Municipal solid waste-sources and types

Solid Waste Management: An Introduction

The term "solid waste management" refers to the collection, treatment, and disposal procedure for solid wastes. Wastes are gathered from various sources and are disposed of through the waste management process, which involves the collection, transportation, treatment, analysis, and disposal.

It is a serious worldwide problem as it causes both water and air pollution. It shows its direct effect on health, economic growth, and degradation of the environment. It can lead to pollution of the environment and outbreaks of vector-borne diseases (diseases spread by rodents and insects).

Solid waste is a non-liquid, non-soluble material ranging from municipal garbage to industrial waste that sometimes contains complex and hazardous substances. It includes domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste, bio-medical waste, and e-waste.

Several tonnes of garbage are left uncollected on the streets of most developing cities each day. It acts as a breeding ground for pests that spread disease, obstruct the sewers, and cause other infrastructural issues.

India produces 277.1 million tonnes of solid waste every year, which is likely to touch 387.8 million tonnes in 2030 and 543.3 million tonnes by 2050 due to 'rapid urbanisation, population growth, and economic development.'

Municipal solid waste

Municipal Solid Waste (MSW)—more commonly known as trash or garbage—consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses.

Types of Municipal Solid Wastes

Municipal solid waste can be divided into the following categories given below:

1. **Kitchen Waste:** This waste contains fruits and vegetable peels. It is biodegradable and can be used to increase the fertility of the soil.
2. **Office or School Waste:** This waste contains paper, cardboard, plastic clips, crayons, markers etc. these are usually recyclable and non-biodegradable.

3. **Hazardous Waste:** this waste is collected from hospitals, clinics, or medical centres. They contain chemicals and already used syringes, pieces of cotton, creams, or ointments. These must be disposed of very carefully using special treatments to avoid infections or diseases.

Types of Solid Waste Management

- **Landfill:** It involves burying the waste in vacant locations around the city. The dumping site should be covered with soil to prevent contamination.

  Benefits: A sanitary disposal method if managed effectively.

  Limitations: A reasonably large area is required.

- **Incineration:** It is the controlled oxidation (burning/thermal treatment) of mostly organic compounds at high temperatures to produce thermal energy, CO_2, and water.

  Benefits: Burning significantly reduces the volume of combustible waste.

  Limitations: Smoke and fire hazards may exist.

- **Composting:** It is a natural process of recycling organic matter like leaves and food scraps into beneficial fertilizers that can benefit both soil and plants.

  Benefits: It is beneficial for crops and is an environment-friendly method.

  Limitations: Requires high-skilled labour for large-scale operation.

- **Recycling:** It is a process of converting waste material into new material. Examples: wood recycling, paper recycling, and glass recycling.

  Benefits: It is environment-friendly.

  Limitations: It is expensive to set up and not reliable in case of an emergency.

- **Vermicomposting:** Vermicomposting is a bio-conversion technique that is commonly used to handle solid waste. Earthworms feed on organic waste to reproduce and multiply in number, vermicompost, and vermiwash as products in this bio-conversion process.

  Benefits: It reduces the need for chemical fertilizers and enhances plant growth.

  Limitations: It is time-consuming, cost-ineffective, and requires extra care.

Various Methods of Solid Waste Management

Municipal Solid Waste

- Every day goods such as product packaging, yard trimmings, furniture, clothing, bottles, cans, food, newspapers, appliances, electronics, and batteries make up the municipal solid waste.
- With rising urbanisation and change in lifestyle, the amount of municipal waste is also rising.

Different Sources of Municipal Solid Waste

- It is roughly classified into five categories:
    1. **Recyclable Material:** Glasses, bottles, cans, paper, metals, etc.
    2. **Composite Wastes:** Tetra packs, toys.
    3. **Biodegradable Wastes:** Kitchen waste, flowers, vegetables, fruits, and leaves.
    4. **Inert Waste:** Rocks, debris, construction material.
    5. **Domestic Hazardous and Toxic Waste:** E-waste, medication, light bulbs, etc.
- Municipal solid waste management is the need of the hour and is important for the safety of public health and better environmental quality.

