SOLID WASTE MANAGEMENT (15CV651)

1.a. Properties of Solid waste:

Importance: Information on properties of solid waste is important in evaluating alternative equipment needs, system and management programmes and plans especially with reference to the implementation of disposal and resource and energy recovery operations.

Physical Properties:-

a) Individual components
b) Particle size
c) Moisture content
d) Density

Chemical composition or properties:

a) Proximate analysis
   - → Moisture (loss at 105^0C for 1 hour)
   - → Volatile (Additional loss matter on ignition at 950^0C)
   - → Ash (Residue after burning)
   - → Fixed carbon (Remaining un burnt material)

b) Fusing point of Ash
c) Ultimate analysis - % C,H,O,N,S and Ash
d) Heating value (energy value)

Physical properties:

Information and date of physical properties include.

1) Identification of Individual components that make up MSW.
2) **Particle Size:** The size distribution of the component materials in solid waste include consideration in the recovery of materials specially with mechanical means such as magnetic separators.
3) **Moisture content:**
   The moisture content of solid waste usually expressed as the mass of moisture per unit mass of weight of wet or dry material. In the wet mass of method of measurement the moisture in a sample is expressed as % of wet mass of the material. In dry mass method it is expressed as % of dry mass of the material. In equation form the wet mass moisture content is expressed as follows.

   Moisture content (%) = $\frac{a-b}{a} \times 100$

   where

‘a’ = initial mass of mass of sample as delivered.
‘b’ = mass of sample after drying.

4. Density: The density of solid waste vary markedly with geographic location, season of the year, length of time in storage, great care should be used in selecting the typical values. Density of a material is its mass per unit volume. Density differs with buoyancy, purity and packaging. Density of material varies with temperature and pressure.

Chemical composition or properties:

Proximate analysis:

Proximate analysis for the combustible components for MSW includes the following tests.

a) Moisture – when heated to 105^0c for 1 hour.
b) Volatile combustible matter – additional loss of weight at 950^0C in a covered crucible.
c) Fixed carbon - Combustible residue left after volatile matter is removed.
d) Ash – Weight of residue after combustion in an open crucible.
e) It is important to note that the test used to determine volatile combustible matter in a proximate analysis is different from the volatile solids test used in biological determination.

Energy Content

In general the data on the energy content of the organic components of MSW are based on the results of bomb calorimeter tests. The energy content values are on as discarded basis.

The energy values may be converted to a dry basis by the following equation

$$\text{kJ/kg (dry basis)} = \text{unit energy content kJ/kg (as discarded)} * \frac{100}{100 - \%\, moisture}$$

The corresponding equation on as Ash free dry basis is

$$\text{KJ/kg (dry basis)} = \text{kJ/kg (as discarded)} = \text{unit energy content x } \frac{100}{100 - \%Ash - \%\, moisture}$$

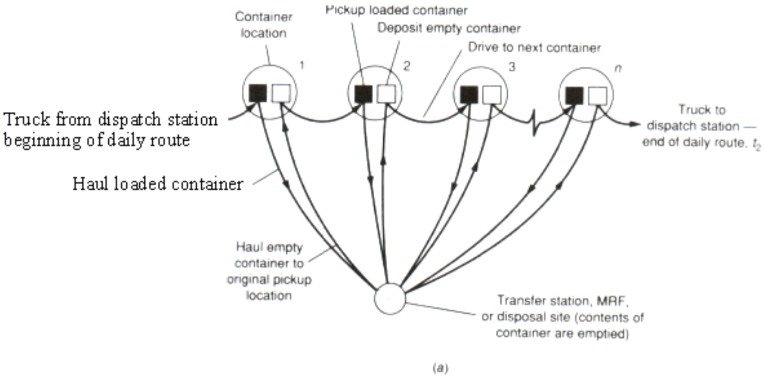
Ultimate Analysis:

To identify % of C,H,O,N,S and Ash.

2.a. **Hauled container system** (HCS):

Containers used for the storage of wastes are hauled to the disposal site, emptied and returned to either their original location or some other location. Hauled containers systems are ideally suited for the removal of wastes from sources, where the rate of generation is high. In this system containers of different sizes and shapes can be used and the use of such large containers reduce handling time. Hauled container systems have the advantage of requiring only truck and driver to accomplish the collection cycle. These are three main types hauled container system:

1. **Hoist truck systems**: It is used for the collection of wastes by a collector who has a small operation and collects from only a few pick up points at which considerable amounts of wastes are generated.
2. **Tilt Frame container system**
3. **Trash – trailer systems**



