Unit 4

Solid Waste Management

- Refuse, Garbage, Rubbish, Ash, types of solid waste
- Necessity of safe disposal, Impacts on human health and environment
- Classification of solid wastes- Quantity and composition of MSW, Collection of solid waste- methods
- Disposal of solid waste-Sanitary land-fill
- E-waste- Problems and solutions
- Biomedical waste-Impacts on human health, storage, treatment methods and disposal
- Numerical problems on moisture content, density & area land fill

Solid waste: The term solid waste includes all those solid and semi-solid materials that are discarded by a community. The solid waste generated through domestic and commercial activities is called as municipal solid waste (MSW). The waste generated by industries is known as industrial waste.

Solid waste generates from human and animal activities and solid waste comprise both commercial and domestic wastes. The solid wastes are commonly referred as refuse. Solid waste consists of garbage (kitchen waste), packaging materials such as plastic, paper, metals etc. Construction waste (rubbish), abandoned vehicles, industrial process waste, pathological wastes (medical waste) etc. Rapid industrialization, population growth and urbanization have lead to generation of enormous quantity of solid waste. Improper management of solid waste contributes for land pollution. Generally the wastes are disposed in open dumps, which create considerable nuisance and environmental problems. The health risks involved are breeding of flies and rat. Flies transmit diseases such as cholera, dysentery and rats infect by direct bites, spreading disease like plague and destroy property. The more serious one is the contamination of ground and surface water by leachates formed from solid waste dumps.

Putrescible organic wastes causes odour nuisance. Air pollution can be caused by gases released by the anaerobic degradation of waste and improper burning of wastes, either in open or in incinerators. The industrial hazardous waste causes fire hazards, explosions, corrosion, and bioaccumulation in the food chain and can cause cancer or injury to human and animal life. The proper management of solid waste is very important to avoid the severe environmental problems.

Classification of solid wastes:

1. **Garbage:** It is highly putrescible organic waste such as vegetable, fruit or meat and food residues generated from kitchens, restaurants, hotels etc.
2. **Rubbish:** These wastes do not decompose rapidly such as paper, textiles, leather, cardboard, plastics, rubber, metals, glass etc.
3. **Ashes:** These are the remaining of materials from the burning of coal, coke, wood and other combustible materials such as cinders, clinkers and so on.
4. **Agricultural wastes:** These include crop residues from agricultural field, farm manure etc such as cotton, jute, sugarcane wastes, rice straw etc.
5. **Construction and demolition wastes:** These are wastes from construction and demolition activities that includes stones, bricks, dust, concrete, wood, plumbing and sanitary parts etc.
6. **Industrial wastes:** These are wastes generated from industrial activities that includes fly ash, chemicals, paints, package wastes, glass, toxic metals etc
7. **Biomedical wastes:** These are wastes generated from nursing homes, hospitals, veterinary institution etc.
8. **Hazardous wastes:** These are the wastes that are chemically or biologically toxic, flammable, reactive, explosive or corrosive. These wastes cause adverse effects on human, plant or animals.
9. **Miscellaneous waste:** Wastes those are not included in the above categories, such as dead animals, street sweepings, road side litter, tyres, electronic wastes, abandoned vehicles, sewage treatment plant sludge etc.

Necessity for safe disposal of solid waste: The disposal of solid waste is a problem. This problem continues to grow with the growth of population and development of industries. Disposal of waste in open pits has become routine in majority of places. Semisolid or solid matters that are creating by human or animal activities and which are disposed because they are hazardous or useless are known as solid waste. Most of the solid wastes like paper, plastic containers, bottles, cans, used cars and electronics are not biodegradable, which means they do not get broken through organic process. Thus when they accumulate they pose a health threat to people and decaying waste also attract household pests and results in urban areas becoming unhealthy, dirty and unsightly places to reside. It also causes damage to terrestrial organisms, while also reducing the uses of land for other useful purposes. In addition to causing possible outbreaks of diseases, the improper management of solid wastes

causes adverse effects on ecology. Dumping of solid waste at a particular waste dumping site may lead to the formation of leachate during rain which may seep down and contaminate ground water. This happens when the dumped refuse contains non-biodegradable and carcinogenic substances such as plastics, unused medicines, paints, insecticides, etc which may start troubling on coming in contact with rain water seeping through the dumped garbage producing a colored liquid called leachate. This highly poisonous leachate containing organic compounds like chlorinated hydrocarbons such as benzene, toluene, xylene etc and toxic elements such as arsenic, copper, uranium etc are likely to seep to the ground water-table to pollute the ground water leading to various diseases.

