GE 302 - Industry and the Environment

Chapter IV

Solid Waste Engineering and

Hazardous Waste Management

(Review Chapters 13 and 14 of the textbook for more information)

TABLE OF CONTENTS

I - Municipal Solid Waste (MSW)

Definition

MSW, also called urban solid waste or refuse, is a waste type that includes predominantly household waste (domestic waste) with sometimes added commercial/industrial wastes collected by a municipality within a given area. MSW is in either solid or semisolid form and generally exclude industrial hazardous wastes.

Main Categories of MSW

1- Biodegradable waste: food and kitchen waste, green waste (garden & park wastes with high nitrogen content) and paper.

2- Recyclable material: paper, glass, bottles, cans, metals, certain plastics, etc.

3- Inert waste: construction and demolition waste, dirt, rocks and debris.

4- Composite wastes: waste clothing and waste plastics such as toys.

5- Domestic hazardous waste & toxic waste: medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish, etc.

Factors Affecting the Production Rate

1- Life Style and Economic Conditions

2- Habits of the People

3- Environmental Awareness of the Society

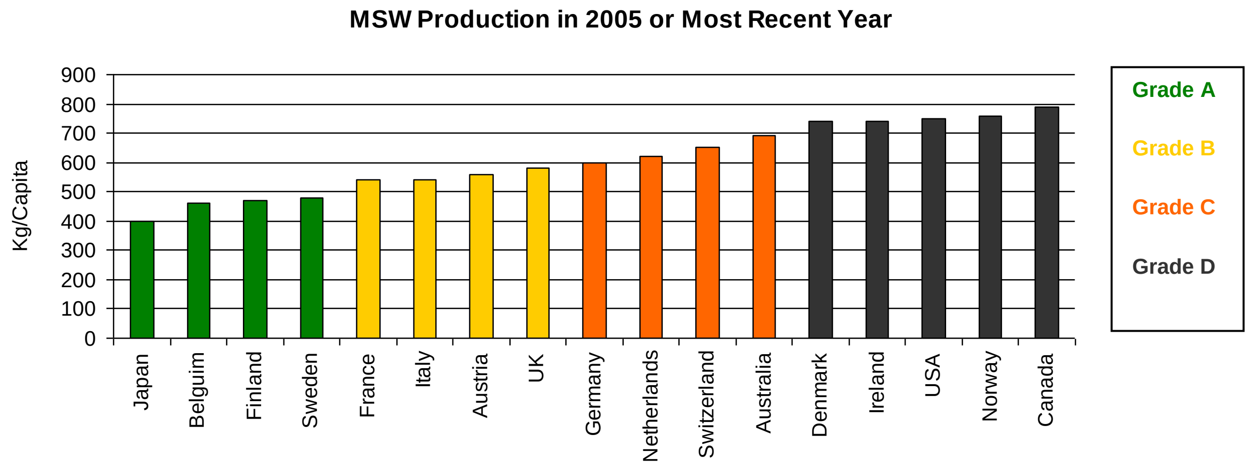
4- Geographical Location

5- Season of the Year

6- MSW Collection Frequency

7- Availability of Recycling Programs

8- Existence of Environmental Protection Acts



Source: The Conference Board of Canada
(http://www.conferenceboard.ca/HCP/Details/Environment/municipal-waste-generation.aspx) Dec 4, '09

MSW Statistics of the City of Riyadh (1427-1428H / 2006-2007G):

- Average Daily MSW reaching Al-Solay Landfill = 12,000 tons (1600 compressions); of which 55% are domestic and the rest is inert and industrial waste
- Biodegradable wastes are approximately 51% of the total domestic solid waste
- Paper and cartoon wastes are approximately 20% of the total domestic solid waste
- Number of scrap cars = 7,000 annually
- Cost of cleaning the city = 15 million SR monthly
- MSW production rate = (1-2) kg/capita/day; i.e. (360-720) kg/capita/year
- Average domestic solid waste production rate = (0.5-1) kg/capita/day

Waste Production Quantities (Tons) in Saudi Arabia (Environment and Development Magazine, 1998)

City	Quantity
Riyadh	1,514,000
Jeddah	971,000
Mecca	697,000
Dammam	501,000
Amadenah	360,000
Taif	338,000
Buraidah	272,000
Hofuf	224,000
Tabuk	216,000
Jizan	180,000
Total	5,273,000

Recycling and Treatment of Municipal Solid Waste (MSW)

a. Recyclable Materials and Their Re-use

1- Materials that are recyclable and may be re-used include: paper, aluminum, iron, plastic, glass and organic wastes (food waste, trees' leaves, plants and sludge)

