

EN 6501 - MUNICIPAL SOLID WASTE MANAGEMENT

UNIT-IV - OFF SITE PROCESSING.

Objectives of waste processing - physical processing techniques and equipments ; Resource recovery from solid waste composting and biomethanation ; Thermal processing options - case studies under Indian conditions.

objectives of processing MSW:-

The major objectives of off-site processing of MSW are :

- * To promote safe disposal of MSW, without producing any environmental health hazard to the public, other living beings and the eco-system.

- * To apply 3R principle/ concept, ie, 'Reduce, Reuse and Recover' policy to MSW.

- To reduce the SW load for disposal, in terms of environmental impact aspects, by segregation and off-site processing of wastes.

- To find Reuse materials from wastes and make use of them as raw materials for producing new useful material.

→ To recover energy from wastes & make use of the energy for other constructive activities.

* Finally to make the disposal process easier and make it in an eco-friendly and economical manner, by doing the above practices.

Physical processing techniques & equipments:-

* Unit operations used for the separation and processing of separated and commingled wastes are designed

* to modify the physical characteristics of the waste so that waste components can be removed more easily.

* to remove specific components and contaminants from the waste stream.

* to process and prepare the separated materials for subsequent uses.

Size Reduction :-

Size reduction is the unit operation in which as collected waste materials are mechanically reduced in size. In practice, the terms shredding, grinding and milling are used interchangeably to describe mechanical size-reduction operations.

The objective of size reduction is to obtain a final product that is reasonably uniform and considerably reduced in size in comparison with its original form. Note that size reduction does not necessarily imply volume reduction. In some situations, the total volume of the material after size reduction may be greater than that of the original volume.

Shredders — size reduction equipment.

The three most common types of shredding devices used to reduce the size of MSW are the hammer mill, the flail mill or shredder, & the shear shredder.

Other examples of shredding devices include cutters, cage disintegrators, drum pulverizers & wet pulpers.

In operation, the hammers in the hammer mill, attached to a rotating element, strike the waste material as it enters & eventually force the shredded material through the discharge of the unit, which may or may not be equipped with bottom grates of varying sizes.

The flail mill is similar to the hammer mill, but provides only coarse shredding, as the hammers are spaced further apart.

Operationally, flail mills are single-pass devices, whereas material remains in a hammer mill until it will pass through the openings in the bottom grate. Flail mills are often used as bag breakers.

The shear shredder is composed of two parallel counterrotating shafts with a series of discs mounted perpendicularly that serve as cutters.

The waste material to be shredded is directed to the center of the counterrotating shafts. The size of the waste material is reduced by the shearing or tearing action of the cutter discs. The shredded material drops or is pulled through the unit. Shear shredders have also been used as bag breakers.

Glass Crushers:-

Glass crushers are used to crush glass containers and other glass products found in MSW. Glass is often crushed after it has been separated to reduce storage & shipping costs. In some mechanical separation operations, glass is crushed, after one or more separation steps, to effect its removal by screening. Crushed glass can also be separated optically by color.

Wood Grinders:-

Typically, most wood grinders are wood chippers, used to shred large pieces of wood into chips, which can be used as a fuel & finer material, which can be composted. Tub grinders are used to process yard wastes. A tub grinder consists of a large tub having a revolving upper section, and a stationary lower section containing a hammer mill. The tub grinder is fed by a front-end loader. & the revolving action of the tub ensures that material flows continuously to the hammer mill. The continuous stream of shredded material is carried away from the grinder by a conveyor. The wood that has been ground in a tub grinder is usually sorted by size using trommel, disc or vibrating screens. Optical sorters have also been developed but are not used commonly because of their maintenance requirements & high initial cost. The larger-size material is used as a biomass fuel or as a bulking agent in composting operations. The fine material is usually composted.

Screening:-

Screening is a unit operation used to separate mixtures of materials of different sizes into two or more

Size fractions by means of one or more screening surfaces. Screening may be accomplished either dry or wet, with the former being more common in solid waste processing systems. The principal applications of screening devices in the processing of MSW include

- * Removal of oversized materials
- * Removal of undersized materials.
- * Separation of the waste into light combustibles & heavy non combustibles.
- * Recovery of paper, plastics & other light materials from glass & metal.
- * Separation of glass, grit & sand from combustible materials.
- * Separation of rocks & other oversized debris from soil excavated at construction sites.
- * Removal of oversized materials from combustion ash.