Although the natural processes possess enough capacity to dilute, disperse, degrade, absorb or otherwise dispose of unwanted materials, but that capacity has now come under tremendous stress due to the enormous quantities of waste being generated by the modern society. Hence there is necessary for safe disposal of solid waste to control all kinds of pollution.

Composition and quantity of solid wastes: The municipal solid waste is a heterogeneous mixture of various kinds of solid wastes which are not transported with water as sewage and may include biodegradable food wastes called garbage and non-biodegradable solid wastes like paper, glass, metal items etc called rubbish.

The garbage includes all sorts of putrescible (bio-degradable) organic wastes obtained from kitchens, hotels, restaurants, etc; All waste foods, vegetable peelings, fruit peelings, etc are thus included in this term. These wastes are organic in nature and thus likely to decompose quickly producing foul odours and health hazards. They may also result in breeding of flies, mosquitoes, insects, etc. Hence garbage must be disposed of properly and quickly. When it is scientifically processed and composted, then it is possible to obtain valuable products like grease, fertilizer etc from the garbage. The density of garbage usually varies between 450 to 900 $kg/m^{3.}$

The rubbish can include a variety of materials, which may either be combustible (such as paper, plastic, textiles etc) or incombustible (such as broken glass, crockery, metal, masonry etc). Most of these types of wastes are discarded on a regular basis from homes, offices and small commercial establishments. The density of rubbish usually varies between 50 to 400 $kg/m^{3.}$

In addition, ashes from household hearths may also get included in municipal solid wastes, although its quantity is getting reduced in modern urban homes, due to increasing use of cooking gas, kerosene oil stoves and lesser use of firewood. The density of ashes generally varies between 700 to 850 kg/$m^{3.}$

The municipal solid waste may also include the fine dust, silt and sand obtained from street sweepings, certain special wastes such as construction debris, abandoned appliances and automobiles etc.

In addition there are many other solid wastes that are normally not the responsibility of municipal bodies. These may include ashes from thermal power plants, sludge from water and waste-water treatment plants, wastes from animal feed lots (cattle dung), mine tailings, biomedical wastes and other industrial wastes. All such wastes require separate arrangements for their disposal.

The quantity of municipal solid waste produced by a society depends upon the living standards of its residents. The degree of commercialization, urbanization and industrialization has resulted in a vast increase in the amount of refuse generated per person. For example, the average per capita daily refuse production in United States is as high as about 2.8 kg, whereas, the average per capita daily refuse production in India is only about 0.5 kg. The average composition of refuse (by weight) is estimated to be as shown in table

Particulars	**Percentage**
Garbage	45
Rubbish	15
Ashes	15
Fine dust, silt and sand	25

Solid waste management:

Indiscriminate disposal of solid waste causes adverse effects on environment. The main objective of solid waste management is to minimize or eliminate the adverse effects before it becomes too difficult to identify in the future.

Solid waste management involves the following activities:

a) **Collection of solid wastes**
b) **Transportation of solid wastes**
c) **Disposal of solid wastes**
d) **Waste utilization.**

a) Collection of solid wastes: Activities associated with the gathering of solid waste and hauling it to the location from where it will be transferred to the collection vehicles. Ultimately the collection vehicle transports it to the disposal site.

There are four basic methods of collection are

(i) **Door to door collection:** In this method collection person enter the backyard and collect the solid waste in to large container or to push cart. The collection methods are labor intensive and cheaper compared to mechanized collection.

(ii) **Community storage system:** In this method the individuals deposit their waste in metal or concrete bins located at street corners. The waste is stored till the waste collection agency comes and collects it in to vehicles. The frequency of collection will be daily, alternative days, twice a week or once in a week. Community storage may reduce the cost of waste collection and can minimize the problem associated with the onsite storage.

(iii) **Kerb side collection:** In this method the waste is brought in containers by the individuals and placed on the footpath prior to the collection time from where it is collected by the waste collection agency.

(iv) **Block collection:** Individual brings the waste in containers and the collection staff empties it into the waiting collection vehicles.

b) Transportation of solid wastes: The transporting trucks should be of high quality, of special design and be properly maintained. They should be strong, durable and water tight and made up of stainless steel with smooth interior, having rounded corners for facility of cleaning. They should have a loading line, say upto 1.5 m, so that minimum of time and effort is required in filling them. They should have a cover, which should be as a part of the body with hatches, which can be opened during collection. Mechanical devices should be installed in these vehicles, for lifting the body to the sides or back, or for pushing the refuse out, so that they can be quickly and easily emptied

c) Disposal of solid waste:

Sanitary land filling: In majority of the cities the solid waste is being disposed-off by dumping in low-lying areas. The disposal sites are selected on the basis of closeness to collection areas and availability of land. In open dumping the waste is uncompacted, leachate and gas control systems are not provided. Soil cover is rarely provided and opens burning to

reduce volume and easy rag picking is quite common. The disposal sites are unfenced. This leads to the air pollution, ground water pollution, aesthetic problems and fly breeding.

