Uttar Pradesh Rajarshi Tandon Open University

M.Sc.

Environmental Science

PGEVS-108 (N)

Solid and Hazardous Waste Management

COURSE INTRODUCTION

The objective of this course is to provide knowledge of Solid and hazardous waste management. In this courses the characterization, handling, disposal, and treatment of waste materials to minimize environmental impact is discussed. It includes strategies such as recycling, incineration, and landfilling for solid waste, while hazardous waste demands special attention due to its potential harm. Recycling, refurbishing, or safely disposing of electronic devices is essential to prevent the release of harmful substances like lead and mercury into the environment. Managing radioactive waste is a complex challenge due to its potential long-term hazards. Strategies involve containment, isolation, and, in some cases, geological disposal. Effective management requires regulatory compliance, public awareness, and the promotion of sustainable practices to reduce the overall environmental footprint. The course is organized into following blocks:

Block 1 covers the introduction to municipal Solid Waste

Block 2 deals the hazardous and Biomedical Waste

Block 3 describes the radioactive waste and Waste Recycling

Block 4 this block covers the waste Management Handling and Rules

Block-1 **PGEVS-108N**

Rajarshi Tandon Open University, Prayagraj

Solid and Hazardous Waste Management

Block- 1

Municipal Solid Waste

UNIT -1

Introduction of Solid waste

UNIT-2

Municipal and Industrial Solid Waste

UNIT-3

Disposal of Solid Wastes

PGEVS-108N

Rajarshi Tandon Open University, Prayagraj

Solid and Hazardous Waste Management

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Unit-1: Introduction of Solid waste

1.1. Introduction

Solid waste is a growing problem that requires effective management strategies to ensure public health and environmental safety. The sources of solid waste are diverse, and effective waste management strategies involve reducing waste generation, maximizing resource recovery, and ensuring safe disposal practices. Proper solid waste management is critical for the health and well-being of communities, as well as for the preservation of the environment.Solid waste can also serve as a breeding ground for disease vectors such as rats and mosquitoes, which can spread diseases to humans. Additionally, the economic costs of waste management can be significant, particularly in developing countries where inadequate waste management infrastructure can result in environmental degradation, lost productivity, and increased healthcare costs. The improper disposal of solid waste has significant environmental and health implications. Improperly disposed waste can pollute the air, water, and soil, leading to environmental degradation and health problems.

Objectives:

- To define the solid waste and its types
- To discuss the chemical composition of solid waste
- To discuss the characterization of solid waste
- To discuss the impact of solid waste on Human health and environment

1.2. Solid waste

Solid waste is any refuse or garbage generated from human activities that is no longer useful or valuable and must be disposed of in a manner that is safe for public health and the environment. It is a growing problem globally, with the amount of waste produced by humans increasing steadily over the years. The improper disposal of solid waste has significant environmental, health, and economic implications, and therefore, it is important to understand the nature of solid waste, its sources, and its management strategies.Solid waste can be categorized into various types based on its composition, including organic, inorganic, recyclable, hazardous, and biomedical waste. Organic waste is waste that can be decomposed biologically, including food waste, yard waste, and paper. Inorganic waste includes non-biodegradable materials such as plastics, glass, and metals. Recyclable waste refers to materials that can be processed and reused, such as paper, plastic, and metal. Hazardous waste is any waste that poses a potential threat to human health or the environment, such as batteries, pesticides, and chemicals. Biomedical waste is generated from healthcare facilities and includes sharps, infectious waste, and medical equipment. In contrast, in developing countries, the primary sources of solid waste are agriculture and livestock activities, as well as inadequate infrastructure and poor waste management practices.Solid waste management involves the collection, transportation, processing, and disposal of waste in a manner that is safe for public health and the environment. The primary objective of waste management is to reduce the amount of waste generated and to maximize the recovery of resources through recycling and reuse. Effective waste management strategies include source reduction, recycling, composting, incineration, and landfilling. Source reduction involves reducing the amount of waste generated by reducing the consumption of resources and minimizing waste production. Recycling involves the processing of waste materials into new products, thereby reducing the need for raw materials. Composting involves the biological decomposition of organic waste, producing a nutrient-rich soil amendment. Incineration is the controlled burning of waste materials, which can generate energy. Finally, landfilling involves the disposal of waste in a designated area, with appropriate environmental safeguards in place.

Definition

Solid waste refers to any discarded materials, substances, or products that are not intended for further use or have completed their intended purpose. It includes a wide range of materials generated by human activities, such as residential, commercial, and industrial processes. Solid waste can be categorized based on its composition, which includes organic, inorganic, recyclable, hazardous, and biomedical waste.

Source

The sources of solid waste are diverse, ranging from residential and commercial activities to industrial processes. In developed countries, the majority of solid waste comes from households, with significant contributions from commercial activities, agricultural activities and construction and demolition activities.

1.3. Classification of solid waste

Solid waste can be classified into different categories based on their nature, composition, and origin. Here are some common classifications of solid waste with examples:

- **Municipal Solid Waste (MSW):** It is the waste generated by households, commercial establishments, and institutions. Examples include food waste, paper, plastics, glass, metal cans, and textiles.
- **Hazardous Waste:** These are wastes that can be harmful to human health and the environment if not properly managed. Examples include batteries, chemicals, pesticides, medical waste, and electronic waste.
- **Industrial Waste:** This is waste generated by industries, factories, and construction sites. Examples include construction debris, manufacturing waste, and scrap metal.
- **Agricultural Waste:** This is waste generated by farming activities, including animal waste, crop residue, and pesticides.

- **Biodegradable Waste:** These are wastes that can be broken down naturally by microorganisms. Examples include food waste, yard waste, and paper.
- **Non-biodegradable Waste**: These are wastes that cannot be broken down naturally. Examples include plastics, glass, and metals.
- **E-waste:** This is waste generated from electronic devices like computers, cell phones, and televisions.
- **Construction and Demolition Waste:** This is waste generated from building and demolition activities, including concrete, bricks, and asphalt.
- **Medical Waste:** This is waste generated from hospitals and medical facilities. Examples include sharps, syringes, and medical equipment.
- **Radioactive Waste:** This is waste that contains radioactive materials. Examples include spent nuclear fuel and contaminated soil.

1.4. Chemical composition of solid waste

The chemical composition of solid waste can vary greatly depending on the type of waste and its source. Generally, solid waste is composed of organic and inorganic materials, including:

- **Organic matter:** food waste, yard waste, paper, cardboard, wood, and textiles. Organic matter is mainly composed of carbon, hydrogen, and oxygen.
- **Inorganic matter:** glass, metals, plastics, ceramics, rubber, and other synthetic materials. Inorganic matter can contain a wide range of elements, including carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, and metals such as aluminum, copper, iron, and zinc.

The exact composition of solid waste can also vary depending on the geographic location and economic conditions of the area. For example, industrial areas may have higher levels of hazardous waste, while residential areas may have more organic waste.Overall, it is difficult to provide a specific chemical composition for solid waste, as it can vary greatly depending on the specific waste stream being considered.

1.5. Characterization of solid waste

Solid waste refers to any garbage or refuse that is generated by human activities, which may include household waste, industrial waste, commercial waste, or construction waste. The characterization of solid waste involves identifying its composition, physical properties, and chemical properties. Here are some key aspects of the characterization of solid waste:

- **Composition:** The composition of solid waste varies depending on the source of the waste. For example, household waste typically consists of food waste, paper, plastic, and other miscellaneous items, while industrial waste may include hazardous chemicals, metals, and construction debris. The composition of solid waste can be determined through visual inspection or by analyzing representative samples.
- **Physical properties:** Solid waste can have a variety of physical properties, including size, shape, density, and moisture content. These properties can impact how the waste is managed and disposed of. For example, waste that is bulky or has a low density may take up a lot of space in a landfill, while waste with high moisture content may generate more leachate (liquid waste) that needs to be treated
- **Chemical properties**: Solid waste can contain a range of chemical substances that can impact human health and the environment. Hazardous waste, for example, may contain toxic chemicals such as lead, mercury, or asbestos. Analyzing the chemical properties of solid waste can help identify potential hazards and determine the appropriate disposal methods.

Overall, the characterization of solid waste is an important step in developing effective waste management strategies that prioritize safety, efficiency, and environmental protection.

1.6. Impact of solid waste on environment

Solid waste, also known as garbage, trash or refuse, refers to the non-liquid materials generated by human activities such as household, commercial, and industrial waste. The accumulation of solid waste has a significant impact on the environment. Here are some of the impacts:

- **Land pollution:** The accumulation of solid waste on land can cause soil pollution, which can have a detrimental effect on the soil's fertility and composition. The waste can also release harmful chemicals that can leach into the groundwater.
- **Air pollution:** The decomposition of organic waste generates gases such as methane and carbon dioxide, which contribute to global warming and climate change. In addition, burning waste releases toxic gases and particles into the air.

- **Water pollution:** When solid waste is not disposed of properly, it can contaminate water bodies, which can affect aquatic life and human health.
- **Habitat destruction:** Improper disposal of solid waste can lead to habitat destruction, as waste can cover and destroy natural habitats. This can have a significant impact on the wildlife and plants that rely on these habitats.
- **Health hazards:** The accumulation of solid waste can lead to the proliferation of disease-carrying organisms such as rats, cockroaches, and mosquitoes. This can lead to the spread of diseases such as malaria, dengue fever, and cholera.
- **Aesthetic degradation:** The presence of solid waste can negatively impact the aesthetic value of an area, reducing its attractiveness and appeal.

In conclusion, the accumulation of solid waste has a significant impact on the environment, and proper waste management is crucial to minimizing its effects. It is important to implement sustainable waste management practices such as reducing waste, recycling, composting, and safe disposal to mitigate these impacts.

1.7. Impact of Solid Waste on Human Health:

The impact of solid waste on human health is enormous. When solid waste is not disposed of correctly, it can cause a wide range of health problems. Solid waste is an issue that has been increasingly affecting human health around the world. The generation of solid waste is increasing at an alarming rate due to the increasing population and economic growth. The improper management of solid waste can lead to numerous health problems. In this essay, we will discuss the impact of solid waste on human health and provide examples of such impacts. The impact of solid waste on human health can be divided into three categories: physical, chemical, and biological.

1.7.1. Physical Impact:

Physical impact of solid waste on human health includes various problems, including injury, infection, and contamination. Sharp objects such as glass, needles, and metal can be dangerous if not disposed of correctly, leading to injury and infection. Children playing near unmanaged solid waste dumps can injure themselves by stepping on sharp objects, and if the wound is not treated properly, it can lead to severe infection. In addition, unmanaged solid waste can also contain hazardous materials such as asbestos, which can cause lung cancer if inhaled.

1.7.2. Chemical Impact:

The chemical impact of solid waste on human health can be harmful as it can cause toxic chemicals to enter the environment, such as groundwater, air, and soil. When toxic chemicals enter the environment, they can cause serious health problems such as cancer, respiratory problems, and reproductive problems. For example, lead and mercury, which are commonly found in solid waste, can cause neurological problems, especially in children.

1.7.3. Biological Impact:

Solid waste can also have biological impacts on human health. Improper disposal of solid waste can lead to the growth of bacteria, viruses, and other microorganisms, leading to infections and diseases. For example, if solid waste is not disposed of correctly, it can lead to the breeding of mosquitoes, which can carry diseases such as malaria and dengue fever. Solid waste can have a significant impact on human health if not properly managed. Here are some ways in which solid waste can affect human health:

- **Infectious diseases:** Improperly disposed solid waste can lead to the breeding of disease-causing organisms such as bacteria, viruses, and parasites. These organisms can spread through contaminated water, food, or air, and cause diseases such as cholera, typhoid, dysentery, and hepatitis.
- **Respiratory problems:** Burning of waste releases harmful gases and particulate matter into the air, which can cause respiratory problems such as asthma, bronchitis, and lung cancer.
- **Water pollution:** Solid waste can contaminate water sources such as rivers, lakes, and groundwater, leading to the spread of water-borne diseases and other health problems.
- **Accidents:** Improper handling and disposal of solid waste can lead to accidents such as cuts, puncture wounds, and needle sticks, which can cause infections and other health problems.
- **Vector-borne diseases:** Solid waste can provide breeding grounds for mosquitoes, flies, and other pests that can transmit diseases such as malaria, dengue fever, and Zika virus.

- **Mental health:** Living in areas with poor waste management can cause mental health problems such as stress, anxiety, and depression due to the unsanitary and unpleasant living conditions.

Examples of the Impact of Solid Waste on Human Health:

There are numerous examples of the impact of solid waste on human health. Some of the most significant examples are:

- **Cholera Outbreak in Haiti:**

  In 2010, a massive earthquake hit Haiti, which left the country with massive piles of debris and rubble. The waste was not managed correctly, and as a result, it led to a cholera outbreak. The cholera outbreak affected thousands of people and caused over 10,000 deaths.
- **Leachate Contamination:**

  Leachate is the liquid that is produced when rainwater comes in contact with solid waste. If not managed correctly, leachate can contaminate groundwater, leading to various health problems. In 2008, the residents of Ivory Coast suffered from skin burns, respiratory problems, and nausea when leachate from a waste dump was dumped in the city.
- **Bhopal Gas Tragedy**

  In 1984, a pesticide plant in Bhopal, India, leaked toxic gases, leading to the death of thousands of people. The solid waste from the plant was not managed correctly, leading to the release of toxic chemicals into the air, causing severe respiratory problems and other health issues.

1.8. Impact of solid waste on plant health

Solid waste, which includes both biodegradable and non-biodegradable materials, is a major environmental issue that has been recognized as a significant challenge in the management of waste across the world. Solid waste management is becoming increasingly important, as improper disposal of waste can have significant impacts on both human health and the environment. One of the major impacts of solid waste on the environment is the effect it can have on plant health. In this essay, we will discuss the impacts of solid waste on plant health, with specific examples. Before delving into the impact of solid waste on plant health, it is essential to understand the different types of solid waste that exist. Solid waste can be classified into two categories: biodegradable and non-biodegradable waste. Biodegradable waste refers to organic waste that can be broken down by microorganisms, such as food waste, yard waste, and other plant or animal-based materials. Non-biodegradable waste, on the other hand, is waste that cannot be broken down by microorganisms and includes materials such as plastic, glass, metal, and rubber.

