Unit II:Solid Waste Management and treatment Technology: Solid waste and its Treatment: Collection, segregation, transportation and disposal. Different types of waste like e-waste, plastic waste, biomedical waste and Agriculture waste

E –Waste (Electronic Waste)

E-waste is electronic products that are unwanted, not working, and nearing or at the end of their ―useful life.‖ Computers, televisions, VCRs, stereos, copiers, and fax machines are everyday electronic products. E-waste is particularly dangerous due to toxic chemicals that naturally leach from the metals inside when buried.

Categories of e-waste

• **Large Household equipment's**:
Refrigerators, Washing machine, cloth dryers, dish washing machine, large printing machines, photovoltaic panels, copying machines etc.

• **Small Household equipment's**: Vacuum cleaners, microwaves, toasters, electric kettles, ventilation equipment's etc.

• **Small IT and telecommunication equipment's:**
Mobile phones, pocket calculators, routers etc.

E-waste has two primary characteristics:

•**E-waste is hazardous -** E-waste contains over 1,000 different substances, many of which are toxic, and creates serious pollution upon disposal.

E-waste is generated at alarming rates due to obsolescence - Due to the extreme rates of obsolescence; E-waste produces much higher volumes of waste in comparison to other consumer goods. The increasingly rapid evolution of technology combined with rapid product obsolescence has effectively rendered everything disposable

Proposed Solutions to the Problem of e waste

• Need to spread awareness for safe disposal of domestic waste.
• Awareness Camps/Campaign
• Improvement in Take-Back policies
• Attract investment in this sector
• Link up activities of informal sector with formal sector
• Social media can spread awareness
• Promote adequate technologies for recycling
• Training to generators on e-waste handling
• e-certificate to dealers for managing e-waste
• Tax benefit if company is having e-certificate
e-waste fair

Why we need to manage e-waste?

• Consists of hazardous heavy metals
• Acids
• Toxic chemicals
• Non degradable plastics
• Adverse effect on human health
• Burning will emit lot of toxins which can affect health as well as causing severe air Pollution.

Table 1. Hazardous substances found in E-waste their sources and impact on human life

Hazardous Substances	Source	Impact on human health
Lead	Mechanical breaking of CRTs and removing solder from microchips release lead as powder and fumes.	A neurotoxin that affects the kidneys and the reproductive system. High quantities can be fatal. It affects mental development in children.
Plastics	circuit boards, cabinets and cables	Carcinogens BFRs or brominated flame retardants give out carcinogenic brominated dioxins and furans. Dioxins can harm reproductive and immune systems.
Chromium	Used to protect metal housings and plates in a computer from corrosion	Inhaling hexavalent chromium or chromium 6 can damage liver and kidneys and cause bronchial maladies including asthmatic bronchitis and lung cancer.
Mercury	It is released while breaking and burning of circuit boards and switches.	Affects the central nervous system, kidneys and immune system. It impairs fetus growth and harms infants through mother‘s milk. Mercury in water bodies can form methylated mercury through

		microbial activity. Methylated mercury is toxic and can enter the human food chain through aquatic.
Cadmium	Cadmium is released into the environment as powder while crushing and milling of plastics, CRTs and circuit boards.	A carcinogen. Long-term exposure causes *Itai-itai* disease, which causes severe pain in the joints and spine. It affects the kidneys and softens bones.
Acid	Sulphuric and hydrochloric acids are used to separate metals from circuit boards	Fumes contain chlorine and sulphur dioxide, which cause respiratory problems. They are corrosive to the eye and skin.
Sulphur	found in lead acid batteries	Cause damage to liver, kidney heart, eye and throat irritation.
Polybrominateddiphenyl ethers (PBDEs	PBDE is one of several classes of **brominated flame retardants** used to prevent the spread of fire in a wide variety of materials, including **casings and components of many electronic goods**	They are environmentally persistent chemicals, some of which are highly **bio-accumulative and capable of interfering with normal brain development in animals.** Several PBDEs are suspected **endocrine disruptors, demonstrating an ability to interfere with hormones involved in growth .** Effects on the **immune system** have also been reported.
PCBs (polychlorinated biphenyls	PCB is widely used in **insulating fluids for electrical transformers and capacitors, as well as flame-retardant plasticizers in PVC** and other polymer applications	They are highly persistent and bio-accumulative chemicals, rapidly becoming widespread through the environment and building up several thousand-fold in body tissues of wildlife. PCBs exhibit a wide range of toxic effects including **suppression of the immune system, liver damage, cancer promotion, damage to the nervous system, behavioural changes and damage to reproductive systems.**
Barium	Barium is a soft silvery-white metal that is used in **computers in the front panel of a CRT, to protect users from radiation**	Studies have shown that short-term exposure to barium has caused **brain swelling, muscle weakness, damage to the heart, liver, and spleen.** There is still a lack of data on the effects of chronic barium exposures to humans. Animal studies, however, reveal

		increased blood pressure and changes in the heart from ingesting barium over a long period of time.
Toners	One of the ubiquitous computer peripheral scraps and post consumer E-waste is the **plastic printer cartridge containing black and color toners**. The main ingredient of the black toner is a pigment commonly called, **carbon black** - the general term used to describe the commercial powder form of carbon	Inhalation is the primary exposure pathway, and acute exposure may lead to **respiratory tract irritation**. The International Agency for Research on Cancer has classified carbon black as a class 2B carcinogen, possibly **carcinogenic** to humans. Little information exists on the hazards of colored toners. Some reports indicate that such toners (cyan, yellow and magenta) contain heavy metals.
Phosphor and additives	**Phosphor** is an inorganic chemical compound that is applied as a coat on the interior of the **CRT faceplate.** Phosphor affects the display resolution and luminance of the images that is seen in the monitor	The phosphor coating contains **heavy metals, such as cadmium, and other rare earth metals, e.g. vanadium, etc. as additives.** These metals and their compounds are **very toxic**. There is a serious hazard posed for those who dismantle CRTs by hand.

Methods of treatment & disposal

- **Landfill**
- **Incineration**
- **Pyrolysis**
- **Recycle & Reuse**

Landfilling:

Landfilling is the most common and economic method of solid waste disposal in many countries

An ideal sanitary landfill site should satisfy the following criteria

i) It should be cheap, accessible and at a reasonable distance

ii) It should be at least $1^{1/2}$Km downwind from the commercial and residential neighboring area.

iii) It should be reasonably leveled, clear and well drained, with capacity of use for at least 3 years.

iv) Its soil should be of low permeability so that it can be used as satisfactory cover material.

v) It should be well above the ground water table so that the underground water supplies are not polluted.

vi) The site selected for landfilling should not be deleterious or offensive to the surrounding environment .It should be consistent with the topography, climatic conditions, hydrogeological requirements and economic considerations

The planning of a sanitary landfill operation should be based on the following considerations

i) The quantity and nature of the solid waste to be treated

ii) Overall suitability of the land for such operation

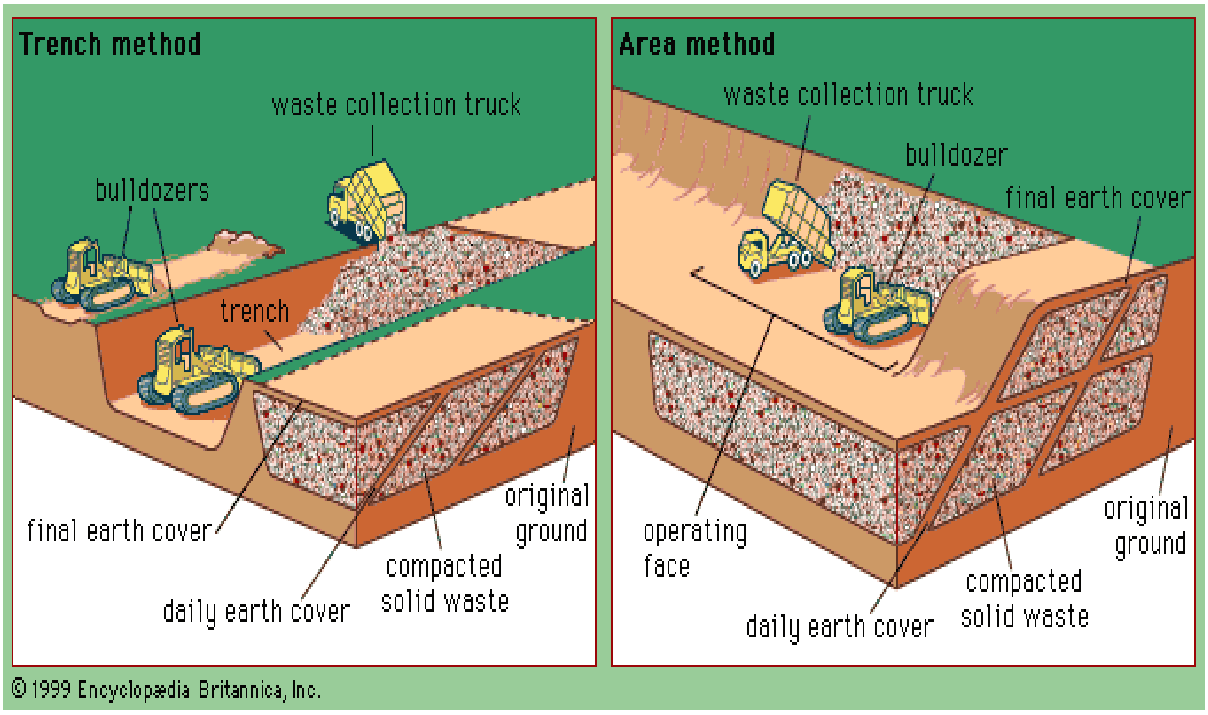
iii) Economic considerations of the landfilling process as compared to other available solid waste treatment processes

iv) Public health criteria

v) Proper design of the sanitary landfill operation with respect to the appropriate method of the landfill suitable for the chosen site and efficient organization of the possible pollution problems such as leachate generation, escape of gases etc.

Preparation of the landfill site involves fencing, grading, stockpiling of the cover material, construction of berms, landscaping and the installation of leachate collection system, gas collection system and monitoring system.

Mixed solid wastes with varying degrees of compaction are delivered to the landfill site by packed trucks or trailer units. After hand sorting the wastes, pulverizing or high pressure compaction and bailing for volume reduction may be done before placement. Loose material is placed in the lower part of the pit or trench. It is then spread and compacted by machines in layers of about 0.5 m thickness. After the end of each days operation and when the depth is about 3m, the refuse is covered with 15 to 30 cm of the earth. This consolidated solid waste enclosed by earth at the end of a day's operation is called a cell.



Problems with Landfilling

a) Economic problems: The land used as landfill cannot be used in future as a productive farm land. Even after closure of the landfill site, its further use should be restricted only to some type of open development such as a park or recreational area. Building construction in the site must be controlled.

b) Environmental Problems: During landfilling operations of municipal solid wastes, aerobic degradation occurs initially for periods varying from a few weeks (in wet areas) to a few months (in dry areas).After all the oxygen is exhausted, anaerobic degradation of the organic wastes takes place. While these processes are taking place liquid from the waste seepage from ground water, rain water and surface run off percolates through the refuse. This produces a contaminated liquid called –leachate‖ The leachates having high organic content, soluble salts and other constituents can contaminate the ground water.

Further methane (CH_4) and carbon dioxide (CO_2) are generated during the anaerobic decomposition of organic matter in the landfill. Methane constitutes about 60% of the gas generated in a sanitary landfill. Methane is heavier than air, odourless and explosive when its concentration in air reaches over 55.Hence its hazardous potential should be given due consideration.

Carbon dioxide combines with water giving carbonic acid. The resultant acidic environment may help in dissolution of minerals and salts of Ca, Mg, Fe , Cd, Pb and Zn present in the refuse or in the soil. If these dissolved salts move into the ground water, increased hardness and heavy metal toxicity of the water may result.

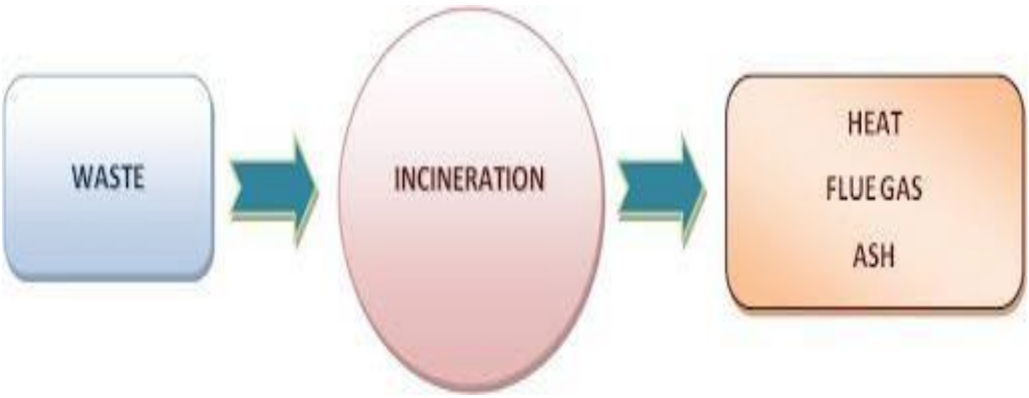
In order to control the contamination of the ground water by leachate, **certain regulations are prescribed for sanitary landfills.** These include

1. Mandatory minimum distance of the location of the landfills above the ground water table
2. Minimum distance from the nearest point of water use
3. Use of soil of low permeability