Vibrating Screens:-

Vibrating screens are used to remove undersized materials from source-separated and commingled MSW and to process construction & demolition wastes.

Vibrating screens can be designed to vibrate from side to side

vertically or lengthwise. Vibrating screens used for the separation[↑] of MSW are inclined and use a vertical motion. The vertical motion allows the material that is to be separated to contact the screen at different locations each time.

Rotary Screens:-

The most common type of rotary screen used in the processing of wastes is a trommel screen. Trommels, also known as rotary drum screens, were first developed in England in the 1920's. Trommels are used to separate waste materials into several size fractions. Operationally, the material to be separated is introduced at the front end of the inclined rotating trommel. As the screen rotates, the material to be separated tumbles & contacts the screen numerous times as it travels down the length of the screen. Small particles will fall through the holes in the screen, while the oversized material will pass through the screen.

Trommels equipped with metal blades or teeth that protrude into the drum are also used as bag breakers. Having passed through the trommel, the oversize wastes are then sorted manually. In some systems, magnetic separation of ferrous metals will occur before

manual separation. Ferrous metals will also be removed from the undersize waste materials passing through the trommel.

Disc screens:-

Disc screens consist of sets of parallel horizontal shafts equipped with interlocking lobed discs. The under-sized materials to be separated fall between the spaces in the discs & oversized materials ride over the top of the discs as in a conveyor belt. Different-sized materials can be separated using the same screen by adjusting the spacing between the rotating discs. Disc screens have several advantages over other types of screens, including self-cleaning & adjustability w.r.t spacing of the discs on the drive shafts. Disc screens are used in the same applications as trommels.

Density Separation :-

Air classification is the unit operation used to separate light materials such as paper & plastic from heavier materials such as ferrous metal, based on the weight difference of the material in an air stream. If materials of different weights are introduced into an

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air stream moving with sufficient velocity, the light materials will be carried away with the air while the heavier materials will fall in the counter-current direction. Air classification has been used for a number of years in industrial operations for the separation of various components from dry mixtures.

In MRFs, air classification is used to separate the organic material - or, as it is often called light fraction - from the heavier, inorganic material, which is called the heavy fraction. Air classification has also been used for the separation of the solid materials from the air stream. Because there is movement away from the shredding of commingled MSW, air classification systems of the type are not commonly used today. In installations where one or more trommels are used, a device known as a stoner, which also involves the use of air to fluidize the wastes to be separated, is used to separate the heavy grit from the organic material in the trommel underflow waste stream.

Magnetic Separation:-

Magnetic separation is a unit operation whereby ferrous metals are separated from other waste

materials by utilizing their magnetic properties. Magnetic separation is used to recover ferrous materials from source-separated, commingled & shredded MSW. Magnetic separation is used commonly to separate aluminium cans from tin cans in source-separated waste where the two types of metals are mixed. Ferrous materials are usually recovered either after shredding & before air classification or after shredding & air classification.

Densification:-

Densification (compaction) is a unit operation that increases the density of waste materials so that they can be stored & transported more efficiently & as a means of preparing densified refuse-derived fuels.

Technologies - baling, cubing, pelleting.

Balers:-

Balers reduce the volume of waste for storage, prepare the wastes for marketing & increase the density of the waste thereby reducing shipping costs.