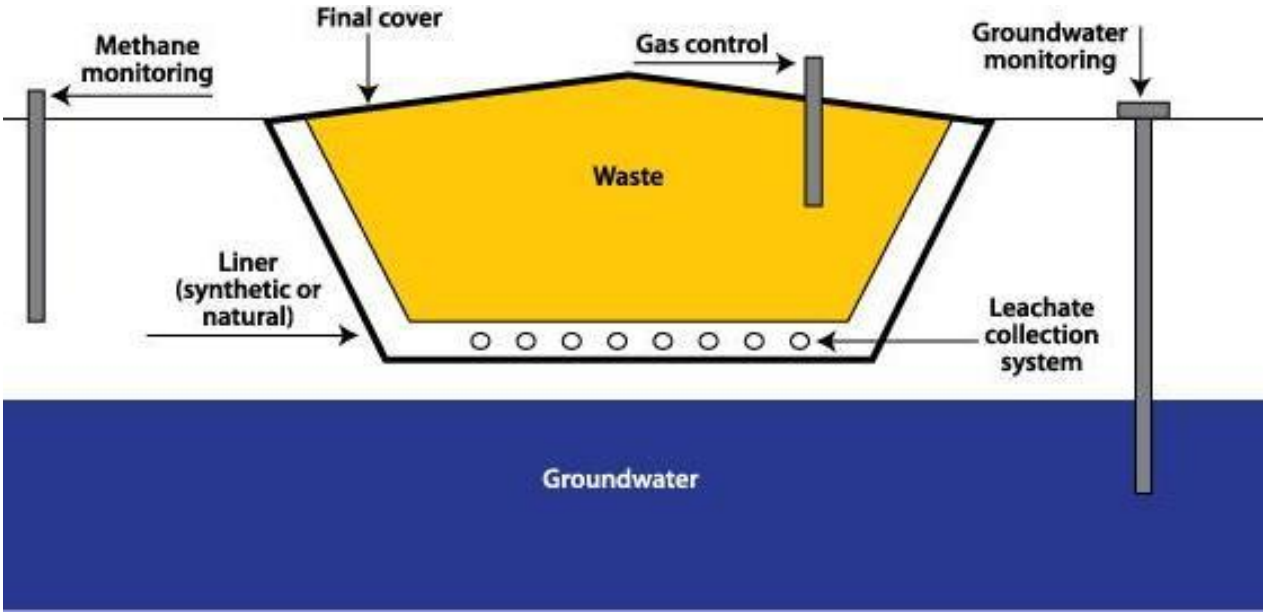

Fig: Schematic layout of Sanitary landfill

To overcome these problems an engineered method of solid waste disposal method called sanitary landfill is adopted in developed countries. This is the method of disposing of solid waste on land in a manner that minimizes environmental hazards by spreading the solid waste, compacting and applying cover material daily at the end of each day. The final layer is about one meter thick top layer to prevent rodents from burrowing into the waste and scattering. Sanitary landfill is a biological method of waste treatment. The bacteria present in the waste decomposes the degradable organics and produces the gas containing CH_4, CO_2, NH_3 and H_2S that can be used as renewable source of energy.

Advantages:

1. This method is most simple and economical. No costly plant or equipment is required in this method.
2. Separation of different kinds of refuse, as required in incineration method is not required in this method.
3. There are no residues or byproducts left out/evolved in this method and hence no further disposal is required; this being a complete method in itself.
4. Low lying water-logged areas and odd quarry pits can be easily reclaimed and put to better use. The mosquito-breeding places are also, thus, eliminated

Disadvantages:

1. Low lying depressions or dumping sites may not always be available; or even if they are available today, they may ultimately become scarce or unavailable in future, since the production of solid waste ia a continuous process.
2. There is a continuous evolution of foul gases near the fill site, especially during the times the refuse is being dumped there. These gases may often be explosive in nature and are produced by the decomposing or evaporating organic matter. These gases known as land fill gases, become a serious environmental problem at sanitary land fill sites and may, hence, need be collected installing gas recovery wells.
3. Use of environmentally harmful insecticides may be required to prevent fly nuisance.
4. Since the dumped garbage may contain harmful and sometimes carcinogenic non-biodegradable substances, such as plastics, unused medicines, paints, insecticides, etc., they may start troubling on a later date, particularly during rainy season, when excess water seeping through the area, may come out of the dump, as a colored liquid, called leachate.