Harmful Effects of Solid Waste

- Bad odour of waste
- Production of toxic gases
- Degradation of natural beauty
- Air pollution
- Water pollution
- Soil pollution
- Spread of diseases
- Effect on biodiversity

Important Points About Solid Waste Management

- With rapid urbanisation, industrialisation, and an explosion in population in India, solid waste management will be a key challenge for state governments and local municipal bodies in the 21st century.
- Solid waste management is vital to the health and well-being of city dwellers.
- The urban poor is particularly vulnerable, as they generally live in informal settlements with little or no access to solid waste collection and in locations near open landfills.

- The **‘Swachh Bharat Abhiyan’** was created to tackle these issues related to waste management, and it created awareness among the people about the proper treatment of solid waste. Since the launch of this campaign, the waste management concept has started to gain momentum.

Generation Rates

Solid waste generation rates estimate the amount of waste created by residences or businesses over a certain amount of time (day, year, etc.). Waste generation includes all materials discarded, whether or not they are later recycled or disposed in a landfill. Waste generation rates for residential and commercial activities can be used to estimate the impact of new developments on the local waste stream.

Factors affecting municipal solid waste

1. Geographic location
2. Season of the year
3. Collection frequency
4. Use of kitchen waste grinders
5. Characteristics of populace
6. Extent of salvaging and recycling
7. Public attitude

Characteristics of solid waste

Physical characteristics

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities. The following physical characteristics are to be studied in detail.

Density

Density of waste, i.e., its mass per unit volume (kg/m^3), is a critical factor in the design of a solid waste management system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density of 100 kg/m^3 to 400 kg/m^3. In other words, a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted. Significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition

Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total wet weight of the waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour. In the main, wastes should be insulated from rainfall or other extraneous water. We can calculate the moisture percentage, using the formula given below

[Moisture content(%)=\frac{Wet\cdot weight-Dry\cdot weight}{Wet \cdot weight}x 100\]

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not uncommon. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.

Size of Waste constituents

The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process. This varies widely and while designing a system, proper analysis of the waste characteristics should be carried out.

Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of $25^{O}C$ from the combustion of a dry sample is measured.

The physical properties that are essential to analyse of wastes disposed at landfills are:

Field capacity

The field capacity of municipal solid waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is a critical measure because water in excess of field capacity will form leachate, and leachate can be a major problem in landfills. Field capacity varies with the degree of applied pressure and the state of decomposition of the wastes.

Permeability of compacted wastes

The hydraulic conductivity of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill. Permeability depends on the other properties of the solid material include pore size distribution, surface area and porosity. Porosity represents the amount of voids per unit total volume of material. The porosity of municipal solid waste varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste.

Compressibility

It is the degree of physical changes of the suspended solids or filter cake when subjected to pressure.

Chemical characteristics

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system. The products of decomposition and heating values are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following

Chemical: Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides, Toxicity test for Leachates (TCLP), etc.

Lipids

This class of compounds includes fats, oils and grease. Lipids have high calorific values, about 38000 kcal/kg, which makes waste with a high lipid content suitable for energy recovery processes. Since lipids in the solid state become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. They are biodegradable but because they have a low solubility in waste, the rate of biodegradation is relatively slow.

Carbohydrates

Carbohydrates are found primarily in food and yard waste. They include sugars and polymers of sugars such as starch and cellulose and have the general formula $(CH_2O)_X$. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates are particularly attractive for flies and rats and for this reason should not be left exposed for periods longer than is necessary.

Proteins

Proteins are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH_2). They are found mainly in food and garden

wastes and comprise 5-10% of the dry solids in solid waste. Proteins decompose to form amino acids but partial decomposition can result in the production of amines, which have intensely unpleasant odours.