The impact of solid waste on plant health can be classified into two categories: direct and indirect impacts. Direct impacts refer to the physical damage caused by solid waste to plants, while indirect impacts refer to the chemical and biological effects of waste on plant growth and development. Let us discuss these impacts in detail.

1.8.3. Direct Impacts

Soil compaction: Improper disposal of solid waste can lead to soil compaction, which is the process of soil becoming densely packed due to the weight of waste. Soil compaction can make it difficult for plant roots to penetrate the soil, leading to stunted growth and reduced yield.

Physical damage to plant roots: Solid waste can physically damage plant roots, making it difficult for them to absorb water and nutrients from the soil. For example, plastic waste, such as bags and bottles, can wrap around the roots, restricting their growth and causing them to rot.

Air pollution: The burning of solid waste can release harmful gases and chemicals into the air, which can negatively impact plant health. These pollutants can cause leaf damage and reduced photosynthesis rates, leading to reduced plant growth and yield.

1.8.4. Indirect impacts

Soil contamination: Solid waste can contaminate soil with harmful chemicals and heavy metals, which can negatively impact plant growth and development. For example, heavy metals such as lead and cadmium can accumulate in the soil, making it toxic to plants.

- **Water pollution:** Improper disposal of solid waste can lead to water pollution, which can negatively impact plant health. Chemicals and other pollutants released into water bodies can be absorbed by plants, affecting their growth and yield.

- **Nutrient depletion:** Solid waste can reduce the availability of nutrients in the soil, leading to nutrient depletion. For example, excessive use of chemical fertilizers can lead to soil salinization, making it difficult for plants to absorb nutrients from the soil.

Examples

- **Heavy Metal Contamination in plants:** Heavy metal contamination of plants can occur through various sources such as soil, water, air, and fertilizers. Heavy metals such as lead, cadmium, mercury, arsenic, and chromium are toxic to plants and can affect their growth, development, and metabolism. The extent of heavy metal contamination in plants depends on the concentration of the metal in the environment, the duration of exposure, and the ability of the plant to absorb and tolerate the metal. Plants that are exposed to high levels of heavy metals can accumulate them in their tissues, which can lead to toxicity and negatively impact human health if consumed. To prevent heavy metal contamination of plants, it is important to monitor and control the sources of contamination. This can involve testing the soil and water for heavy metal levels before planting, using organic fertilizers instead of chemical fertilizers, and avoiding industrial areas and other sources of pollution.
- **E-waste Contamination in Soil:** Electronic waste, or e-waste, contains several toxic chemicals, including lead, cadmium, and mercury. Improper disposal of e-waste can contaminate soil with these chemicals, leading to reduced plant growth and yield. A study conducted in China found that soil contaminated with e-waste showed reduced plant growth and yield due to heavy metal toxicity.
- **Plastic Waste and Soil Degradation:** Plastic waste can reduce the availability of nutrients in the soil, leading to nutrient depletion. For example, plastic waste can reduce the water-holding capacity of the soil, making it difficult for plants to absorb nutrients from the soil.Plastic waste can release harmful chemicals into the soil, which can contaminate the soil and negatively impact plant health. For example, plastic waste can release phthalates, bisphenol A (BPA), and other toxic chemicals into the soil, which can reduce plant growth and yield.Microplastics are tiny plastic particles less than 5 mm in size. Microplastic pollution is a significant issue, and it can have several negative impacts on plant growth and development. A study conducted in China found that micro plastic pollution reduced the germination rate, root length, and shoot length of

wheat seedlings plastic mulching, a common agricultural practice, involves covering the soil with plastic film to conserve moisture and control weeds. However, plastic mulching can negatively impact plant growth and soil health. Plastic mulch can cause soil compaction, reduce soil aeration, and negatively impact soil microbial activity, leading to reduced plant growth and yield

1.9. Summary

Solid waste refers to any garbage, refuse, or sludge that comes from homes, businesses, and industries. It includes a wide range of materials such as paper, plastics, metals, glass, and organic waste. Proper management of solid waste is critical for public health and environmental protection. Solid waste can have negative impacts on air and water quality, as well as soil and wildlife habitats. The management of solid waste includes collection, transport, processing, recycling, and disposal. Waste management practices can vary widely depending on factors such as local regulations, available technology, and economic factors. Some common waste management strategies include landfilling, incineration, composting, and recycling. Efforts to reduce solid waste generation and promote sustainable waste management practices are gaining momentum globally. This includes measures such as reducing packaging waste, promoting the use of reusable products, and increasing recycling rates. The proper management of solid waste is crucial for achieving sustainable development goals and ensuring a healthy environment for current and future generations.

1.10. Terminal questions

2. . What is waste? Write the source and sink of solid waste.

Answer:--
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3. Write the classification of solid waste and its composition.

Answer:--
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4. Discuss the impact of solid waste on human health and environmental health.

Answer:--
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5. Write the characterization of solid waste.

Answer:--
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6. Discuss the impact of solid waste on soil and plants

Answer:--

1.11.Further suggested readings

1. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.
2. E-waste: Implications, regulations and management in India and Current global best practices, TERI press, Johri, Rakesh.
3. Bio- medical waste management, Sahai, Sushma, APH Publishing.
4. Electronic waste management, design, analysis and application, R E Hester ,Cambridge Royal Society of Chemistry
5. Solid and Hazardous Waste Management, Rao, M.N. and Sultana ,BS Publications, Hyderabad.

Unit -2: Municipal and Industrial Solid Waste

Contents

2.12. Further suggested readings

2.1. Introduction

Municipal solid waste (MSW) refers to the waste generated from households, commercial establishments, and institutions within a municipality. It includes items such as food waste, paper, plastic, glass, metal, and other household items. MSW is also referred to as trash, garbage, or refuse. In other word, the material that is not needed to uses by owner, producer or processer is called waste. These discarded materials are produced by both of sources like municipal and non municipal waste. Manufacturing industries generate municipal solid waste from offices and canteens and industrial wastes from manufacturing processes. Some industrial wastes are hazardous and this part of the waste stream requires special management, separate from other wastes. Small workshops in urban areas generate both municipal and process wastes, some of which may be hazardous. Hospitals and healthcare establishments/ services generate municipal solid waste fractions that include food waste, newspapers and packaging, alongside specialized healthcare hazardous wastes that are often mixed with body fluids, chemicals and objects. Construction sites generate some municipal solid waste, including packaging and food and office wastes, wastes containing materials such as concrete, bricks, wood, windows and roofing materials. Construction and demolition wastes from household repairs and refurbishment, particularly 'do-it-yourself' wastes, are most likely to enter the municipal solid waste stream. In most cities, municipal solid waste includes 'household hazardous wastes' Cities in developed countries have systems that are designed to collect and handle these separately, or to prevent their generation and reduce their toxicity; but there are few cities in which this works completely and most MSW streams include some of these hazardous components when they reach disposal. Parallel collection systems sometimes exist for end-of-life vehicles and for waste electrical and electronic equipment (WEEE), some parts of which may again be classified as hazardous waste. The management of MSW is a crucial aspect of urban planning and public health, as improper disposal can lead to environmental degradation, contamination of water and air, and the spread of diseases. Therefore, municipalities and local governments are responsible for developing and implementing waste management plans that ensure proper collection, transportation, treatment, and disposal of MSW.There are various methods of MSW disposal, including landfilling, incineration, composting, and recycling. Each method has its advantages and disadvantages, and the choice of method depends on factors such as cost, environmental impact, and availability of technology and infrastructure.Effective MSW management requires the cooperation of individuals, businesses, and local governments. By reducing, reusing, and recycling waste, we can reduce the amount of MSW that needs to be disposed of and minimize its impact on the environment.

2.2. Municipal solid waste

Municipal solid waste (MSW) refers to the waste generated from households, commercial establishments, and institutions within a municipality. It includes items such as food waste, paper, plastic, glass, metal, and other household items. MSW is also referred to as trash, garbage, or refuse.The management of MSW is a crucial aspect of urban planning and public health, as improper disposal can lead to environmental degradation, contamination of water and air, and the spread of diseases. Therefore, municipalities and local governments are responsible for developing and implementing waste management plans that ensure proper collection, transportation, treatment, and disposal of MSW.There are various methods of MSW disposal, including landfilling, incineration, composting, and recycling. Each method has its advantages and disadvantages, and the choice of method depends on factors such as cost, environmental impact, and availability of technology and infrastructure.Effective MSW management requires the cooperation of individuals, businesses, and local governments. By reducing, reusing, and recycling waste, we can reduce the amount of MSW that needs to be disposed of and minimize its impact on the environment.

Definition

Municipal solid waste (MSW) is defined as the waste generated by households, commercial establishments, and institutions within a municipality. This type of waste includes everyday items such as food waste, paper, plastic, glass, metal, and other household items that are discarded by individuals or organizations. MSW is also commonly referred to as trash, garbage, or refuse. Effective management of MSW is essential for public health and environmental sustainability, as improper disposal can lead to pollution, environmental degradation, and the spread of diseases.

Source

Municipal solid waste (MSW) is generated from a variety of sources, including:

- **Households**: Waste generated from households is one of the primary sources of MSW. This includes items such as food waste, packaging, paper, plastic, and textiles.
- **Commercial establishments:** Waste generated by businesses, such as restaurants, stores, and offices, contributes to MSW. This waste may include food waste, packaging, paper, and other materials.
- **Institutions:** Waste generated by institutions such as schools, hospitals, and government offices also contributes to MSW. This waste may include food waste, paper, and other materials.
- **Construction and demolition:** Waste generated during construction and demolition activities, such as concrete, wood, and metal, contributes to MSW.
- **Special events:** Waste generated from festivals, concerts, and other special events contributes to MSW. This waste may include food waste, packaging, and other materials.

2.3. Types of municipal solid waste:

The municipal solid waste is generally mixtures of different types of waste generated from different sources of urban and industrial area. The nature and chemical composition of municipal solid waste varied from region to region that based on the economic condition of residential society. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources. The waste can be categories as major two components such as organic and inorganic components. It’s also categories into biodegradable and non degradable waste. However, the organic waste generated from urban area further categories into three broad categories such as

i. putrescible,
ii. fermentable,
iii. Non-fermentable.

i. **Putrescible wastes** tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odors and visual unpleasantness.

ii. **Fermentable wastes** tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction.

iii. **Non-fermentable wastes** tend to resist decomposition and, therefore, break down very slowly. A major source of putrescible waste is food preparation and consumption.

In India, the waste generated form humid, tropical and subtropical region has characteristics changes and mostly contained plant debris; whereas those generated in areas subject to seasonal changes in temperature or those in which coal or wood are used for cooking and heating may contain an abundance of ash. There are several types of waste generated from different sources such as

- **Domestic waste or household waste:** Domestic waste is waste that is generated as a result of the ordinary day-to-day use of domestic products. It includes include food waste, paper, glass, metals, plastics, textiles, etc. A large part of domestic wastes consists of plant and animal waste such as vegetables, fruit peel, bone and meat waste, chicken and fish waste are considered as wet wastes.
- **Industrial waste:** Industrial waste is characterized as waste generated by fabrication or industrial processes. Cafeteria refuse, dirt and gravel, masonry and mortar, scrap metals, gasoline, solvents, pesticides, weed grass and trees, wood and scrap lumber are examples of industrial waste. The waste from the extraction industries are mining, quarrying and dredging create solid waste whereas concrete, plastics metals and unused products are released from construction side are also considered as industrial wastes. In addition all types of Solids and effluents form released form factories are also considered in industrial waste
- **Waste from food processing:** Organic solid and liquid waste from discarded food materials.
- **Biomedical waste:** Discarded waste mainly by hospital and clinics which includes bloods, poisonous medicines, medical apparatus, etc.
- **E-waste:** Waste discarded by electronic equipments.
- **Nuclear waste:** Nuclear Thermal Power Plants use radioactive materials as fuels, Their discarded or dismantle plants produce radiations which cause health effects on livings for thousands of years.

- **Waste from natural disorder**: Earthquake, ash from volcanoes, floods, cyclones causes damage to the natural and manmade resources generating waste.
- **Miscellaneous waste :** the miscellaneous waste is considered all types of waste such as deadly materials such as nuclear weapons, bombs, bio-weapons, etc

Ideally, solid waste should not contain faecal matter or urine, and the mixing of these materials with household waste should be prohibited by law. However, enforcement difficulties, combined with variations in way of life, necessitate some tolerance in this matter.

Special type of Waste

Apart from above mentioned the based is categories as special types waste on the basis of their comical composition :

1. Plastics waste
2. Biomedical waste
3. Slaughterhouse waste
4. Electric and electronic waste (e-waste)
5. Waste Tyres
6. Battery Waste

2.4. Classification of municipal solid waste

Municipal solid waste (MSW) can be classified into different categories based on its characteristics and properties. The following are the common classifications of MSW:

- **Biodegradable waste**: This includes organic waste such as food waste, garden waste, and paper. Biodegradable waste can be decomposed by natural processes and is suitable for composting.
- **Recyclable waste:** This includes materials such as paper, plastics, glass, and metal, which can be processed and turned into new products. Recycling helps to conserve resources and reduce the amount of waste that ends up in landfills.
- **Hazardous waste:** This includes waste that is potentially harmful to human health or the environment, such as batteries, chemicals, and electronic waste. Hazardous waste requires special handling and disposal methods.

- **Inert waste:** This includes waste that does not decompose or react with other substances, such as construction and demolition waste, and soil.
- **Medical waste:** This includes waste generated from medical facilities, such as hospitals and clinics, which may be infectious or hazardous.