Shredding and pulverization: The size and volume reduction of municipal solid waste (MSW) is accomplished by the physical processes of shredding and pulverization. Shredding refers to the actions of cutting and tearing, whereas, pulverization refers to the actions of crushing and grinding. Shredding and pulverization may help in reducing the overall volume of the original MSW by as much as 40%. The shredding and pulverizing not only helps in reducing the volume of MSW, but also helps in changing the physical character of the waste, which becomes practically odourless and unattractive to the insects.

The pulverization is usually achieved in a hammer mill, where the raw solid waste is camped with a force sufficient to crush or tear individual components of the waste. Impact is provided by several hammers that rotate at high speeds (up to 1500 revolution/minute) around a central or vertical shaft. The mill helps to produce a uniform or homogeneous mass of solid waste. Such a hammer mill proves to be very versatile device for size reduction of solid wastes, because it accepts almost any type of solid waste material (except very bulky or dense ones such as tree stumps, engine blocks etc). A hammer mill thus makes it possible to reduce the size of the various components of solid waste material to uniform fragments of size 25 to 50 mm or so.

Composting: Composting of refuse is a biological method of decomposing solid wastes. This decomposition can be affected either under aerobic conditions or under anaerobic conditions or both. The final end product is manure, called the compost or humus.

Basically, composting is considered to be and aerobic process, because it involves piling up of refuse and its regular turning, either manually or by mechanical devices, so as to ensure sufficient supply of air and oxygen during its decomposition by bacteria, fungi and other micro-organisms. Initially the process starts with the mesophilic bacteria, which oxidize the organic matter (in the refuse) to carbon dioxide and liberate heat. The temperature rises to about 45^0C and at this point, the thermophilic bacteria take over and continue the decomposition. During this phase, the temperature further rises to about 60^0C, which has to be maintained for at least 3 days in order to destroy pathogenic bacteria. This temperature control is crucial because optimal decomposition occurs between 55 and 60^0C, but if the temperature exceeds 60^0C, decomposition slows down. In about 4 to 5 weeks, the easily biodegradable fraction gets consumed and the temperature of the compost mass starts falling. Complete stabilization occurs after the compost is allowed to cure for another 2 to 8 weeks.

During the active early decomposition phase, the thermophilic bacteria act as the principal decomposers, while fungi are more active during the curing stage. The entire composting thus gets completed in about 3-4 months time. Volume reductions of the original organic material of up to 50% are achieved under ideal conditions. The finally produced compost usually, has earthy smell and a dark brown colour.

Moisture content of the compost mass should, however, be controlled to ensure optimum aerobic decomposition, because excessive moisture will make it difficult to maintain aerobic conditions, while deficient moisture inhibits biological life. A moisture content of about 55% should be established, so that aerobic biological activity may proceed at an optimum rate. It may therefore, become necessary to add water to the compost mass during its turning, for maintaining satisfactory moisture content.

The Municipal Solid Wastes (Management and Handling) Rules, 2000 has laid down the following specifications for compost quality, to ensure its safe application.

Composition/Quality standards for compost

Sl. No.	Parameter	Concentration not to exceed in mg/kg of dry compost, except for pH and C/N ratio.
1	Arsenic	10.00
2	Cadmium	5.00
3	Chromium	50.00
4	Copper	300.00
5	Lead	100.00
6	Mercury	0.15
7	Nickel	50.00
8	Zinc	1000.00
9	C/N ratio	20-40
10	pH value	5.5-8.5

In India, the composting is practiced in rural areas on the mixture of night soil and refuse. Two methods which are generally adopted are

1. **Indore method of composting:** In Indore method of composting, refuse, night soil and animal dung are placed in small brick lined pits, 3 m x 3 m x 1 m deep, in alternate layers of 7.5 to 10 cm height, so as to make a total height of 1.5 m. Chemicals such as DDT is added to prevent fly breeding. The material is turned regularly for a period of about 8 to 12 weeks and then stored on the ground for 4-6 weeks. In about 6-8 turnings and in about 4 months time, the compost becomes ready for use as manure.
2. **Bangalore method of composting:** In Bangalore method of composting, the refuse is stabilized an-aerobically. Earthen trenches of size 10 x 1.5 x 1.5 m deep are filled up in alternate layers of refuse and night soil/cow dung. The material is covered with 15 cm layer of good earth and left for decomposition. In about 4-5 months, the compost becomes ready for use.