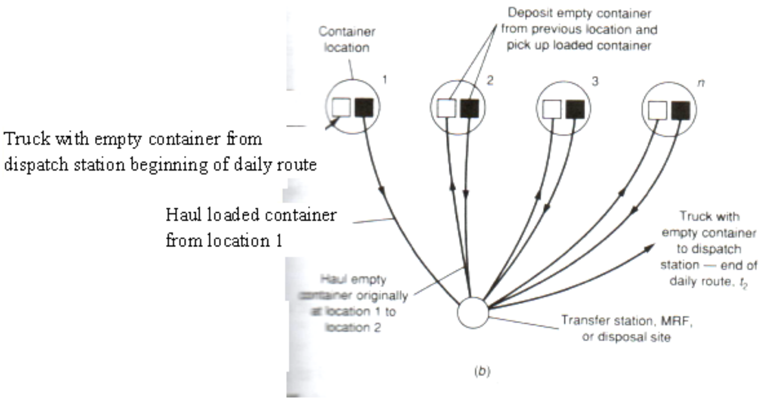


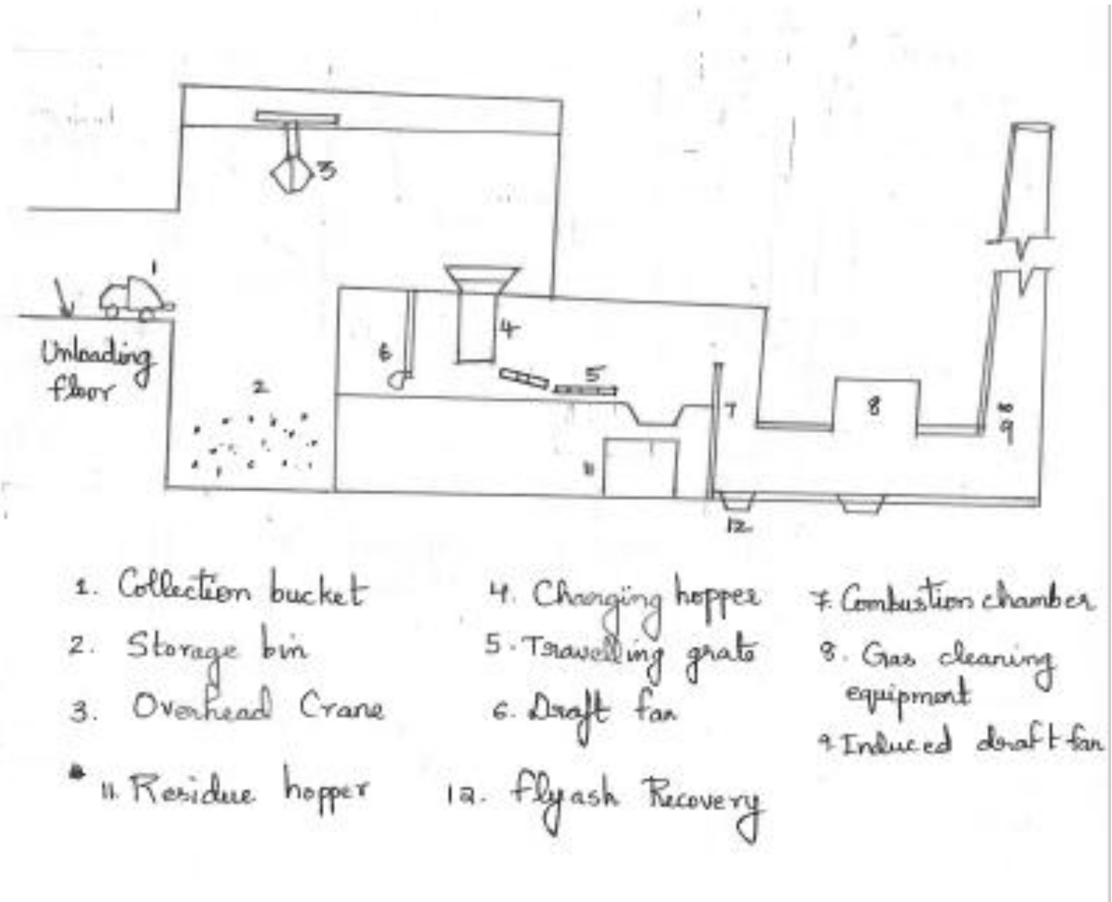
Figure: Schematic of operational sequence for hauled container system a) conventional mode and b) exchange container mode

3.a. **Incineration of Municipal wastes:**

The most attractive feature of the incineration process is that it can be used to reduce the original volume of combustible solid wastes by 80 to 90%. In some of the newer incinerators designed to operate at temperatures high enough to produce a molten material before cooling it may be possible to reduce the volume to about 5% or less. Although technology of incineration has advanced in the past two decades, air pollution control remains a major problem in implementation. In addition to the use of large municipal incinerators, on site incineration is also used at individual residences apartments, stores, industries, hospitals and other institutions.

<u>Section through a typical municipal incinerator</u>

The basic operations involved in the incineration of solid wastes are identified in the figure. The operation begins with the unloading of solid wastes from collection trucks into a storage bin. The length of the unloading platform and storage bin is a function of the number of trucks that must unload simultaneously. The over head crane is used to batch load waste into the charging hopper. The crane operators can select the mix of waste to achieve a fairly even moisture content. Large or incombustible items are also removed from the wastes. Solid wastes from the charging hopper fall into the stokers where they are mass fired. Several different types of mechanical stokers are commonly used. Air may be introduced from the bottom of the grates (under fire air) by means of a forced draft fan or above the grates (over-fire air) to control burning rates and furnace temperature. The hottest part of the fire is above the burning grate various gases are driven off in the combustion process taking place in the furnace, where the temperature is about 1400^0F. These gases and small organic particles pass into a secondary chamber commonly called a “combustion chamber” and burnt at temperatures above 1600^0F. To meet local air pollution control regulations space must be provided for air cleaning equipment as well as to supply air to the incinerator itself, an induced draft fan may be needed. The end products of incineration are the cleaned gases that are discharged to the stack. Ashes and unburnt materials from the grates fall into a residue hopper located below the grates where they are quenched with water. Fly ash which settles in the combustion chamber is removed by means of a fly ash sluice way. Residue from the storage hopper may be taken to a sanitary landfill.



3.b.(i) Volume reduction or compaction refers to densifying wastes in order to reduce their volume. Some of the benefits of compaction include:

a. Reduction in the quantity of materials to be handled at the disposal site;

b. Improved efficiency of collection and disposal of wastes;

c. Increased life of landfills;

d. Economically viable waste management system.
Equipment used for compaction Based on their mobility, we can categorise the compaction equipment used in volume reduction under either of the following:

(i) Stationary equipment: This represents the equipment in which wastes are brought to, and loaded into, either manually or mechanically. In fact, the compaction mechanism used to compress waste in a collection vehicle, is a stationary compactor.

(ii)Movable equipment: This represents the wheeled and tracked equipment used to place and compact solid wastes, as in a sanitary landfill.

According to their compaction pressure, we can divide the compactors used at transfer stations as follows:

(i) Low-pressure (less than $7kg/cm^2$) compaction
(ii) High-pressure (more than $7kg/cm^2$) compaction

(ii) Size reduction or shredding

This is required to convert large sized wastes (as they are collected) into smaller pieces. Size reduction helps in obtaining the final product in a reasonably uniform and considerably reduced size in comparison to the original form.

In the overall process of waste treatment and disposal, size reduction is implemented ahead of:

(i)Land filling to provide a more homogeneous product.

(ii)Recovering materials from the waste stream for recycling.

(iii)Baling the wastes – a process sometimes used ahead of long distance transport of solid wastes – to achieve a greater density.

(iv)Making the waste a better fuel for incineration

(v)Reducing moisture, i.e., drying and dewatering of wastes

The most frequently used shredding equipment are the following:

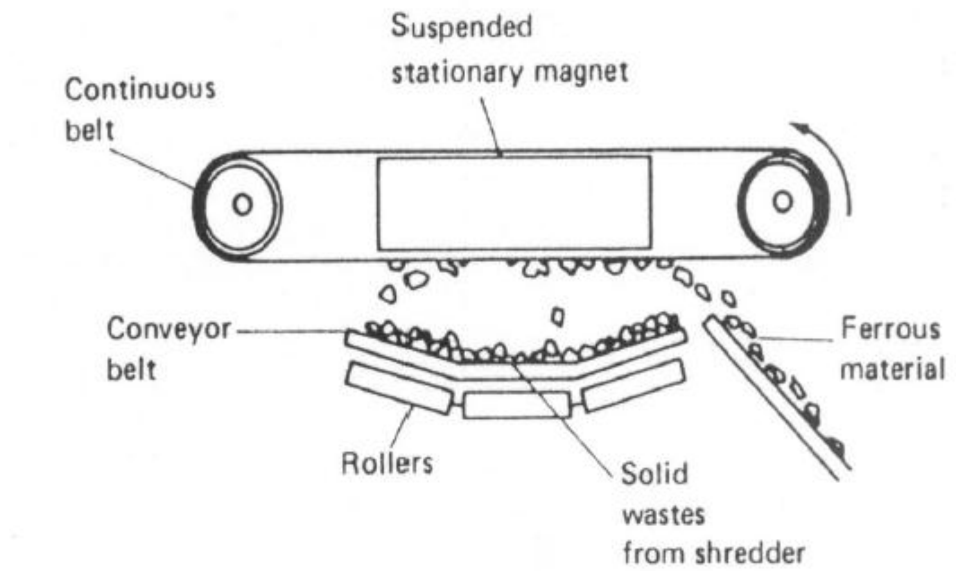
(i) Hammer mill: These are used most often in large commercial operations for reducing the size of wastes. Hammer mill is an impact device consisting of a number of hammers, fastened flexibly to an inner disk. Solid wastes, as they enter the mill, are hit by sufficient force, which crush or tear them with a velocity so that they do not adhere to the hammers. Wastes are further reduced in size by being struck between breaker plates and/or cutting bars fixed around the periphery of the inner chamber. This process of cutting and striking action continues, until the required size of material is achieved and after that it falls out of the bottom of the mill.