2.5. Characterizationand Composition and of municipal solid waste

Municipal solid waste (MSW) is a heterogeneous mixture of various types of waste generated by households, businesses, and institutions. Even samples obtained from the same place (sampling point) on the same day, but at different times may show totally different characteristics. But also Municipal solid waste composition and characteristics vary considerably, not only between cities but also within an Urban Local Bodies, daily, seasonal and temporal fluctuations are usually observed. Quartering & coning method is a well established technique for waste characterization.

2.5.1. Physical characteristic

The physical characteristic of the of municipal solid waste includes moisture content, waste particle size, waste density, temperature and pH as these affect the extent and rate of degradation of waste.

a. Density of waste

The density of waste (mass per unit volume, kg/m^3) determines the storage and transportation volume requirements. Usually it refers to uncompacted waste. It varies with geographic location, season of the year, and length of time in storage. MSW density in India is typically around 450-500 kg/m^3. Low density wastes e.g. packaging wastes, plastic waste and high density wastes e.g. street sweeping waste, metal waste etc. however, the significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by weather etc

b. Particle size and distribution

Waste materials is a key element in solid waste management it is important to have knowledge on the size and distribution of the waste constituents. The particle size and shape of MSW are challenging to measure due to reasons such as their complex shape, difficulty in the movement of MSW particles along the sieve surface and variation in their area depending on the forces acting on it. The major means of controlling particle size is through shredding. Shredding increases homogeneity, increases the surface area/volume ratio and reduces the potential for preferential liquid flow paths through the waste.

c. Permeability

Permeability is defined as the hydraulic conductivity of compacted waste. It is an important physical property and it governs movement of liquid and gases in landfill. It depends on pore size, surface area and pore size distribution. Permeability is inversely related to density, implying that denser refuse is less permeable. The reported range of permeability of refuse is 10-1 to 10-5 cm/sec.

d. Specific gravity

Specific gravity is the ratio of the mass of unit volume of waste at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The average specific gravity of MSW obtained was about 1.15. The lower value of specific gravity can be attributed to the presence of decomposed organic matter. The specific gravity is a basic material property used in the design calculations of the landfill. Knowing the specific gravity of MSW makes it easier to evaluate the values of voids ratio, porosity and degree of saturation.

The typical specific weight values

Components	**Specific weight (density) kg/m^3**	
	Range	**Typical**
Food waste	130-480	290
Paper	40-130	89
Plastics	40-130	64
Yard waste	65-225	100
Glass	160-480	194

Tin can	50-160	89
Aluminum	65-220	160

e. Moisture Content

Moisture content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material.Extraneous water. Solid waste with high moisture content results in increasing collection and transportation costs. A typical range of moisture content is 20 – 45% representing the extremes of wastes in an arid climate and in the wet season of a region having large precipitation. Moisture content is a critical determinant in the economic feasibility of incineration processes since energy must be supplied for evaporation of water and in raising the temperature of the water vapor. Moisture content is generally found to be high in wastes containing a higher proportion of food wastes. The moisture contain is calculated by using following formula:

$$\text{Moisture Content (\%)} = \frac{\text{Wet weight} - \text{dry weight}}{\text{Wet weight}} \text{ x } 100$$

Moisture content also plays an important role in other processing methods such as composting and anaerobic digestion. Most micro-organisms including bacteria require a minimum of approximately 12% moisture for growth.

Table: Typical moisture contents of waste

Waste components	**Moisture contents (%)**	**Physical composition by weight (%)**
Ash, bricks, dust	8.00	18.13
Cardboard	5.00	6.70
Food waste	76.44	30.82
Glass	2.00	6.08
Leather	10.00	1.11
Metals	8.00	3.66
Paper	6.00	5.89
Plastic	2.00	8.75
Rubber	2.00	1.10
Textile	10.00	2.07
Wood	20.00	1.84

2.5.2. Chemical characteristic of MSW

The Chemical composition of solid wastes is important while evaluating alternative processing and recovery options. Especially while looking at waste to energy processes where waste is used as fuel it is important to have knowledge of proximate and ultimate analysis of the substrate.

Proximate analysis: A typical proximate analysis includes moisture, ash, volatile matter, and fixed carbon contents.

Moisture:

The moisture content of the sample is determined by drying 1 gram of sample at 1050 C for one hour. Weight loss is expressed in % of initial weight of sample as

Moisture (%) = (weight loss/weight of sample) ×100

Volatile matter:

Volatile matter is the weight loss obtained on heating 1 gm sample of substance at 950oC for 7 minutes in the absence of air

Weight loss due to VM = Total weight loss – moisture

Volatile Matter (%) = (weight loss due to VM/ weight of sample) ×100.

Ash: Ash is the weight of the residue obtained after complete combustion of one gram of the substance at 700-750 o

Ash (%) = (weight of residue/weight of sample) × 100

Fixed carbon:

Fixed carbon is the material, other than ash, that does not vaporize when heated in the absence of air. It is usually determined by subtracting the sum of the first three values (i.e) moisture, ash, and volatile matter in weight percent from 100 percent.

Fixed carbon (W% wet basis) =100− (%M+%Ash + %VM)

In India as mentioned earlier the moisture content of municipal solid waste is in the range of 15-40%. Likewise, the volatile matter and fixed carbon is 40-60% and 5-12%, respectively.

Fusing point of ash

The fusing point ash is defined as that temperature at which the ash resulting from the burning of waste will form a solid by fusion and agglomeration. Typical fusing temperature for the formation of clinker from solid waste range from 1100 to 1200 °C.

f. Calorific Value

Calorific value of waste is defined as the amount of heat generated from combustion of a unit weight of the waste, expressed as kJ/kg. The calorific value is determined experimentally using a Bomb Calorimeter, in which the heat generated from the combustion of a dry sample is measured, at a constant temperature of 25°C. The calorific value of waste is depends on the composition of the waste. The CV of the waste depends on the composition of the waste. Waste with a lot of PVC has a higher calorific value then waste with less PVC and more paper. To estimate the calorific value of the waste mix you have, you can make an average on your composition.

Calorific Value of mixed solid waste

Material-fraction	**Calorific value**	**% amount**
Hazardous waste	12	20
Medical Waste	19	50
Plastics - PVC	35	30

2.5.3 .Bio-Chemical Characteristics

Bio-chemical characteristics of waste determine the suitability of specific treatment processes. ULBs should use this information to select the most appropriate treatment process. Chemical characteristics of waste are essential in determining the efficacy of any treatment process.

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

b. **Bio-Chemical characteristics:** carbohydrates, proteins, natural fiber, and biodegradable factor.
c. **Toxicity:** Toxicity profile of MSW includes heavy metals, Persistent Organic Pollutants (POPs), pesticides and insecticides. The Toxicity Characteristic Leaching Procedure (TCLP) is used for ascertaining the toxicity profile of MSW.

2.5.4. Chemical composition of MSW:

- The chemical composition of MSW can vary depending on a number of factors, including the location, season, and types of waste management practices used in the area. The recognition of MSW is based on critical parameters that is used the appropriate processing technology which are density, specific gravity, moisture, calorific values, toxicity etc.

However, generally speaking, the composition of MSW can be broken down into the following categories:

- **Organic waste:** This category includes food waste, yard waste, and other biodegradable materials. Organic waste is typically high in moisture and can decompose quickly, which can contribute to the production of methane gas if not properly managed.
- **Paper and cardboard:** This category includes newspaper, magazines, office paper, and cardboard boxes. Paper and cardboard can be recycled, but they can also contribute to the production of greenhouse gases if they are sent to landfills.
- **Plastics:** This category includes a wide range of materials, such as bottles, bags, and packaging materials. Plastics can take hundreds of years to decompose, and they can also release toxic chemicals into the environment as they break down.
- **Metals**: This category includes aluminum cans, steel cans, and other types of scrap metal. Metals can be recycled indefinitely without losing their quality, making them a valuable resource.
- **Glass:** This category includes bottles, jars, and other types of glass containers. Glass can also be recycled indefinitely without losing its quality.
- **Other materials**: This category includes textiles, rubber, leather, and other miscellaneous materials.

It's worth noting that the chemical composition of MSW can also vary depending on the types of waste management practices used in the area. For example, areas with high rates of recycling and composting may have lower levels of organic waste and higher levels of recyclable materials.

2.6. Impact of municipal solid waste on environment and human health

Municipal solid waste (MSW) is the term used to describe household and commercial waste that is generated in urban areas. MSW includes a wide range of materials such as food waste, paper, plastics, glass, and metals. The disposal of MSW can have significant impacts on both the environment and human health. In this essay, we will examine the various ways in which MSW can impact the environment and human health, and explore potential solutions to mitigate these impacts.

Environmental Impacts

- **Landfill Gas Emissions:** One of the primary environmental impacts of MSW is the emission of landfill gases. As organic waste decomposes in landfills, it produces methane and other greenhouse gases that contribute to climate change. Methane is a potent greenhouse gas that is around 25 times more effective at trapping heat than carbon dioxide. According to the US Environmental Protection Agency (EPA), landfills are the third-largest source of methane emissions in the United States. These emissions can be reduced by capturing the gas and using it for energy generation.
- **Air Pollution:** MSW can also contribute to air pollution. When waste is burned, it releases toxic gases such as carbon monoxide and nitrogen oxides. These gases can cause respiratory problems and other health issues. In addition, the burning of waste produces particulate matter, which can lead to lung cancer, heart disease, and other health problems. Landfills can also contribute to air pollution by releasing volatile organic compounds (VOCs) and other pollutants.
- **Water Pollution**: MSW can also contribute to water pollution. When waste is dumped in landfills, it can seep into the soil and contaminate groundwater. Leachate, which is the liquid that is produced when water percolates through the landfill, can contain heavy metals, pesticides, and other pollutants. This leachate can then contaminate surface water and groundwater, which can lead to health problems for humans and animals.

Human Health Impacts.

- **Exposure to Hazardous Chemicals**: MSW can contain hazardous chemicals such as lead, mercury, and arsenic. When these chemicals are released into the environment, they can cause a wide range of health problems such as neurological damage, cancer, and reproductive problems. Exposure to these chemicals can occur through air pollution, water pollution, and direct contact with contaminated soil.
- **Disease Transmission:** MSW can also be a source of disease transmission. When waste is not properly managed, it can attract insects and rodents that can carry diseases such as Salmonella, E. coli, and Hantavirus. In addition, uncontrolled dumping of waste can lead to the breeding of mosquitoes that can transmit diseases such as malaria and dengue fever.
- **Injury and Fatality:** Improperly managed MSW can also lead to injury and fatality. For example, when waste is not properly disposed of, it can create hazards for pedestrians and motorists. In addition, waste collection workers can be injured or killed on the job when handling waste..

Solutions to Mitigate Impacts

- **Reduce, Reuse, Recycle:** One of the most effective ways to mitigate the impacts of MSW is to reduce the amount of waste that is generated. This can be achieved through strategies such as reducing packaging, using reusable bags and containers, and composting food waste. In addition, materials such as paper, plastics, and metals can be recycled, reducing the amount of waste that ends up in landfills.
- **Waste-to-Energy**: Another solution is to use waste-to-energy technologies to capture the energy from MSW. This can be achieved through incineration or by capturing landfill gas and using it to generate electricity. Waste-to-energy technologies can help reduce greenhouse gas emissions and generate renewable energy.
- **Landfill Management:** Proper landfill management is critical to reducing the environmental and human health impacts of MSW.

2.7. Composition and State of municipal solid waste in India

Municipal solid waste (MSW) is a significant environmental and public health issue in India. India is in a rapid phase of urbanization with nearly 32% of the population of the country staying in the urban areas according to 2011 census. This rapid urbanization is putting immense demand on its resources, infrastructure and energy requirements. With a population of over 1.3 billion people and rapid urbanization, the country generates a large amount of waste. The state of MSW management in India has been a cause for concern due to the lack of proper infrastructure and resources. The average per capita waste in India is about 670 grams per day. According to the World Bank's 2020 data, the per capita municipal solid waste generation in India is 0.56 kilograms per day, in the United States it is 2.58 kilograms per day, and in China it is 1.02 kilograms per day. The per capita waste generation in the country is increasing at the rate of 1.3% per year. The per capita waste generation refers to the amount of waste generated by one person in one day in a country. This is affected by the economic ability and hence is strongly correlated to the GDP of the country.

As of my knowledge cutoff date, the per capita municipal solid waste generation of India, USA, and China was:

India: 0.33 kg/person/day

USA: 2.58 kg/person/day

China: 1.0 kg/person/day

Cities in the Southern states of India generate highest per capita waste of 570grams/day. While the cities in the western states of the country produce the least amount of per capita waste of 440grams/day.

It's important to note that waste generation can vary depending on factors such as population density, economic development, and cultural practices, among others. Additionally, these numbers may have changed since my knowledge cutoff date.Generally, MSW in India is composed of organic and inorganic waste. Organic waste, such as food waste, accounts for the largest percentage of the total waste generated in India. Other components of organic waste include yard waste, animal waste, and human waste. Inorganic waste, such as plastics, paper, metals, and glass, also contribute to the waste generated in India.According to a report by the Central Pollution Control Board (CPCB), the composition of MSW in India is as follows:

Organic waste: 51%	Recyclables: 17%
Inerts: 11%	Plastic: 6%

Paper: 5%	Textiles: 3%
Leather and rubber: 2%	Metals: 1%
Others: 4%	

The high percentage of organic waste in MSW is a challenge for waste management in India. Presently there is no proper system of management of this waste. Firstly there is lack of storage and segregation of waste at source as people lack awareness and so do not participate in managing the waste. Secondly, there is no proper public system of waste collection from the primary sources and so municipal sanitation workers collect the waste thrown in streets and public open spaces on an irregular basis. Wastes are collected mostly using handcarts and tricycles and are stored in temporary storage spaces before being transported by motorized vehicles. These temporary storage spaces are usually concrete bins and small open spaces in the street corners

Organic waste is highly biodegradable and can quickly degrade, releasing harmful gases such as methane if not properly managed. Additionally, the high percentage of inorganic waste, including plastics, paper, and textiles, presents a challenge for recycling and waste management.