Vermi-composting: Vermi-composting uses the natural composting process of decomposition of biodegradable organic matter by the soil bacteria by taking the assistance of cultured earth worms. These earth worms help in quicker decomposition of the organic matter. The method helps in adopting the composting technique in individual bungalows and institutions to dispose of the yard and garden wastes particularly the leaves and grass clippings. The various steps involved in applying vermin-composting technique are:

1. Dig a small pit of about 0.5 m square and I m deep.
2. Line the pit with straw or dried leaves and grass.

3. Organize the disposal of organic domestic waste into the pit as and when generated.
4. Introduce a culture of worms that is not produced commercially.
5. Cover the pit contents daily by sprinkling of dried leaves and soil every day.
6. Water the pit once or twice a week to keep it moist.
7. Turn over the contents of the pit every 15 days.
8. In about 45 days, the waste will be decomposed by the action of the micro-organisms.
9. The produced humus (soil) in the pit is fertile and rich in soil nutrients. It can, hence, be used in the garden.

E-waste: Electronic waste may be defined as discarded computers, office electronic/electrical equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This definition includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal. Others define the reusable's (working and repairable electronics) and secondary scrap (copper, steel, plastic, etc.) to be "commodities", and reserve the term "waste" for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations. Because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable), several public policy advocates apply the term "e-waste" broadly to all surplus electronics.

The problem of E- waste: Electronic waste isn't just waste — it contains some very toxic substances, such as mercury, lead, cadmium, arsenic, beryllium and brominates flame retardants. When the latter are burned at low temperatures, they create additional toxins, such as halogenated dioxins and furans – some of the most toxic substances known to humankind. The toxic materials in electronics can cause cancer, reproductive disorders, endocrine disruption, and many other health problems if this waste stream is not properly managed. Many of the toxic constituents are elements, which mean they never disappear, even though they may change form. Other toxic chemicals in electronics do not break down over time, instead accumulating in the food chain and biosphere. Not only do these toxins present risks to communities and the global ecosystem, but also to electronics recycling workers around the world.

Solution for E- waste: Waste Electrical and Electronic Equipment (WEEE) is increasing every day. The volume of WEEE is becoming a serious environmental problem that has yet to become recognised by the greater public. Nearly 250 million computers will become

obsolete in the next five years, according to the EPA. Discarded electronics (e-waste) can contain toxic lead, mercury, cadmium, hexavalent chromium, and fire retardant. Of particular concern are the cathode ray tubes (CRTs) in computer monitors, which contain high concentrations of lead. Though the EPA considers each of these materials dangerous, household electronics aren't classified as hazardous waste and aren't subject to federal regulation. Therefore, in most states it's up to individuals to decide the fate of discarded equipment.

The manufacturers of electronic goods, who have benefited from sales of their products, should take responsibility for them from production through to the end of their lives. To prevent an e-waste crisis, manufacturers must design clean electronics with longer lifespan, that are safe and easy to recycle and will not expose workers and the environment to hazardous chemicals. Electronics manufacturers must stop using hazardous materials. In many cases, safer alternatives currently exist.

The taxpayer should not bear the cost of recycling old electrical goods. Manufacturers should take full life cycle responsibility for their products and, once they reach the end of their useful life, take their goods back for re-use, safe recycling or disposal.

The consumers should

Support companies that make clean products.

Before buying, think twice about whether you really need a new device.

Return your equipment to the manufacturer when you have finished with it.

d) Waste utilization: This is the concept of Reuse, Recycle and Recovery (3 Rs).

The advantages of waste utilization are

- Waste utilization helps in conservation of natural resources.
- Waste utilization helps in generating employment.
- Utilization of waste prevents the air and water pollution.
- Compost (manure) can be obtained by utilizing solid waste.
- Solid waste is a renewable source of energy, electricity can be generated.
- Utilizing the waste directly or indirectly contributes to economical growth of the country or region.

Some of waste utilization are:

- Cattle dung can be used in gobar gas plant.
- Cattle dung is used as manure.

- Garbage in production of compost.
- Scrap glass in manufacturing new glass.
- Plastic is recycled to make new articles, greases, waxes etc.
- Used tyre in manufacturing of rubber.
- Fly ash is used in cement manufacturing.
- Sugarcane solid waste (bio-gas) for electricity production.

Biomedical wastes and their impacts on health and environment:

The wastes (solid as well as liquid wastes) produced by hospitals, nursing homes, clinics, research laboratories, diagnostic centers, veterinary hospitals, etc are called biomedical wastes. They are potential source of hazards and need to be specially treated and disposed off.

The greatest risk of clinical waste is from the infectious and sharp components like needles, syringes etc. Health care workers and people associated with the hospital waste disposal often get needle prick injuries and can even get AIDS/HIV or other types of infections like Hepatitis B & C, through skin route. In addition to its infectivity, the medical waste is highly toxic and may possess variable radioactivity.