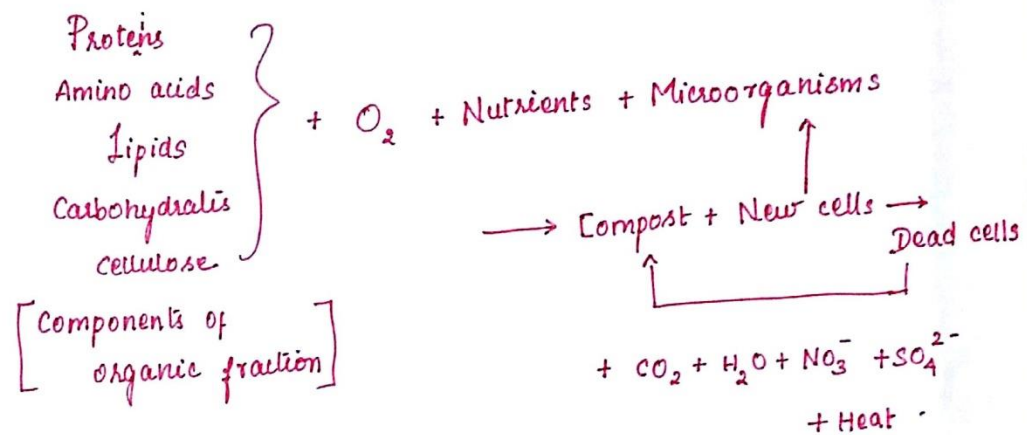
Can crushers:-

These are used to crush aluminium & tin cans, thus increasing their density and reducing handling & shipping costs.

Waste transformation through aerobic composting :-

With the exception of plastic, rubber & leather components, the organic fraction of most MSW can be considered to be composed of proteins, amino acids, lipids, carbohydrates, cellulose, lignin & ash.

If these organic materials are subjected to aerobic microbacterial decomposition, the end product remaining after microbiological activity commonly known as compost.



Objectives of composting :-

* To transform the biodegradable organic materials into a biologically stable material & in the process reduce the original volume of waste.

* To destroy pathogens, insect eggs & other unwanted organisms & weed seeds that may be present in MSW.

- * To retain the maximum nutrient (Nitrogen, phosphorous, potassium) content.

- * To produce a product that can be used to support plant growth & as a soil amendment.

In general, the chemical & physical characteristics of compost vary according to the nature of the starting material, the condition under which the composting operation was carried out & the extent of the decomposition. Some of the properties of compost that distinguish it from other organic materials are,

- * A brown-to very dark brown color.

- * A low carbon-nitrogen ratio.

- * A continually changing nature due to the activities of microorganisms.

- * A high capacity for cation exchange & water absorption.

Process Description:-

The organic material present in the municipal solid waste can be converted to a stable form either aerobically or anaerobically. During aerobic decomposition,

aerobic micro-organisms oxidize organic compounds to CO_2 , NO_2 and NO_3 . Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to exothermic reaction, the temperature of the mass rises.

The carbon, protein & water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of the raw material.

Composting Technologies:-

Windrow composting:-

A windrow is a pile, Δ like in cross section, whose length exceeds its width & height. The width is usually about twice the height. The ideal pile height allows for a pile large enough to generate sufficient heat and maintain temperatures, yet small enough to allow oxygen to diffuse to the centre of the pile.

For most materials, the ideal height is between 1.25 & 2.75 metres, a width from 4.75 m to 5.25 m.

Turning the pile re-introduces air into the pile & increases porosity so that efficient passive aeration from atmospheric air continues at all times. The windrows must be placed on a firm surface so the piles can be easily turned. Piles may be turned as frequently as once per week, but more frequent turning may be necessary if high proportions of bio-solids are present in the feedstock.

Turning the pile also moves materials from the pile's surface to the core of the windrow, where it can undergo composting.

Piles may be placed under a roof or out-of-doors. Placing the piles out-of-doors, however, exposes them to precipitation, which can result in run-off or leachate. Piles with initial moisture content within the optimum range have a reduced potential for producing leachate.

The addition of moisture from precipitation, however, increases this (leachate emission) potential.

Any leachate or run-off created must be collected & treated or added to a batch of incoming feedstock to increase its moisture content. To avoid problems with leachate or run-off, piles can be placed under a roof, but doing so adds to the initial cost of the operation.

Aerated Static pile composting:

Aerated static pile composting is a non-proprietary technology that requires the composting mixture (of pre-processed materials mixed with liquids) to be placed in piles that are mechanically aerated.

The piles are placed over a network of pipes connected to a blower, which supplies the air for composting. Air can be supplied under +ve or -ve pressure. When the composting process is nearly complete, the piles are broken up for the first time since their construction. The compost is then taken through a series of post-processing steps.