2.8. State of Municipal Solid Waste Management in India

The state of MSW management in India is inadequate due to various challenges, including insufficient infrastructure, lack of resources, and poor governance. According to the Ministry of Housing and Urban Affairs (MoHUA), only about 60% of the total waste generated in urban areas is collected, and only 15% of the collected waste is processed. The remaining waste is either dumped in open landfills or burnt, leading to environmental pollution and health hazards.The state of MSW management in India is inadequate due to various challenges, including insufficient infrastructure, lack of resources, and poor governance. According to the Ministry of Housing and Urban Affairs (MoHUA), only about 60% of the total waste generated in urban areas is collected, and only 15% of the collected waste is processed. The remaining waste is either dumped in open landfills or burnt, leading to environmental pollution and health hazards.Open landfills are a common practice for disposing of waste in India. However, open landfills pose significant environmental and health risks. Open landfills can contaminate groundwater, soil, and air with harmful pollutants, leading to health problems such as respiratory diseases, skin disorders, and cancer.

In addition to open landfills, the practice of burning waste is also prevalent in India. Burning waste releases harmful gases and toxins into the air, leading to air pollution and respiratory problems. The informal sector also plays a significant role in the waste management system in India, with many informal waste collectors collecting waste from households and selling it to recyclers. However, this sector often operates under poor working conditions and without proper safety equipment, leading to health risks for workers.The lack of infrastructure and resources, including waste collection vehicles, processing facilities, and trained personnel, also presents challenges for MSW management in India. Additionally, the lack of awareness and participation from the public regarding waste management practices and environmental sustainability poses a challenge for effective waste management.

2.9. Opportunities for Improvement

Despite the challenges, there are opportunities for improvement in MSW management in India. One approach is to reduce the amount of waste generated in the first place. This can be achieved through initiatives such as source segregation of waste, composting, and recycling. Source segregation involves separating waste at the source into different categories, such as organic waste, recyclables, and non-recyclables. Composting involves converting organic waste into nutrient-rich compost that can be used as a soil conditioner. Recycling involves the collection and processing of recyclable materials, such as paper.

2.10.Summary

Municipal solid waste (MSW) refers to the waste generated by households, businesses, and institutions in urban areas. This includes a wide range of materials, such as paper, plastics, food waste, yard waste, metals, and glass.The amount of MSW generated varies by country and region, but it is generally a significant environmental issue. Improperly managed MSW can lead to pollution, greenhouse gas emissions, and health hazards.There are several methods for managing MSW, including landfilling, incineration, and recycling. Landfills involve burying waste in designated areas, while incineration involves burning waste to produce energy. Recycling involves separating materials from the waste stream and processing them into new products. Efforts to reduce MSW typically focus on waste reduction and diversion, which involves diverting materials from landfills and incinerators through recycling, composting, and other methods. Waste-to-energy technologies, such as anaerobic digestion and gasification, are also being developed as alternatives to traditional disposal methods.

2.11. Terminal questions

1. What is the municipal solid waste? Discuss is characterization.

Answer:--

2. Discuss the classification and impact of municipal solid waste.

Answer:--

3. Discuss about solid waste generation in India and its characterization.

Answer:--

4. Discuss about municipal solid disposal and management.

Answer:--

5. Discuss the impact of solid waste on environment and human health.

Answer:--

2.13. Further suggested readings

2. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.
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4. Bio- medical waste management, Sahai, Sushma, APH Publishing.
5. Electronic waste management,design, analysis and application, R E Hester ,Cambridge Royal Society of Chemistry
6. Solid and Hazardous Waste Management, Rao, M.N. and Sultana ,BS Publications, Hyderabad

Unit-3: Disposal of Solid Wastes

3.1. Introduction

Disposal of solid waste refers to the management and final destination of waste materials produced by human activities. Solid waste can come from various sources such as households, commercial establishments, industries, and construction sites.The proper disposal of solid waste is critical to public health and the environment. If waste is not disposed of properly, it can lead to the spread of diseases, pollution of air, water, and soil, and contribute to climate change.There are various methods for the disposal of solid waste, including landfilling, incineration, and composting, recycling, and waste-to-energy technologies. Each method has its advantages and disadvantages, and the appropriate method depends on the type and quantity of waste, as well as local regulations and infrastructure. Effective management of solid waste requires a comprehensive approach that includes reducing waste generation, reusing and recycling materials, and promoting responsible disposal practices.

Objectives

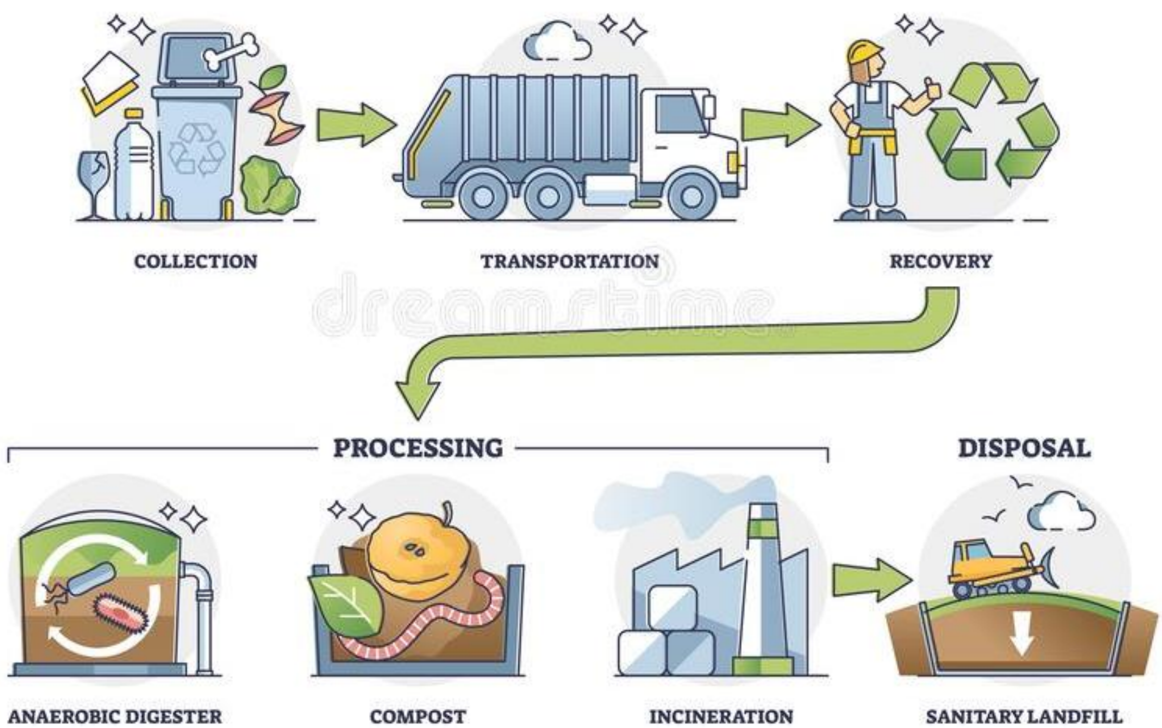
- to discuss the solid waste and its segregation and storage
- to discuss the Various methods for solid waste disposal
- to discuss the Sanitary Land filling
- to discuss the Waste-to-Energy generation

3.2. Solid waste Disposal overview

Disposal of solid waste refers to the final stage of waste management, which involves the safe and proper disposal of waste materials. The solid waste disposal is carried out in proper way in which follow engineering techniques to avoid environmental and health hazardous. In the solid waste management involved various namely waste collection, segregation, transportation, processing, treatment and finally disposal. However, in solid waste management the waste disposal process is final or last stage but is so crucial task. For waste disposal, it is very difficult task to select waste disposal sites. Most of developing and under developing country dispose or dump the solid waste in an open land without any protection or environmental control. Such dumping is not safe and is called as open dumps or open dumping. Solid waste is also disposed off in water bodies e.g. Sea, ocean, lake, river etc. Sometimes they are also burned in open areas, the phenomenon termed as open burning. Developed countries are practicing a system of safe or controlled dumping called the landfill. Landfill is an engineered structure where the waste is safely disposed and contained.

Landfillsis the most common method of solid waste disposal, where waste is buried in large, lined pits in the ground. Landfills are designed to prevent pollution of the environment and are typically monitored and managed by government agencies.

Incinerationmethod involves burning solid waste at high temperatures about 1850 °C to convert it into ash, gas, and heat and reduced the volume of solid waste. Incineration of waste depends on the various factors like moisture contents heating value, inorganic content, sulphur and halogen content



Compostingalsoinvolves the controlled decomposition of organic waste, such as food and yard waste, to produce a nutrient-rich soil amendment. Composting can be done at home or on a large-scale at a composting facility.

Recyclingmethod involves the collection, sorting, and processing of waste materials to produce new products. Examples of materials that can be recycled include paper, plastic, glass, and metal.

Waste-to-energy technologies are technologies that convert waste into energy, such as electricity or heat. Examples of waste-to-energy technologies include anaerobic digestion, gasification, and pyrolysis.

Effective solid waste disposal requires a comprehensive approach that involves reducing waste generation, reusing and recycling materials, and promoting responsible disposal practices. This can be achieved through public education, policy development, and investment in infrastructure and technologies.

3.3. Segregation and shorting of solid waste

Segregation and sorting of solid waste refer to the process of separating waste materials into different categories based on their characteristics, such as material type, biodegradability, and toxicity. This process is important to enable the efficient and effective treatment, recycling, and disposal of waste materials.Segregation and sorting of solid waste can be done at the source of generation, such as households, commercial establishments, and industries, or at a centralized sorting facility. The following are some common categories into which waste materials are segregated and sorted.

- **Biodegradable waste**: This includes organic waste, such as food scraps and yard waste, which can be composted to produce nutrient-rich soil amendment
- **Recyclable waste:** This includes materials such as paper, plastic, metal, and glass, which can be sorted and processed to produce new products..
- **Hazardous waste:** This includes materials that are toxic, flammable, or reactive, such as batteries, chemicals, and electronic waste. These materials require special handling and disposal to prevent harm to human health and the environment.
- **Inert waste**: This includes materials that do not decompose or pose a risk to human health or the environment, such as construction and demolition debris.

Segregation and sorting of solid waste require adequate infrastructure, such as waste collection systems, sorting facilities, and recycling and disposal facilities. It also requires public education and awareness to promote responsible waste disposal practices and encourage waste reduction, reuse, and recycling.Overall, segregation and sorting of solid waste are essential components of sustainable waste management, as they enable the recovery of valuable resources, reduce waste sent to landfills and incinerators, and minimize the environmental and health impacts of waste disposal.

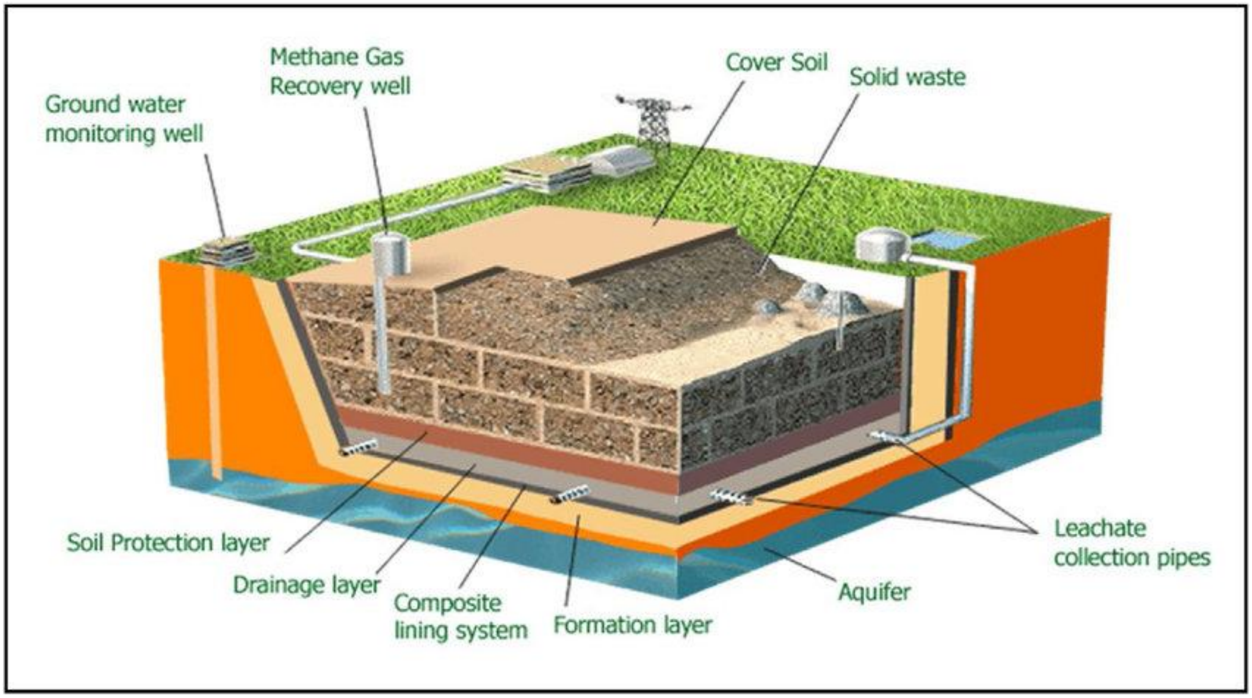
3.4. Various methods of solid waste Disposal

There are several methods for solid waste disposal, including:

- Sanitary Land filling
- Incineration
- Open dumping
- Recycling
- Composting
- Waste-to-Energy
- Pyrolysis
- Plasma Gasification

3.4.1. Sanitary Land filling

This is the most common method of solid waste disposal. Waste is placed in a designated area, usually lined with an impermeable layer to prevent leaching of pollutants into the soil and groundwater. As waste decomposes, it produces gases, which can be collected and used for energy production. The land fillings site is engineered structure for disposal or containment of solid waste. In land filling keep understanding environmental protection and health of people. It is the largest route of waste disposal that follow the waste disposal standard to safe local, regional and global environment. Landfills are not homogeneous. They are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier. This landfill option of waste disposal is suitable only when the land is available at an affordable price, availability of adequate workforce, availability of technical resources to operate and manage the site. Landfill helps in protecting the environment from various effects. The main purpose of designing a landfill is to contain the waste and protect the environment through a geological barrier and liner system at the base, sides and on top named the cap of the system landfill. The landfills are composed of three main components.