2- After separating the MSW components, some of them can be directly recycled to produce the same original product; for example used paper and clothes. Other components can be used as raw material in industry to produce the same original product or another different product; for example glass bottles may be recycled into glass, compute chips, etc.

b. Types of Treatment of MSWs

MSWs can be treated to produce **energy** and **compost**; the latter being a combination of decomposed plant and animal materials and other organic materials that are recycled into a rich black soil.

b.1) Biological Treatment

- Aerobic decomposition of organic materials is largely used to produce compost that can enrich and improve soil properties for agricultural use. The process of composting is simple and can be practiced by individuals in their homes, farmers on their land, and industrially by industries and cities.

- Anaerobic decomposition of organic materials that produces gases used for energy production.

b.2) Thermal Treatment

- MSW Combustion (Incineration) with Energy Recovery
    - MSW combustion produces flue gases with high temperature, and the thermal energy can be used to raise steam to drive a turbo-generator to produce electricity. In a modern waste-to-energy facility, MSW combustion and energy recovery are accomplished in an integrated design. Figure xx shows the basic process of a MSW combustion facility with integral heat recovery.

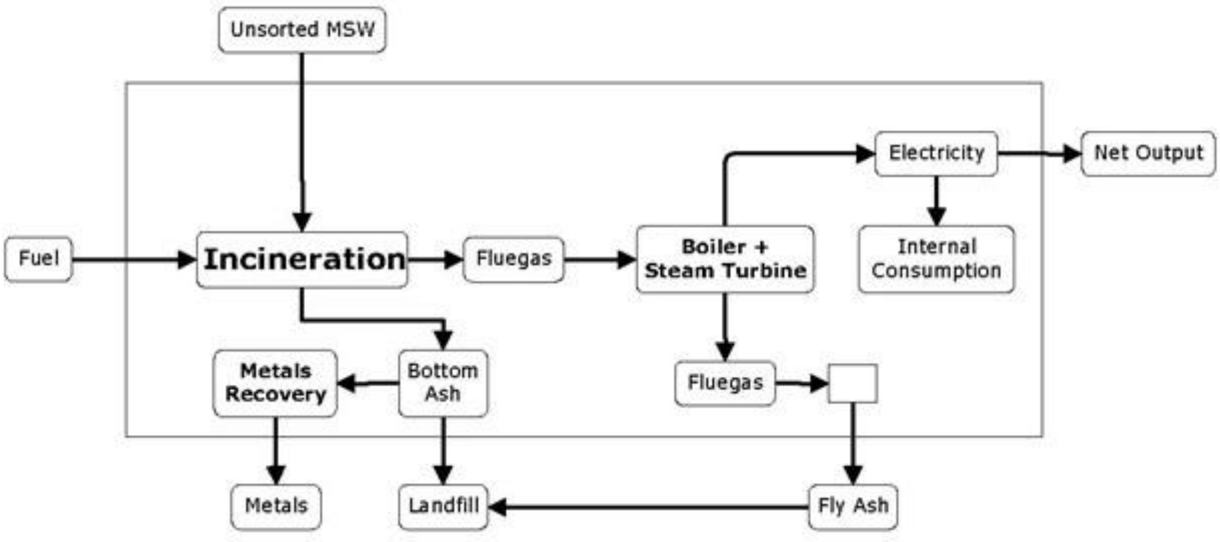


Figure 4-1: Basic Processes of a MSW Combustion Facility (extracted from the textbook)

    - MSW combustion typically reduces the volume of wastes by 90%. MSW combustion facilities are considered primarily as waste management facilities rather than renewable energy facilities.

- Thermal Decomposition of MSWs
    - It is done anaerobically (in the absence of air); to produce oils and tar that can be used in paving roads.

- MSWs Gasification
    - Gasification is another thermal treatment option for MSW to recover energy from the organic portions of the wastes. The gasification

process turns carbon-based substances into energy-rich fuel by heating under controlled conditions (burning in limited amounts of oxygen) to produce a syngas which is the mixture of carbon monoxide and hydrogen. The produced gas is combustible; hence can be used to produce energy.

- Pretreatment of MSW is required t to ensure better performance of the gasification process, this includes: separation of inorganic ingredients, and controlling the size and moisture of feedstock.

Environmental & Economic Gains of Recycling

1- Reducing the amount of wastes that are required to be gotten rid of. This, subsequently, limits environmental pollution.