Aerated static pile composting systems have been used successfully for MSW, yard trimmings, bio solids and industrial composting. It requires lesser land than windrow composting. Producing compost using this technology usually takes 6-12 weeks.

In-vessel composting systems:-

In-vessel composting systems enclose the feed-stock in a chamber or vessel that provides adequate mixing, aeration & moisture.

A major advantage of this method is that ~~or~~ all environmental conditions can be carefully controlled to allow rapid composting. The material to be composted is frequently turned & mixed to homogenize the compost & promote rapid oxygen transfer. Retention times range from less than one week to as long as four weeks.

The vessels are placed in a building. These systems, if properly operated, produce minimal odours & little or no leachate.

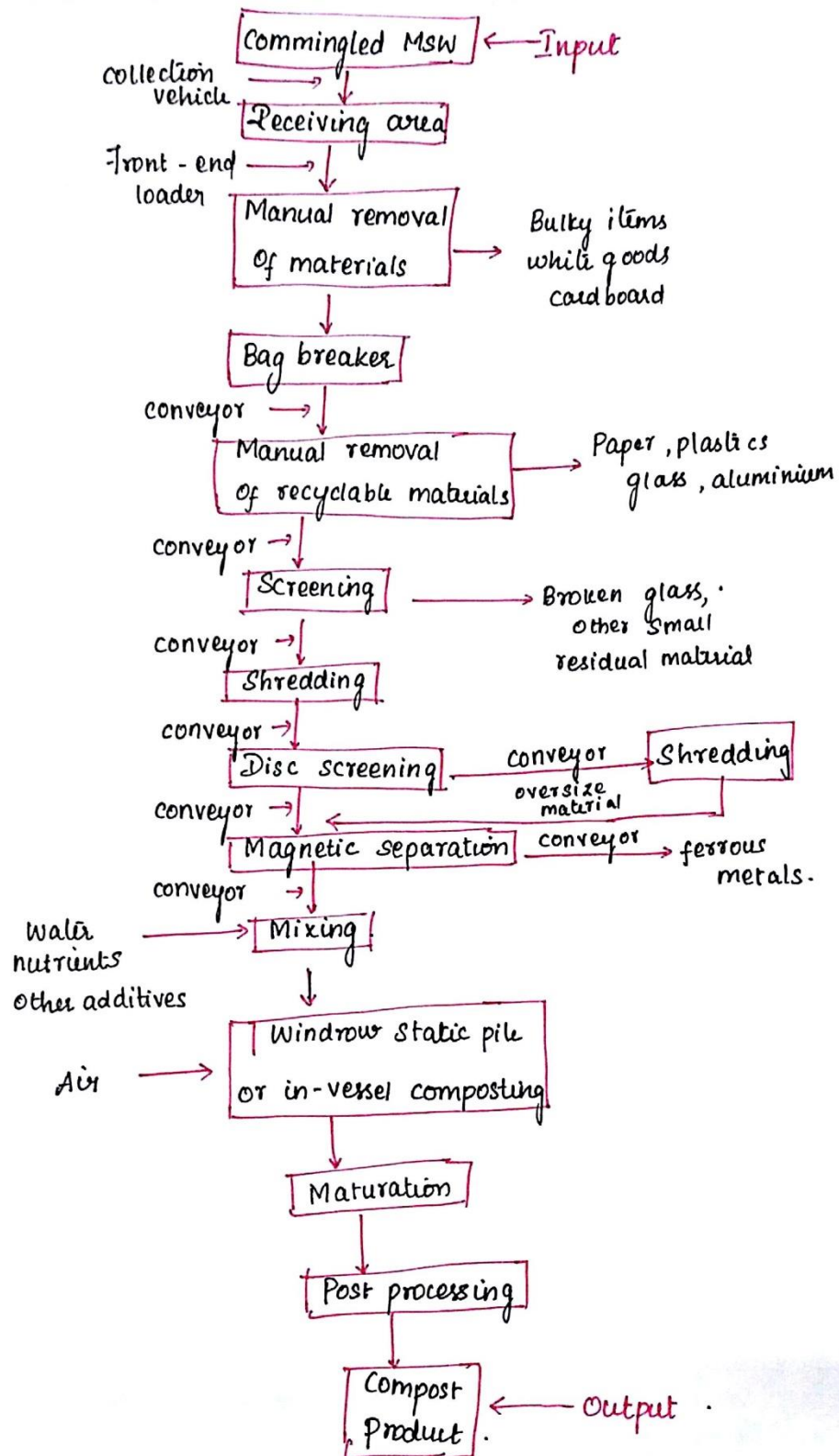


Fig: Generalized flow diagram for Composting process

Vermi Composting :-

Composting using earthworms as the biological agent to produce high quality compost is termed Vermicomposting. Vermicompost contains major & minor nutrients in plant-available forms such as enzymes, vitamins & plant growth hormones. Vermicomposting can be adopted for the large-scale commercial production of compost as well as for household composting.

Segregated biodegradable waste is fed to the bed prepared in alternate layers of waste and cowdung slurry. Each layer may have a thickness of 15-20 cm. For the first 25 days, the heap has to be kept moist by watering & mixed at random to distribute the worms. It is advisable to cover the pits to prevent the top layer from getting dried. After 45 days, the manure shall be kept heaped for a few days for maturity and then can be packed & marketed.

Vermicompost consists mostly of worm casts plus some decayed organic matter. In ideal conditions, worms can eat at least their own weight of

organic matter in a day. Worm casts contain 5 times more nitrogen, 7 times more phosphorus & 11 times more potassium than ordinary soil, the main materials needed for plant growth, but the large numbers of beneficial soil micro-organisms in worm casts have at least as much to do. The casts are also rich in humic acids, which condition the soil, have a perfect pH balance & contain plant growth factors.

Two breeds of worms used in vermi composting are:

- * *Eisenia foetia*.
- * *Lumbricus rubellus*.

Nearly 1000 worms are needed to start a worm box, may be twice that if you want to process your garden waste too.