Liner system – used at the bottom to protect the soil and ground water.

Waste emplacement cells – pattern by which waste is loaded into the landfill

- Cover or capping – It is the top most protection layer that prevents the entry of water or other animals into the waste pile
- Leachate collection system
- Groundwater monitoring system
- Methane gas monitoring system

The sites selection for land filling is most responsible task which depend on certain criteria

- The land filling sites should not present near residential or industrial area it should be way from source of waste generation or form boundary of the side of residential area, agricultural or urban area.
- Therese should be proper roads transport infrastructure to connect waste disposal sites and filling sites.
- The impact of the landfills on the local environment should be studied.
- The geological and hydro geological stability of the site should be assessed
- Ground water levels, Distances from the boundary of the site to waterways should be measured to avoid contamination of the water bodies.

- Rainfall, wind speed and direction should be collected to prevent the waste from rainfall so that leachate production is minimized and further contamination is avoided.
- Assessment of the direct and indirect effects of the project on human beings, fauna, flora, soil, water, air, climate and landscape, material assets and the cultural heritage.
- Land with agricultural productivity should not be chosen.

Types of sanitary land fill

- There are different types of sanitary landfills that vary in design and operation based on several factors such as the type of waste being disposed of, local regulations, and available technology. Here are some of the common types:
- **Municipal Solid Waste (MSW) Landfills:** These are the most common type of landfill and are designed to receive household and commercial waste generated by communities.
- **Construction and Demolition (C&D) Debris Landfills:** These landfills are designed to accept waste generated from construction and demolition activities such as concrete, wood, bricks, and other building materials.
- **Industrial Waste Landfills**: These landfills are designed to receive waste generated by industrial facilities such as factories and power plants. Industrial waste may contain hazardous materials that require special handling and treatment.
- **Hazardous Waste Landfills:** These landfills are specifically designed to manage hazardous waste materials such as chemicals, solvents, and other toxic materials. They are regulated under strict rules and regulations to prevent any harm to the environment or public health.
- **Bioreactor Landfills:** These are newer landfills that use technology to speed up the decomposition process of waste by increasing moisture and oxygen levels. This accelerates the production of biogas, which can be collected and used as a source of energy. Regardless of the type, all sanitary landfills aim to minimize the impact of waste on the environment and public health. The choice of a specific type of landfill depends on the type of waste being disposed of and the local regulations in place.

Advantages of sanitary land fill

- There are several advantages to using sanitary landfills for waste disposal:

- **Reduction of Environmental Impacts**: Sanitary landfills are designed to minimize the negative environmental impacts of waste disposal. They have liners and other features to prevent contamination of soil, groundwater, and air. They also use methods to control odors, pests, and other nuisances.
- **Efficient Use of Land:** Sanitary landfills can be designed to take up less land than traditional landfills because they are built with liners and compacted waste. This means they can be located in more densely populated areas and still take up less land.
- **Waste Management:** Sanitary landfills provide a central location for waste disposal that can be managed more efficiently than other methods. They also provide a source of revenue for local governments through fees charged for use.
- **Energy Generation**: Modern sanitary landfills are capable of producing energy in the form of biogas, which is generated by the decomposition of organic waste. This biogas can be collected and used as a source of renewable energy.
- **Cost-Effective**: Compared to other waste disposal methods such as incineration, sanitary landfills are generally more cost-effective. The cost of building and operating a landfill can be spread over many years, making it a cost-effective solution for long-term waste management.

While there are advantages to using sanitary landfills, it is important to note that they are not without their drawbacks. The long-term environmental impacts of landfills, such as the release of greenhouse gases and leachate, must be carefully managed to minimize their negative impacts on the environment and public health.

Disadvantages of sanitary land fill

Solid waste landfills have several disadvantages, including:

- **Environmental pollution**: Landfills can pollute the surrounding environment by releasing harmful chemicals and gases such as methane, carbon dioxide, and leachate into the air and water.
- **Health risks:** Landfills can pose health risks to nearby communities due to the release of hazardous materials and air pollutants that can cause respiratory problems, skin irritation, and other health issues.

- **Health risks:** Landfills can pose health risks to nearby communities due to the release of hazardous materials and air pollutants that can cause respiratory problems, skin irritation, and other health issues.
- **Land use:** Landfills take up valuable land space that could be used for other purposes such as residential or commercial development.
- **Long-term management**: Landfills require long-term management and maintenance, including monitoring for potential environmental and health risks, and the eventual closure and restoration of the site.

Consideration Landfill sites

- A waste landfill is major design and engineering project and requires a number of considerations. The following considerations are very important
- Site capacity: The capacity of the site is a key factor in design of a landfill. The capacity is decided based on
  - amount of waste generated
  - waste density
  - Amount of intermediate and daily cover
  - Thickness of capping system
  - Amount of settlement
- Waste density: The density of the waste within the landfill depends
- on the degree of pre-compaction of the waste before emplacement
- the variation of components within the waste
- the extent of biodegradation
- the amount of daily and intermediate cover and
- the mass of overlying waste.
- The degree of pre-compaction influences the amount of waste to be loaded into the landfill and amount of waste settlement in landfill. The waste densities range from 0.65 to 0.85 tons/m3
- Settlement: Settlement of the waste in the landfill occurs due to physical rearrangement of the waste soon after loading. However, inert waste shows low settlement. Settlement occurs in three ways.

- **Initial compression** – it is instantaneous and occurs due to compaction of void space and particles caused by the compression of the overlying waste and the compaction vehicles
- **Primary compression** – occurs due to the dissipation of pore water and gases from the void space and usually takes around 30 days 10 Environmental Sciences Solid and Hazardous Waste Management Solid waste disposal, open dumping and landfills
- **Secondary compression** – it takes years and occurs due to biodegradation of waste. Leachate and landfill gas reduces mass and volume.

- Material requirement: Landfill construction requires lot of materials Eg. natural fill material such clay, sand, gravel and soil – used as lining material.
- Drainage: It is another important factor that needs consideration during construction of a landfill.
- Operation practice: During landfill construction and operation, daily operation of the landfill including traffic movement, cover material storage and laying, security should be considered.

3.4.2. Incineration

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. This process is typically carried out at high temperatures in specialized incineration facilities or plants.The primary purpose of incineration is to reduce the volume and weight of waste materials while also destroying harmful pollutants and pathogens that may be present. Incineration can be used to treat a wide range of waste materials, including municipal solid waste, medical waste, hazardous waste, and industrial waste.While incineration can be an effective waste treatment method, it also has some potential drawbacks. One concern is the emission of air pollutants, such as particulate matter, nitrogen oxides, and sulfur dioxide, from the incineration process. These pollutants can have negative impacts on air quality and public health. Another concern is the potential for the release of toxic substances, such as heavy metals and dioxins, from the combustion of certain types of waste materials. Proper regulation and monitoring of incineration facilities are necessary to minimize these risks. Overall, incineration can be a useful waste treatment method when properly implemented and regulated, but it should not be the sole solution to waste management challenges. Other waste reduction and diversion strategies, such as recycling and composting, should also be pursued to minimize the amount of waste that requires treatment in the first place.

Incineration is often used for medical and hazardous waste disposal. Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. This process is typically carried out at high temperatures in specialized incineration facilities or plants.The primary purpose of incineration is to reduce the volume and weight of waste materials while also destroying harmful pollutants and pathogens that may be present. Incineration can be used to treat a wide range of waste materials, including municipal solid waste, medical waste, hazardous waste, and industrial waste.While incineration can be an effective waste treatment method, it also has some potential drawbacks. One concern is the emission of air pollutants, such as particulate matter, nitrogen oxides, and sulfur dioxide, from the incineration process. These pollutants can have negative impacts on air quality and public health.Overall, incineration can be a useful waste treatment method when properly implemented and regulated, but it should not be the sole solution to waste management challenges. Other waste reduction and diversion strategies, such as recycling and composting, should also be pursued to minimize the amount of waste that requires treatment in the first place. There are several methods used in practice for waste incineration

a) Open PIT incinerator
b) Single Chamber
c) Multiple chambers
d) Teepee burner
e) Control air incinerator
f) Rotatory Kiln incinerator

3.4.3. Open dumping

The open dumping is very old practice in which waste are dumped at a designated site or land without any environmental protection or control. Dumping sites are open area where disposed waste remains form long time and affect the local as well as regional environment. But do to problems associated with open dumping it is not recommended as a safe option. There are several problems associated with open dumping sites such as

a. It causes contamination to soil, water and air During uncontrolled dumping the leach ate (a watery liquid that oozes out from the waste
b. percolates into the soil and contaminates it with various toxic pollutants It also affects the microbial diversity of the soil and vegetation of the area
c. Through the soil medium the leach ate can percolate into the ground water and contaminate them
d. Environmental Sciences Solid and Hazardous Waste Management Solid waste disposal, open dumping and landfills during precipitation, the rain water can mix with leachate and be carried off as surface run.
e. Through this they also pollute the water bodies it acts as a source of non point pollution.
f. It affects the biodiversity of the location
g. It produce harmful green house gases such as methane, cobon dioxides etc that contributes in global warming. In addition, it also produces Dioxins, a carcinogen during burning of plastics materials.
h. It also effect the aesthetics of the area is affected when waste is dumped in open areas
i. The waste dumps or piles attract lot of insect, rodent, birds and animals. The contaminates are toxic and affect these species.

The incineration process is significance to reduce waste but it also has lots of disadvantage such as

i. It has high capital cost and economic burden
ii. It also needs skilled operator and observer
iii. It also needs fuel
iv. It creates both air and water pollution

During incineration process the various compounds are left after the burning of refuse like Pb, NO_2, SO_2, HCl, H_2SO_4 and fluorides etc. the most dangerous material produced by incinerator is Dioxin. The Dioxin is the group of organic compounds which causes skin cancer, birth defect and various form of cancer. Due to highly toxic chemical compounds dioxin are formed as by-products during the combustion of certain organic materials, including waste materials. They belong to a larger group of chemicals known as persistent organic pollutants (POPs), which means they are resistant to environmental degradation and can remain in the environment for a long time. ioxins are known to be harmful to human health, even in small amounts. Exposure to dioxins can cause a range of health problems, including cancer, reproductive and developmental problems, immune system damage, and hormonal imbalances. Dioxins can also have harmful effects on the environment, including damage to wildlife and ecosystems. Due to the harmful effects of dioxins on human health and the environment, there are strict regulations in place to limit their production and release into the environment. Proper waste management practices, such as reducing the amount of waste generated, recycling, and safe disposal, can help to reduce the production of dioxins and other harmful pollutants.

3.4.4. Recycling

This method involves processing and reusing waste materials to make new products.In the recycling process, collecting and processing the materials that would otherwise be thrown away as trash and turning them into new products. Recycling helps to conserve natural resources, reduce pollution, and save energy. The municipal solid waste recycling involves the collection, sorting, processing, and conversion of materials such as paper, glass, plastics, metals, and electronics into new products. Here are some common examples of solid waste recycling:

- **Paper Recycling:** Paper is one of the most common materials that can be recycled. Paper recycling involves collecting used paper, sorting it by type and quality, and then processing it into new paper products.
- **Plastic Recycling:** Plastic recycling involves collecting and sorting different types of plastic waste and then processing them into new products. The recycling process usually involves melting the plastic down and then shaping it into new products.
- **Glass Recycling**: Glass recycling involves collecting used glass bottles and jars, sorting them by color and quality, and then processing them into new glass products. The glass recycling process involves melting the glass down and then shaping it into new products.
- **Metal Recycling:** Metal recycling involves collecting and processing different types of metal waste, such as aluminum, steel, and copper, into new products. The recycling process usually involves melting the metal down and then shaping it into new products.
- **Electronic Waste Recycling:** Electronic waste, or e-waste, refers to discarded electronics such as computers, TVs, and cell phones. E-waste recycling involves collecting and

processing these electronics to recover valuable materials such as copper, gold, and silver, and to prevent hazardous materials from entering the environment.

Recycling helps to reduce the amount of waste that ends up in landfills and can conserve natural resources by reducing the need to extract new raw materials. It also helps to reduce pollution and energy consumption by reducing the amount of energy needed to extract and process new materials.

Advantages of waste recycling:

- Conservation of Natural Resources: Recycling helps to conserve natural resources by reducing the need for new raw materials, such as trees, minerals, and petroleum.
- Energy Conservation: Recycling saves energy by reducing the need for energy-intensive processes, such as mining, refining, and manufacturing.
- Reducing Pollution: Recycling reduces pollution by reducing the amount of waste that ends up in landfills, reducing greenhouse gas emissions, and reducing the amount of energy used in the manufacturing process.
- Economic Benefits: Recycling can create jobs in the recycling industry and help to generate revenue through the sale of recycled materials.
- Reducing Waste: Recycling helps to reduce the amount of waste that ends up in landfills, which can help to reduce the amount of land required for waste disposal.

Disadvantages of recycling:

- Limited Materials: Not all materials can be recycled, and some materials, such as certain types of plastic, are difficult to recycle.
- High Cost: Recycling can be expensive due to the cost of collection, sorting, and processing.
- Contamination: Contamination of recycled materials can be a problem, as contaminated materials cannot be recycled.
- Increased Energy Consumption: Recycling can sometimes require more energy than the production of new products, especially if the recycling process is inefficient.
- Transportation: The transportation of materials to recycling facilities can result in additional energy consumption and greenhouse gas emissions.