2- Reducing the overuse of natural resources. For example, recycling paper and wood reduces forest overharvesting. Likewise, recycling some metals; such as iron and aluminum, prolongs the duration of using their reserves.

3- Saving energy consumed in manufacturing processes. For example; producing aluminum from aluminum wastes requires 20% less energy than if it is produced from raw aluminum.

4- Reducing importing raw materials

Other examples that show the importance of recycling:

One recycled tin can would save enough energy to power a television for 3 hours.

One recycled glass bottle would save enough energy to power a computer for 25 minutes.

One recycled plastic bottle would save enough energy to power a 60-watt light bulb for 3 hours.

70% less energy is required to recycle paper compared with making it from raw materials.

Management of Municipal Solid Waste

To get rid of MSWs, they pass through several stages starting from their collection at the production source points all the way up to their final destination at the treatment facilities. The different processes are summarized as follows:

1- Collection and Transfer of Wastes

The costs of colleting and transferring MSWs are approximately 50% of the total costs for waste management. Collection System Types include:

a) Hauled Container System (HCS)

Container is moved to disposal site (commercial, construction, institutions)

One driver and frequent trips

b) Stationary Container System (SCS)

Container remains at site (residential and commercial)

2- Separation of Wastes

2.1 Separation at Source (manual)

- Curbside, where the producer puts the MSWs by the road for collection vehicles to pickup.

- Drop-off Centers and Buy-Back Centers, where these centers have large containers for different waste types (plastics, cans, glass, newsprint, rubber, etc.).

- Buy-Back Centers pay back money to the waste producer in return for the latter delivering the waste to the center.
- Drop-Off Centers are located usually in marketplaces, by charity organizations or near grocery stores.

2.2 Separation at Materials Recovery Facility (MRF)

- Processing of separated materials - clean MRF (baling, crushing)
- Separation of commingled MSW - dirty MRF
- Improving quality of recovered material (cleaning, separation of glass/plastics, contaminant removal).

3- Separation and Processing Stations

These stations are equipped with systems for separating the components of MSWs, pressing them into smaller volumes and cutting them into smaller units to facilitate their processing. The stations have units for the biological and/or thermal treatment of the wastes.

The main unit processes that take place in these stations are:

a) Compaction/Densification

- Reducing the size of wastes and blending constituents lead to more uniform material for processing. Glass crushers, wood grinders, tube grinders and hammer mills are used for these purposes.

- Screening of constituents using rotary screen, vibrating screen and disc screens that are useful in separating glass, aluminum cans and cardboards. The opening size is adjustable based on desired separation. Also useful in removing heavy/light components and under/over-sized material.

b) Mechanical Separation

- Ferrous metal - most successful, magnetism

1. Non-ferrous – flotation

c) Air Classification - major MSW unit process (second to magnetic) - current of air is used to effect material separation based on density, viscous drag

    i. Separation of light organics (combustible) fraction from heavy inorganics

4- Transfer Stations

These stations receive bales of compressed materials from MSWs to be transferred through large trucks that deliver them either to the final processing stations or to the separation and processing stations especially if the former are too far away.

5- Disposing the Waste and Residual Components of the Separation and Processing Stations

a) Traditional Methods

    a. Disposal out of urban areas

    b. Incineration in remote areas

c. Disposal in seas and oceans

d. Mixing the bio-waste with soils

These methods have negative impacts on the environment leading to environmental pollution of air, water and soil. They also provide breeding grounds for insects, rodents and other disease-carriers.

b) Incineration (high capital cost and causes environmental pollution problems - Waste reduction is immediate, no long term residency required)

c) Sanitary Landfills – they are simply engineered excavations in the ground, the purpose of which is to get rid of the waste in an environmentally clean way.

Sanitary Landfill (selection, leachate, gasses)

The building block of a sanitary landfill is the daily cells. All the solid wastes received are spreaded and compressed in layers within a confined area. At the end of each working day, or more frequently, it is covered completely with a thin, continuous layer of soil, which is then also compacted. The compacted waste and soil cover constitute a cell. Figure 4-2 shows a schematic cross-section in a modern landfill.