Collection and treatment of Biomedical wastes:

The various types of medical wastes are divided into different categories and collected in different coloured bins or containers, as to help in segregation of hazardous and non-hazardous wastes, needing different types of treatments. The process is known as **waste segregation.** The correct classification for collection of different waste items in different coloured dust bins is to be done by the various hospitals and it is the duty of the hospital doctors and nurses to ensure correct disposal of different waste items in their respective dust bins or containers. The system of using different coloured bins and bags to collect different types of solid medical wastes is known as **colour coding**. Such a system eventually helps in separately collecting the non-hazardous medical waste items, such as the uncontaminated packaging materials like plastics, paper, card board, food and kitchen waste, garden waste etc. Such non-hazardous waste can then be easily and economically be disposed off by landfill, but only if it is free of biomedical waste that would cause adverse effects on human health and environment.

Proper segregation of wastes helps in the following ways:

1. It minimizes the amount of potentially hazardous wstes that requires the specialized and costly treatment and disposal.
2. It facilitates proper packaging and labeling of wastes.
3. It reduces occupational health and safety risks to the health care workers and rag pickers.
4. It improves infection control within the hospital.
5. It helps in establishing uniform waste management practice and to comply with the national laws and legislgitation.

According to the 1998 Indian rules notified for the disposal of biomedical wastes, such wastes are to be segregated in the bins or containers of the following colors:

1. Yellow
2. Red
3. Blue/White
4. Black

The most important aspects of management of biomedical waste is that the hazardous bio-medical waste should not be mixed with the non-hazardous general waste. In order to achieve this, different types of wastes in hospital should be collected in different colored bins and containers and disposed suitably.

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

Collection of sharp wastes: In collection of various types of biomedical wastes, special attention is required to be given to the sharp wastes, as they constitute a unique category of medical wastes and always pose a risk factor of many infectious pathogens. Sharp may be defined as objects that are capable of puncturing or cutting due to any points or proturbences

and may include syringes, needles, blades, Pasteur pipettes and broken glasses or plastics. As a matter of fact, 98 % of all health facilities generate sharp wastes.

During medical procedures, health care workers get a large number of injuries due to sharps. Similarly, a significant amount of injuries are caused by sharp wastes to the solid waste workers, who handle their collection.

To render their safe handling, manufactures must develop mechanisms to render the syringes 'non-sharp', immediately after use. This will reduce the needle stick injury, by preventing the punctures. Self-shearing syringes, self-blunting blood collection needle are gaining popularity.

No loose sharp wastes should be disposed of into plastic bags, as these bags can get punctured or cut by the sharps, which may cause injuries to the waste handlers or the content of the bag may spill during transportation. The sharp wastes should, therefore, be placed in puncture-resistant containers or should be mutilated at the point of generation by some needle destroyer.

Labeling for identification of bio-medical wastes: Labeling is essential for the correct identification and safe management of medical wastes. Labeling makes the identification and handling of different types of medical wastes easier. It will also warn the workers, patients and the public about the existence of the wastes and their potential health hazards.

All labeling and sign posting should follow the international symbols and colour coding. All the infected, soiled, pathological, human and sharp wastes should be marked with biohazard symbol in black colour, representing cytotoxic wastes.

The symbol of cytotoxic hazard, i.e. C in a triangle () is used for this labeling. Labeling of the wastes at the generation point should be in the form of tag or adhesive label, attached to the collection bag or container, prior to it being collected by the cleaning staff. This waste tagging system will allow waste audits conducted at the treatment/disposal site, to identify those areas that are in compliance or non-compliance with the required hospital waste management practices. If needed, a corrective action can then be easily initiated. It would be better, if the bags and bins provided are already labeled with appropriate hazard symbol.

Storage of Bio-medical wastes: According to the rules the infectious waste can not be stored for more than 48 hours. However, hospital wastes may need to be stored, if immediate

treatment and disposal cannot be done. These wastes should be refrigerated on site to prevent rotting and evolution of offensive smells. These wastes may then be carted and stored in off-site storage facilities, built in R.C.C., in notified areas, away from general public. These storage houses must be properly designed to allow proper out flow of wash down water and rain water.

Transportation of Bio-medical wastes to the Treatment and Disposal sites: Wastes in hospitals should be frequently lifted from well marked designated collection points in hospital wards or rooms. Open trolleys are often used to collect wastes from individual bins. In all such cases, each bin and each trolley must be thoroughly cleaned and disinfected with 1 % solution of bleaching powder (hypo chlorite) at least once a week. The movement of the sanitation staff should be prevented or minimized through the designated clean areas of the hospital. Automated waste handling and transport system is much better than the manual ones. The vehicle used for waste transport to the disposal sites should not be used for any other purpose. Such vehicles should be labeled and designated for the purpose by the authorities.