3.4.5. Composting

Composting is often used in agriculture and landscaping. Composting is a natural process that involves the decomposition of organic materials, such as food waste, yard waste, and paper, into a nutrient-rich soil amendment known as compost. Composting is a simple and effective way to reduce waste and create a valuable resource for gardening and agriculture. This method is also involves the decomposition of organic waste such as food and yard waste into a nutrient-rich soil amendment. Composting is an easy and effective way to reduce waste and create a valuable resource for gardening and agriculture. With the right mix of organic materials and proper management, anyone can create nutrient-rich compost for their gardens or landscapes. The process of composting involves several stages:

- **Collection:** Organic waste materials, such as food scraps and yard waste, are collected and placed in a compost bin or pile.
- **Carbon-Nitrogen Ratio:** A balanced mix of carbon-rich materials, such as leaves or shredded paper, and nitrogen-rich materials, such as food scraps or grass clippings, is added to the compost pile. The ideal carbon-nitrogen ratio is 30:1.
- **Moisture:** The compost pile should be kept moist, but not too wet, to support the growth of microorganisms that break down the organic matter.
- **Turning:** The compost pile should be turned regularly to ensure that oxygen is distributed evenly throughout the pile and to prevent the formation of anaerobic (oxygen-poor) conditions.
- **Maturation:** After several months to a year, the compost will mature and turn into a dark, crumbly material that can be used as a soil amendment.

Types of composting

There are several types of solid waste composting methods that can be used to produce high-quality compost. Here are some common types of solid waste composting:

- **Windrow Composting**: Windrow composting is a traditional composting method that involves piling organic waste materials in long rows, or windrows, and periodically turning them to aerate the compost and promote decomposition.
- **Aerated Static Pile Composting:** Aerated static pile composting involves placing organic waste materials in a large pile and using a system of pipes to blow air through the pile to promote aerobic decomposition.

- **Vermicomposting:** Vermicomposting involves using worms to decompose organic waste materials, such as food scraps and paper, into nutrient-rich compost. Worms eat the organic matter and excrete nutrient-rich castings, which can be used as a soil amendment.
- **In-Vessel Composting:** In-vessel composting involves placing organic waste materials in a closed container, such as a drum or tank, and controlling the temperature, moisture, and aeration to promote decomposition.
- **Bokashi Composting:**Bokashi composting is a method that involves fermenting organic waste materials, such as food scraps, using a special mixture of microorganisms, such as lactobacillus, to break down the waste. The fermented waste can then be added to a compost pile or buried in soil.

Each type of composting method has its own advantages and disadvantages, depending on factors such as the type and quantity of waste, available space, and desired end product. Choosing the right composting method can help to maximize the benefits of composting and produce high-quality compost for use in gardening and agriculture.

Advantage of Composting

- **Reduced Waste**: Composting reduces the amount of organic waste that ends up in landfills, which can help to reduce greenhouse gas emissions.
- **Soil Health:** Compost provides valuable nutrients and improves soil structure, which can help to improve plant growth and yield.
- **Water Retention**: Compost helps soil to retain water, which can reduce water use in gardens and agriculture.
- **Reduced Chemical Use**: Compost can reduce the need for chemical fertilizers and pesticides, which can help to reduce pollution and protect the environment.
- **Cost Savings**: Composting can save money on waste disposal fees and the purchase of chemical fertilizers.

Disadvantages of composting:

- **Space Requirements:** Composting requires space for compost bins or piles, which can be a challenge for people with limited yard space.

- **Time:** Composting can take several months to a year to produce mature compost, which can be a drawback for people who want to see results quickly.
- **Labor Intensive:** Composting requires regular turning and management, which can be labor-intensive for people with busy schedules or physical limitations.
- **Potential for Contamination:** Composting can be contaminated with materials that are not suitable for composting, such as plastics or chemicals, which can affect the quality of the compost.
- **Not Suitable for All Waste:** Composting is not suitable for all types of waste, such as meat, dairy, or pet waste, which can attract pests or cause odors.

Overall, the advantages of solid waste composting outweigh the disadvantages. Composting is an easy and effective way to reduce waste, create a valuable resource for gardening and agriculture, and protect the environment. With proper management and attention to detail, anyone can produce high-quality compost for their gardens or landscapes.

3.4.6.Waste-to-Energy

This method involves using solid waste as a fuel source to generate electricity typically through combustion. Waste-to-energy facilities typically use incineration or gasification technologies to convert waste into energy.

Advantages of waste-to-energy

WTE generates energy from waste materials that would otherwise be disposed of in landfills or incinerators. This energy can be used to power homes, businesses, and industries, reducing reliance on fossil fuels and helping to mitigate climate change.

- **Waste reduction:** WTE reduces the amount of waste that goes into landfills, which can help to conserve landfill space and extend the life of existing landfills. This can be especially important in areas where landfill space is limited.
- **Greenhouse gas reduction:** WTE can help to reduce greenhouse gas emissions by diverting waste materials from landfills and incinerators, which can release methane and other harmful gases. Additionally, the energy produced by WTE can help to reduce the need for fossil fuel-based energy sources.

- **Economic benefits:** WTE can provide economic benefits by generating electricity and heat, creating jobs, and reducing the cost of waste disposal. Additionally, some WTE facilities may be eligible for renewable energy incentives and subsidies.
- **Resource recovery:** WTE can recover valuable resources from waste materials, such as metals and glass, which can be recycled or reused. This can help to conserve natural resources and reduce the need for virgin materials.

Overall, WTE generation offers a range of benefits, including energy production, waste reduction, greenhouse gas reduction, economic benefits, and resource recovery. However, it is important to consider the potential environmental impacts and emissions associated with WTE, as well as the need to prioritize waste reduction and recycling efforts.

3.4.7. Pyrolysis of solid waste

This method involves heating solid waste in the absence of oxygen to produce oil, gas, and char. Pyrolysis is a thermal treatment process that can be used to convert solid waste into valuable products, such as biochar, oil, and gas. During pyrolysis, the waste material is heated in the absence of oxygen, which causes it to decompose and produce volatile gases and char. The process of pyrolysis of solid waste typically involves the following steps:

- **Preparation:** The waste material is prepared by shredding, drying, and sorting to remove any contaminants.
- **Heating:** The waste material is heated to a high temperature, usually between 300-500°C, in the absence of oxygen to prevent combustion.
- **Pyrolysis:** The waste material decomposes into volatile gases, such as methane and hydrogen, and solid char.
- **Cooling and Condensation:** The gases are cooled and condensed to produce liquid oil and gas.
- **Separation:** The char is separated from the liquid oil and gas and can be used as a soil amendment or as a raw material for producing activated carbon.
- Pyrolysis of solid waste has several advantages, including:

Advantages of pyrolysis

- **Waste Reduction**:. Pyrolysis can significantly reduce the volume of solid waste by up to 90%, which can help to reduce landfill space and associated costs.

- **Energy Recovery:** Pyrolysis can recover energy from waste by producing bio-oil and gas, which can be used as a fuel for heating or electricity generation.
- **Resource Recovery:** Pyrolysis can recover valuable resources, such as metals and activated carbon, from waste.
- **Environmental Benefits:** Pyrolysis can reduce greenhouse gas emissions by diverting waste from landfills and reducing the need for fossil fuels.
- **Versatility:** Pyrolysis can be used to process a variety of waste materials, including biomass, plastics, and rubber.

Disadvantages of pyrolysis:

- **High Capital Costs:** Pyrolysis equipment can be expensive to purchase and install, which can make it cost-prohibitive for some communities.
- **Operational Challenges:** Pyrolysis requires careful monitoring and management to prevent equipment damage and ensure product quality.
- **Emissions:** Pyrolysis can produce emissions of greenhouse gases, such as carbon dioxide and methane, and air pollutants, such as nitrogen oxides and particulate matter, which can have negative environmental impacts if not properly controlled.
- **Feedstock Limitations:** Pyrolysis is most effective with certain types of waste, such as wood or agricultural waste, and may not be suitable for all types of waste.
- **Residue Management:** Pyrolysis generates a residue that must be disposed of or reused, which can add to the overall costs of the process.

3.4.8. Plasma Gasification

This method involves using plasma, a high-temperature ionized gas, to convert solid waste into a gas that can be used as a fuel source or disposed of safely. Plasma gasification is an emerging technology that has the potential to be more efficient and environmentally friendly than traditional incineration methods. During the plasma gasification process, waste is fed into a gasifier, where it is exposed to a plasma arc that ionizes and vaporizes the waste materials. Plasma gasification from solid waste has the potential to offer several benefits, including waste reduction, energy recovery, and resource recovery. However, it also presents some challenges, such as high capital costs, emissions, and operational challenges. Careful consideration of the advantages and disadvantages is necessary to determine if plasma gasification is a viable option for a particular community or situation.The process of plasma gasification of solid waste typically involves the following steps:

- **Preparation:** The waste material is prepared by shredding, drying, and sorting to remove any contaminants.
- **Feeding:** The waste material is fed into a gasifier, where it is exposed to a plasma arc.
- **Gasification:** The plasma arc vaporizes the waste material and breaks down the molecules into their constituent elements, such as carbon, hydrogen, and oxygen.
- **Quenching:** The gas produced in the gasification process is cooled rapidly in a quench chamber, where it is converted into a syngas.
- **Cleanup:** The syngas is cleaned and processed to remove any impurities and contaminants, such as sulfur and nitrogen compounds.
- **Energy Recovery:** The cleaned syngas can be used as a fuel for electricity generation or other industrial processes.

Advantages of plasma gasification

- **Waste Reduction:** Plasma gasification can significantly reduce the volume of solid waste by up to 95%, which can help to reduce landfill space and associated costs.
- **Energy Recovery:** Plasma gasification can recover energy from waste by producing a syngas, which can be used as a fuel for heating or electricity generation.
- **Resource Recovery:** Plasma gasification can recover valuable resources, such as metals and glass, from waste.
- **Environmental Benefits:** Plasma gasification can reduce greenhouse gas emissions by diverting waste from landfills and reducing the need for fossil fuels.
- **Versatility:** Plasma gasification can be used to process a variety of waste materials, including municipal solid waste, medical waste, and hazardous waste.

Disadvantages of plasma gasification

- High Capital Costs: Plasma gasification equipment can be expensive to purchase and install, which can make it cost-prohibitive for some communities.
- Operational Challenges: Plasma gasification requires careful monitoring and management to prevent equipment damage and ensure product quality.

- Emissions: Plasma gasification can produce emissions of greenhouse gases, such as carbon dioxide and methane, and air pollutants, such as nitrogen oxides and particulate matter, which can have negative environmental impacts if not properly controlled.

3.5. Solid waste disposal in India

Solid waste disposal is a significant challenge in India due to the country's large population, rapid urbanization, and insufficient waste management infrastructure. According to the Ministry of Environment, Forests and Climate Change, India generates around 62 million tonnes of solid waste annually, with about 43 million tonnes collected and only 11.9 million tonnes treated. here are different methods of solid waste disposal in India, including landfilling, incineration, composting, and recycling. However, the majority of the waste is still disposed of in open landfills or dumpsites, leading to environmental and health hazards. The government of India has taken several initiatives to address the solid waste disposal issue, such as the Swachh Bharat Abhiyan (Clean India Mission) and the National Clean Energy Fund. Under the Swachh Bharat Abhiyan, the government aims to make India clean by providing proper waste management infrastructure and promoting behavior change towards cleanliness and sanitation. Many non-governmental organizations and private sector companies are also working towards solid waste management in India. They are implementing different waste management practices, including the segregation of waste at source, recycling, and composting. Despite these efforts, there are still significant challenges in solid waste management in India, such as lack of awareness among citizens, inadequate funding and resources, and insufficient infrastructure. It is crucial to continue implementing and enforcing effective waste management policies and practices to address this issue and ensure a clean and healthy environment for all.

Advantages of solid waste disposal:

- Waste Reduction: Municipal solid waste treatment and disposal can significantly reduce the volume of solid waste by up to 90%, which can help to reduce landfill space and associated costs.
- Energy Recovery: Some waste treatment methods, such as incineration, can recover energy from waste by producing electricity or heat.
- Environmental Protection: Proper disposal of municipal solid waste can help to protect the environment by preventing pollution of soil, water, and air.

- Resource Recovery: Some waste treatment methods, such as recycling and composting, can recover valuable resources, such as metals and organic matter, from waste.
- Public Health: Proper disposal of municipal solid waste can help to protect public health by preventing the spread of disease and reducing the risk of exposure to hazardous substances.

Disadvantages of solid waste disposal:

- Environmental Impacts: Some waste treatment methods, such as incineration, can produce air emissions that can harm the environment and public health.
- Costs: Municipal solid waste treatment and disposal can be expensive, particularly for methods that require specialized equipment and technology.
- Limited Capacity: Landfills, which are a common method of municipal solid waste disposal, have limited capacity and can quickly become full.
- NIMBY (Not In My Backyard) Syndrome: Some communities may resist the siting of waste treatment facilities near their homes, which can make it difficult to establish new facilities.
- Health Risks: Workers at waste treatment facilities can be exposed to hazardous substances, which can pose health risks if proper safety measures are not taken.