(ii) Hydropulper: An alternative method of size reduction involves the use of a hydropulper

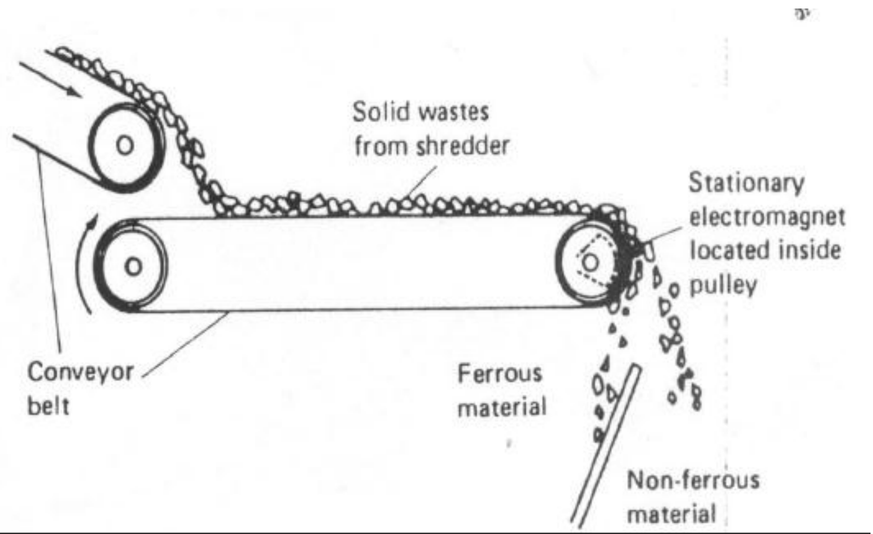
4.a. Magnetic separation

Various types of equipment are in use for the magnetic separation of ferrous materials. The most common types are the following:

(i) Suspended magnet: In this type of separator, a permanent magnet is used to attract the ferrous metal from the waste stream. When the attracted metal reaches the area, where there is no magnetism, it falls away freely. This ferrous metal is then collected in a container.



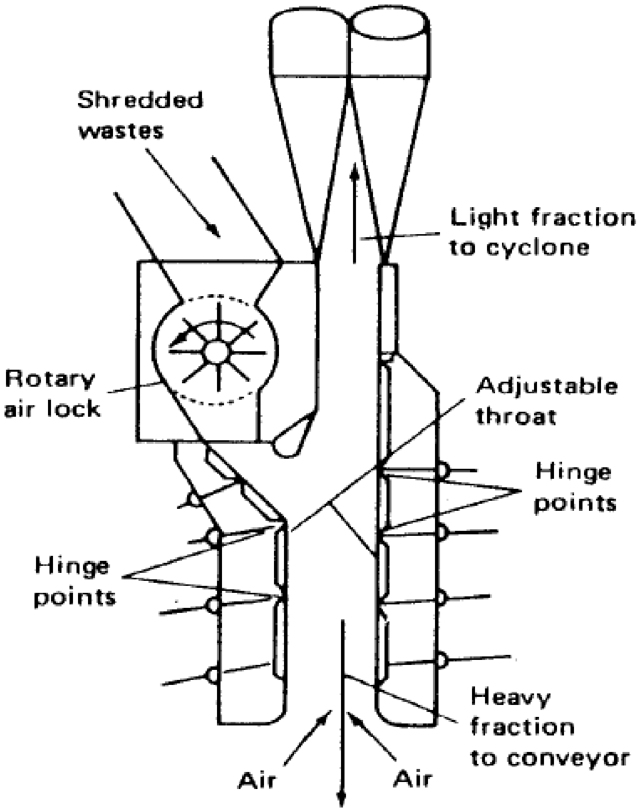
(ii) Magnetic pulley: This consists of a drum type device containing permanent magnets or electromagnets over which a conveyor or a similar transfer mechanism carries the waste stream. The conveyor belt conforms to the rounded shape of the magnetic drum and the magnetic force pulls the ferrous material away from the falling stream of solid waste.



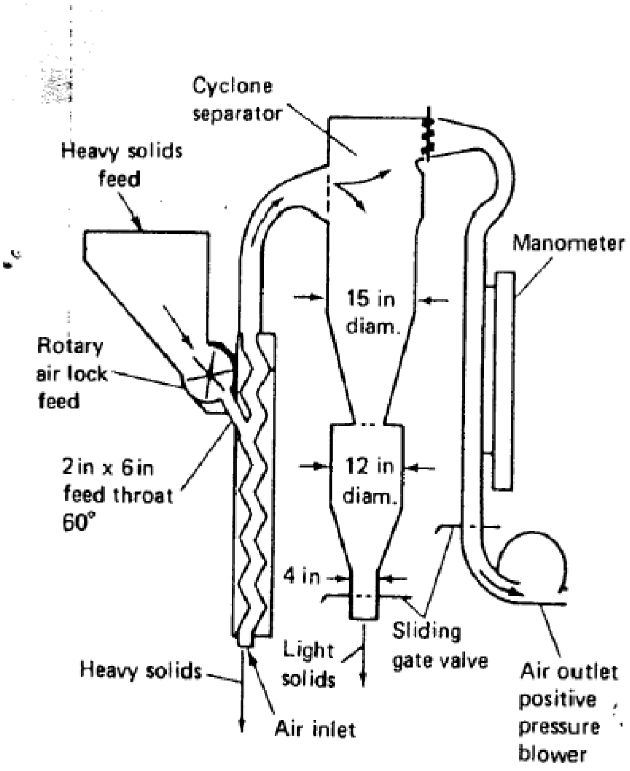
4.a.(ii) Air separation

Air separation is primarily used to separate lighter materials (usually organic) from heavier (usually inorganic) ones. The lighter material may include plastics, paper products and other organic materials. Generally, there is also a need to separate the light fraction of organic material from the conveying air streams, which is usually done in a cyclone separator.

Conventional chute type: In this type, when the processed solid wastes are dropped into the vertical chute, the lighter material is carried by the airflow to the top while the heavier materials fall to the bottom of the chute. The control of the percentage split between the light and heavy fraction is accomplished by varying the waste loading rate, airflow rate and the cross section of chute. A rotary air lock feed mechanism is required to introduce the shredded wastes into the classifier.