Treatment and Disposal of Bio-medical wastes: The various methods which may be used for disposing of the hazardous wastes from hospitals include:

1. **Chemical disinfection:** In this method, the waste is disinfected by using chemicals like chlorine compounds such as bleaching powder etc. Other chemicals like iodine, alcohols, phenolic compounds, hexachlorophene, formaldehydes etc may also be sometimes used.
2. **Autoclaving:** Autoclaving (steam sterilization) is a low heat thermal process, and is designed to bring steam into direct contact with the wastes, in a controlled manner and for sufficient duration to disinfect the waste.
3. **Hydroclaving:** An innovation of the autoclave is the hydroclave. Here, indirect heating is done by providing steam into the outer jacket of a double walled container, while the waste inside the inner container is turned by a suitable mechanism. This causes the waste to be fragmented and continuously tumbled against the hot vessel walls. The moisture content of the waste changes into steam and the vessel starts to pressurize. In the absence of enough moisture in the waste to pressurize the vessel, a small amount steam is added until the desired pressure is reached. The treatment time is hardly 15 minutes at 132^0C or 30 minutes at 121^0C. In the process, sufficient

sterilization occurs and the resultant waste is fragmented and dehydrated with reduction in volume and weight.

4. **Micro waving:** In the microwave, heating occurs inside the waste material. This process involves pre-shredding the waste, injecting it with steam and heating it for 25 minutes at 25^0C under a series of microwave units.
5. **Incineration:** Incineration systems involve high temperature combustion, under controlled conditions, to convert wastes containing infections and pathological material to inert mineral residue and gases.

Problems on Solid Waste Management:

Problem 1: Estimate the density of solid waste for the following data:

Components of Solid wastes	% by mass in kgs	Typical density kg/m^3
Food waste	60	290
Paper	15	85
Grass	15	105
Cardboards	10	50

Solution:

Hints:

i. Solid Waste is a heterogeneous mass, in the above sample 100kg is taken for analysis Eg. % by mass in kg => Solid waste consists of one component and it's mass in 60kgs in 100kgs of sample. When all samples are added i.e., 60 + 15 + 15 + 10 = 100kgs

ii. Typical density: On an average Food waste of 1 m^3 weighs 290kgs

Therefore, 60kgs of food constitute a volume of $\frac{1\text{m}^3}{290\text{kgs}} \times 60\text{kgs} = 0.206\ \text{m}^3$

The calculation of volume of each component is shown in the table below:

SL. No.	Components	% by mass in kgs	Typical density inkg/m^3	Volume Calculations in m^3
1	Food Waste	60	290	$\frac{1}{290} \times 60 = 0.206$
2	Paper	15	85	$\frac{1}{85} \times 15 = 0.176$
3	Grass	15	105	$\frac{1}{105} \times 15 = 0.142$
4	Cardboard	10	50	$\frac{1}{50} \times 10 = 0.2$

Total 100kgs; Total volume of all components$= 0.206 + 0.176 + 0.142 + 0.2 = 0.724\text{m}^3$

$$\text{Density of Solid waste} = \frac{\text{Total mass of all components}}{\text{Total volume of all components}}$$

$$Density\ of\ Solid\ waste = \frac{100}{0.724} = 138.12\ {}^{kg}/_{m^3}$$

Problem 2: Estimate the unit solid waste generation for a residential area having 20,000 dwellings with an average of 5 persons in each dwelling. The observation takes for a week at a disposal facility revealed the following information. Also determine the land area required for a municipality if compacted density of land fill is 504 kg/m^3 and depth of compacted solid waste at site is 3 m.

Vehicle	No. of Loads	Average Volume in m^3	Density in kg/m^3
Truck	100	22	350
Tractor	100	1.5	150
Trailer	200	0.3	100

(**Hint:** The density of Solid Waste in transporting vehicles may vary of inbuilt compacting systems)

i) Unit solid waste generation is also known as percapita generation (It means that in a city/town on an average an individual generates how much mass of solid waste).

Calculation of mass of solid waste (kgs) transported to disposal facility in a week i.e 7 days.