3.6. Summary

Solid waste disposal refers to the methods used for managing and disposing of solid waste, which includes household, commercial, and industrial waste. There are several methods of solid waste disposal, including landfilling, incineration, recycling, and composting.Landfills are the most common method of solid waste disposal, and they are designed to minimize negative environmental impacts through the use of liners, leachate collection systems, and other features. Incineration involves the burning of waste, which can reduce the volume of waste but also produces air pollution and ash.Recycling is the process of converting waste materials into new products, which can reduce the amount of waste that is sent to landfills or incinerated. Composting involves the decomposition of organic waste into a soil-like material that can be used for gardening or farming.The choice of a solid waste disposal method depends on several factors, including the type and amount of waste being generated, local regulations, and available technology. Each method has its own advantages and disadvantages, and the best approach is often a combination of methods that takes into account both environmental and economic considerations. Solid waste treatment and disposal can provide several benefits, including waste reduction, energy recovery, and environmental protection. However, it also presents some challenges, such as environmental impacts, costs, and limited capacity. Careful consideration of the advantages and disadvantages is necessary to determine the most appropriate method of municipal solid waste treatment and disposal for a particular community or situation.

3.7. Terminal questions

1. What is waste material? How to define different types of waste material in nature.

Answer:--
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2. Discuss the waste disposal and its significance in nature.

Answer:--
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3. What do you understand about waste segregation? Discuss segregation methodology in brief.

Answer:--
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4. How many types of waste disposal methods? Discuss the sanitary land fill method of waste disposal.

Answer:--
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5. Discuss the advantage and disadvantage of waste disposal methods.

Answer:--
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6. Discuss the impact on sanitary landfill on local, regional, and global levels.

Answer:---

3.8. Further suggested readings

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Block-2

PGEVS-108N

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Solid and Hazardous Waste Management

Block- 2

Hazardous and Biomedical Waste

UNIT -4

Hazardous Waste

UNIT-5

Hazardous Waste Treatment Methods

UNIT-6

Biomedical wastes

PGEVS-108N

Rajarshi Tandon Open University, Prayagraj

Solid and Hazardous Waste Manaaement

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Unit-4: Hazardous Waste

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4.2 Definition

4.3 Sources of hazardous waste

4.3.1 Agricultural land and agro-industry

4.3.2 Domestic

4.3.3 Mines and mineral processing sites

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4.3.6 Institutional hazardous waste sources

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4.4 Types of Hazardous waste

4.4.1 Chemical waste

4.4.2 Household hazardous waste (HHW)

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4.4.4 Paints and solvents

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4.4.6 Pesticides and herbicides

4.4.7 Batteries

4.4.8 Electronics

4.4.9 Electronic waste

4.4.10 Medical waste

4.4.11 Radioactive waste

4.4.12 Industrial waste

4.4.13 Flammable wastes

4.1 Introduction

Hazardous waste is a combination of waste that pose substantial danger now or in the future to human, plant or animal life otherwise they cannot be handled or disposed of without special precautions. Hazardous wastes are the wastes with at least one hazardous characteristic (explosive, flammable, liable to oxidation organic peroxide, acutely poisonous, infectious, and liable to corrosion releases poisonous gases in contact with air or water. Hazardous waste can come from a variety of sources, including industrial processes, chemical and pharmaceutical manufacturing, agriculture, healthcare, and households. These materials can take the form of liquids, solids, or gasses, and can include chemicals, batteries, medical waste, pesticides, and outdated electronics, among others. Proper disposal of hazardous waste is essential to prevent harm to human health and the environment. In many countries, the management and disposal of hazardous waste is regulated by the government to ensure that it is done safely and responsibly. This often involves transportation of the waste to a properly licensed and equipped treatment, storage or disposal facility, where it is managed in a manner that minimizes the risk of harm. It is important to note that hazardous waste should never be thrown away with regular household trash, poured down the drain, or released into the environment, as this can cause harm to people and the environment. Instead, it is important to follow local regulations and guidelines for the proper disposal of hazardous waste.

Objectives

- To study about the characteristics of hazardous waste.
- To study the classification of hazardous waste.
- To understand the collection, segregation and transportation of hazardous waste.
- To study the treatment and disposal options of hazardous waste.

4.2 Definition of hazardous waste

Hazardous waste is used as a broad term to denote industrial by product and waste materials discarded from homes commercial establishment and institutions that pose an unreasonable risk to human health and environment. Hazardous waste can be solid, liquid or gases and semi-liquids like mining sludge and drilling mud. Simply defined, “a hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment”. Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes to batteries and may come in many forms, including liquids, solids, gasses, and sludges.. U. S. Environment Protection Agency (EPA) developed a regulatory definition and process that identifies specific substances known to be hazardous and provides objective criteria for other materials in the regulated hazardous waste universe. Hazardous waste is any material that is potentially dangerous or harmful to human health or the environment. It includes liquids, solids, gasses or sludges that are discarded as a result of industrial, commercial, or medical activities. Hazardous waste is a type of dangerous goods. They usually have one or more of the following hazardous traits:

Ignitability, reactivity, corrosively, toxicity. This include familiar items like used motor oil and mercury, agricultural pesticides and industrial material such as asbestos and PCBS.

4.3 Sources of hazardous waste

The term hazardous waste often includes by-products of industrial, domestic, commercial, and health care activities. Rapid development and improvement of various industrial technologies, products and practices may increase hazardous waste generation. Most hazardous wastes are produced in the manufacturing of products for consumption or further industrial application. Hazardous waste sources include industry, institutional establishments, research laboratories, mining sites, mineral processing sites, agricultural facilities and the natural environment. All sources that discharge liquid, gaseous or solid wastes that fit the above definition can be regarded as sources of hazardous wastes. Major hazardous waste sources and their pollution routes in the environment are listed below.

4.3.1 Agricultural land and agro-industry:

Hazardous wastes from agricultural land and agro-industry can expose people to pesticides, fertilizers and hazardous veterinary product wastes. Farms are a major source of these wastes, and agrochemicals can leach into the environment while in storage or can cause damage after their application.

4.3.2 Domestic:

Households stock various hazardous substances such as batteries and dry cells, furniture polishes, wood preservatives, stain removers, paint thinners, rat poisons, herbicides and pesticides, mosquito repellents, paints, disinfectants, and fuels (i.e. kerosene) and other automotive products. These can present a variety of dangers during storage, use and disposal.

4.3.3 Mines and mineral processing sites: Mining and mineral processing sites handle hazardous products that are present in the additives, the products and the wastes.

4.3.4 Health care facilities: Health care facilities are sources of pathological waste, human blood and contaminated needles. Specific sources of these wastes include dentists, veterinary clinics, home health care, blood banks, hospitals, clinics and medical laboratories.

4.3.5 Commercial wastes: Commercial waste sources include gasoline stations, dry cleaners and automobile repair shops (workshops). The types of hazardous wastes generated by these sources depend on the services provided.

4.3.6 Institutional hazardous waste sources: Institutional hazardous waste sources are mainly research laboratories, research centers and military installations. Military establishments also carry out activities that generate other types of hazardous wastes of household, commercial and industrial nature.

4.3.7 Industrial hazardous waste sources: Hazardous wastes are created by many industrial activities. For example, the hazardous wastes from the petroleum fuel industry include the refinery products (fuels and tar), impurities like phenol and cyanides in the waste stream, and sludge flushed from the storage tanks.

4.3.8 Solid waste disposal sites: These are mainly disposal sites for municipal solid waste, but hazardous wastes that have not been properly separated from other wastes are also at these sites.

4.3.9 Contaminated sites: These are sites that are contaminated with hazardous wastes due to activities that use or produce hazardous substances or due to accidental spills. Former sites of industries that used or produced hazardous materials belong to this group.

4.3.10 Building materials: Roofs and pipes made of materials incorporating asbestos, copper, or other materials may present a source of hazardous waste

4.4 Types of Hazardous waste

Hazardous waste is any material that poses a threat to human health or the environment. The types of hazardous waste can vary, but some common examples include:

4.4.1 Chemical waste: This can include waste generated from manufacturing processes, laboratory experiments, and medical facilities. Examples include solvents, acids, and pesticides.

4.4.2 Household hazardous waste (HHW) Any waste that is generated in households that is potentially hazardous to human health or the environment. Examples of HHW include:

4.4.3 Cleaning products: This includes household cleaners, drain openers, oven cleaners, and other products that contain corrosive or toxic chemicals.

4.4.4 Paints and solvents: These include oil-based and latex paints, varnishes, and stains, as well as paint thinners and other solvents.

4.4.5 **Automotive products**: These include motor oil, transmission fluid, antifreeze, and brake fluid.

4.4.6 **Pesticides and herbicides:** These are chemicals used to control pests and weeds in and around the home.

4.4.7 **Batteries:** This includes rechargeable batteries, automotive batteries, and other types of batteries that contain hazardous materials.

4.4.8 **Electronics:** This includes televisions, computers, printers, and other electronic devices that may contain hazardous materials such as lead, mercury, and cadmium.

4.4.9 **Electronic waste:** Electronic waste or e-waste includes discarded electronics, such as computers, televisions, and cell phones. These products can contain hazardous materials such as lead, mercury, and cadmium.

4.4.10 **Medical waste:** This includes any waste generated in healthcare settings, such as hospitals and clinics. Medical waste can include sharps, contaminated gloves, and expired medications.

4.4.11 **Radioactive waste:** Radioactive waste is generated by nuclear power plants, medical facilities, and research laboratories. Examples of radioactive waste include contaminated equipment and materials used in nuclear medicine.

4.4.12 **Industrial waste:** This includes waste generated from industrial processes, such as mining, oil and gas production, and construction. Examples include asbestos, lead, and PCBs.

4.4.13 **Flammable wastes:** Most flammable wastes are also identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing of flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticisers and organic sludges.

4.4.14 **Explosives:** Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

4.5. Identification of hazardous waste

By using either or both of the following criteria, we can identify as to whether or not a waste is hazardous:

- The list provided by government agencies declaring that substance as hazardous.
- Characteristics such as ignitibility, corrosively, reactivity and toxicity of the substance. Let us now explain these two criteria.

4.4.15 Listed hazardous wastes (priority chemicals)

A specific list showing certain materials as hazardous wastes minimises the need to test wastes as well as simplifies waste determination. In other words, any waste that fits the definition of a listed waste is considered a hazardous waste. Four separate lists cover wastes from generic industrial processes, specific industrial sectors, unused pure chemical products and formulations that are either acutely toxic or toxic, and all hazardous waste regulations apply to these lists of wastes. We will describe these wastes, classified in the F, K, P, and U industrial waste codes, respectively, below

4.5.11 F-list: The F-list contains hazardous wastes from non-specific sources, that is, various industrial processes that may have generated the waste. The list consists of solvents commonly used in degreasing, metal treatment baths and sludges, wastewaters from metal plating operations and dioxin containing chemicals or their precursors. Examples of solvents that are F-listed hazardous wastes, along with their code numbers, include benzene (F005), carbon tetrachloride (F001), cresylic acid (F004), methyl ethyl ketone (F005), methylene chloride (F001), 1,1,1, trichloroethane (F001), toluene (F005) and trichloroethylene (F001). Solvent mixtures or blends, which contain greater than 10% of one or more of the solvents listed in F001, F002, F003, F004 and F005 are also considered F-listed wastes.

4.5.1.2K-list: The K-list contains hazardous wastes generated by specific industrial processes. Examples of industries, which generate K-listed wastes, include wood preservation, pigment production, chemical production, petroleum refining, iron and steel production, explosive manufacturing and pesticide production.

4.5.1.3 P and U lists: The P and U lists contain discarded commercial chemical products, off-specification chemicals, container residues and residues from the spillage of materials. These two lists include commercial pure grades of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. An example of a P or U listed hazardous waste is a pesticide, which is not used during its shelf-life and requires to be disposed in bulk. The primary distinction between the two lists is the quantity at which the chemical is regulated. The P-list consists of acutely toxic wastes that are regulated when the quantity generated per month, or accumulated at any time, exceeds one kilogram (2.2 pounds), while U-listed hazardous wastes are regulated when the quantity generated per month exceeds 25 kilograms (55 pounds). Examples of businesses that typically generate P or U listed wastes include pesticide applicators, laboratories and chemical formulators.

4.5.2 Characteristics of Hazardous Wastes

A hazardous waste characteristic is a property that indicates that a waste poses a sufficient threat to deserve regulation as hazardous. EPA tried to identify characteristics which, when present in a waste, can cause death or illness in humans or ecological damage. EPA also decided that the presence of any characteristic of hazardous waste should be detectable by using a standardized test method or by applying general knowledge of the waste's properties. EPA believed that unless generators were provided with widely available and uncomplicated test methods for determining whether their wastes exhibited hazardous characteristics, this system of identifying hazardous wastes would be unfair and impractical. Given these criteria, EPA only finalized four hazardous waste characteristics. These characteristics are a necessary supplement to the hazardous waste listings. They provide a screening mechanism that waste handlers must apply to all wastes from all industries. In this sense, the characteristics provide a more complete and inclusive means of identifying hazardous wastes than do the hazardous waste listings. The four characteristics of hazardous waste are:

1. Ignitability
2. Corrosivity
3. Reactivity
4. Toxicity.

4.5.2.1 IGNITABILITY Ignitable wastes are wastes that can readily catch fire and sustain combustion. Many paints, cleaners, and other industrial wastes pose such a fire hazard.

Most ignitable wastes are liquid in physical form. EPA selected a flash point test as the method for determining whether a liquid waste is combustible enough to deserve regulation as hazardous. The flash point test determines the lowest temperature at which a chemical ignites when exposed to flame. Many wastes in solid or no liquid physical form (e.g., wood, paper) can also readily catch fire and sustain combustion, but EPA did not intend to regulate most of these no liquid materials as ignitable wastes. A no liquid waste is only hazardous due to ignitability if it can spontaneously catch fire under normal handling conditions and can burn so vigorously that it creates a hazard. Certain compressed gases and chemicals called oxidizers can also be ignitable.

4.5.2.2CORROSIVITY Corrosive wastes are acidic or alkaline (basic) wastes which can readily corrode or dissolve flesh, metal, or other materials. They are also among the most common hazardous waste streams. Waste sulfuric acid from automotive batteries is an example of a corrosive waste. EPA uses two criteria to identify corrosive hazardous wastes. The first is a pH test. Aqueous wastes with a pH greater than or equal to 12.5, or less than or equal to 2 are corrosive under EPA's rules. A waste may also be corrosive if it has the ability to corrode steel in a specific EPA-approved test protocol.