The size of the unit should be geared to your household's production of kitchen waste. Use 2ft x 2ft box and 8" deep for two people.

Any inert, non-toxic, fluffy material that holds moisture & allows air to circulate do the purpose of a box.

Waste transformation through incineration / combustion:-

The basic operations involved in the combustion of commingled MSW are identified in the figure. The operation begins with the unloading of solid wastes from collection trucks (1) into a storage pit (2). The width of the unloading platform & storage bin is a function of the size of the facility & the number of trucks that must unload simultaneously. The depth & width of the storage bin are determined by both the rate at which waste loads are received & the rate of burning. The capacity of the storage pit is usually equal to the volume of waste for two days.

The overhead crane (3) is used to batch load wastes into the feed chute (4) which directs the wastes to the furnace. (5) The crane operator can select the mix of wastes to achieve a fairly even moisture content in the charge. (6) When they are mass-fired. Several different types of mechanical stokers are commonly used.

Air may be introduced from the bottom of the grates by means of a forced-draft fan

or above the grates to control burning rates and furnace temperature. Because most organic wastes are thermally unstable, various gases are driven off as the combustion process takes place in the furnace. These gases and small organic particles rise into the combustion chamber & burn at temperatures in excess of 1600°F . Heat is recovered from the hot gases using water-filled tubes in the walls of the combustion chamber & with a boiler (8) that produces steam, which is converted to electricity by a turbine-generator. (8) that produces steam, which is converted to electricity by a turbine-generator.

(9) Air pollution control equipment may include ammonia injection for NO_x control. (10) a dry scrubber for SO_2 and acid gas control (11) and a baghouse for particulate removal (12) To secure adequate air flows to provide for head losses through air pollution control equipment, as well as to supply air to the combustor itself, an induced-draft fan (13) may be needed. The end products of combustion are hot combustion gases & ash. The cleaned gases are discharged to the stack (14) for atmospheric dispersion. Ashes & unburned materials from the

grates fall into a residue hopper (15) located below the grates, where they are quenched with water. Flyash from the dry scrubber & the baghouse is mixed with the furnace ash and conveyed to ash treatment facilities. (16)

