazardous waste
- Amended 1984
    - **Requires 2 liners or equivalent and leachate collection system**
- Subtitle D
    - Federal requirements for MSW landfills

CERCLA (Comprehensive Env. Response, Compensation & Liability Act):

- Superfund
- Created tax on chemical and petroleum industries
- Created priority list of sites targeted for remediation

- **Garbage** (food waste) is animal and vegetable residue from preparation, cooking, and serving food; not large facilities like canneries, slaughter houses, etc…

- **Rubbish** is tin cans, newspaper, tires, packaging materials, bottles, yard trimmings, plastics, etc…

- **Trash** is combustible portion of rubbish.

Hazardous waste landfills:

- Double liners
- Leachate
- Collection
- Groundwater monitoring
- Well monitoring
- Surveillance system