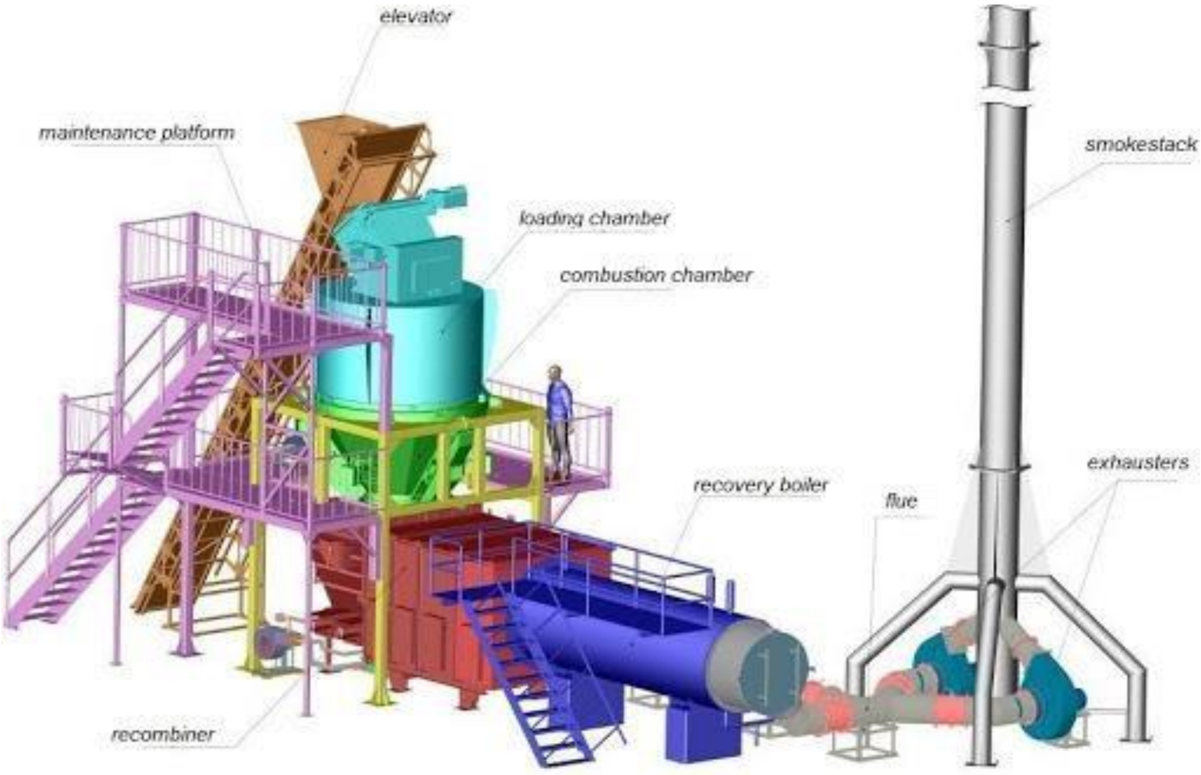
- Preventing the build-up of the leachate within the landfill
- Extensive hydrogeological investigation of the actual landfill site including topography, soil stratigraphy, drainage and groundwater characteristics (e.g depth and movement etc)
- Supplementary measures such as inclusion of clay and or membrane covers or liners for the landfill, leachate collection, removal and treatment facility, installation of monitoring system are also suggested to ensure that the buried refuse remains as dry as possible and the leachate does not reach the ground water. In spite of these precautions, if some leakage of the leachate still occurs, the soil beneath serves as an additional barrier to attenuate the contaminants before reaching the groundwater by mechanisms such as filtration, adsorption, precipitation and biological activity.
- The gases produced in sanitary landfills by the anaerobic digestion of organic waste are generally vented to the atmosphere through gravel packed seams or wells. In some landfills, the escaping gases are burnt off with the help of burners installed at the top of vents. These measures are meant for preventing undue accumulation and lateral movement and migration of the gases under the landfill cover to nearby residential areas which may cause fires and explosions.

c) **Aesthetic Problems**: Poorly operated landfill operations may cause problems due to bad odours , insects, vermin , blowing papers ,rats, and scavenger birds, apart from the dust and noise from waste transporting vehicles and compacting operations. Continuous field compaction of the loose refuse and proper covering with earth at the end of each day‘s operation reduce these problems. Volume reduction by pulverization or high pressure compaction may ensure an aesthetically acceptable operation.

3) Thermal Processes: The important thermal processes used in solid waste treatment are incineration and pyrolysis.



Incineration:



- **Incineration (E-waste)**

It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators at a high temperature (900-1000ºC).

Advantage of incineration of e- waste

1) The reduction of waste volume

2) The utilization of the energy content of combustible materials.

3) Some plants remove iron from the slag for recycling.

4) By incineration some environmentally hazardous organic substances are converted into less hazardous compounds.

Disadvantage of incineration are

1) the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion.
2) E- waste incineration plants contribute significantly to the annual emissions of cadmium and mercury.
3) In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can re-enter the environment on disposal.
   Therefore, e-waste incineration will increase these emissions, if no reduction measures like removal of heavy metals are taken.

The design of an incinerator should be based on the following considerations

i) The quantity of the waste to be handled, its composition and characteristics
ii) Measure to ensure that there will not be any pollution of air, water or land resulting from the operation of the incinerator.

On economic considerations, the size of the incinerators is determined on the basis of weekly quantity of the waste to be incinerated. For unsorted wastes, two types of incinerators are used

i) The batch type incinerator
ii) The continuous type incinerator

The batch type incinerator which is manually stocked and has a relatively small rated capacity .These plants have several disadvantages

a) Owing to the intermittent operation, the burning temperature cannot be maintained in a uniform manner. This may result in an inadequate and irregular combustion of the waste.
b) The output of particulate matter is more
c) The volume reduction of the waste is lesser than the optimal value expected.
d) This may end up with an unstable residue still containing some putrescible matter. Thus it may still possess some pollution potential.
e) The intermittent incinerator plants are unsuitable for larger urban centers

The continuous-type incinerators are equipped with large storage bins, automatic feed hoppers, varied types of moving gates and ash discharging systems. These units are capable of maintaining uniform temperatures for combustion and can be equipped with pollution control devices such as gas scrubbers and electrostatic precipitators. These units are capable of yielding a stable residue which is non- polluting although the capital and operating costs are very high, these units, which provide controlled furnace temperatures of 760 to 980^0C,can remove odours and also bring about a substantial reduction in waste volume, in an environmentally acceptable form. Since the final residue is stable, the cost of cover material required to ultimately dispose it in the landfill will be substantially minimized or even eliminated in some cases.

The modern municipal incinerators are of continuous burning type.

Many of them have ―water-wall‖ construction in the combustion chamber instead the older and more common refractory lining. The water-wall consists of joined vertical boiler tubes (made of steel) through which water is circulated. These water tubes absorb heat to provide hot water for steam generation and at the same time control the furnace temperature. Thus the heat recovery is simpler and the waste heat of combustion can be utilized for space heating, power generation, desalination,etc.,as has been done in some recent installations.

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When the wastes are burnt only for volume reduction, there is no need for an auxiliary fuel., except at the startup. When steam production is the objective, supplementary fuel must be used with the pulverized refuse. Ferrous metals are usually recovered from the ash.

High temperature incineration is a recent innovation where temperatures of the order of 1,650 ^{0} C are attained using supplementary fuels. In this process, non- combustible fractions of refuse (e.g metal and glass)are melted in a bed of high temperature coke I the refractory lined incinerator and are drained of as molten Further the water-well units help in eliminating the costly maintenance of refractory lining and also reduce the pollution control requirement (By reducing the volumes of quench water and gas, that require treatment)

However corrosion of the water-well units may be a serious problem as experienced by some installations in European countries.

Putrefiable organic wastes from slaughter house have to be dried in special driers before being incinerated. Hospital wastes are generally disposed of by pathological incinerationslag. This technique can achieve volume reduction of the refuse by 97%.In spite of the fact that the first high temperature incinerator was installed on pilot plant scale as early as in 1966, application to full scale commercial units was not followed up enthusiastically for a long time due to the high costs involved.

Emission standards waste incinerators

S.No	**Contaminant**	**Limit**
1	Total Particulate	20 mg/m^3
2	Carbon Monoxide	55 mg/m^3
3	Sulphur Dioxide	180 mg/m^3
4	Nitrogen Oxides (NOx as NO_2)	380 mg/m^3
5	Hydrogen Chloride	50 mg/m^3 or 90% removal
6	Hydrogen Fluoride	4 mg/m^3
7	Total Hydrocarbons (as Methane CH_4)	32 mg/m^3
8	Arsenic	4 $\mu g/m^3$

9	Cadmium	100 µg/m^3
10	Chromium	10 µg/m^3
11	Lead	50 µg/m^3
12	Mercury	200 µg/m3
13	Chlorophenols	1 µg/m3
14	Chlorobenzenes	1 µg/m3
15	Polycyclicaromatic Hydrocarbons	5 µg/m3
16	Polychlorinated Biphenyls	1 µg/m3
17	Total Polychlorinated dibenzodioxins (PCDDs) & Polychlorinated dibenzofurans (PCDFs) Opacity	0.5 ng/m3 5%

- **Pyrolysis (E-Waste)**

Pyrolyis is a process of **thermochemical decomposing** organic materials at elevated temperatures in the **absence of oxygen**.

The process occurs at temperatures above 430 degree Celsius (800 degree farenheit) and under pressure. Extreme pyrolysis yields carbon and the process is called carbonization.

It involves changes of chemical composition and physical phase.

In the pyrolysis process organic material, that is a part of electronic waste, is decomposed to molecular products that can be used e.g. as fuel.

Pyrolysis of organic materials produces **gas** and **liquid products** and leaves a **solid residue** rich in carbon (char). Proportionsof solid, liquid and gas yields depend on material that is pyrolyzed and process conditions.

(Zhou conducted experiments of vacuum pyrolysis of waste printed circuit boards at 240°C. The solid residue consisted of the glass fiber, electronic components, metals and other inorganic materials that could be recycled for further processing.)

Gaseous product of the process was rich in CO, CO_2, CH_4, H_2, etc. which makes this gas valuable for combustion. Energy recovered from combustion of the gas may be used in the process and therefore make pyrolysis a self-sustain.

The residue of pyrolysis contained various metals (e.g., Cu, Fe, Al, Au, Ag, Pt, Pd etc.)that could be recovered in further processing. Content of those metals may vary depending on type of waste that is processed. The metals may be separated and recovered in further processing. Each metallic element maybe recovered in different physical and chemical processes, according to its characteristics.

Pyrolysis can be considered as an alternative method of recycling electronic waste, because during the process organic content of waste is decomposed to product that can be used for energy recovery – the gas and to the solid combination of char and nonorganic materials, including metals,that can be recovered.

In addition, pyrolysis significantly reduces the volume of the waste which is beneficial for further treatment. The combination of mechanical methods (separation, shredding), pyrolysis and chemical processing could increase efficiency of electronic waste recovery.

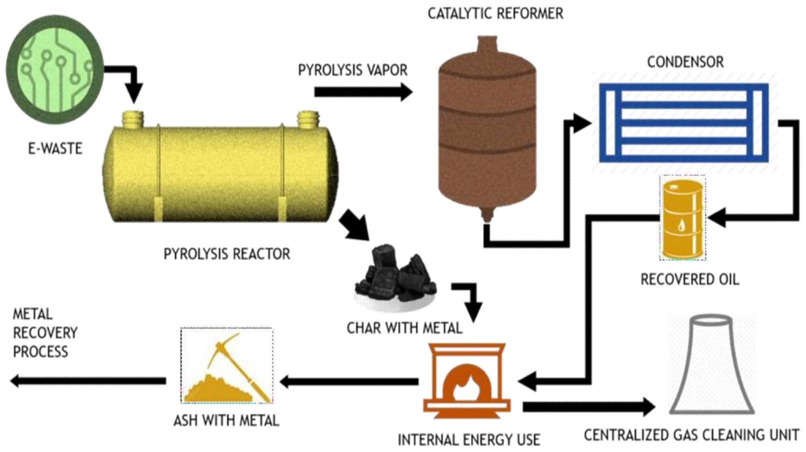


Fig:Pyrolysis

Bio-medical waste

'Bio-medical waste' means any waste generated during diagnosis, treatment or immunization of human beings or animals

Categories of Biomedical Waste

Category	Source of waste	Treatment and Disposal
1	Human Anatomical Waste (human tissues, organs, body parts)	Incineration /deep burial
2	Animal Waste (animal tissues, organs, body parts, carcasses, bleeding parts,	
	fluid, blood and experimental animals used in research, waste generated by veterinary hospitals, colleges, discharge from hospitals, animal houses)	Incineration /deep burial
3	Microbiology & Biotechnology Waste (wastes from laboratory cultures, stocks	
	or specimens of micro-organisms live or attenuated vaccines, human and animal cell culture used in research and industrial laboratories, wastes from production of biological, toxins, dishes and devices used for transfer of cultures)	Local autoclaving / microwaving incineration
4	Waste Sharps(needles, syringes, scalpels, blades, glass, etc. that may cause puncture and unused sharps)	Disinfection (chemical treatment /autoclaving/ microwaving and mutilation/ shredding‖
5	Discarded Medicines & Cytotoxic drugs (wastes comprising of outdated, contaminated and discarded medicines)	Incineration /destruction and drugs disposal in secured landfills
6	Soiled Waste (items contaminated with blood and body fluids including cotton, dressings, soiled plaster casts, lines, beddings, other material contaminated with blood.	Incineration autoclaving/ microwaving
7	Solid Waste (wastes generated from disposable items other than waste sharps such as tabbing, catheters, intravenous sets etc.)	Disinfection by chemical treatment autoclaving/ microwaving and mutilation/ shredding‖
8	Liquid Waste(waste generated from laboratory and washing, cleaning, house- keeping and disinfecting activities)	Disinfection by chemical treatment and discharge into drains
9	Incineration Ash (ash from incineration of any bio-medical waste)	Disposal in municipal landfill
10	Chemical Waste (chemicals used in production of biological, chemicals used in disinfection, as insecticides, etc.)	Chemical treatment and discharge into drains for liquids and secured landfill for solids.

- Other wastes generated in healthcare settings include radioactive wastes, mercury containing instruments and polyvinyl chloride (PVC) plastics. These are among the most environmentally sensitive by-products of healthcare

WHO stated that 85% of hospital wastes are actually non-hazardous, around 10% are infectious and around 5% are non-infectious but hazardous wastes. In the USA, about 15% of hospital waste is regulated as infectious waste. In India this could range from 15% to 35% depending on the total amount of waste generated (Glenn & Garwal, 1999; Anonymous, 1998; Chitnis et al., 2005)

Effects of Biomedical waste

- Air Pollution
- Water Pollution
- Radioactive Effluent
- Land Pollution

The improper management in bio-medical waste causes stern environmental problems that causes to air, water and land pollution. The pollutants that cause damage can be classified into biological, chemical and radioactive. There are several legislations and guidelines in India concerning environmental problems, which can be addressed. The classification of radioactive waste generated as part of bio-medical waste is covered. Some of the effects of pollution on air, radio activities, land, health and hazards are discussed

Air Pollution

Air pollution can be caused in both indoors and outdoors atmosphere. Biomedical waste that generated by air pollution

In-door air pollution

Pathogens present in the waste can enter and remain in the air for a long period in the form of spores or as pathogens Segregation of waste, pre-treatment at source etc., can also reduce this problem to a great extent. Sterilizing the rooms will also help in checking the indoor air pollution due to biological (Askarian et al 2004b; Baveja et al 2000). The indoor air pollution caused due to the above chemicals from poor ventilation can cause diseases like Sick Building Syndrome (SBS). Proper building design and well-maintained air conditioners can reduce the SBS. Chemicals should be utilized as per prescribed norms. Over use of chemicals should be avoided (Bdour 2004, Saurabh & Ram 2006).