Combustion products:-

For carbon



For hydrogen



For sulfur

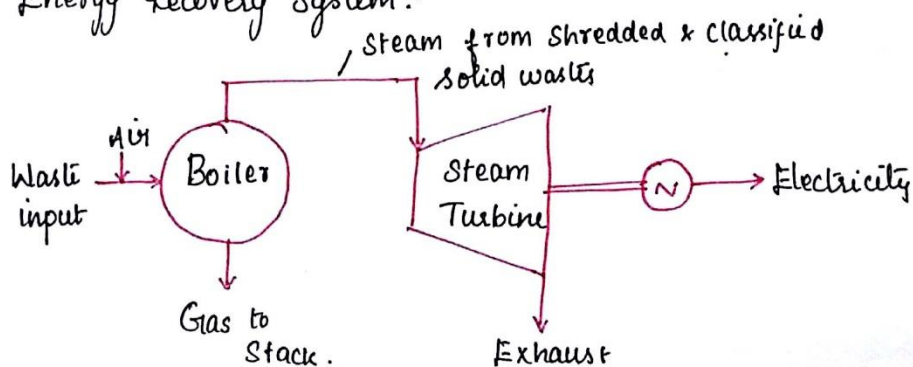


Types of Combustors:-

* Mass-fired combustors

* RDF-fired combustors.