Natural fibres

This class includes the natural compounds, cellulose and lignin, both of which are resistant to biodegradation. They are found in paper and paper products and in food and yard waste. Cellulose is a larger polymer of glucose while lignin is composed of a group of monomers of which benzene is the primary member. Paper, cotton and wood products are 100%, 95% and 40% cellulose respectively. Since they are highly combustible, solid waste having a high proportion of paper and wood products, are suitable for incineration. The calorific values of ovendried paper products are in the range 12000 – 18000 kcal/kg and of wood about 20000 kcal/kg, which compare with 44200 kcal/kg for fuel oil.

Synthetic organic material (Plastics)

They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in solid waste management. Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which make them very suitable for incineration. But, one should note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

Non-combustibles:

This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

Heating value

An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg). The heating value is determined experimentally using the *Bomb calorimeter test*, in which the heat generated, at a constant temperature of 25°C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100°C), the

combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100°C, and the resultant water is in the vapour form. While evaluating incineration as a means of disposal or energy recovery, one has to consider the heating values of respective constituents.

Ultimate analysis

This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and it is done to perform mass balance calculation for a chemical or thermal process. Besides, it is necessary to determine ash fraction because of its potentially harmful environmental effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc. One should note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic.

The following table shows an ultimate analysis of a typical municipal solid waste

Element	**Range (% dry weight)**
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

Proximate analysis

This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:

- moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel;
- ash, which adds weight without generating any heat during combustion;

Components	**Value (%)**	
	Range	Typical
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

- volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion;
- fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

Waste segregation at source

Waste segregation at source refers to the process of identifying and segregating various types of solid wastes at the place or location of their generation. The management of municipal solid waste in India has continued to be a problem not only because of environmental and aesthetic concerns, but also because of the enormous quantities generated every day.

The Union Ministry of Environment, Forests and Climate Change (MoEF&CC) had in 2016 brought the new Solid Waste Management Rules (SWM). It defines segregation as sorting and separate storage of various components of solid waste namely biodegradable wastes including agriculture and dairy waste, non-biodegradable wastes including recyclable waste, non-recyclable combustible waste, sanitary waste and non-recyclable inert waste, domestic hazardous wastes, and construction and demolition wastes.

The Fundamental Duties enshrined in the Constitution of India, under Article 51-A provide for duties of citizens for protection and improvement of the natural environment.

What are the rules for waste segregation at source?

- The Solid Waste Management Rules have mandated the source segregation of waste to channelize the waste to wealth by recovery, reuse and recycling.
- The new rules are applicable beyond municipal areas.
- It includes urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, airports, special economic zones, places of pilgrimage, religious and historical importance, and State and Central Government organizations in their ambit.
- Waste generators would now have to segregate waste into three streams- Biodegradable, Dry (Plastic, Paper, Metal, Wood) and Domestic Hazardous waste (diapers, mosquito repellents, cleaning agents) before handing it over to the collector.

Collect back scheme for packaging waste?

- Brand owners who sell or market their products in non-biodegradable packaging materials should put in place a system to collect back the packaging waste generated due to their production.

What are the Provisions for the Large Waste Generators?

- Institutional generators, market associations, event organisers and hotels and restaurants are directly responsible for segregation and sorting the waste and managing partnerships with local bodies.
- In case of an event, or gathering of more than 100 persons at any licensed/ unlicensed place, the organiser will have to ensure segregation of waste at source and handing over of segregated waste to waste collectors or agencies, as specified by the local authority.
- All hotels and restaurants will also be required to segregate biodegradable waste and set up a system of collection to ensure that such food waste is utilised for composting / bio-Examination.
- The rules mandate that all resident welfare and market associations and gated communities with an area of above 5,000 sq m will have to segregate waste at the source.

Objectives of waste disposal are as follows:

1. To protect our environment from pollution and contamination and repair and reduce the damage caused by pollution.
2. Irresponsibly disposed of waste can lead to various diseases and can harm people.
3. Therefore, we should carefully dispose of waste to encourage health standards.
4. Having proper waste disposal methods available supports recycling and saves precious materials.
5. With the help of bioremediation, it is removing contaminants, pollutants, and toxins from soil, water, and other environments.