Zigzag air classifier: Consists of a continuous vertical column with internal zigzag deflectors through which air is drawn at a high rate. Shredded wastes are introduced at the top of the column at a controlled rate, and air is introduced at the bottom of the column. As the wastes drop into the air stream, the lighter fraction is fluidised and moves upward and out of column, while the heavy fraction falls to the bottom.



4.b.(a) Garbage chute: Garbage chute means a duct in which deposited material descends from one level to another within a building due to gravity. This system has all components to make a garbage chute including loading hoppers, service openings and service compartments.

High rised buildings have a large no of floors. These buildings have built in vertical trash chutes with openings on each floor. Residents drop their waste into a container. The chute containers are then periodically taken to the load out dock, where they are emptied into the buildings trash compactor which compacts the waste and pushes into a large roll of container. To empty the container a roll of truck is driven to the building where the container is pulled on to the truck which takes it to disposal site for emptying and returned to the building.

(b) Bailing and compacting:

Bailing is a process of reducing the volume of waste into blocks and prepare the waste for marketing or can be stacked at a landfill or bailfill. This increases the density of the waste and reduces shipping costs. The materials most commonly baled are paper, cardboard, plastics, aluminium and tin cans and large metal components. By bailing the waste scatter by animals and birds is reduced, reduces amount of cover material needed, reduces maintenance at land fill/ balefill makes balefill operation easier and results in cleaner facility. The disadvantages are that balers need power source, use a lot of electricity, frequent maintenance and upkeep is required.

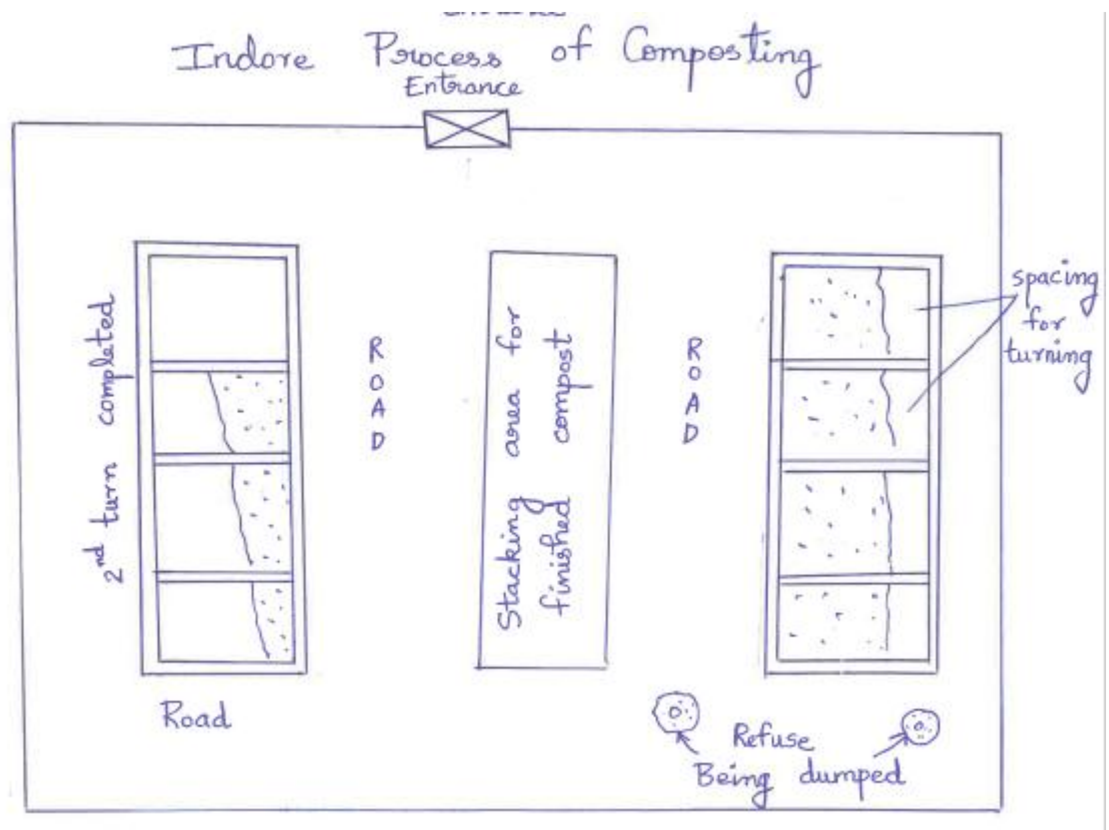
5.a. Factors that must be considered in the selection of a site for a sanitary landfill.

Factors	Remarks
Available land area	Site should have a useful life of more than five years (minimum value)
Haul distance	Length of the haul significantly affects the overall design and will have significant impact on operating cost.
Soil conditions and topography	Cover material must be available at or near the site.
Surface water hydrology	Impacts drainage requirements.
Geology and Hydrology conditions	Probably most important factor in landfill site, especially with respect to site preparation.
Climatological condition	Provision must be made for wet weather operation.
Local environmental conditions	Noise, odour and aesthetics
Ultimate use of site	Affects long term management for site.
Location restrictions	Restrictions apply with respect to siting land near Airports, wet lands, area with known faults, in seismic impact zone and in unstable areas.
Site access	As the number of operating landfills continues to decrease, new landfills are sited where roadways are accessible.

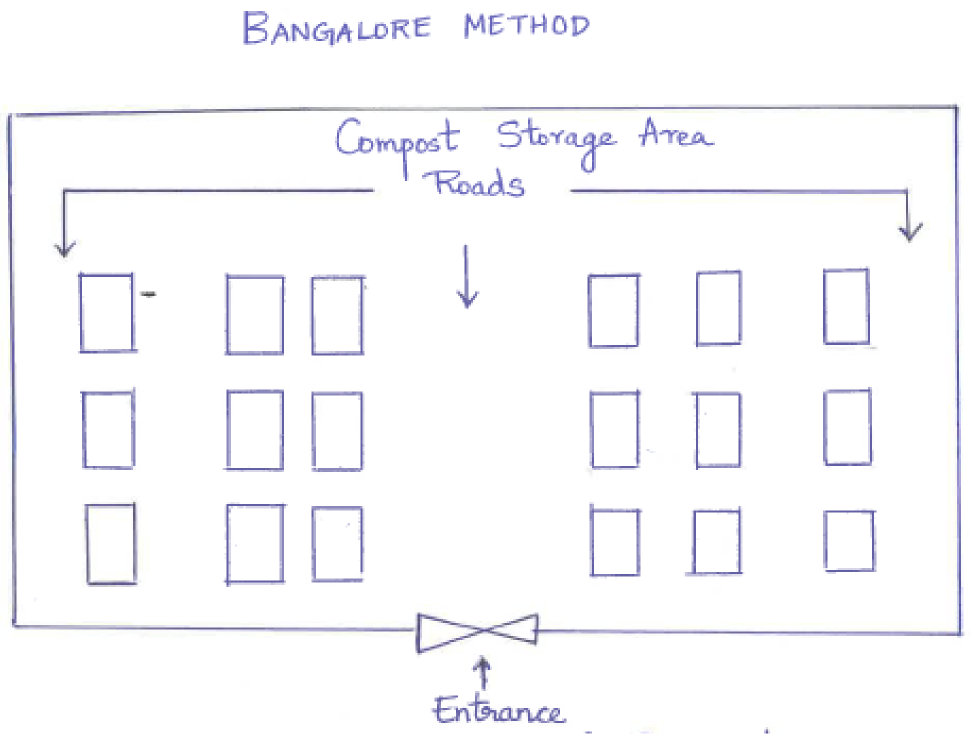
6.a.