Out-door air pollution

Outdoor air pollution can be caused by pathogens. The biomedical waste without pre-treatment if transported outside the institution, or if it is dumped in open areas, pathogens can enter into the atmosphere. Chemical pollutants that cause outdoor air pollution have two major sources-open burning and incinerators. Open burning of bio-medical waste is the most harmful practice. When inhaled can cause respiratory diseases. Certain organic gases such as dioxins and furans are carcinogenic (Burd 2005). The design parameters and maintenance of such treatment and disposal technology should be as per the prescribed standards (Bdour 2004).

- ***Radioactive emissions***

Research and radio-immunoassay activities may generate small quantities of radioactive gas. Gaseous radioactive material should be evacuated directly to the outside. The use of such device requires maintenance of the trap and monitoring of the off-gas

Water Pollution

The liquid waste generated when let into sewers can also lead to water pollution if not treated properly. Water pollution can alter parameters such as pH, BOD, DO, COD, *etc*. There are instances where dioxins are reported from water bodies near incinerator plants. Dioxins enter the water body from the air

- ***Radioactive effluent***

Radioactive waste in liquid form can come from chemical or biological research, from body organ imaging, from decontamination of radioactive spills, from patient‘s urine and from scintillation liquids used in radioimmunoassay. Under normal circumstances, urine and faeces can be handled as no radioactive waste so long as the patient‘s room is routinely monitored for radioactive contamination

- ***Land Pollution***

Soil pollution from bio-medical waste is caused due to infectious waste, discarded medicines, chemicals used in treatment and ash and other waste generated during treatment processes. Heavy metals such as cadmium, lead, mercury etc., which are present in the waste will get absorbed by plants and can then enter the food chain. Nitrates and phosphates present in leachates from landfills are also pollutants. Excessive amounts of trace nutrient elements and other elements including heavy metals in soil are harmful to crops and are also harmful to animals and human beings

Management of biomedical waste

The Hospital Waste Management is part of hospital hygiene and maintenance activities and it involves range of activities, which are mainly engineering functions, such as collection, Segregation, transport, treatment/processing and disposal waste. Initial segregation and storage activities are direct responsibility of nursing personal who are engaged in the hospital.

Collection of Medical Waste

Medical waste must be collected and stored prior to treatment in a way that reduces the possibility of interaction with humans, animals, or the environment. Medical waste containers are generally red, contain the word "biohazard" and are imprinted with the universal three-sided biohazard symbol .

The most visible form of medical waste collection is the sharps container. Sharps containers are found in every medical office, and often in public places, for medical personnel and the general public to safely dispose of hypodermic needles. These containers are designed so the user is never exposed to any of the sharps already in the container, eliminating the possibility of contact or puncture by any of the used needles. Sharps containers are generally made of thick plastic, and have a door that opens and the user can insert the sharp into the container. When the door is closed, the sharp is dropped down into the main chamber of the container.

Contaminated reusable sharps must be placed in containers that are puncture resistant, closeable, leak-proof on sides and bottoms, and labeled or color coded, much like a standard post office mailbox, in that the user cannot reach the sharps inside the container via the door. Sharps containers are also used for other categories of sharps, including scalpels and lancets.

- Reusable sharps that are contaminated with blood or other potentially infectious materials must not be stored or processed in a manner that requires employees to reach by hand into the containers,
- Specimens of blood or other potentially infectious material are required to be placed in a container that is labeled and color coded and closed prior to being stored, transported or shipped,
- Regulated wastes (liquid or semi-liquid) must be placed in containers that are constructed to contain all contents and prevent leakage of fluids, labeled or color coded, and closed prior to removal,
- Labels must include the biohazard symbol, be fluorescent orange or orange-red or predominantly so, with lettering and symbols in contrasting color, and affixed as closely as possible to the container by adhesive or wire to prevent loss or removal

All bins, pails, cans, and similar receptacles intended for reuse are required to be inspected and decontaminated on a regularly scheduled basis

Animal Waste	Animal tissue, animals used in research, waste from veterinary hospitals, colleges, and animal houses	Incinerations / deep burial
Microbiology&Biotechnology Waste	Wastes from laboratory cultures, stocks or specimens of microorganisms live or attenuated vaccines, toxins, dishes and devices used for transfer of cultures	Incinerations
Waste sharps	Needles, syringes, scalpels, blades, glasses, etc.	Autoclaving / shredding
Discarded Medicines and Cytotoxic Drugs	Outdated, contaminated and discarded medicines	Incinerations and secured landfills
Solid Waste	Items contaminated with blood and body fluids, including cotton, dressing, soiled plaster casts, beddings	Autoclaving, microwaving
Solid Waste III	Waste generated from disposable items like tubings, catheters, intravenous sets etc.	Autoclaving, microwaving and shredding
Liquid Waste	Laboratory and washing, cleaning, housekeeping in hospitals	Treatment and discharge into

Segregation:

SEGREGATION OF WASTE IN COLOR CODED BAGS			
BLACK CARBOY	**BLUE BAGS**	**RED BAGS**	**YELLOW BAGS**
Needles without syringes, blades, sharps and metal articles	All types of glass bottles and broken glass articles outdated & discarded medicines	Plastic waste such as catheters, injections, syringes, tubings i.v.bottles	Infectious waste, bandage, gauzes, cotton, or any other things in contact with body fluids, human body parts, placenta

Fig. 3. Segregation of waste in color coded bags [25]

Color coding-biomedical waste (management and handling) rules, 1998 (Schedule II)

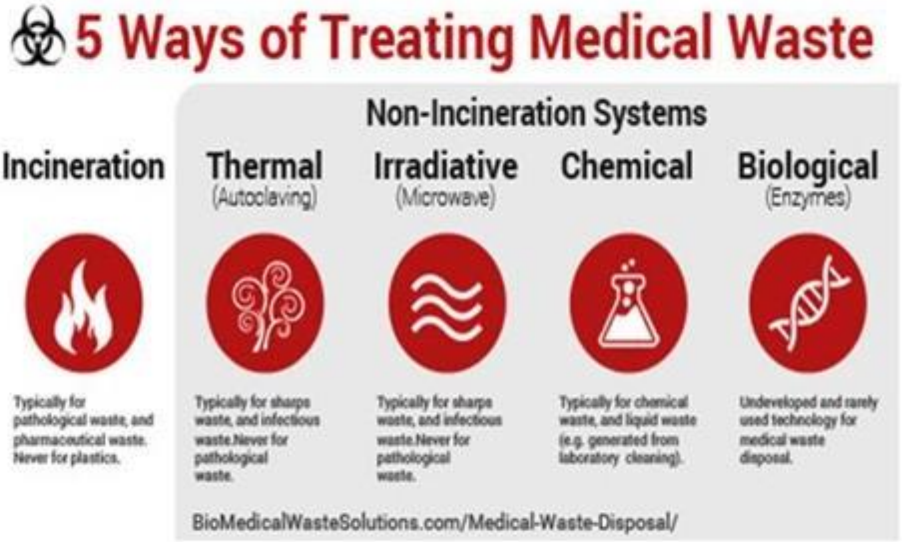
Color-coding	Type of container	Waste categories
Yellow	Plastic bags	Cat 1 human anatomical waste, Cat 2 animal waste, Cat 3 microbiology waste, Cat 6 soiled waste.
Red	Disinfected container plastic bags	Cat 3 Microbiological Cat 6 soiled Cat 7 solid waste (Waste IV tubes catheters, etc.)
Blue/White	Plastic bag/puncture proof containers	Cat 4 waste sharps Cat 7 plastic disposable tubings, etc.
Black	Plastic bag/puncture proof containers	Cat 5 discarded medicines Cat 9-incineration ash Cat 10 chemical wastes

Fig Medical waste Containers

Storage & Handling /Transportation

Storage refers to keeping the waste until it is treated on-site or transported off-site for treatment or disposal. There are many options and containers for storage. Regulatory agencies may limit the time for which waste can remain in storage. Handling is the act of moving biomedical waste between the point of generation, accumulation areas, storage locations and on-site treatment facilities. Workers who handle biomedical waste must observe *standard precautions*

Treatment of Medical waste/Disposal Methods/Technology options for ‘treatment



The treated waste (if sufficiently sterile) can generally be disposed with general waste in a sanitary landfill, or in some cases discharged into the sewer system. In the past, treatment of medical waste was primarily performed on-site at hospitals in dedicated medical waste facilities. Over time, the expense and regulation of these facilities have prompted organizations to hire contractors to collect, treat, and dispose medical waste, and the percentage of medical organizations that perform their own treatment and disposal is expected to drop . To ensure that each treatment method provides the proper environment for the destruction of biologicals, test indicators for microbiological spores measure the treatment effectiveness. Microbiological spores are the most difficult of biologicals to destroy, so when the test package cannot be cultured after treatment, the waste is considered properly treated. In treatment methods where shredding or maceration is employed, the test package is inserted into the system after the shredding process to avoid physical destruction of the test package. The test package is then retrieved from the waste after treatment.

- Chemical processes
- Thermal processes
- Mechanical processes
- Irradiation processes
- Biological processes

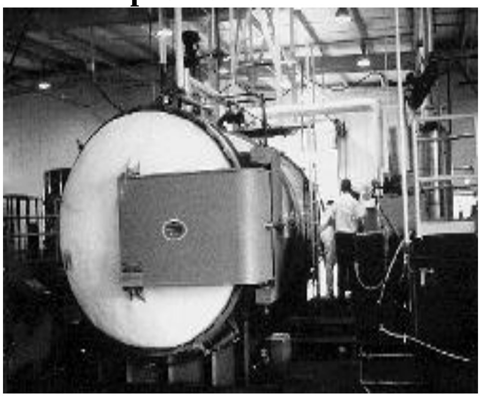
Chemical processes

- ***Standard for liquid waste***:
- Table . shows the effluent generated from the hospital should conform to the following limits

Parameters	Permissible limits
pH	6.3-9.0
Suspended solids	100 mg/L
Oil and grease	10 mg/L
BOD	30 mg/L
COD	250 mg/L

- Chemical disinfection, primarily through the use of chlorine compounds, is another method to treat medical waste
- These processes use chemicals that act as disinfectants. Sodium hypochlorite, dissolved chlorine dioxide, per-acetic acid, hydrogen peroxide, dry inorganic chemical and ozone are examples of such chemicals.
- Most chemical processes are water-intensive and require neutralising agents.
- The use of chlorine bleach for cleaning and disinfecting is well known and this method has been in use for many years.
- The chemical disinfection process provides control and consistency to the disinfection process.
- The EPA identifies chemical disinfection as the most appropriate method to treat liquid medical waste.
- Chemical disinfection processes are often combined with a mechanical process, such as shredding or maceration, to ensure sufficient exposure of the chemicals to all portions of the waste

Thermal processes



- These processes utilise heat to disinfect. Depending on the temperature they operate, it is been grouped into two categories, which are Low-heat systems and High-heat systems
- Low-heat systems (operates between 93 -177^{o}C) use steam, hot water, or electromagnetic radiation to heat and decontaminate the waste. Autoclave & Microwave are low heat systems.
- i. 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.

- ii. Microwaving is a process which disinfects the waste by moist heat and steam generated by microwave energy.
- High-heat systems employ combustion and high temperature plasma to decontaminate and destroy the waste. Incinerator & Hydroclaving are high heat systems

Autoclaving

- Autoclaving is a low-heat thermal process where steam is brought into direct contact with waste in a controlled manner and for sufficient duration to disinfect the wastes.
- For ease and safety in operation, the system should be horizontal type and exclusively designed for the treatment of bio-medical waste.
- For optimum results, pre-vacuum based system be preferred against the gravity type system.
- It shall have tamper-proof control panel with efficient display and recording devices for critical parameters such as time, temperature, pressure, date and batch number etc
- Autoclaves are closed chambers that apply both heat and pressure, and sometimes steam, over a period of time to sterilize medical equipment.
- Autoclaves have been used for nearly a century to sterilize medical instruments for re-use.
- Autoclaves are used to destroy microorganisms that may be present in medical waste before disposal in a traditional landfill .
- Heat is applied Externally in autoclaving
- The autoclave should be dedicated for the purpose of disinfecting and treating biomedical waste.
- When operating a **gravity flow autoclave**, medical waste shall be subjected to:
    - A temperature of not less than 121^{o} and pressure of about 15 pounds per square inch (psi) for an autoclave residence time of not less than 60 minutes; or (A temperature of not less than 135 ^{o}C and a pressure of 31 psi for an autoclave residence time of not less than 45 minutes; or A temperature of not less than 149 ^{o}C and a pressure of 52 psi for an autoclave residence time of not less than 30 minutes.)
- When operating a **vacuum autoclave**, medical waste shall be subjected to a minimum of one per vacuum pulse to purge the autoclave of all air. The waste shall be subjected to the following :
    - A temperature of not less than 121^{o}C and a pressure of 15 psi per an autoclave residence time of not less than 45 minutes; or (temperature of not less than 135 ^{o}C and a pressure of 31 psi for an autoclave residence time of not less than 30 minutes);
    - or Medical waste shall not be considered properly treated unless the time, temperature and pressure indicate stipulated limits.
    - If for any reason, these were not reached, the entire load of medical waste must be autoclaved again until the proper temperature, pressure and residence time were achieved.

Microwaving

- **Microwaving** is a process which disinfects the waste by moist heat and steam generated by microwave energy.
- The use of microwaves to disinfect medical waste has only recently been introduced in the United States.
- Microwave treatment units can be either on-site installations or mobile treatment vehicles.
- In this type of disinfection process, the waste is first shredded.
- The shredded waste is then mixed with water and subjected to microwaves.
- The microwaves internally heat the waste(rather than applying heat externally, as in an autoclave)
- Microwave treatment shall not be used for cytotoxic, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items.
- The microwave system shall comply with the efficacy tests/routine tests
- The microwave should completely and consistently kill bacteria and other pathogenic organism that is ensured by the approved biological indicator at the maximum design capacity of each microwave unit

- **Incineration (Explained at the end)**

Mechanical processes

- These processes are used to change the physical form or characteristics of the waste either to facilitate waste handling or to process the waste in conjunction with other treatment steps. The two primary mechanical processes are
  Compaction - used to reduce the volume of the waste
  Shredding - used to destroy plastic and paper waste to prevent their reuse. Only the disinfected waste can be used in a shredder

Shredding:

Shredding is a process by which waste are deshaped or cut into smaller pieces so as to make the wastes unrecognizable. It helps in prevention of reuse of bio-medical waste and also acts as identifier that the wastes have been disinfected and are safe to dispose off. A shredder is to be used for shredding in bio-medical waste with minimum requirements

Irradiation processes

- Another method used to sterilize medical equipment or waste is irradiation, generally through exposure of the waste to a cobalt source.
- The gamma radiation generated by the cobalt inactivates microbes.
- Dedicated sites are required for this form of treatment, while mobile versions are available for other non-incineration methods.
- In these processes, wastes are exposed to ultraviolet or ionizing radiation in an enclosed chamber.
- These systems require post shredding to render the waste unrecognizable.