Functional Elements of Solid Waste Management System comprises of six basic elements including:

1. Generation of the solid waste
2. On-site handling & storage
3. Collection
4. Transfer & transport
5. Material and resource recovery and
6. Disposal

Generation of Solid Waste

Solid waste generation refers to the creation of waste materials by residential, commercial, and industrial activities. This function involves understanding the sources, quantities, and composition of waste to develop appropriate waste management strategies. Waste generation rates can be estimated using the following equation:

Waste Generation = Population × Per Capita Waste Generation Rate

For example, if a city has a population of 100,000 and the per capita waste generation rate is 1.2 kg/person/day, the estimated waste generation would be 120,000 kg/day.

The handling, storage, and separation of solid waste at the source before they are collected is a critical step in the management of residential solid waste

Waste Handling

Handling refers to activities associated with managing solid wastes until they are placed in the containers used for their storage before collection or return to drop-off and recycling centers.

On-site handling and storage involve the proper containment and temporary storage of waste at the point of generation. It includes activities such as waste segregation, waste minimization, and the use of appropriate containers or bins. For instance, households may use separate bins for recyclable materials (e.g., paper, plastic, glass) and non-recyclable waste. On-site storage ensures that waste is properly managed until it is collected.

Waste Storage

The first phase to manage solid waste is at the home level. It requires temporary storage of refuse on the premises. The individual household or businessman has responsibility for the onsite storage of solid waste. For individual homes, industries, and other commercial centers, proper on-site storage of solid waste is the beginning of proper disposal, because unkept solid waste or simple dumps are sources of nuisance, flies, smells, and other hazards.

Collection

The collection is the process of gathering and transporting waste from various sources to a central location or transfer station. Efficient collection systems are designed based on factors such as population density, waste generation rates, and transportation logistics. Collection methods include curbside collection, door-to-door collection, and community drop-off points. Collection vehicles, such as garbage trucks, are used to transport waste to the next stage.

Transfer and Transport

Transfer and transport involve the movement of waste from the collection points or transfer stations to treatment or disposal facilities. Waste transfer stations act as intermediate hubs where waste is consolidated from smaller collection vehicles into larger transport vehicles. Proper handling, containment, and transport equipment are essential to prevent spillage, littering, and odor nuisances during transfer and transport processes.

Resource Recovery and Processing

Examples of material and resource recovery include:

- **Recycling:** Separating and processing recyclable materials such as paper, plastic, metal, and glass for remanufacturing into new products.
- **Composting:** Decomposing organic waste materials, such as food scraps and yard waste, to produce nutrient-rich compost for soil amendment.
- **Energy Recovery:** Utilizing waste as a fuel source through processes like waste-to-energy (WTE) or anaerobic digestion to generate electricity or heat.

Disposal

Disposal is the final stage of solid waste management when waste that cannot be recovered or recycled is safely and responsibly disposed of. Common disposal methods include landfilling and incineration.

- **Landfilling**: Waste is placed in a specially engineered landfill, where it undergoes controlled decomposition over time. Landfills are designed with liners, leachate collection systems, and gas management infrastructure to minimize environmental impacts.
- **Incineration**: Waste is burned at high temperatures in waste-to-energy facilities, reducing its volume and generating electricity or heat. Modern incineration plants are equipped with air pollution control technologies to minimize emissions.

People's Participation in solid waste management

Role of people is Essential in the Following Areas

1. Reduce, Reuse & Recycling (R R R) of waste.

2. Not to throw the waste/litter on the streets, drains, open spaces, water bodies, etc.

3. Storage of organic/bio-degradable and recyclable waste separately at source.

4. Primary collection of waste

5. Community storage/collection of waste in flats, multi-storied buildings, societies, commercial complexes, etc.

6. Managing excreta of pet dogs and cats appropriately.

7. Waste processing/disposal at a community level (optional)

8. Pay adequately for the services provided.