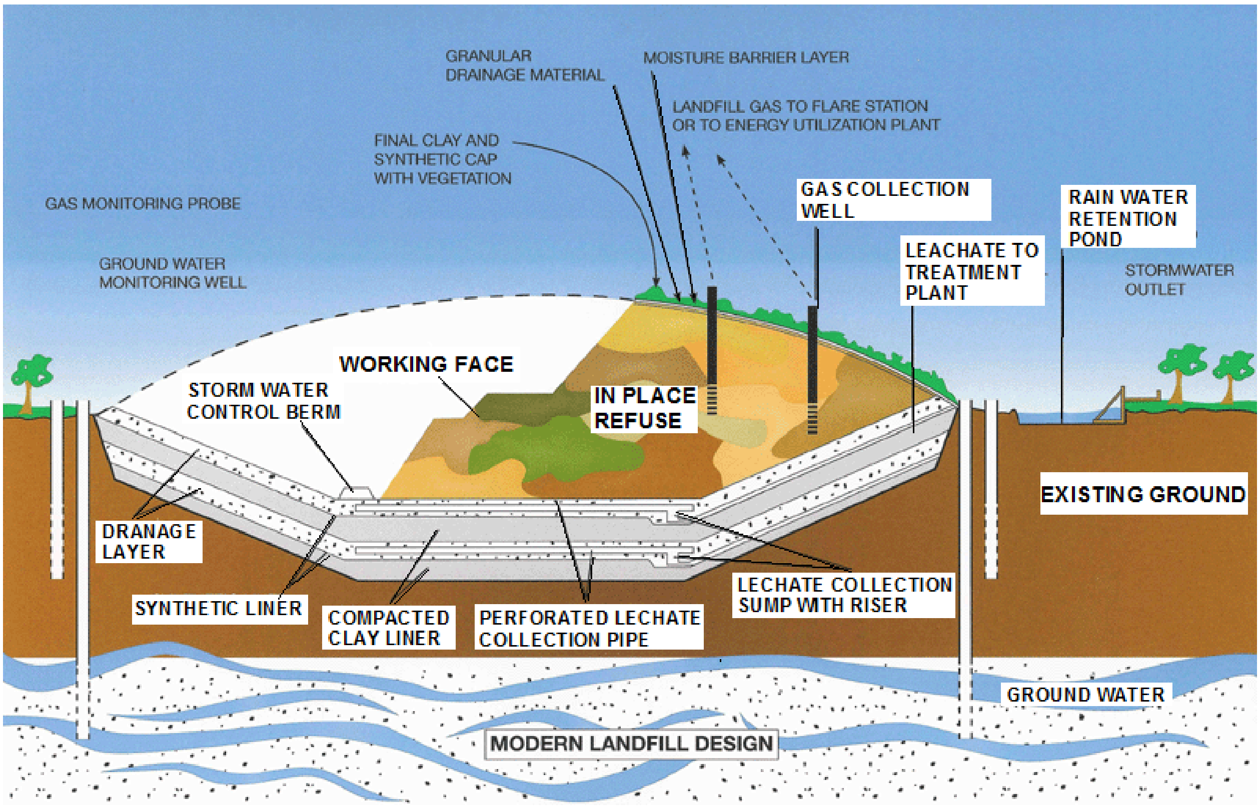


Figure 4-2: Labelled cross-section of an engineered landfill.

Different reactions occur to the disposed wastes in a landfill: these are chemical, physical and biological in nature and happen to both organic and inorganic compounds. The following text describes the main outcomes of these reactions.

Leachate: Groundwater or infiltrating surface water moving through solid waste can produce leachate; a solution containing dissolved and finely suspended solid matter and microbial waste products. All landfills produce some leachate whether sanitary landfill or open dumping site. The leachate may also contain dissolved heavy metals and organic chemicals.

Produced Gases:
Gases are produced naturally when solid wastes are decomposed whether in a sanitary landfill or open dumping site. Biological activity within a landfill follows a set pattern. Landfill gas is important to consider when evaluating the effect a landfill may have on the environment. Common gases are: methane (CH_4) and carbon dioxide (CO_2). Methane can explode if not properly captured and because mineralization of ground water can occur, carbon dioxide is generated and may dissolve in ground water and forms carbonic acid.

The gases produced by decomposition of landfill wastes can be used for energy production. If the production of gases proves commercially feasible, gas recovery facilities may be installed at the landfill sites.

Sanitary Landfill Design and Design Example

For modern sanitary landfill design, geosynthetics are commonly used. Geosynthetic means the generic classification of all synthetic materials used in geotechnical applications.

Public health aspects:
In industrial landfill leachate, 32 chemicals may cause cancer; 10 may cause birth defects, and 21 may cause genetic damage. In municipal landfill leachate, 32 chemicals may cause cancer, 13 may cause birth defects, and 22 may cause genetic damage.