Indore process and Bangalore process of composting of Muncipal Solid Waste

Indore process of composting of Muncipal Solid Waste:Uses manual turning of piled up mass (refuse+night soil), for its decomposition under aerobic conditions. In this method, layers of vegetable wastes and night soil are alternatively piled in depths of about 7.5 to 10cm each, to a total depth of about 1.5m in a trench, or above the ground to form a mound called a windrow. A windrow is a long mound or stack of MSW (mixed with cattle dung and human excreta if needing disposal) dumped on land in a height of about 1.5m to 2m, usually about 2.5m to 3m wide at the base. Most windrows are conical in crossection and about 50m in length. The composting waste is aerated by periodically turning the waste mix in the windrow, or in the trench, as the case may be. The manual turning with a pitchfork can be adopted at smaller instillations, while at larger plants, mechanical devices like self-propelled overcab loaders, rotary ploughs etc may be used to turn the refuse once or twice per week, which serves to introduce oxygen and to control the temperature. The moisture content of the turning mass is maintained at about 55% for getting optimum decomposition of the waste mass. This process of turning is continued for about 4 to 5 weeks, during which time biodegadable organics are consumed. The waste component mass is finally allowed to cure for another 2 to 8 weeks without any turning. The entire composting process thus takes about 3-4 months time to complete, after which compost becomes ready for being taken out for use or for sale.



Bangalore process of composting of Muncipal Solid Waste: Anaerobic decomposition of wastes and doesnot involve any turning or handling of the mass and hence cleaner than Indore method. The refuse and night soil, in this method are piled up in layers in an underground earthern trench (about 10m*1.5m*1.5m). This mass is covered at its top by layer of earth of about 15cm depth, and is finally left over for decomposition. Within 2 to 3 days of burial, intensive bioloigical action starts taking place and organic matter begins to be destroyed. Considerable heat gets evolved in the process, which raises the temperature of the decomposing mass to about 75°C. The heat prevents the breading of flies by destroying the larvae. After 4 to 5 months (depending upon the season), the refuse gets fully stabilised and changes into a brown coloured odourless innocuous powdery dry mass, called humus. This humus is removed from the trenches, sieved on 12.5mm sieves to remove stones, broken glass, brick bats, etc and then sold out in the market as manure. The empty trenches can again be used for receiving further batches of refuse. The initial C-N ratio and moisture content of the compost heap are the two important controlling factors in the success of anaerobic digestion, which finally produces a compost free from pathogens and contains 1% N, 1.1% P(as P_2O_5)and 1.5% K(as K_2O) on dry basis, thus proving to be a valuable nutrient for the soils, along with producing biogas as a by-product.



7.a. Hazardous wastes refer to wastes that may, or tend to, cause adverse health effects on the ecosystem and human beings. These wastes pose present or potential risks to human health or living organisms, due to the fact that they are non-degradable or persistent in nature; can be biologically magnified; are highly toxic and even lethal at very low concentrations

Characteristics of hazardous wastes

a.Ignitability : A waste is an ignitable hazardous waste, if it has a flash point of less than 60° C; readily catches fire and burns so vigorously as to create a hazard; or is an ignitable compressed gas or an oxidiser.

b.Corrosivity: A liquid waste which has a pH of less than or equal to 2 or greater than or equal to 12.5 is considered to be a corrosive hazardous waste.

c. Reactivity: A material is considered a reactive hazardous waste, if it is unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials, or if it is capable of detonation or explosion when exposed to heat or a flame.

d. Toxicity: To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory.

Containers and facilities used in hazardous waste storage and handling are selected on the basis of waste characteristics. For example, corrosive acids or caustic solutions are stored in fibreglass or glass-lined containers to prevent deterioration of metals in the container. Great care must also be exercised to avoid storing incompatible wastes in the same container or locations. Treatment processes convert hazardous waste to less hazardous or non hazardous substances include a) Incineration b) Chemical treatments c) Thermal treatments and d) Pyrolysis

7.b. Biomedical waste: The waste (solid waste as well as liquid waste) produced by hospitals, nursing homes, clinics, research laboratories, diagonostic centres, vetenary hospitals,etc are potential sources of health hazards, and need to be specially treated and disposed off. The greatest risk of clinical waste is from the infectious and sharp components like needles, syringes,etc.

Collection and Treatment of Biomedical Wastes

The various types of medical wastes are divided into different categories, and collected in different coloured bins or containers, so as to help in segregation of hazardous and non-hazardous wastes, needing different types of treatments. The process is known as waste segregation. The system using different coloured bins and bags to collect different types of solid medical wastes is known as colour coding.

Contents of Bags

1. Yellow bin wastes: These wastes need to be incinerated or buried deep, and may include: human anatonomical wastes, animal wastes, pathological wastes, micro-biological wastes, sharp wastes, discarded medicines, cytotoxic drugs, and solid wastes.
2. Red bin wastes: These wastes will have to be autoclaved, disinfected with chemicals, or microwaved. They may include : plastic wastes and disposable items like tubes, catheters, blood or urine bags, gloves etc.
3. Black bin wastes: These wastes can be sent for disposal to secure landfills/burials, and may include, chemical solid wastes and incinerated ash,etc.
4. Blue bags: Used sharps, solid disposal waste

Treatment methods include Autoclaving, Microwave Treatment and Incineration

Autoclaving is a low heat thermal process and it uses steam for disinfection of waste. Autoclaves are of two types depending on the method they use for removal of air pockets. They are gravity flow autoclave and vacuum autoclave.

Microwaving is a process which disinfects the waste by moist heat and steam generated by microwave energy. The microwave is based on the principle of generation of high frequency waves. These waves cause the particles within the waste material to vibrate, generating heat. This heat generated from within kills all pathogens.

High-heat systems employ combustion and high temperature plasma to decontaminate and destroy the waste. Incinerator & Hydroclaving are high heat systems.

Chemical Methods: 1 % hypochlorite solution can be used for chemical disinfection

Plasma Pyrolysis

Plasma pyrolysis is technology for safe disposal of medical waste. It is an environment-friendly technology, which converts organic waste into commercially useful by products. The intense heat generated by the plasma enables us to dispose all types of waste including municipal solid waste, biomedical waste and hazardous waste in a safe and reliable manner. Medical waste is pyrolysed into CO, H_2, and hydrocarbons when it comes in contact with the plasma-arc. These gases are burned and produce a high temperature (around $1200^{o}C$).