Biological processes

- **Biological enzymes** are used for treating medical waste. It is claimed that biological reactions will not only decontaminate the waste but also cause the destruction of all the organic constituents so that only plastics, glass, and other inert will remain in the residues

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It is important to underline that the management of medical waste takes over the strict control and record the waste from the spot of occurrence and up to final storage. This process requires the preparation of strict procedures to be applied to the site of occurrence (e.g. in a hospital room, clinic, laboratory, etc.). In this way, the problem with the management of medical waste in health care could be reduced to the level of no risk or less risky waste.

In each health institution, actions should be organized and controlled with regards to the occurrence of the medical waste stream and reduce the amount of hazardous materials medical waste, as well as on-site waste collection. It's important to clearly define the responsibility for proper waste management, to the process of its final processing. It is necessary to develop a comprehensive and planned management system that beside responsibility should provide funds for safe implementation of waste. This is a long process that despite organizational structure requires individual and professional commitment.

Shortcomings in the existing system

- The segregation of waste in almost all hospitals is not satisfactory.
- Color-coding for various categories of waste is not followed.
- The storage of bio-medical waste is not in isolated area and proper hygiene is not maintained.
- Personal protective equipment and accessories are not provided.
- Most of the hospitals do not have proper waste treatment and disposal facilities. In the cities where common treatment facilities have come up, many medical establishments are yet to join the common facility.
- Most of the incinerators are not properly operated and maintained, resulting in poor performance.
- Sometimes plastics are also incinerated leading to possible emission of harmful gases.
- General awareness among the hospital staff regarding bio-medical waste is lacking.

Threats due to poor biomedical waste Management

- The status of poor waste management currently practiced in the city poses a huge risk towards the health of the general people, patients, and professionals, directly and indirectly through environmental degradation.
- Communicable diseases like gastro-enteritis, hepatitis - A and B, respiratory infections and skin diseases are associated with hospital waste either directly as a result of waste sharp injuries or through other transmission channels.
- The hosts of micro organisms responsible for infection are enterococci, non-haemolytic streptococci, anaerobic cocci, clostridium tetani, klebsiella,HIV and HBV
- The potential risk to health care workers comes from the handling of infected sharps; 60 percent of them sustain an injury from sharps knowingly or unknowingly during various procedures.
- The practice of reheating the needle after use is the major factor for needle stick injuries.
- Through poor waste management practices, all health care workers (nurses, doctors, lab technicians), service personnel, rag pickers and the general public are at risk of contracting infections while handling, storage, and treatment.
- Incinerators operating at sub-optimal conditions are an added environmental and health hazard

Recommendation by WHO

- To wear helmet, protective face mask, goggles , special jumpsuits , industrial aprons, feet guards , boots etc.

Solid Waste

Any unwanted or discarded material from residential, commercial, industrial, mining and agricultural activities that cause environmental problems may be termed as solid waste.

Types of Solid Wastes

- Household Hazardous Waste (HHW)
- Construction and Demolition Debris.
- Industrial/Commercial Waste.
- Hazardous Waste Lamps.
- Regulated Medical Waste.
- Used Electronic Equipment.
- Used Oil.
- Waste Tires.

Classification of solid waste

Domestic wastes: These include waste from household preparation, cooking and serving of food, waste paper and plastics, cloth, rags, etc.

Municipal wastes:-These include garbage and rubbish from households, offices, hotels, markets, etc. and also the street refuse such as street sweepings, dirt, leaves, content of litter receptacles etc.

Industrial Waste: These include

a) **Non process wastes** such as office and cafeteria wastes, packing wastes, etc, which are common to all industries and
b) **Process wastes** which depend upon the type of the products being manufactured, such as tannary wastes, weaving and dying wastes, food processing wastes, plastic wastes, rubber wastes, metal scraps etc. from the respective industrial establishments. Mineral wastes from mining and mineral processing units also fall under this category.

Agricultural wastes: These wastes result from farms, feedlots and livestock yards. The agricultural wastes include paddy husk, bagasse from sugarcane, tobacco and corn residues, slaughter house wastes, manures, etc.

Special Wastes: These include hazardous wastes from different sources e.g

a) Radioactive wastes from nuclear power plants, laboratories, hospitals etc.
b) Toxic substances such as heavy metal sludge , pesticides, pharmaceuticals etc
c) Biological products such as enzymes, antibiotics, pathogenic and pathological wastes etc
d) Miscellaneous products such as inflammable substances, corrosive materials, explosives, security wastes etc.

Magnitude of the problem

- Due to increase in industrialization
- Due to increase in population
- Resulted in increase in generation of solid waste

- The quantity of domestic and municipal solid waste generated in major cities of India is 300 to 600 g per person per day.

Throw away concept

Characteristics of solid waste

1. **Composition**: Wide variations in the composition of domestic and municipal waste may occur depending on the following factors
   a) Degree of urbanization and industrialization of the area
   b) Per capita income
   c) Social customs
   d) Climatic conditions of the area
   e) Acceptability of packaged foods
   f) Frequency of collection by municipality etc

2 .**Density**: The density of municipal wastes varies from 150 kg/m3 to 800 kg/m3 depending upon the waste composition and degree of compaction for land filled pulverized refuse

3.**Energy Content**: Municipal solid waste contains about 50% of combustible matter. Hence the waste is often burnt as a means of disposal and occasionally used as a source of energy. The average calorific value of the urban solid wastes produced in India is about 1500Kcal/Kg.

Objectives and Considerations in Solid Waste Management

Objectives: The principal objectives of solid waste management are to control, collect, treat, utilize and dispose of the solid wastes in an economical manner consistent with the protection of public health.

Considerations

a) Public Health
b) Waste separation for recovery and recycling
c) Energy recovery

Waste Treatment and Disposal Methods

1) Composting
2) Sanitary Landfilling
3) Thermal Process (Incineration and Pyrolysis)
4) Recycling and reuse

- **1) Composting:** Composting is the aerobic and hemophilic decomposition of organic matter present in the refuse by microorganisms, primarily bacteria and fungi. The organic matter is transformed into a stable humus like substance during this process. The reactions taking place during composting generate heat and hence the compost temperature rises during the process. Depending upon the composition and nature of the waste, the waste volume is reduced by about 30 to 60%.

- It is an aerobic, biological **process** which uses naturally occurring microorganisms to convert biodegradable organic matter into a humus-like product(**COMPOST**).

- **Composting** is the biological reclamation of organic materials by natural decomposition **process**.

For an optimum composting operation, the following control parameters are usually adhered to

1	**Temperature**	40 to 50 ^{0} C (If the temp. goes beyond 66 ^{0} C ,biological activity will be reduced)
2	**pH**	4.5 to 9.5 (It is better to maintain pH below 8.5 to minimize loss of nitrogen in the form of ammonia as gas)
3	**Moisture**	40 to 70% (The optimum value is about 55%)
4	**Particle Size**	0.63 to 2.54 cm
5	**Air**	0.5 to 0.8 m^3/day/kg of volatile compost solids
6	**Carbon to Nitrogen Ratio**	(35 to 50):1
7	**Carbon to Phosphorous ratio**	100:1

The composting process usually consist of following three steps

a) **Waste Preparation**: The solid waste is placed on slow moving conveyor belts. Materials like corrugated paper are handpicked and then the ferrous materials are removed by magnetic separation. The waste is then ground in hammer mills or wet pulper to the desired size range (0.6 to 2.5 cm).Then it is mixed with nutrient source, filler and water (to provide 50% moisture)

b) **Digestion**: The mixture is placed in the windrows for 4/6 weeks, while turning it once or twice a week. The waste is decomposed by hemophilic micro-organisms during this period. The material is then allowed to stabilize for another 2 to 5 weeks.
c) **Product up-gradation**: In order to ensure quick and better marketing prospects, the product is sometimes upgraded by operations such as curing, grinding, screening , pelletizing and bagging.

4) Sanitary Landfilling:

Landfilling is the most common and economic method of solid waste disposal in many countries

An ideal sanitary landfill site should satisfy the following criteria

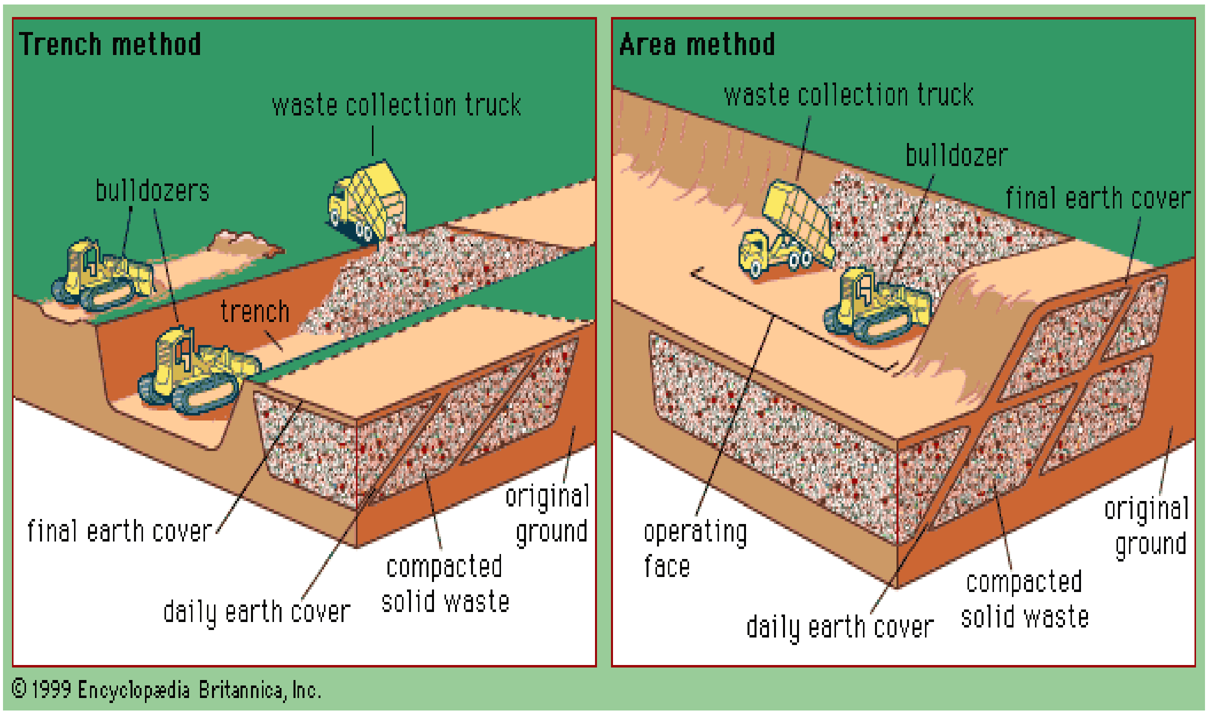
i) It should be cheap, accessible and at a reasonable distance
ii) It should be at least $1^{1/2}$Km downwind from the commercial and residential neighboring area.
iii) It should be reasonably leveled, clear and well drained, with capacity of use for at least 3 years.
iv) Its soil should be of low permeability so that it can be used as satisfactory cover material.
v) It should be well above the ground water table so that the underground water supplies are not polluted.
vi) The site selected for landfilling should not be deleterious or offensive to the surrounding environment .It should be consistent with the topography, climatic conditions, hydrogeological requirements and economic considerations

The planning of a sanitary landfill operation should be based on the following considerations

vi) The quantity and nature of the solid waste to be treated
vii) Overall suitability of the land for such operation
viii) Economic considerations of the landfilling process as compared to other available solid waste treatment processes
ix) Public health criteria
x) Proper design of the sanitary landfill operation with respect to the appropriate method of the landfill suitable for the chosen site and efficient organization of the possible pollution problems such as leachate generation, escape of gases etc.

Preparation of the landfill site involves fencing, grading, stockpiling of the cover material, construction of berms, landscaping and the installation of leachate collection system, gas collection system and monitoring system.

Mixed solid wastes with varying degrees of compaction are delivered to the landfill site by packed trucks or trailer units. After hand sorting the wastes, pulverizing or high pressure compaction and bailing for volume reduction may be done before placement. Loose material is placed in the lower part of the pit or trench. It is then spread and compacted by machines in layers of about 0.5 m thickness. After the end of each days operation and when the depth is about 3m, the refuse is covered with 15 to 30 cm of the earth. This consolidated solid waste enclosed by earth at the end of a day‘s operation is called a cell.



Problems with Landfilling

d) Economic problems: The land used as landfill cannot be used in future as a productive farm land. Even after closure of the landfill site, its further use should be restricted only to some type of open development such as a park or recreational area. Building construction in the site must be controlled.

e) Environmental Problems: During landfilling operations of municipal solid wastes, aerobic degradation occurs initially for periods varying from a few weeks (in wet areas) to a few months (in dry areas).After all the oxygen is exhausted, anaerobic degradation of the organic wastes takes place. While these processes are taking place liquid from the waste seepage from ground water, rain water and surface run off percolates through the refuse. This produces a contaminated liquid called ―leachate‖ The leachates having high organic content, soluble salts and other constituents can contaminate the ground water.

Further methane (CH_4) and carbon dioxide (CO_2) are generated during the anaerobic decomposition of organic matter in the landfill. Methane constitutes about 60% of the gas generated in a sanitary landfill. Methane is heavier than air, odourless and explosive when its concentration in air reaches over 55.Hence its hazardous potential should be given due consideration.

Carbon dioxide combines with water giving carbonic acid. The resultant acidic environment may help in dissolution of minerals and salts of Ca, Mg, Fe , Cd, Pb and Zn present in the refuse or in the soil. If these dissolved salts move into the ground water, increased hardness and heavy metal toxicity of the water may result.