Energy Recovery System:-



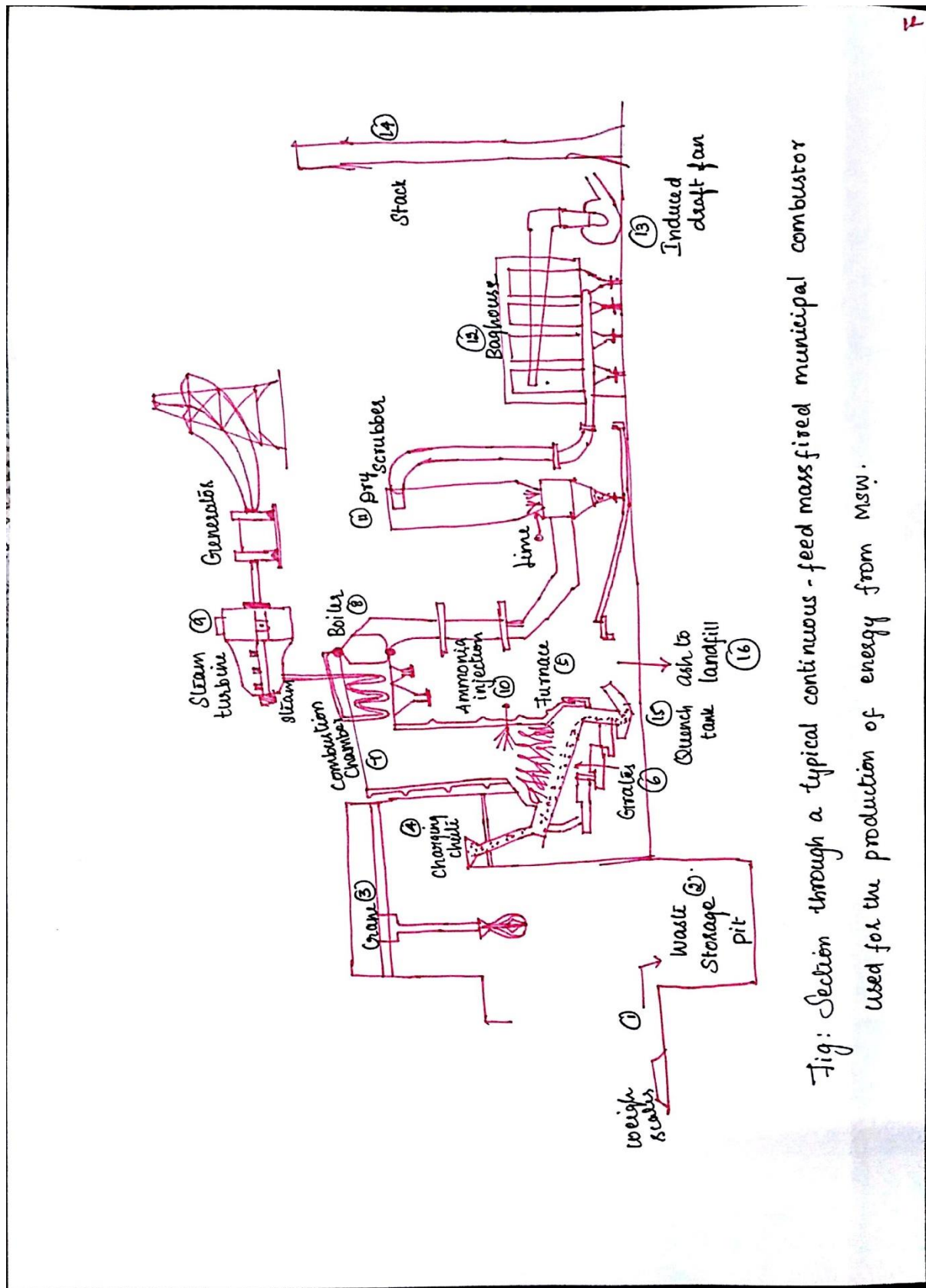


Fig: Section through a typical continuous-feed mass-fired municipal combustor used for the production of energy from MSW.

Pyrolysis:-

It is the destructive distillation of a solid, carbonaceous, material in the presence of heat & in the absence of stoichiometric oxygen. It is an exothermic reaction, i.e., heat must be applied for the reaction to occur. A gas is produced containing methane, carbon monoxide (CO) and moisture.

Pyrolysis is a thermal pre-treatment method, which can be applied in order to transform organic waste to a medium calorific gas, liquid & a char fraction aimed at separating or binding chemical compounds in order to reduce emissions & leaching to the environment. Pyrolysis can be a self-standing treatment, but is mostly followed by a combustion step & in some cases, extraction of pyrolytic oil (liquefaction).

ANAEROBIC DIGESTION/ BIOMETHANATION :-

Low solids anaerobic digestion :-

Low solids anaerobic digestion is a biological process in which organic wastes are fermented at solids concentrations equal to or less than 4 to 8 %. The low-solids anaerobic fermentation process is used in many parts of the world to generate methane gas from human, animal & agricultural wastes & from the organic fraction of MSW.

Process Description :-

There are three basic steps involved whenever the low-solids anaerobic digestion process is used to produce methane from the organic fraction of MSW.

The first step involves the preparation of the organic fraction of the MSW. Typically, for commingled solid waste the first step involves receiving, sorting & separation & size reduction.

The 2nd step involves the addition of moisture & nutrients, blending, pH adjustment to about 6.8 & heating of the slurry to between 55 & 60°C

And the anaerobic digestion is carried out in a continuous-flow reactor whose contents are mixed completely. In some operations, a series of batch reactors have been used instead of one or more continuous-flow complete mix reactors.

In most operations, the required moisture content & nutrients are added to the wastes to be processed, in the form of wastewater sludge or cow manure. Depending on the chemical characteristics of the sludge or manure, additional nutrients may also have to be added. Because foaming and the formation of surface crusts have caused problems in the digestion of solid wastes, adequate mixing is of fundamental importance in the design & operation of such systems.

The third step in the process involves the capture, storage & if necessary separation of the gas components. The dewatering & disposal of the digested sludge is an additional task that must be accomplished. In general, the processing of the digested

Sludge produced from low-solids anaerobic digestion is so expensive that the process has seldom been used.

Process Microbiology:-

The first step in the process involves the enzyme-mediated transformation of higher-molecular mass compounds into compounds suitable for use as a source of energy & cell tissue.

The second step involves the bacterial conversion of the compounds resulting from the first step into identifiable lower-molecular-mass intermediate compounds.

The third step involves the bacterial conversion of the intermediate compounds into simpler end products, principally methane & carbon-di-oxide.

The entire process is described in the following figure.