Truck	100 loads x 22 m^3x 350 kgs	7,70,000
Tractor	100 loads x 1.5 m^3x 150 kgs	22,500
Trailer	200 loads x 0.3 m^3x 100 kgs	6000
	Total	7,98,500

$$\text{Percapita of waste generation per day} = \frac{\text{Total Solid waste generated in kgs per week}}{\text{No. of persons} \times 7 \text{ days}}$$

No of persons in the city = 20,000 dwellings x 5 persons = 100,000 persons

$$\text{Percapita of waste generation per day} = \frac{798{,}500}{100{,}000 \times 7} = 1.140 \text{ kg/person/day}$$

(Generally waste generation in cities in the range of 0.6 kgs/day – 1.2 kgs/day)

ii) To find the land area:

$$\text{Amount of solid waste generated in the town per day} = \frac{798500}{7} = 114071.4 \text{ kgs}$$

$$\text{Volume of Solid waste after compacting in field per day} = \frac{114071.4}{504} = 226 \, {}^{m^3}/_{day}$$

$$\text{Area of land required per day} = \frac{\text{Volume/day}}{\text{Depth}} = \frac{226}{3} = 75.33 \, {}^{m^2}/_{day}$$

Problem 3: Estimate the unit solid waste generation for a residential area having 10,000 dwellings with an average of 5 persons in each dwelling. The observation takes for a week at a disposal facility revealed the following information. Find the area required for landfill per day, if the compacted density of waste at site is 350 kg/m^3 and depth of feeling is 3 m.

Vehicles	No. of Loads	Average Volume in m^3	Density in kg/m^3
Tractor	50	2	150
Truck	50	10	300
Medium Truck	30	12	400
Private vehicle	25	1.5	100

Solution:

Tractor:	50 x 2 x 150 =	15,000 kgs
Truck:	50 x 10x 300 =	150,000 kgs
Medium Truck:	30 x 12x 400 =	144,000 kgs
Private vehicle:	25 x 1.5x 100 =	3750 kgs
	Total	312,750 kgs

$$\text{Percapita of waste generation per day} = \frac{\text{Total Solid waste generated in kgs per week}}{\text{No. of persons} \times 7 \text{ days}}$$

No of persons in the city = 10,000 dwellings x 5 persons = 50,000 persons

$$\text{Percapita of waste generation per day} = \frac{312750}{50{,}000 \times 7} = 0.89 \text{ kg/person/day}$$

$$\text{Amount of solid waste generated in the town per day} = \frac{312750}{7} = 44678.57 \text{ kgs}$$

$$\text{Volume of Solid waste after compacting in field per day} = \frac{44678.57}{350} = 2127.65 \, {}^{m^3}/_{day}$$

$$\text{Area of land required per day} = \frac{\text{Volume/day}}{\text{Depth}} = \frac{127.65}{3} = 42.55 \, {}^{m^2}/_{day}$$

Problem 4: Estimate the moisture content of 100 kg sample of solid waste for the following composition.

Component	Food waste	Paper	Plastic	Card board	Wood
% by mass	40	6	14	20	20
Moisture content (%)	67	5	3	5	20

Solution:

Component	% by mass	% moisture content	Mass of moisture	Dry mass in kgs
Food waste	40	67	$\frac{40 \times 67}{100} = 26.8$	40 - 26.8=13.2
Paper	6	5	$\frac{6 \times 5}{100} = 0.3$	6 - 0.3=5.7
Plastic	14	3	$\frac{14 \times 3}{100} = 0.7$	14 - 0.7=13.3
Cardboards	20	5	$\frac{20 \times 5}{100} = 1.0$	20 - 1.0=19.0
Wood	20	20	$\frac{20 \times 20}{100} = 4.0$	20 - 4.0=16.0
		Total	**32.80**	**67.20**

$$\text{Moisture content of solid waste} = \frac{\text{Wet mass} - \text{Dry mass}}{\text{Wet mass}} \times 100$$

$$\text{Moisture content of solid waste} = \frac{100 - 67.2}{100} \times 100 = \mathbf{32.8}\%$$

Problem 5: Estimate the moisture content of 1000 kg sample of solid waste for the following composition.

Component	Food waste	Paper	Card board	Plastic	Wood
% by mass	45	5	15	15	20
Moisture content (%)	70	6	5	2	20

Solution:

Component	% by mass	% moisture content	Mass of moisture	Dry mass in kgs
Food waste	45	70	$\frac{70 \times 45}{100} = 31.5$	45 – 31.5=13.5
Paper	5	6	$\frac{6 \times 5}{100} = 0.3$	5 - 0.3=4.7
Cardboards	15	5	$\frac{15 \times 5}{100} = 0.75$	15 - 0.75=14.25
Plastic	15	2	$\frac{15 \times 2}{100} = 0.3$	15 – 0.3=14.7
Wood	20	20	$\frac{20 \times 20}{100} = 4.0$	20 - 4.0=16.0
		Total	**36.85**	**63.15**

$$\text{Moisture content of solid waste} = \frac{\text{Wet mass} - \text{Dry mass}}{\text{Wet mass}} \times 100$$

$$\text{Moisture content of solid waste} = \frac{100 - 63.15}{100} \times 100 = \mathbf{36.85}\%$$

1000kg of solid waste contains = **368.5 kgs of moisture**