In order to control the contamination of the ground water by leachate, **certain regulations are prescribed for sanitary landfills.** These include

4. Mandatory minimum distance of the location of the landfills above the ground water table
5. Minimum distance from the nearest point of water use
6. Use of soil of low permeability

- Preventing the build-up of the leachate within the landfill
- Extensive hydrogeological investigation of the actual landfill site including topography, soil stratigraphy, drainage and groundwater characteristics (e.g depth and movement etc)
- Supplementary measures such as inclusion of clay and or membrane covers or liners for the landfill, leachate collection, removal and treatment facility, installation of monitoring system are also suggested to ensure that the buried refuse remains as dry as possible and the leachate does not reach the ground water. In spite of these precautions, if some leakage of the leachate still occurs, the soil beneath serves as an additional barrier to attenuate the contaminants before reaching the groundwater by mechanisms such as filtration, adsorption, precipitation and biological activity.
- The gases produced in sanitary landfills by the anaerobic digestion of organic waste are generally vented to the atmosphere through gravel packed seams or wells. In some landfills, the escaping gases are burnt off with the help of burners installed at the top of vents. These measures are meant for preventing undue accumulation and lateral movement and migration of the gases under the landfill cover to nearby residential areas which may cause fires and explosions.

f) **Aesthetic Problems**: Poorly operated landfill operations may cause problems due to bad odours , insects, vermin , blowing papers ,rats, and scavenger birds, apart from the dust and noise from waste transporting vehicles and compacting operations. Continuous field compaction of the loose refuse and proper covering with earth at the end of each day‘s operation reduce these problems. Volume reduction by pulverization or high pressure compaction may ensure an aesthetically acceptable operation.

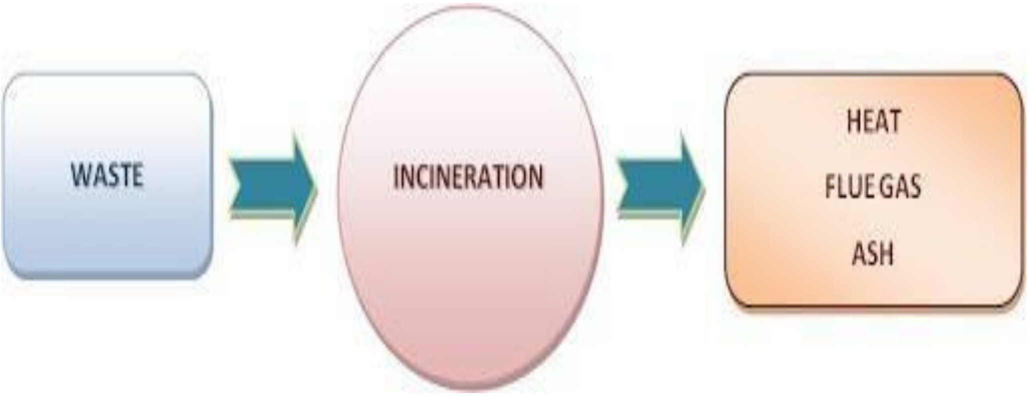
- **Landfill (E-waste)**

It is one of the most widely used methods for disposal of e- waste. In land filling, trenches are made on the flat surfaces. Soil is excavated from the trenches and waste material is buried in it, which is covered by a thick layer of soil (Fig. 4 and 5). Modern techniques like secure landfill are provided with some facilities like, impervious liner made up of plastic or clay, leachate collection basin that collects and transfer the leach ate to waste water treatment plant. The degradation processes in landfills are very complicated and runs over a wide time span.

The environmental risks from land filling of e- waste cannot be neglected because the conditions in a landfill site are different from a native soil, particularly concerning the leaching behavior of metals. Mercury, cadmium and lead are the most toxic leachates. Lead has been found to leach from broken lead- containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. Cadmium also leaches into soil and ground water. In addition, it is known that cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant. Landfills are also prone to uncontrolled fires, which can release toxic fumes.

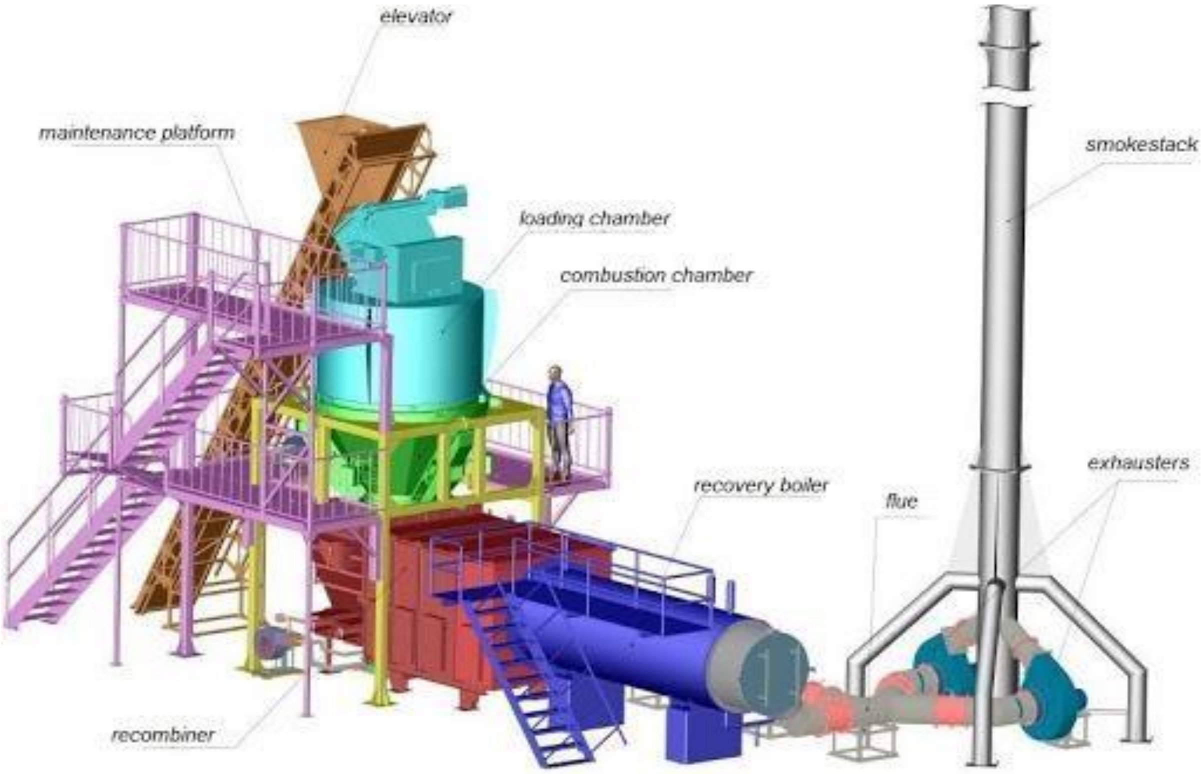
Therefore, land filling does not appear to be an environmentally sound treatment method for substances, which are volatile and not biologically degradable (Cd, Hg,), persistent (Poly Chlorinated Biphenyls) or with unknown behaviour in a landfill site (brominated flame retardants).

5) Thermal Processes: The important thermal processes used in solid waste treatment are incineration and pyrolysis.



Incineration: Incinerators are burning plants capable of burning a large amount of materials at high temperature. The initial cost is very high. During incineration high levels of dioxins, furans, lead and cadmium may be emitted with the fly ash of incinerator. Dioxin level may reach many times more than in the ambient environment. For incineration of materials ,it is better to remove batteries containing heavy metals and plastic containing chlorine before burning the material. Prior removal of plastics will reduce emissions of dioxins and polychlorinated biphenyls(PCBs)

In this process, the solid organic wastes are subjected to controlled combustion so as to convert them into incombustible residue and gaseous products.



The advantages of this process are

i) The volume of waste is reduced to more manageable levels thereby reducing the transportation costs to the ultimate disposal site.
ii) Waste from a bigger community of people can be accommodated for a given acreage available for a landfill. Incineration reduces the land requirement to one third of that required if the reuse is to be landfilled.
iii) The residue after incineration if properly carried out is free from any degradable materials and hence is no longer a source of pollution. Moreover the stabilized residue thus produced, minimizes or even eliminates the need to transport the cover material to the landfill site.

The disadvantages of this process are

i) High capital and operation costs
ii) The possibility of air pollution if not carried out properly
iii) Ordinary incinerators cannot be used for radioactive wastes

Incineration process involves the following steps

i) Handling and feeding the waste to incinerator
ii) Combustion of the waste within the incinerator
iii) Removal of the incombustible residues to the disposal site
iv) Removal of gaseous and gas borne residues

The major problems associated with incineration process are

i) Air pollution control, particularly the removal of the fine particulates and toxic gases e.g dioxin, are the most difficult
ii) Disposal of liquid wastes from the floor drainage, quench water and scrubber effluent.
iii) Disposal of ash containing heavy metal residues in landfills.

- **Incineration (E-waste)**

It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators at a high temperature (900-1000^{o}C).

Advantage of incineration of e- waste

1) The reduction of waste volume

2) The utilization of the energy content of combustible materials.

3) Some plants remove iron from the slag for recycling.

4) By incineration some environmentally hazardous organic substances are converted into less hazardous compounds.

Disadvantage of incineration are

4) the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion.

5) E- waste incineration plants contribute significantly to the annual emissions of cadmium and mercury.

6) In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas

residues and can re-enter the environment on disposal.
Therefore, e-waste incineration will increase these emissions, if no reduction measures like removal of heavy metals are taken.

The design of an incinerator should be based on the following considerations

iii) The quantity of the waste to be handled, its composition and characteristics
iv) Measure to ensure that there will not be any pollution of air, water or land resulting from the operation of the incinerator.

On economic considerations, the size of the incinerators is determined on the basis of weekly quantity of the waste to be incinerated. For unsorted wastes, two types of incinerators are used

iii) The batch type incinerator
iv) The continuous type incinerator

The batch type incinerator which is manually stocked and has a relatively small rated capacity .These plants have several disadvantages

f) Owing to the intermittent operation, the burning temperature cannot be maintained in a uniform manner. This may result in an inadequate and irregular combustion of the waste.
g) The output of particulate matter is more
h) The volume reduction of the waste is lesser than the optimal value expected.
i) This may end up with an unstable residue still containing some putrescible matter. Thus it may still possess some pollution potential.
j) The intermittent incinerator plants are unsuitable for larger urban centers

The continuous-type incinerators are equipped with large storage bins, automatic feed hoppers, varied types of moving gates and ash discharging systems. These units are capable of maintaining uniform temperatures for combustion and can be equipped with pollution control devices such as gas scrubbers and electrostatic precipitators. These units are capable of yielding a stable residue which is non- polluting although the capital and operating costs are very high, these units, which provide controlled furnace temperatures of 760 to 980^{0}C,can remove odours and also bring about a substantial reduction in waste volume, in an environmentally acceptable form. Since the final residue is stable, the cost of cover material required to ultimately dispose it in the landfill will be substantially minimized or even eliminated in some cases.

The modern municipal incinerators are of continuous burning type.

Many of them have –water-wall‖ construction in the combustion chamber instead the older and more common refractory lining. The water-wall consists of joined vertical boiler tubes (made of steel) through which water is circulated. These water tubes absorb heat to provide hot water for steam generation and at the same time control the furnace temperature. Thus the heat recovery is simpler and the waste heat of combustion can be utilized for space heating, power generation, desalination,etc.,as has been done in some recent installations.

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When the wastes are burnt only for volume reduction, there is no need for an auxiliary fuel., except at the startup. When steam production is the objective, supplementary fuel must be used with the pulverized refuse. Ferrous metals are usually recovered from the ash.

High temperature incineration is a recent innovation where temperatures of the order of 1,650 ^{0} C are attained using supplementary fuels. In this process, non- combustible fractions of refuse (e.g metal and glass)are melted in a bed of high temperature coke I the refractory lined incinerator and are drained of as molten Further the water-well units help in eliminating the costly maintenance of refractory lining and also reduce the pollution control requirement (By reducing the volumes of quench water and gas, that require treatment)

However corrosion of the water-well units may be a serious problem as experienced by some installations in European countries.

Putrefiable organic wastes from slaughter house have to be dried in special driers before being incinerated. Hospital wastes are generally disposed of by pathological incinerationslag. This technique can achieve volume reduction of the refuse by 97%.In spite of the fact that the first high temperature incinerator was installed on pilot plant scale as early as in 1966, application to full scale commercial units was not followed up enthusiastically for a long time due to the high costs involved.

Incineration (Biomedical waste)

- According to the EPA, 90% of medical waste is incinerated.
- Incineration is the controlled burning of the medical waste in a dedicated medical waste incinerator.
- Among industry folks, these units are often referred to as hospital/ medical/infectious waste incinerators (HMIWIs) .
- It is a controlled combustion process where waste is completely oxidized and harmful microorganisms present in it are destroyed /denatured under high temperature.
- Incineration is popular in countries such as Japan where land is a scarce resource, as they do not consume as much area as a landfill.
- Sweden has been a leader in using the energy generated from incineration over the past 20 years.
- Denmark also extensively uses waste-to- energy incineration in localized combined heat and power facilities supporting district heating schemes.
- Incinerators should be suitably designed to achieve the emission limits.
- Wastes to be incinerated shall not be chemically treated with any chlorinated disinfectants.
- Toxic metals in the incineration ash shall be limited within the regulatory quantities.
- Only low sulphur fuel like diesel shall be used as fuel in the incinerator

Emission standards waste incinerators

S.No	Contaminant	Limit
1	Total Particulate	20 mg/m^3
2	Carbon Monoxide	55 mg/m^3

3	Sulphur Dioxide	180 mg/m^3
4	Nitrogen Oxides (NOx as NO_2)	380 mg/m^3
5	Hydrogen Chloride	50 mg/m^3 or 90% removal
6	Hydrogen Fluoride	4 mg/m^3
7	Total Hydrocarbons (as Methane CH_4)	32 mg/m^3
8	Arsenic	4 $\mu g/m^3$
9	Cadmium	100 $\mu g/m^3$
10	Chromium	10 $\mu g/m^3$
11	Lead	50 $\mu g/m^3$
12	Mercury	200 µg/m3
13	Chlorophenols	1 µg/m3
14	Chlorobenzenes	1 µg/m3
15	Polycyclicaromatic Hydrocarbons	5 µg/m3
16	Polychlorinated Biphenyls	1 µg/m3
17	Total Polychlorinated dibenzodioxins (PCDDs) & Polychlorinated dibenzofurans (PCDFs) Opacity	0.5 ng/m3 5%

Pyrolysis (Solid Waste)

The chemical constituents and chemical energy of some organic wastes can be recovered by destructive distillation (or pyrolysis) of the solid waste. In this process, the combustible constituents of the solid waste are heated in a special retort like chamber known as apyrolysis reactor at 600 to 1000^0 C in a low oxygen or an oxygen free environment. This is anendothermic process and thus differs from the conventional incineration.

Because no oxygen is present the material does not combust but the chemical compounds (i.e. cellulose, hemicellulose and lignin) that make up that material thermally decompose into combustible gases and charcoal.