8.a. E-waste is a term used to cover all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use. It is also referred to as WEEE (Waste Electrical and Electronic Equipment), electronic waste or e-scrap in different regions. E-waste includes a wide range of products, – almost any household or business item with circuitry or electrical components with power or battery supply.

Six categories
Temperature exchange equipment, screens, monitors, lamps, large equipment, small equipment, small IT and telecommunication equipment

Consumers directly dispose of e-waste through the normal dustbins together with other types of household waste. As a consequence, the disposed e-waste is then treated with the regular mixed waste from households. Depending on the region, it can be sent to landfill or municipal solid waste incineration with a low chance of separation. Neither of these two destinations is regarded as an appropriate technique to treat e-waste, because it leads to resource loss and has the potential to negatively impact the environment. The e waste in landfill lead to toxin leaching and if e-waste is incinerated, emissions into air occur.

8.b. Construction waste consists of unwanted material produced directly or incidentally by the construction or industries. This includes building materials such as insulation, nails, electrical wiring, shingle, and roofing as well as waste originating from site preparation such as dredging materials, tree stumps, and rubble. Construction waste may contain lead, asbestos, or other hazardous substances. Building waste is made up of materials such as bricks, concrete and wood damaged or unused for various reasons during construction. Observational research has shown that this can be as high as 10 to 15% of the materials that go into a building, a much higher percentage than the 2.5-5% usually assumed by quantity surveyors and the construction industry. Since considerable variability exists between construction sites, there is much opportunity for reducing this waste
There is the potential to recycle many elements of construction waste. Often roll-off containers are used to transport the waste. Rubble can be crushed and reused in construction projects. Waste wood can also be recovered and recycled.
Drywall—3%: Drywall is 100% recyclable. Gypsum is a nuisance material in picking and sorting operations, producing dust which discomforts labour, and reduces the value of recyclable materials through contamination. Gypsum may be incorporated into new drywall, or used as a soil amendment.
Asphalt roofing—5%: Asphalt roofing shingles may be ground, sized and graded for remelting in asphalt paving applications, road base, new roofing, and fuel oil.

9.a. **Incineration**
3 T's of incineration- temperature, time and turbulence. Solid waste are exposed for sufficient time to turbulent atmosphere for complete combustion . Mixing of each volume of gas with sufficient air for complete burning of combustible matter. Incineration can be defined as a controlled combustion process for burning of solid, liquid and gaseous combustible waste to gases and residue containing non combustible materials. Burning of refuse at high temperatures in furnaces are called Incinerators. Incineration is a chemical process used to reduce the volume of solid wastes. The process can also be called as chemical volume reduction. Chemical process such as pyrolysis, hydrolysis and chemical conversion are also effective in reducing the volume of wastes. Incineration process is preferred over other process because it can be used both for volume reduction and for power production. Normally only the combustible matter such as garbage, rubbish and dead animals are burnt and the incombustible matter like broken glass, china ware, metals etc are either left unburnt or are separated for recycling and reuse before burning the solid wastes. The incinerators

along with the non- recycled incombustible materials may, however, measure as much as 10-25% of the original waste, which in any case has to be disposed either by sanitary land filling or in some other productive manner. For example the clinkers can be used as aggregates for making low grade concrete or as road material and the ashes can be used for making bricks. The heat produced during burning of the refuse is used in the form of steam power for running turbines to generate electricity.

9.b. Pyrolysis is the thermal processing of waste in the complete absence of oxygen. Both pyrolysis and gasification systems are used to convert solid waste into gaseous, liquid and solid fractions. The principal difference between the two systems is that pyrolysis systems use an external source of heat to drive the endothermic pyrolysis reactions in an oxygen free environment, where as gasification systems are self sustaining and use air or oxygen for the partial combustion of solid waste.

Description of the pyrolysis process: Because most organic substances are thermally unstable, they can, upon heating in an oxygen free atmosphere, be split through a combination of thermal cracking and condensation reactions into gaseous, liquid and solid fractions. Pyrolysis is the term used to describe the process. In contrast to the combustion and gasification processes, which are highly exothermic, the pyrolytic process is highly endothermic, requiring an external heat source. For this reason, the term destructive distillation is often used as an alternative term for pyrolysis.

The three major component fractions resulting from the pyrolysis process are the following

1. A gas stream, containing primarily hydrogen, methane, carbon monoxide, carbon dioxide and various other gases, depending on the organic characteristics of the material being pyrolyzed.
2. A liquid fraction, consisting of a tar or oil stream containing acetic acid, acetone, methanol and complex oxygenated hydrocarbons. With additional processing the liquid fraction can be used as a synthetic fuel oil as a substitute for conventional No.6 fuel oil.
3. A char, consisting of almost pure carbon plus any inert material originally present in the solid waste.

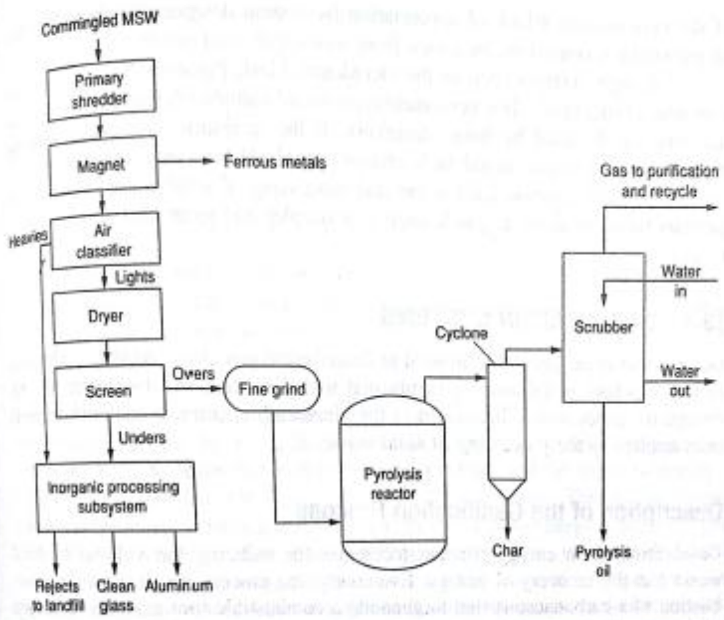
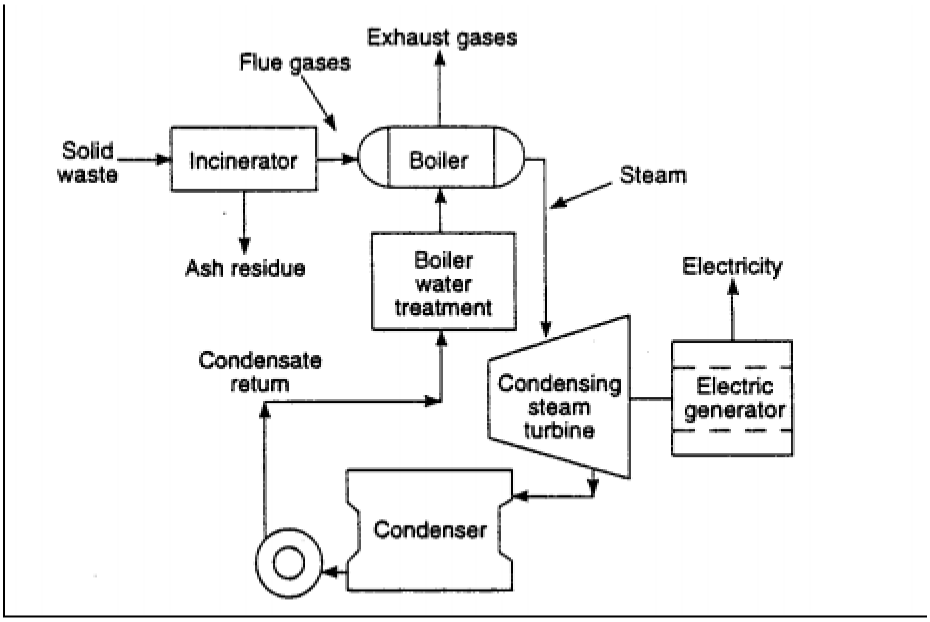