Example:

A city has 600,000 inhabitants. The daily MSW production rate is approximately 2 kg. Estimate the following requirements under the given conditions:

a) If the municipality has 170 vehicles for waste disposal; each has 10 m^3 capacities, estimate the number of additional vehicles required to transfer the daily generated waste to a remote landfill. Assume all vehicles have equipment that compresses the wastes to a density of 320 kg/m^3, and each vehicle makes two trips per day.
b) If the landfill area is approximately 0.5 km x 1.0 km and its average depth is 10.0 m, estimate the number of hijri years (354 days/year) that the landfill will serve. Assume the wastes layers in the landfill will be compacted to a density of 400 kg/m^3

c) If one recycling company proposed reducing the wastes by 20% through recycling, estimate the number of years the landfill will serve in this case.

Solution:

a- Exact No. of vehicles required = (600,000 x 2) / (10 x 320 x 2) = 187.5 or 188 vehicles

Use 12 vehicles standby, No. of vehicles required = 188 + 12 = 200 vehicles

Number of additional vehicles required = 200 – 170 = 30 vehicles

b- Capacity of the landfill = 500 x 1000 x 10 x 400 = 2×10^9 kg

Daily MSW production rate of the city = 600,000 x 2 = 1.2×10^6 kg

Number of hijri years that the landfill will serve = $2 \times 10^9 / (1.2 \times 10^6 \times 354)$= 4.71 years

c- Number of hijri years that the landfill will serve = $2 \times 10^9 / (0.8 \times 1.2 \times 10^6 \times 354)$= 5.89 years

Actions for Better Waste Management

1- Reduce, Reuse and Recycle (the three-Rs)

Source reduction, often called waste prevention, means consuming and throwing away less. Source reduction includes purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxics as possible. We all can use the material again as its original or subsidiary form.

2- Composting

3- Combustion and Incineration

4- Sanitary Landfills

II - Hazardous Wastes

Definition

Hazardous waste is waste that is dangerous or potentially harmful to our health or the environment. Hazardous wastes can be liquids, solids, gases, or sludge. They can be discarded commercial products, like cleaning fluids or pesticides, or the by-products of manufacturing processes. They may be radioactive, corrosive, combustible, exploding and toxic compounds that require special care during their handling, transfer or storage.

Picture: Hazardous wastes

Sources

1- Wastes of workshops, gas stations, auto-service units: they include oils, solvents, petrochemicals, rubber tires, batteries, etc.

2- Wastes of laboratories (universities, research centers, schools, etc.), dry cleaning facilities, film development stores, etc.

3- Wastes of power plants, mining, smelters and other industrial activities.

4- Wastes of medical facilities (medical labs, hospitals, clinics, etc.) that have chemical, biological and radioactive characteristics.

Characteristics of Hazardous Wastes

1. Flammable

- Liquid containing less than 24% alcohol by volume and has a flash point less than 60^0 C.

- Not a liquid and is capable, under std. temperature & pressure of causing fire through friction, absorption of moisture or spontaneous chemical changes, and when ignited burns so vigorously and persistently, thus creates hazard.

- An ignitable compressed gas.

- An oxidizer

- Examples: Waste oils, used organic solvents and PCB).

2. Corrosive (corrosive to human tissues and metals)

- A solution that has a pH less than or equal to 2 or greater than or equal to 12.5.

- A liquid that corrodes steel at a rate greater than 6.35 mm per yr at a test temperature of 55^0C)

- Examples: Strong acids, strong bases

3. Toxic

- It poses danger to human, plant, and animal health through inhalation, inhalation or surface contact.

- Examples: DDT, dioxins

<u>Example of Industrial Hazardous Wastes</u>

1. Acids (sources : petroleum & chemical industries, incinerator ash)
2. Cyanide (sources : metal & chemical industries)
3. Arsenic (sources : glass manufacturing processes, pesticides)
4. Cadmium (sources : paint & plastic industries, battery manufacturers)
5. Lead (sources : electronic industry)
6. Infectious waste (sources : hospitals, clinics)
7. Organic solvents (sources : plastic, adhesive, cosmetic industries)
8. Radioactive waste (sources : nuclear power plant)

Hazardous Waste Recycling

Many industrial hazardous wastes can be recycled safely and effectively. A hazardous waste is recycled if it is used, reused, or reclaimed. Furthermore, hazardous waste regulation makes an important distinction between materials that are used or reused without reclamation and those that must be reclaimed before reuse. A material is reclaimed if it is processed to recover a usable product, or if it is regenerated. Common hazardous waste reclamation activities involve recovery of spent solvents (e.g., recovery of acetone) or metals (e.g., recovery of lead). An example of a material that is reused without reclamation is emission control dust returned directly to a primary zinc smelting furnace.