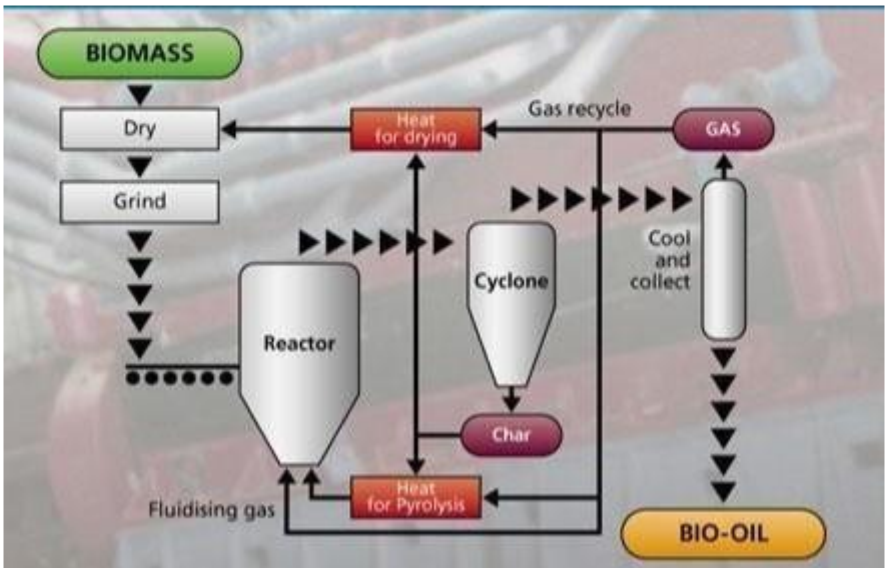


Fig:Pyrolysis

Pyrolysis of the solid waste yields the following components

i) Tar or oil phase containing methanol, acetone, acetic acid etc.
ii) Gaseous phase containing H_2,CH_4,CO,CO_2 etc
iii) Solid phase containing pure carbon char and inert materials like glass, rock, metaletc

The advantages of the pyrolysis process include

i) Volume reduction by about 90%
ii) Possibility of handling potentially hazardous plastics e.g PVC in a safe way
iii) Absence of pollution problems

- **Pyrolysis (E-Waste)**

Pyrolyis is a process of **thermochemical decomposing** organic materials at elevated temperatures in the **absence of oxygen**.

The process occurs at temperatures above 430 degree Celsius (800 degree farenheit) and under pressure. Extreme pyrolysis yields carbon and the process is called carbonization.

It involves changes of chemical composition and physical phase.

In the pyrolysis process organic material, that is a part of electronic waste, is decomposed to molecular products that can be used e.g. as fuel.

Pyrolysis of organic materials produces **gas** and **liquid products** and leaves a **solid residue** rich in carbon (char). Proportionsof solid, liquid and gas yields depend on material that is pyrolyzed and process conditions.

(Zhou conducted experiments of vacuum pyrolysis of waste printed circuit boards at 240°C. The solid residue consisted of the glass fiber, electronic components, metals and other inorganic materials that could be recycled for further processing.)

Gaseous product of the process was rich in CO, CO_2, CH_4, H_2, etc. which makes this gas valuable for combustion. Energy recovered from combustion of the gas may be used in the process and therefore make pyrolysis a self-sustain.

The residue of pyrolysis contained various metals (e.g., Cu, Fe, Al, Au, Ag, Pt, Pd etc.)that could be recovered in further processing. Content of those metals may vary depending on type of waste that is processed. The metals may be separated and recovered in further processing. Each metallic element may be recovered in different physical and chemical processes, according to its characteristics.

Pyrolysis can be considered as an alternative method of recycling electronic waste, because during the process organic content of waste is decomposed to product that can be used for energy recovery – the gas and to the solid combination of char and nonorganic materials, including metals,that can be recovered.

In addition, pyrolysis significantly reduces the volume of the waste which is beneficial for further treatment. The combination of mechanical methods (separation, shredding), pyrolysis and chemical processing could increase efficiency of electronic waste recovery.

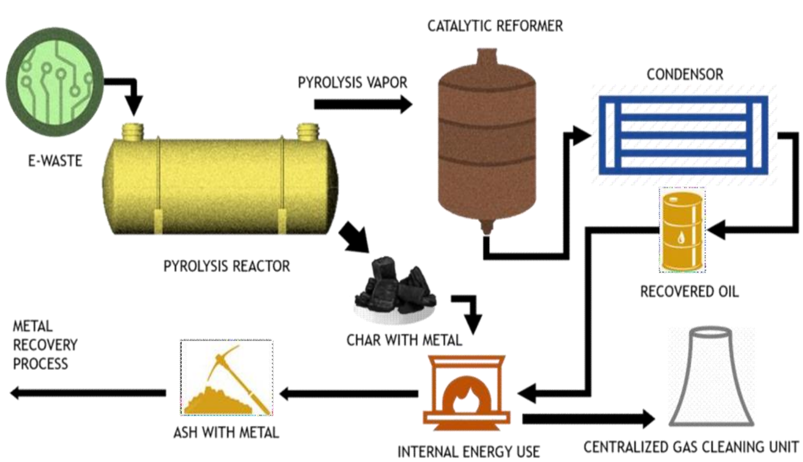


Fig: Pyrolysis

Management of solid waste

Solid waste management is the comprehensive program of waste prevention,recycling, composting and disposal.

Higher standards of living of ever increasing population has resulted in an increase in the quantity and variety of waste generated. It is now realized that if waste generation continues indiscriminately then very soon it would be beyond rectification. Management o solid wastehas, therefore, become very important in order to minimize the adverse effects of solid wastes. For waste management we stress on three **R's'-Reduce, reuse and recycle** before destruction and safe storage of wastes.

i) **Reduction in use of raw materials**: Reduction in the use of raw materials will correspondingly decrease the production of waste. Reduced demand for any metallic product will decrease the mining of their metal and cause less productionof waste.

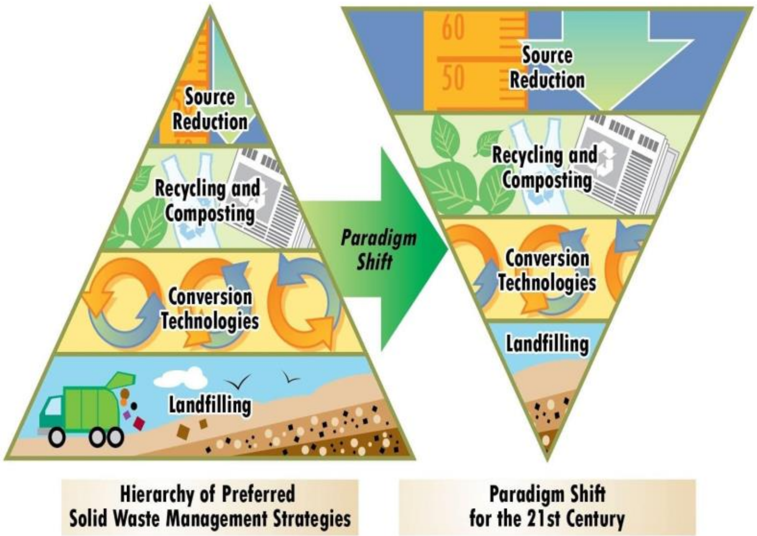
ii) **Reuse of waste material**: The refillable containers which are discarded after usecan be reused. Villagers make casseroles and silos from waste paper and other waste materials. Making rubber rings from the discarded cycle tubes which are used by newspaper vendors. instead of rubber bands, reduce the waste generationduring manufacturing of rubber bands. Because of financial constraints poor people reuse their materials to the maximum.

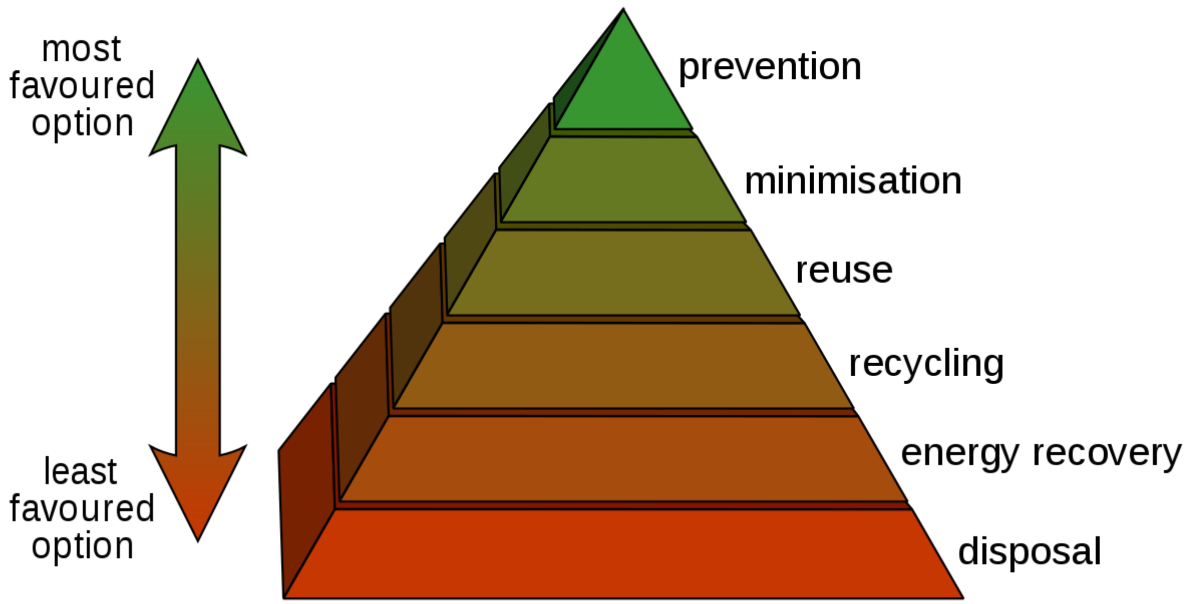
iii) **Recycling of waste materials**: Recycling is the reprocessing of discarded materials into new useful products.

Formation of some old type products e.g old aluminum cans and glass bottles are melted and recast into new cans and bottles.

Formation of new products: Preparation of cellulose insulation from paper, preparation of fuel pellets from kitchen waste. Preparation of automobiles and construction materials fromsteel cans.

The process of reducing, reusing and recycling saves money, energy, raw materials, land space and also reduce pollution. Recycling of paper will reduce cutting of trees. for making fresh paper. Reuse of metals will reduce mining and melting of ores for recovery of metals from ores and prevent pollution.





Waste prevention, as the preferred option, is followed by reuse, recycling, recovery including energy recovery and as a last option, safe disposal. Among engineers, a similar hierarchy of waste management has been known as ARRE strategy: avoid, reduce, recycle, eliminate.

The activities associated with the management of municipal solid wastes from the point of generation to final disposal can be grouped into the six functional elements:
(a) waste generation; (b) waste handling and sorting, storage, and processing at the source; (c) collection; (d) sorting, processing and transformation; (e) transfer and transport; and (f) disposal

Waste Generation: Waste generation encompasses activities in which materials are identified as no longer being of value (in their present form) and are either thrown away or gathered together for disposal. Waste generation is, at present, an activity that is not very controllable. In the future, however, more control is likely to be exercised over the generation of wastes. Reduction of waste at source, although not controlled by solid waste managers, is now included in system evaluations as a method of limiting the quantity of waste generated.

Waste Handling, Sorting, Storage, and Processing at the Source: The second of the six functional elements in the solid waste management system is waste handling, sorting, storage, and processing at the source. Waste handling and sorting involves the activities associated with management of wastes until they

are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Sorting of waste components is an important step in the handling and storage of solid waste at the source. For example, the best place to separate waste materials for reuse and recycling is at the source of generation. Households are becoming more aware of the importance of separating newspaper and cardboard, bottles/glass, kitchen wastes and ferrous and non-ferrous materials.
On-site storage is of primary importance because of public health concerns and aesthetic consideration. Unsightly makeshift containers and even open ground storage, both of which are undesirable, are often seen at many residential and commercial sites. The cost of providing storage for solid wastes at the source is normally borne by the household in the case of individuals, or by the management of commercial and industrial properties. Processing at the source involves activities such as backyard waste composting.
Collection: The functional element of collection includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may be a materials processing facility, a transfer station, or a landfill disposal site.

Sorting, Processing and Transformation of Solid Waste: The sorting, processing and transformation of solid waste materials is the fourth of the functional elements. The recovery of sorted materials, processing of solid waste and transformation of solid waste that occurs primarily in locations away from the source of waste generation are encompassed by this functional element. Sorting of commingled (mixed) wastes usually occurs at a materials recovery facility, transfer stations, combustion facilities, and disposal sites. Sorting often includes the separation of bulky items, separation of waste components by size using screens, manual separation of waste components, and separation of ferrous and non-ferrous metals.
Waste processing is undertaken to recover conversion products and energy. The organic fraction of Municipal Solid Waste (MSW) can be transformed by a variety of biological and thermal processes. The most commonly used biological transformation process is aerobic composting. The most commonly used thermal transformation process is incineration. Waste transformation is undertaken to reduce the volume, weight, size or toxicity of waste without resource recovery. Transformation may be done by a variety of mechanical (eg shredding), thermal (e.g. incineration without energy recovery) or chemical (e.g. encapsulation) techniques.

Transfer and Transport: The functional element of transfer and transport involves two steps: (i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (ii) the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station.

Disposal: The final functional element in the solid waste management system is disposal. Today the disposal of wastes by landfilling or uncontrolled dumping is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from Materials Recovery Facilities (MRFs), residue from the combustion of solid waste, rejects of composting, or other substances from various solid waste-processing facilities. A municipal solid waste landfill plant is an engineered facility used for disposing of solid wastes on land or within the earth's mantle without creating nuisance or hazard to public health or safety, such as breeding of rodents and insects and contamination of groundwater.

HIERARCHY OF WASTE MANAGEMENT OPTIONS
Current thinking on the best methods to deal with waste is centred on a broadly accepted 'hierarchy of waste management' (arrangement in order of rank) which gives a priority listing of the waste management options available The hierarchy gives important general guidelines on the relative desirability of the different management options. The hierarchy usually adopted is **(a) waste minimisation/reduction at source, (b) recycling, (c) waste processing (withrecovery of resources i.e. materials (products) and energy), (d) waste transformation (without recovery of resources) and (e) disposal on land(landfilling).**

- The highest rank of the ISWM hierarchy is **waste minimisation or reduction at source**, which involves reducing the amount (and/or toxicity) of the wastes produced. Reduction at source is first in the hierarchy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts.