FIGURE 13-9
Schematic diagram of the Occidental flash pyrolysis system for the organic portion of MSW [30].

10.a. Most of the MSW incineration currently practice energy recovery in the form of steam, which is used either to drive a turbine to generate electricity or directly for heating or cooling.

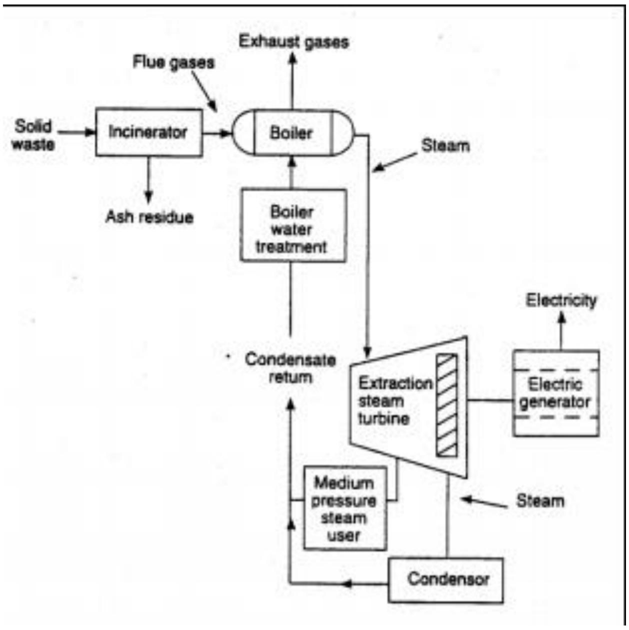
The three basic types of waste-to-energy incineration are:

(i) Generation of electricity: Electricity is the most common form of energy produced and sold from WTE facilities constructed today. By directing the steam produced from a WTE system through a turbine generator, electricity can be produced and sold.



Steam generation: Steam is used widely in a variety of industrial applications. Steam generated in incineration facilities can also be used directly by a customer for manufacturing operations. Steam generated in an incinerator is supplied to a customer through a steam line, and a separate line sometimes returns the condensed steam. It can be used to drive machinery such as compressors, for space heating and generating electricity. Industrial plants, dairies, cheese plants, public utilities, paper mills, tanneries, breweries, public buildings and many other businesses use steam for heating and air conditioning.

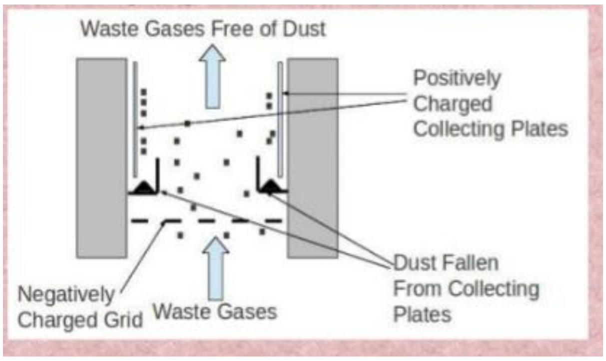
Co-generation: Co-generation refers to combined production of steam and electricity and can occur in two ways. If the energy customer requires steam conditions (pressure and temperature) that are less than the incineration plant's design specifications, a turbine-generator is used to produce electricity and thus reduce steam conditions to appropriate levels for the customer. If the steam purchaser cannot accept all the steam produced by the facility, the excess can be converted to electricity. In cogeneration, high-pressure steam is used first to generate electricity; the steam leaving the turbine is then used to serve the steam users.



10.b. **Incineration**

Incineration can be defined as a controlled combustion process for burning of solid, liquid and gaseous combustible waste to gases and residue containing non combustible materials. Burning of refuse at high temperatures in furnaces are called Incinerators. Incineration is a chemical process used to reduce the volume of solid wastes. The process can also be called as chemical volume reduction. Chemical process such as pyrolysis, hydrolysis and chemical conversion are also effective in reducing the volume of wastes. Incineration process is preferred over other process because it can be used both for volume reduction and for power production. Normally only the combustible matter such as garbage, rubbish and dead animals are burnt and the incombustible matter like broken glass, china ware, metals etc are either left unburnt or are separated for recycling and reuse before burning the solid wastes. The incinerators along with the non- recycled incombustible materials may, however, measure as much as 10-25% of the original waste, which in any case has to be disposed either by sanitary land filling or in some other productive manner. For example the clinkers can be used as aggregates for making low grade concrete or as road material and the ashes can be used for making bricks. The heat produced during burning of the refuse is used in the form of steam power for running turbines to generate electricity.

Electrostatic precipitator: The electrostatic precipitator (ESP) operate on the principle of electrostatic attraction. A high negative voltage , 20,000 to 100,000 volts, applied to the discharge electrodes, produces a strong electric field between the discharge and collector electrodes. Particles in the gas stream acquire a negative charge as they pass through the electrical field. Because of their charge, the particles are then attracted to collector electrode. The efficiency of an ESP is a function of the flue gas characteristics (especially temperature and moisture) and the electrical resistivity of the particles.



ELECTROSTATIC PRECIPITATOR : Consists of six major components,

i) A source of high voltage

ii) Discharge electrodes and collecting electrodes

iii) Inlet and outlet for the gas

iv) An electric cleaning system

v) 'Hopper' for collection and disposal of particulates

vi) An outer casing [called shell] to form an enclosure around the electrodes.

APPLICATIONS

1) Cement factories : Cleaning of flue gas from cement kilns, recovery of cement dust from kilns.