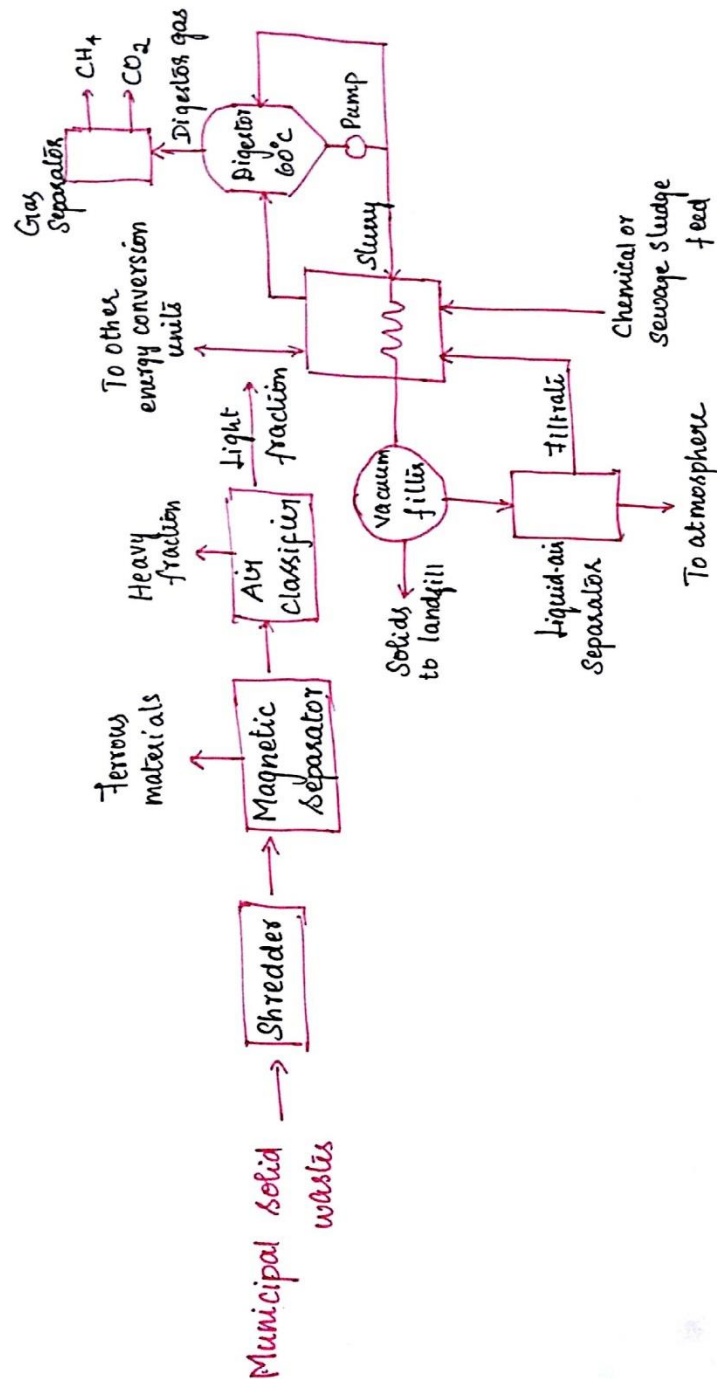


Fig.: Flow diagram for the low-solids anaerobic digestion process for the organic fraction of MSW.

High-Solids anaerobic digestion:-

High-Solids anaerobic digestion is a biological process in which the fermentation occurs at a total solids content of about 22% or higher. The high-solids anaerobic digestion is a relatively new technology & its application for energy recovery from the organic fraction of MSW has not been developed fully.

Two important advantages of the high-Solids anaerobic digestion process are lower water requirements & higher gas production per unit volume of the reactor size.

Process description:-

The three steps described for the low-solids anaerobic digestion are also applied in high-solids anaerobic digestion process. The principal difference is at the end of the process, where less effort is required to dewater & dispose of the digested sludge.

Process Microbiology:-

Because of the high solids concentration, the effects of many environmental parameters on ~~ant~~ microbial population are more severe. For eg, ammonia toxicity can affect the methanogenic bacteria, which will have an adverse effect on system stability & methane production. In most cases, the ammonia toxicity can be prevented by a proper adjustment of the C/N ratio of the input feedstock.