- The second highest rank in the hierarchy is **recycling,** which involves (a) the separation and sorting of waste materials; (b) the preparation of these materials for reuse or reprocessing; and (c) the reuse and reprocessing of these materials. Recycling is an important factor which helps to reduce the demand on resources and the amount of waste requiring disposal by landfilling.
- The third rank in the ISWM hierarchy is **waste processing** which involves alteration of wastes to recover conversion products (e.g., compost) and energy. The processing of waste materials usually results in the reduced use of landfill capacity.
- **Transformation of waste**, without recovery of products or energy, may have to be undertaken to reduce waste volume (e.g. shredding and baling) or to reduce toxicity. This is usually ranked fourth in the ISWM hierarchy.
- Ultimately, something must be done with (a) the solid wastes that cannot be recycled and are of no further use; (b) the residual matter remaining after solid wastes have been pre-sorted at a materials recovery facility; and (c) the residual matter remaining after the recovery of conversion products or energy. **Landfilling** is the fifth rank of the ISWM hierarchy and involves the controlled disposal of wastes on or in the earth's mantle. It is by far the most common method of ultimate disposal for waste residuals. Landfilling is the lowest rank in the ISWM hierarchy because it represents the least desirable means of dealing wi th society's wastes.

WASTE MINIMISATION

- Waste minimisation or reduction at source is the most desirable activity, because the community does not incur expenditure for waste handling, recycling and disposal of waste that is never created and delivered to the waste management system. However, it is an unfamiliar activity as it has not been included in earlier waste management systems.
- To reduce the amount of waste generated at the source, the most practical and promising methods appear to be (i) the adoption of industry standards for product manufacturing and packaging that use less material, (ii) the passing of laws that minimise the use of virgin materials in consumer products, and (iii) the levying (by communities) of cess/fees for waste management services that penalise generators in case of increase in waste quantities.
- Modifications in product packaging standards can result in reduction of waste packaging material or use of recyclable materials. Minimisation of use of virgin raw materials by the manufacturing industry promotes substitution by recycled materials.
- Sorting at source, recycling at source and processing at source (e.g. yard composting) help in waste minimisation.
- One waste management strategy used in some communities in developed countries is to charge a variable rate per can (or ton) of waste, which gives generators a financial incentive to reduce the amount of waste set out for collection. Issues related to the use of variable rates include the ability to generate the revenues required to pay the costs of facilities, the administration of a complex monitoring and reporting network for service, and the extent to which wastes are being put in another place by the generator and not reduced at source

E Waste

- **Re-cycling**

Monitors & CRT, keyboards, laptops, modems, telephone boards, hard drives, floppy drives, Compact disks, mobiles, fax machines, printers, CPUs, memory chips, connecting wires & cables can be recycled. Recycling involves **dismantling** i.e. removal of different parts of e-waste containing dangerous substances like PCB, Hg, separation of plastic, removal of CRT, segregation of ferrous and non-ferrous metals and printed circuit boards.

Proposed Solutions to the Problem of e waste

- Need to spread awareness for safe disposal of domestic waste.
- Awareness Camps/Campaign
- Improvement in Take-Back policies
- Attract investment in this sector
- Link up activities of informal sector with formal sector
- Social media can spread awareness
- Promote adequate technologies for recycling
- Training to generators on e-waste handling
- e-certificate to dealers for managing e-waste
- Tax benefit if company is having e-certificate
- e-waste fair

Recyclers use strong acids to remove precious metals such as copper, lead, gold. The value of recycling from the element could be much higher if appropriate technologies are used.

The recyclers working in poorly-ventilated enclosed areas without mask and technical expertise results in exposure to dangerous and slow poisoning chemicals

The existing dumping grounds in India are full and overflowing beyond capacity and it isdifficult to get new dumping sites due to scarcity of land.. **Therefore recycling is the best possible option for the management of e-waste**

Recycling of E-Waste can be broadly divided into three steps

- Disassembly/dismantling :Removal of components, parts, a group of parts or a subassembly from a product which is in E-Waste
- Upgrading :

Separation of materials using mechanical / physicaland/or metallurgical processing. Methods to recover materials include incinerationand refining.

- Materials Recovery :

The plastic, glass, metals can be recovered bysorting them before mixing with other waste.

What Happens to Devices at the End of Their Useful Life

Unfortunately, the majority of these electronic products end up in landfills, and just 20% of e-waste is recycled.According to a UN study, about 50 million tons of e-waste was discarded worldwide.[2]
Electronics are full of valuable materials, including copper, tin, iron, aluminum, fossil fuels, titanium, gold, and silver. Many of the materials used in making these electronic devices can be recovered, reused, and recycled—including plastics, metals, and glass. In a report, Apple revealed that it recovered 2,204 pounds of gold —worth $40 million— from recycled iPhones, Macs, and iPads in 2015.

Benefits of E-Waste Recycling

Recycling e-waste enables us to recover various valuable metals and other materials from electronics, savingnatural resources (energy), reducing pollution, conserving landfill space, and creating jobs. According to theEPA, recycling one million cell phones can also recover 75 pounds of gold, 772 pounds of silver, 35,000 pounds of copper, and 33 pounds of palladium.

On the other end, e-waste recycling helps **cut down on production waste**. According to the Electronics Take-Back Coalition, it takes 1.5 tons of water, 530 pounds of fossil fuel, and 40 pounds of chemicals to manufacture a single computer and monitor. Eighty one percent of the energy associated with a computer is used during production and not during operation.

The Electronics Recycling Process

Electronics recycling can be challenging because discarded electronics devices are sophisticated devices manufactured from varying proportions of glass, metals, and plastics. The process of recycling can vary, depending on the materials being recycled and the technologies employed, but here is a general overview.

Collection and Transportation: Collection and transportation are two of the initial stages of the recycling process, including for e-waste. Recyclers place collection bins or electronics take-back booths in specific locations and transport the collected e-waste from these sites to recycling plants and facilities.

Shredding, Sorting, and Separation: After collection and transportation to recycling facilities, materials inthe e-waste stream must be processed and separated into clean commodities that can be used to make new products. Efficient separation of materials is the foundation of electronics recycling. Shredding the e-waste

facilitates the sorting and separation of plastics from metals and internal circuitry, and waste items areshredded into pieces as small as 100mm to prepare for further sorting.

A powerful overhead magnet separates iron and steel from the waste stream on the conveyor and then prepares it for sale as recycled steel.
Further mechanical processing separates aluminum, copper, and circuit boards fromthe material stream—which now is mostly plastic.
Water separation technology is then used to separate glass from plastics.
The final step in the separation process locates and extracts any remaining metal remnants from the plastics to purify the stream further.

Preparation For Sale as Recycled Materials: After the shredding, sorting and separation stages have beenexecuted, the separated materials are prepared for sale as usable raw materials for the production of new electronics or other products.

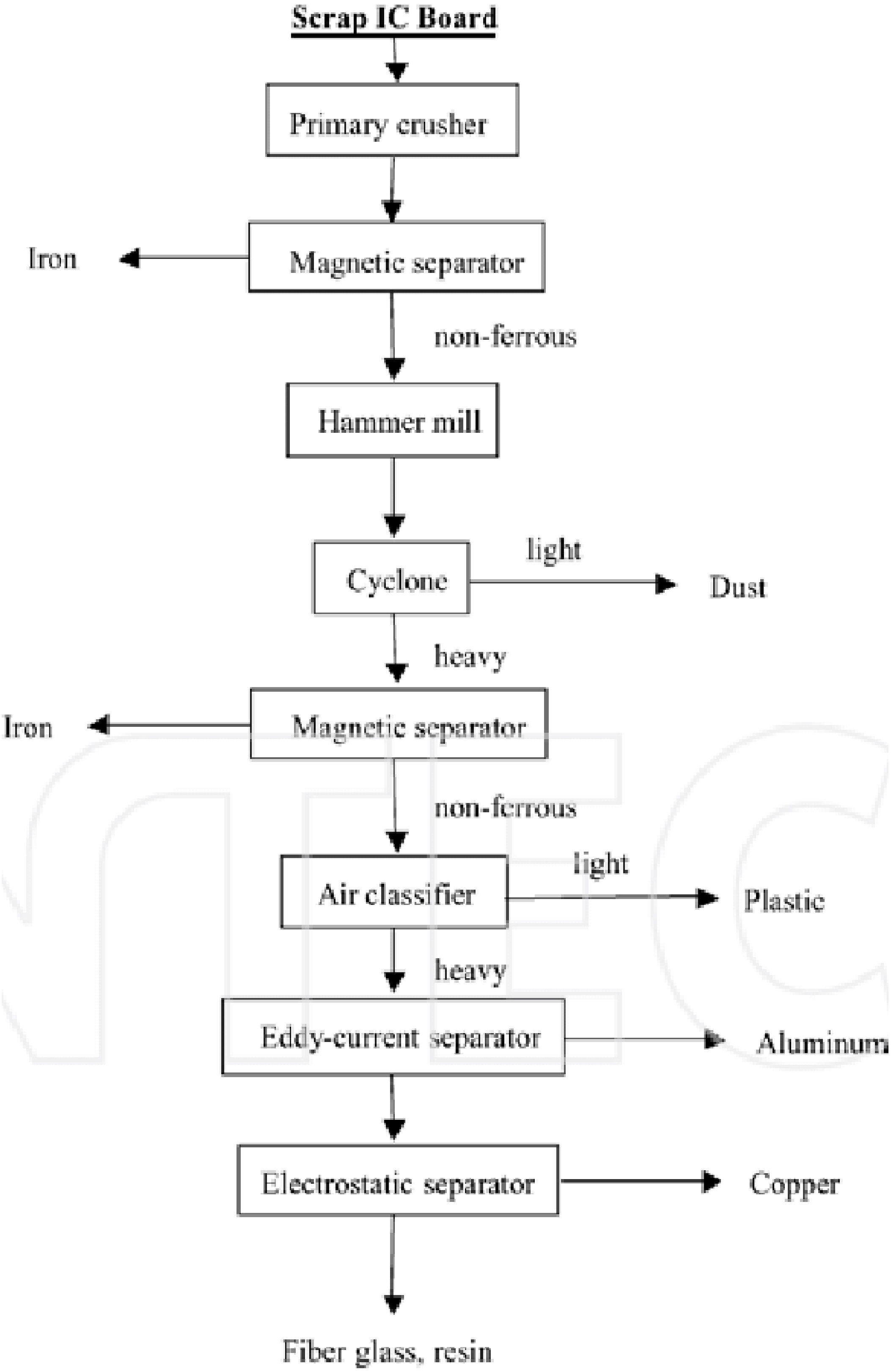


Fig: Recycling of e waste

- **Reuse of e-waste**

It constitutes direct second hand use or use after slight modifications to the original functioning equipment. It is commonly used for electronic equipments like computers, cell phones etc. Inkjet cartridge is also used afterrefilling. This method also reduces the volume of e-waste generation. We can use above mentioned methods for treatment and disposal of e-waste. The better option is to avoid its generation. To achieve this, buy back of old electronic equipments shall be made mandatory. Large companies should purchase the used equipments back from the customers and ensure proper treatment and disposal of e-waste by authorized processes. This can considerably reduce the volume of e- waste generation.

Solid Waste

7. Recycling and Reuse

Recycling and reuse of the waste helps to reduce the problem of waste disposal.

About 70% by weight of municipal solid waste from domestic and commercial areas is combustible. One ton of such a waste is approximately equal to 9 million British Thermal Units (BTU) of heat or 65 gallons of fuel oil or 9000 cubic feet of natural gas. But still only a small percentage of the resources is being recovered.

In some municipal solid waste processing facilities, the combustibles are separated from the non -combustibles. The combustibles are then shredded and burnt in utility boilers or industrial boilers as a primary fuel or as a supplement to fossil fuels. This type of solid waste processing operation is known as a **refuse –derived fuel** (RDF) system. RDF is used to supplement other fuel sources in a ratio of 20%RDF to 80% fossil fuels. It was reported that 29RDF systems were operated in USA for power generation as early as in 1983, processing 1250 to 18000 tons of waste per week. Incineration and RDF technologies seem to be competitive in cost.

A ton of solid waste processed by pyrolysis is believed to yield an energy equivalent of one barrel of oil. The city of Baltimore reportedly operated a commercial scale facility in 1975 to produce 4.8 million pounds of steam daily from low BTU (BTU –British Thermal Unit is the international measure of energy. A BTU is the amount of heat needed to raise one pound of water by one degree Fahrenheit.) gas generated by pyrolysis of municipal solid waste. Thus , saving of 357000 barrels of oil annually was accomplished, in addition to the revenue earned from ferrous metals sorted out and the sale of glassy aggregate for use in concrete manufacture and street paving. Economic viability of full scale commercial pyrolysis facility has still not been proved beyond doubt. The advantage of pyrolysis is that it produces a more generally useful and transportable form of energy.

Rubber Tyres

Rubber tyres continue to pose disposable problems. They do not decompose well in landfills. Incineration of rubber must be done in specially designed facilities to check air pollution and to accommodate the intense heat produced by burning rubber. The BTU content of burning rubber is nearly equal to that of coal. Some systems burning rubber as fuel were successful. However these were necessarily small scale operations due to limited supply of tyres.

Paper

Reclamation of reusable materials such as paper, glass, metal, cardboard and plastics from municipal wastes, though received considerable attention, has not been very successful due to economic considerations.

Paper constitutes nearly 50% by weight of the solid wastes. Total recycling of paper has not been possible so far. Unrecoverable paper is generally disposed by controlled incineration and the gaseous products obtained are CO_2 and water vapour which are non polluting.paper has a high heat of combustion and hence is disposed by converting it to energy. Refuse derived Fuel(RDF) can be used as supplementary fuel for use in boilers or in other combustion processes.

Metals

From the standpoint of energy conservation there is every justification for the recycling and reuse of ferrous metals, aluminium and some other non ferrous metals because the mining of virgin material is energy intensive. Reynolds Metals Company (USA) was reportedly recycling used aluminium cans from packaging industry.

Glass

As far as glass is concerned, it was found that the energy spent on reuse of old glass is more than that required to process new material. Hence energy savings can be realized only by reuse of glass containers than to reprocess them.

Plastic

Recycling of plastic received considerable attention primarily because of ever increasing use of plastics and also because of their non- biodegradable nature. For a satisfactory recycling of plastics the following **two requirements** are to be satisfied.

i) The plastic material should be made up of only one type , i.e it should be homogeneous.
ii) The plastic scrap or waste should be collected from the consumers or intercepted on its way from consumers to the municipal refuse site.

Recycling of plastics may be carried out in any of the following ways

i) **Primary recycling** where the same plastic product is manufactured again
ii) **Secondary recycling** where the material is reprocessed to a new product with different composition and in some cases may be inferior in properties.
iii) **Tertiary recycling** where the plastic is completely processed to a new form as in pyrolysis (where some chemicals are removed).In USA, high density polyethylene bottles used for supplying milk ,are collected from consumers and are converted to flake powder by grinding. This can be used for manufacturing plastic drainage pipes or as inert fill material or as an aggregate for low weight concrete.