2) Pulp and paper : Soda-Fume recovery in kraft pulp mills.

3) Steel plants : Cleaning blast furnace gas, cleaning open hearth and electric furnace gases.

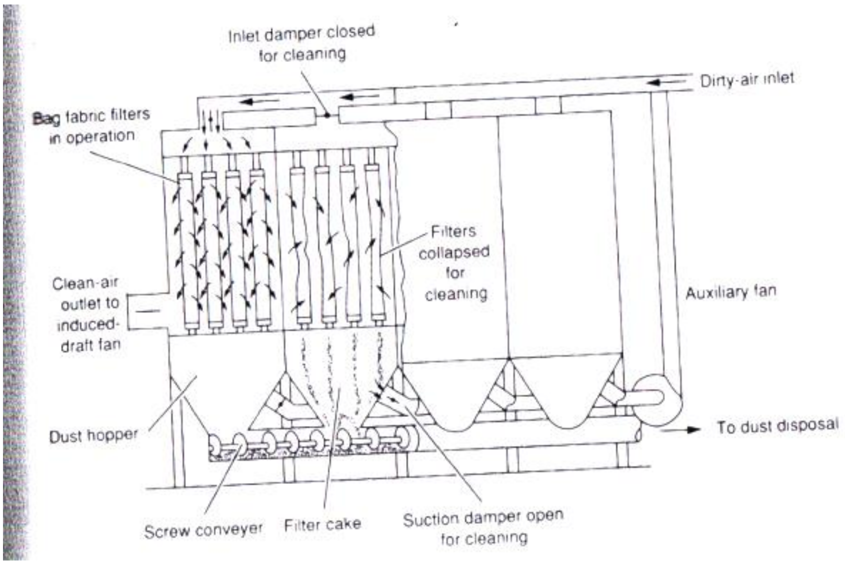
4) Chemical Industries – Collection of SO_x, Phosphoric Acid mist, cleaning various types of gases i.e., hydrogen, CO_2, SO_2, Removing dust from elemental phosphorus in the vapor state.

5) Petroleum industry:- Recovery of catalyst.

6) Carbon black industry :- Agglomeration and collection of carbon black.

7) Thermal Power plants:- Collecting Fly ash from coal fired boilers.

Fabric filter: The fabric filter has become the technology of choice on most recently constructed MSW combustion systems in the United States. The fabric filter, or bag house as it is sometimes referred to, is an intrinsically simple device. A number of filter bags are connected in parallel in a housing. Particles in the flue gas are trapped on a dust bed that gradually builds upon the surface of the fabric. The dust bed allows the fabric to filter particles as small as 0.1µm, much smaller than the 50 to 75µm. As particles build up on the surface of the fabric, the pressure drop across the fabric filter gradually increases. The particles are removed from the filter bags by several techniques, including mechanical shaking, reverse air flow and pulse-jet. A Typical fabric filter installation is illustrated in figure. The major design parameters for fabric filter are filter area, material and method of cleaning. Felted glass and Teflon have been used as fabric filters with some success in MSW combustion applications.



Inlet damper closed
for cleaning
Dirty-air inlet
Bag fabric filters
in operation
Filters
collapsed
for
cleaning
Clean-air
outlet to
induced-
draft fan
Auxiliary fan
Dust hopper
To dust disposal
Screw conveyer
Filter cake
Suction damper open
for cleaning

Q1.b) Total no of houses = 1200

Observation period = 1 week

No of persons per house = 5

Vehicle type	No of loads	Volume of vehicle (m^3)	Sp. wt. of solid waste (kg/m^3)	Weight (kg)
Compactor truck	10	15.3	296.5	45364.5
flat bed load	8	1.53	133.4	1632.816
Private cars/trucks	25	0.23	88.9	511.175
			Total weight	47508.5 kg

Total weight of solid waste generated from the residential area = 47508.5 kg per week

$$\text{Weight per day} = \frac{47508.5}{7} = 6786.93 \text{ kg/day}$$

$$\text{Per capita generation rate} = \frac{6786.93}{1200 \times 5}$$

$$= 1.131 \text{ kg/capita/day}$$

2.b.)

Weight of solid waste sample = 1000 kg

Ash Content = 7 %

Component	food waste	Paper	Cardboad	Plastics	Wood	
% by mass	45	5	15	15	20	
Moisture (%)	70	6	5	2	20	
Bulk density (kg/m^3)	290	85	50	65	240	
Energy content (kJ/kg)	4650	16750	16300	32600	18600	
Dry mass (kg)	135	47	142.5	147	160	631.5
Volume (m^3)	1.55	0.588	3	2.307	0.833	8.278 m^3
Total Energy	2092500	837500	2445000	4890000	3720000	13985000

Based on 1000 kg sample of waste

$$\text{Moisture content} = \left(\frac{1000 - 631.5}{1000}\right) \times 100 = 36.85\%$$

$$\text{Density} = \frac{1000}{8.278} = 120.802\ kg/m^3$$

$$\text{Unit energy content} = \frac{13985000}{1000} = 13985\ kJ/kg$$

$$\text{Energy Content (kJ/kg)} = 13985 \times \left[\frac{100}{100 - 36.85}\right]$$

$$= 22145.685\ kJ/kg$$

$$\text{Energy content (kJ/kg)(ash free basis)} = 13985 \times \left[\frac{100}{100 - 36.85 - 7}\right]$$

$$= 24906.5\ kJ/kg$$

5.b.)

$$C_{50}H_{100}O_{40}N + 54.25\,O_2 \rightarrow 50\,CO_2 + 48.5\,H_2O + NH_3$$

1354   1736   2200   873   17

Oxygen required per tonne

$$O_2 = \frac{1736}{1354} \times 1000 = 1.282 \times 10^3\ kg/tonne$$

the oxygen required to stabilize ammonia

$$NH_3 + 2O_2 \longrightarrow H_2O + HNO_3$$

17   64   18   63

Oxygen required per tonne of waste

$$O_2 = \frac{17}{1354} \times \frac{64}{17} \times 1000 = 47.3\ kg/tonne$$

Assume air contains 23.15% oxygen by weight

density of air = 1.2928 kg/m^3

Amount of oxygen required

$$O_{2,total} = (1282 + 47.3)\ kg/tonne = 1329\ kg/tonne$$

The mass of air required

$$Air_{mass} = \frac{1329\ kg/tonne}{0.2315} = 5742\ kg/tonne$$

Volume of air required

$$V_{air} = \frac{5742 \text{ kg/tonne}}{1.2928 \text{ kg/m}^3} = 4442 \text{ m}^3/\text{tonne}$$

6.b.)

Total amount of solid waste generated in a

day = 50000 × 450

= 22.5×10^6 g/day

= 22.5×10^3 kg/day

$$\text{Volume of solid waste} = \frac{22500 \text{ kg/d}}{504 \text{ kg/m}^3}$$

= 44.642 m^3/day

$$\text{Total landfill area required} = \frac{44.642}{5}$$

= 8.929 m^2