Segregation

Segregation of E waste

Waste segregation is included in law because it is much easier to recycle. Effective segregation of wastes means that less waste goes to landfill which makes it cheaper and better for people and the environment. It isalso important to segregate for public health. In particular, hazardous wastes can cause long term health problems, so it is very important that they are disposed of correctly and safely and not mixed in with the normal waste coming out of your home or office.

Segregation of Biomedical waste

Segregation refers to the basic separation of different categories of waste generated at source and thereby reducing the risks as well as cost of handling and disposal. Segregation is the most crucial step in bio-medical waste management. Effective segregation alone can ensure effective biomedical waste management.

Segregation reduces the amount of waste needs special handling and treatment

Effective segregation process prevents the mixture of medical waste like sharps with the general municipal waste.

Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics.

Provides an opportunity for recycling certain components of medical waste like plastics after proper and thorough disinfection.

Recycled plastic material can be used for non-food grade applications.

Of the general waste, the biodegradable waste can be composted within the hospital premises and can be used for gardening purposes.

Recycling is a good environmental practice, which can also double as a revenue generating activity.

Reduces the cost of treatment and disposal (80 per cent of a hospital’s waste is general waste, which does not require special treatment, provided it is not contaminated with other infectious waste)

Segregation of Solid Waste

Prior to recycling the waste should be segregated

Separating our waste is essential as the amount of waste being generated today causes immense problems.

Certain items are not biodegradable but can be reused or recycled

In fact it is believed that a larger portion can be recycled ,a part of it can be converted to compost and only a smaller portion of it is real waste that has no use and has to be discarded.

Waste can be segregated as 1.Biodegradable

and 2. Non biodegradable

Biodegradable waste include organic waste e.g kitchen waste, vegetable. fruits, flower leaves from garden, and paper.

Non Biodegradable waste can further be segregated into

a) Recyclable waste- plastic, metal, glass, paper
b) Toxic waste-old medicines ,paints, chemicals, bulbs, spray cans, fertilizers and pesticide containers, batteries, shoe polish
c) Soiled-Hospital waste such as cloth soiled with blood and other body fluids

Toxic and soiled waste must be disposed of with utmost care.

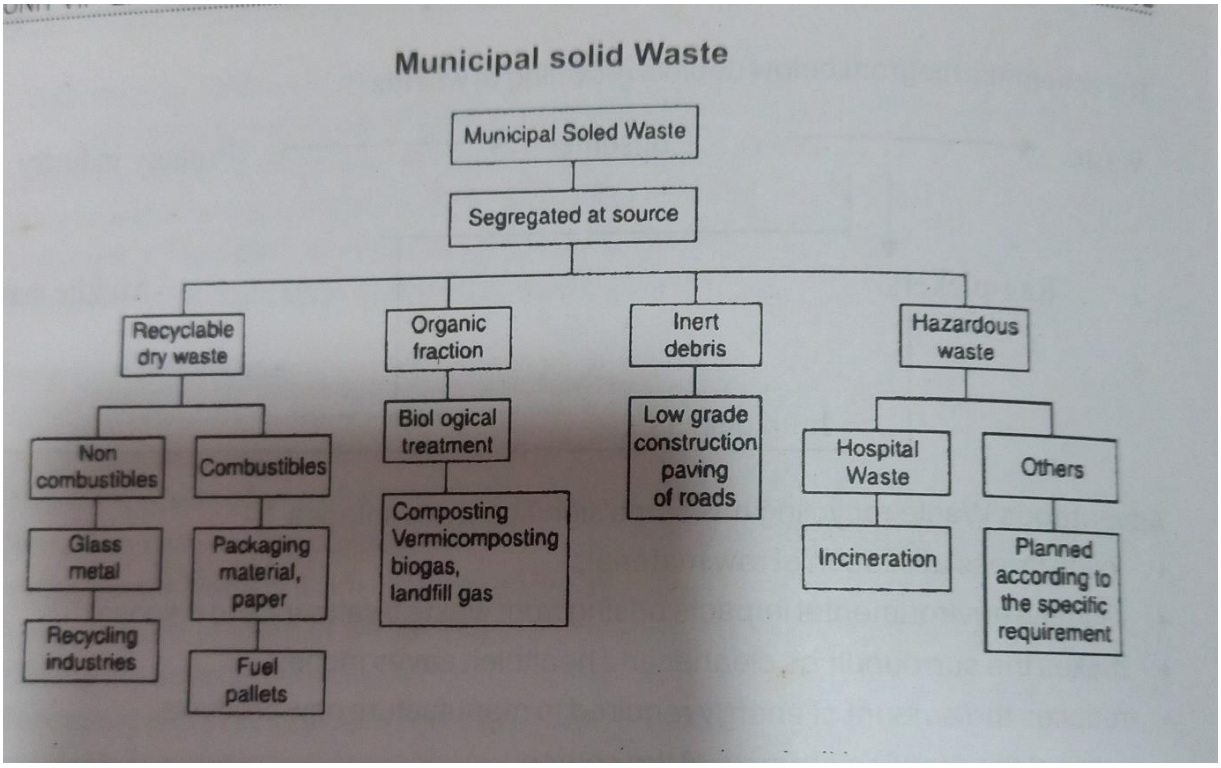


Fig: Schematic Representation of Segregation of solid waste

Plastic Waste

On an average, production of plastic globally crosses 150 Million tonnes per year. Its broad range of application is in packaging films, wrapping materials, shopping and garbage, bags, fluid containers, clothing, toys, household and industrial products, and building materials.
Approximately 70% of plastic packaging products are converted into plastic waste in a short span.

Why study of plastic waste is important?
Once plastic is discarded after its utility is over, it is known as plastic waste. It is a fact that plastic waste never degrades, and remain on landscape for several years. Mostly, plastic waste is recyclable but recycled products are more harmful to the environment as this contains additives and colors.

Harmful Effects of Plastics

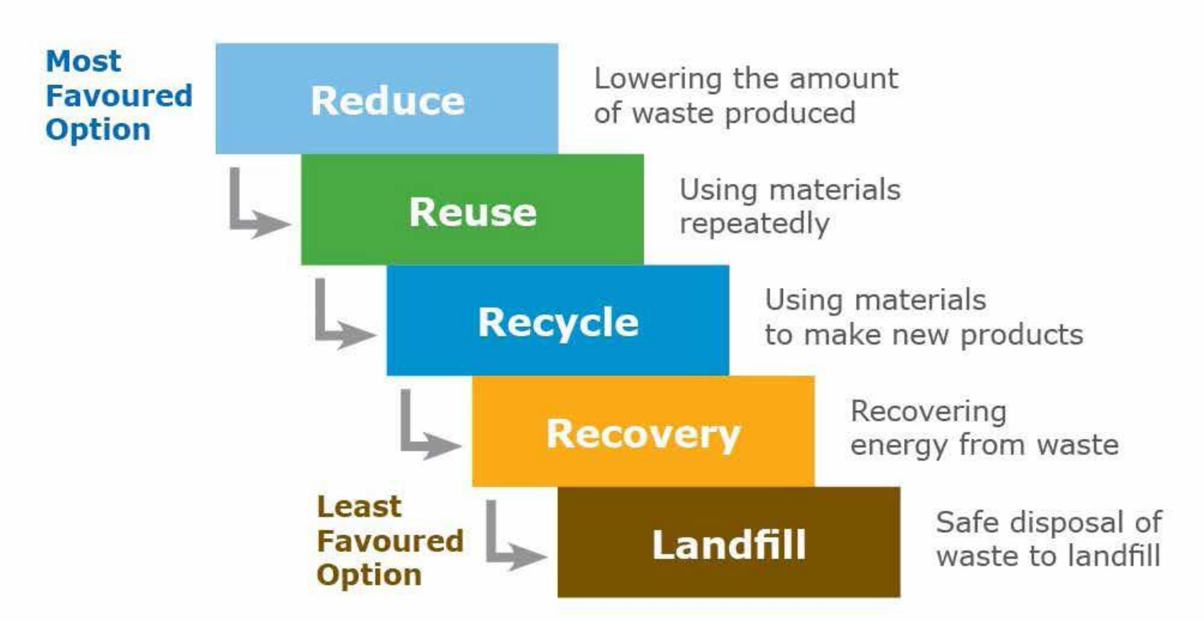
• Groundwater and soil pollution
Plastic is a material made to last forever, and due to the same chemical composition, plastic cannot biodegrade; it breaks down into smaller and smaller pieces5. When buried in a landfill, plastic lies untreated for years. In the process, toxic chemicals from plastics drain out and seep into groundwater, flowing downstream into lakes and rivers. The seeping of plastic also causes soil pollution and have now started resulting in presence of micro plastics in soil.
• Pollution in Oceans
The increased presence of plastic on the ocean surface has resulted in more serious problems. Since most of the plastic debris that reaches the ocean remains floating for years as it does not decompose quickly, it leads to the dropping of oxygen level in the water, severely affecting the survival of marine species. Materials like plastic are non-degradable which means they will not be absorbed and recycled. When oceanic creatures and even birds consume plastic inadvertently, they choke on it which causes a steady decline in their population. The harmful effects of plastic on aquatic life are devastating, and accelerating. In addition to suffocation, ingestion, and other macro-particulate causes of death in larger birds, fish, and mammals, the plastic is ingested by smaller and smaller creatures (as it breaks down into smaller and smaller particles) and bio accumulates in greater and greater concentrations up the food chain—with humans at the top.
• Dangerous for human life
Burning of plastic results into formation of a class of flame retardants called as Halogens.
Collectively, these harmful chemicals are known to cause the following severe health problems: cancer, endometriosis, neurological damage, endocrine disruption, birth defects and child developmental disorders, reproductive damage, immune damage, asthma, and multiple organ damage.
There is a constant increase in plastics waste generation. One of the major reasons for this is that 50% of plastic is discarded as waste after single use.
This also adds to increase in the carbon footprint since single use of plastic products increase the demand for virgin plastic products

Types of Plastics

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 at the urging of recyclers around the country.
The seven types of plastic include:
1. Polyethylene Terephthalate (PETE or PET)
2. High-Density Polyethylene (HDPE) 3. Polyvinyl Chloride (PVC)
4. Low-Density Polyethylene (LDPE)
5. Polypropylene (PP)
6. Polystyrene or Styrofoam (PS)
7. Miscellaneous plastics (includes: polycarbonate, polylactide, acrylic, acrylonitrile butadiene, styrene, fiberglass, and nylon)
Figure: Examples

Plastic Waste Management by Reduce, Reuse, Recycle, and Recovery Principle

Plastic bags are popular with consumers and retailers as they are a functional, lightweight, strong, cheap, and hygienic way to transport food and other products. Most of these go to landfill and garbage heaps after they are used, and some are recycled. Once littered, plastic bags can find their way on to our streets, parks and into our waterways. Although plastic bags make up only a small percentage of all litter, the impact of these bags is nevertheless significant. Plastic bags create visual pollution problems and can have harmful effects on aquatic and terrestrial animals. Plastic bags are particularly noticeable components of the litter stream due to their size and can take a long time to fully break down. Many carry bags end up as unsightly litter in trees, streets, parks and gardens which, besides being ugly, can kill birds, small mammals and other creatures. Bags that make it to the ocean may be eaten by sea turtles and marine mammals, who mistake them for jellyfish, with disastrous consequences. In developed countries billion bags are thrown away every year, most of which are used only once before disposal. The biggest problem with plastic bags is that they do not readily break down in the environment. It has been found that, the average plastic carrier bag is used for five minutes, but takes 500 years to decompose.



Reduce

Plastic, of course, is uniquely problematic because it's non-biodegradable and therefore sticks around for a lot longer than the other forms of waste. Few small steps in day to day life would help to keep plastics a possible out of the waste stream. Some of these steps may include:

1. Discourage the use of disposal plastics

Ninety percent of the plastic items in our daily lives are used once and then abandoned: grocery bags, plastic wrap, disposable cutlery, straws, coffee-cup lids. Take note of how often we rely on these products and replace them with reusable versions. It only takes a few times of bringing our own bags to the store, silverware to the office, or travel mug to office tea areas before it becomes habit.

2.Minimize Buying Water

Each year, close to 20 billion plastic bottles are thrown in the trash. Making a habit of using reusable bottle in the bag, use of water from office, home and work areas where the quality of the water can be trusted 3.

3.Minimize use of Plastics Cutlery Making a habit of using metal utensils instead of plastic cutlery would help saving a lot of plastics that is thrown in thrash every year.

4. Purchase item Secondhand

The newer items comes with lot of packaging materials instead try to use secondhand materials until it is very necessary

5. Support a bag Tax or Ban

Support legislations and by laws which put taxes on ban of single use plastics

Reuse

Reuse is a step up from recycling. It diverts plastic and takes pressure off the recycling services. In fact, reuse is the middle-man between reduce and recycle, and some would be surprised at how many opportunities for reuse there really are. One can reuse plastic-produce bags for sandwiches, plastic grocery bags for small trash bags, and re-use plastic silverware. Most people skip this step and go directly to recycling, but reusing plastics can reduce the demand for new plastics to be created. For instance, since refillable plastic containers can be reused for many times, container reuse can lead to a substantial reduction in the demand for disposable plastic and reduced use of materials and energy, with the consequent reduced environmental impacts.

Recycle

Recycling and re-utilization of waste plastics have several advantages. It leads to a reduction of the use of virgin materials and of the use of energy, thus also a reduction of carbon dioxide emissions.

Benefits of Recycling:

• Reduces Environmental Pollution
• Energy savings: 40 - 100 MJ/kg (depends on the polymer)
• Economic Benefits
• Reduces demand for virgin polymer
• Preferred to Land Filling
• Generates Employment
• Reduces depletion of Fossil fuel reserves

Difficulties in Recycling:

• Hard to separate from non-plastics (no ‘magnet’ equivalent)
• Differing composition of plastic resins means they are largely incompatible
• Degradation of polymer chains on recycling
• Recycled polymer is of lower quality than virgin Polymer

Most waste plastics films specially thin plastics films have limited market value, therefore effort is not spent in collecting them

• Identification of reuse and recycling opportunities
• Markets for Plastics; Lack of Infrastructure

• Low value of recovered Plastics
• Subsidies for recycling program

A number of recycling techniques of the plastics have been collected which can be adopted by the municipality in dealing the issue of plastic waste. It includes technology like
1. Mechanical Recycling
2. Feedstock Recycling
3. Plastic to Road Construction
4. Plastic to Toilet / Pavement Blocks
5. Recycling of Multi-layered plastic

Recovery
Another alternative is recovering the energy stored in residual material. That means turning waste into fuel for manufacturing processes or equipment designed to produce energy. Various mechanical, biological and caloric systems and technologies can convert, reprocess or break up wastes into new materials or energy.