4.5.2.3 REACTIVITY A reactive waste is one that readily explodes or undergoes violent reactions. Common examples are discarded munitions or explosives. In many cases, there is no reliable test method to evaluate a waste's potential to explode or react violently under common handling conditions. Therefore, EPA uses narrative criteria to define most reactive wastes and allows waste handlers to use their best judgment in determining if a waste is sufficiently reactive to be regulated. This is possible because reactive hazardous wastes are relatively uncommon and the dangers they pose are well known to the few waste handlers who deal with them. A waste is reactive if it meets any of the following criteria:

i. It can create toxic fumes or gases when exposed to water or under normal handling conditions

ii. It can explode or violently react when exposed to water, when heated, or under normal handling conditions.

iii. It meets the criteria for classification as an explosive under department of transportation rules.

iv. It generates toxic levels of sulfide or cyanide gas when exposed to a pH range of 2 through 12.5.

4.5.2.4 TOXICITY The leaching of toxic compounds or elements into groundwater drinking supplies from wastes disposed of in landfills is one of the most common ways the general population can be exposed to the chemicals found in industrial wastes. EPA developed a characteristic designed to identify wastes likely to leach dangerous concentrations of certain known toxic chemicals into groundwater. In order to predict whether any particular waste is likely to leach chemicals into groundwater in the absence of special restrictions on its handling, EPA first designed a lab procedure that replicates the leaching process and other effects that occur when wastes are buried in a typical municipal landfill. This lab procedure is known as the Toxicity Characteristic Leaching Procedure (TCLP). Using the TCLP on a waste sample creates a liquid leachate that is similar to the liquid EPA would expect to find in the ground near a landfill containing the same waste. Once the leachate is created in the lab, a waste handler must determine whether it contains any of 39 different toxic chemicals above specified regulatory levels. If the leachate sample contains a sufficient concentration of one of the specified chemicals, the waste exhibits the toxicity characteristic (TC). To recap, determining whether a waste exhibits the toxicity characteristic involves two principal steps: (1) creating a leachate sample using the TCLP; and (2) evaluating the concentration of 39 chemicals in that sample against the regulatory levels.

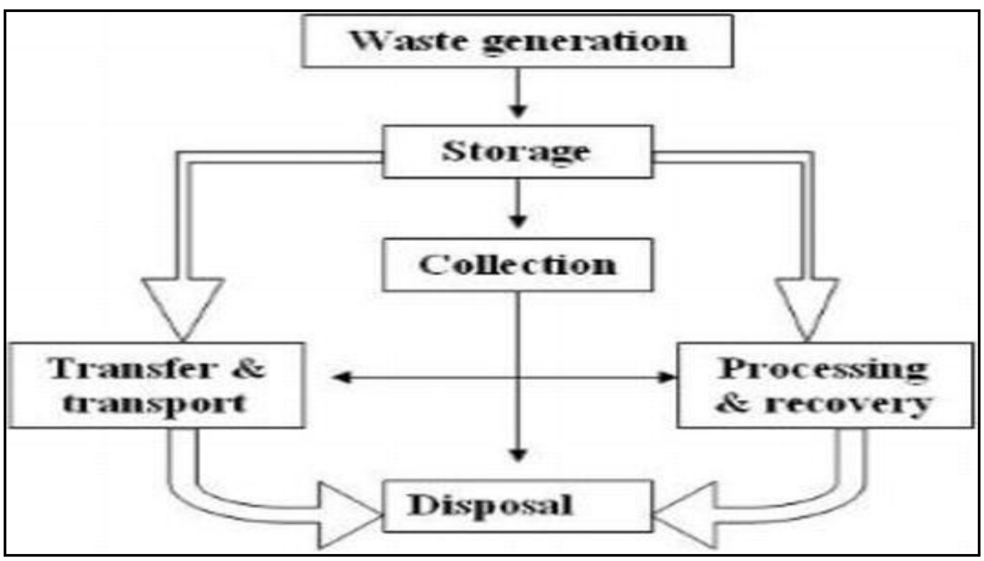
4.6. Hazardous waste management

Hazardous waste was first regulated in 1989 through Hazardous Waste (Management & Handling) Rules, 1989, which subsequently were amended in 2008 to incorporate Basel Convention provisions and lastly recently again in 2016. The Hazardous Waste Management regulations have undergone sea change since its first promulgation in 1989 to take care of requirements of various stakeholders from time to time. Hazardous Waste is regulated by the following agencies in India:

1. Ministry of Environment, Forest & Climate Change, Government of India;
2. Central Pollution Control Board;
3. State Pollution Control Boards and
4. Pollution Control Committees

Hazardous waste management involves reducing the amount of hazardous substances produced, treating hazardous wastes to reduce their toxicity, and applying sound engineering controls to reduce or eliminate exposures to these wastes.

Hazardous waste management is the general term associated with procedures and policies of hazardous waste management that it does not cause any potential threat to man and the environment. Traditionally, hazardous wastes are disposed by dumping in open space and burning. Open dumping results in soil and water pollution and open burning and incineration contribute to air pollution in the form of particulates, nitrogen oxides, noxious odors, and other constituents. After solid waste residues disposed leads to water pollution. Municipal incineration with sophisticated energy recovery systems were popular in large European and American cities at the turn of the century, but became extinct due to high operating costs. In recent years, for hazardous solid waste management incineration has become less popular because of risk associated with increased air pollution control requirements. Because of rapid industrialization the concern of hazardous waste management is increasing. The waste generated from various industrial and domestic activities can result in severe health hazards and also leads to negative impact on the environment. The following procedure illustrates the standard waste management strategy in a developed society. Various steps involved in hazardous waste management was shown in Figure 1 .



4.6.1Generation

Hazardous wastes are generated in limited amounts in a community and very little information is available on the quantities of hazardous waste generated within a community and in various industries. Hazardous waste generation outside the industry is irregular and very less in amount, rendering the waste generation parameter meaningless. The only practical means to overcome these limitations is to conduct a detailed inventory and measurement studies at each potential source in a community. As a first step in developing a community inventory, potential sources of hazardous waste are to be identified. The total annual quantity of hazardous waste at any given source in a community must be established through data inventory completed during onsite visits.

Table 1 below presents a list of hazardous waste generation sources:

4.6.2Common Hazardous Wastes: Community Source

Waste Category	**Sources**
Radioactive substances	Biomedical research facilities, colleges and university laboratories, offices, hospitals, nuclear power plants, etc.
Toxic chemicals	Agricultural chemical companies, battery shops, car washes, chemical shops, college and university laboratories, construction companies, electric utilities, hospitals and clinics, industrial cooling towers, newspaper and photographic solutions, nuclear power plants, pest control agencies, photographic processing facilities, plating shops, service stations etc.
Biological wastes	Biomedical research facilities, drug companies, hospitals, medical clinics, etc.
Flammable wastes	Dry cleaners, petroleum reclamation plants, petroleum refining and processing facilities, service stations, tanker truck cleaning stations, etc.
Explosives	Construction companies, dry cleaners, ammunition production facilities, etc.

In addition to the sources listed, the spillage of containerized hazardous waste must also be considered an important source. The quantities of hazardous wastes that are involved in spillage are usually not known. The effects of spillage are often spectacular and visible to the community. Because the occurrence of spillage cannot be predicted, the potential threat to human health and environment is greater than that from routinely generated hazardous wastes.

4.6.3. Responsibilities of Occupier- Certain responsibilities have been rested on the occupier of hazardous and other wastes generator for safe and environmentally sound management of hazardous wastes starting from pollution prevention to safe disposal. The occupier is required to follow the following steps:

1. Pollution prevention;
2. Waste minimization;
3. 3 R Concept (reuse, recycle and recovery);
4. Utilization including co-processing of hazardous wastes in other industries as raw materials or as a fuel substitute;
5. Efficient treatment and safe disposal;
6. Hazardous waste & other wastes shall be sent or sold to an authorized actual user or disposed in an authorized disposal facility only;
7. Shall transport wastes through an authorized or certified transporter to an authorized actual user or to an authorized disposal facility as per the provisions of these rules;
8. Shall provide specific information to TSDF for treatment and disposal, as required for safe storage and disposal;
9. Shall take all the steps to contain contaminants and prevent accident & limit their consequences on human beings and the environment;
10. Shall provide persons working with appropriate training, equipment and the information necessary to ensure their safety;
11. Shall make an application in Form 1 (Appendix E) to the SPCB for Grant of authorization for managing hazardous and other wastes along with copies of Consent to establish under Water and Air Acts. In case of renewal of authorization, a self-certified compliance report of effluent, emission standards and the conditions specified in earlier authorization of hazardous & other wastes;
12. Shall make renewal application three months before the expiry of authorization;

4.6.4. Storage Requirements

The occupiers of facilities generating hazardous & other wastes may store for a period of not more than ninety (90) days and a maximum quantity of ten (10) tonnes. The State Pollution Control Board may extend the said period of ninety days in the following cases:

Figure 2: Containers for hazardous waste

- Small generators (up to ten tons per annum) up to one hundred and eighty (180) days of their annual capacity;
- Actual users and disposal facility operators up
    - to one hundred and eighty (180) days of their annual capacity;
- Occupiers who do not have access to any TSDF in the concerned State; or
- The waste which needs to be specifically stored for development of a process for its recycling, recovery, pre-processing, co-processing or utilization;
- In any case on justification grounds up to one hundred and eighty (180) days;

4.6.5. Labeling Requirements

The occupier must mark the hazardous waste containers with the labels as specified in Form 8 (Appendix E) of the Rules with fluorescent yellow colour background written in RED words as 'HAZARDOUS WASTES' and 'HANDLE WITH CARE' in Hindi, English and vernacular language. The word 'OTHER WASTES' to be written prominently in orange in Hindi, English and vernacular language.

Waste Category and characteristics as **per Part C of Schedule II &III of Rules……….**	Incompatible wastes and substances……………………
Total Quantity…………….	Date of Storage………….
Physical State of the waste (Solid/Semi-solid/liquid): **'HAZARDOUS WASTES' 'HANDLE WITH CARE' OR'OTHER WASTES'**	
Sender's name and address	Receiver's name and address
Phone……………	Phone……………
E-mail…………….	E-mail…………….
Tel. and Fax. No……………..	Tel. and Fax. No……………..
Contact Person………………..	Contact Person………………..
In case of Emergency please Contact……………………..	

4.6.6. Hazardous Waste Accumulation/Storage Area In a large establishment where a number of wastes are being generated, an area be designated as a storage area known as central hazardous waste accumulation area. This is an area where hazardous wastes are accumulated prior to being picked up for treatment, recycling or disposal. Requirements for these areas include:

Figure – 3: Sample for Labeling of Containers of Hazardous and Other Wastes

- The accumulation area must be locked or protected from unauthorized entry. A fence around the area is not required if it is in an area that is already restricted from unauthorized personnel.
- Containers must be labeled with the appropriate hazardous waste label.
- There must be appropriate signage identifying the area as hazardous waste storage, and a "No Smoking" signage.

Weekly inspections must be conducted at these areas using the weekly inspection checklist.

4.6.7.Storage and collection of Hazardous waste

- Onsite storage practices are a function of the types and amounts of hazardous
- Usually, when large quantities are generated, special facilities are used that have sufficient capacity to hold wastes accumulated over a period of several days.
- When only a small amount is generated, the waste can be containerized, and limited quantity may be stored.
- For example, corrosive acids or caustic solutions are stored in fiber glass or glass-lined containers to prevent deterioration of metals in the container.
- Great care must also be exercised to avoid storing incompatible wastes in the same container or locations. Typical drum containers used for the storage of hazardous waste:
- Light-Gauge Closed Head Drum
- Light-Gauge Open Head Drum

- The waste generator, or a specialized hauler, generally collects the hazardous waste for delivery to a treatment or disposal site. The loading of collection vehicles is completed in either of the following ways: • Wastes stored in large-capacity tanks are either drained or pumped into collection vehicles
- Wastes stored in sealed drums or sealed containers are loaded by hand or by mechanical equipment onto flatbed trucks. The stored containers are transported to the treatment and disposal facility. To avoid accidents and the possible loss of life, two collectors should be assigned when hazardous wastes are to be collected. The equipment used for collection vary with the waste characteristics.

Waste Category	**Collection Equipment and Accessories**
Radioactive substances	Various types of trucks and railroad equipment depending on characteristics of wastes; special marking to show safety hazard; heavy loading equipment to handle concrete-encased lead containers.
Toxic chemicals	Flatbed trucks for wastes stored in drums; tractor-trailer tank truck combination for large volumes of wastes; railroad tank cars; special interior linings such as glass, fiberglass or rubber.
Biological wastes	Standard packers' collection truck with some special precautions to prevent contact between wastes and the collector; flatbed trucks for wastes stored in drums.
Flammable wastes	Same as those for toxic chemicals, with special colorings and safety warning printed on vehicles.
Explosives	Same as those for toxic chemicals with some restriction on\ transport routes, especially through residential areas.

4.6.8.Transport of hazardous waste

Hazardous waste generated at a particular site often requires transport to an approved treatment, storage, or disposal facility (TSDF). Because of potential threats to public safety and the environment, transport is given special attention by governmental agencies. In addition to the occasional accidental spill, hazardous waste has, in the past, been intentionally spilled or abandoned at random locations in a practice known as "midnight dumping." This practice has been greatly curtailed by the enactment of laws that require proper labeling, transport, and tracking of all hazardous wastes.

4.6.8.1.Transport vehicles

Hazardous waste is generally transported by truck over public highways. Only a very small amount is transported by rail, and almost none is moved by air or inland waterway. Highway shipment is the most common because road vehicles can gain access to most industrial sites and approved TSDFs. Railroad trains require expensive siding facilities and are suitable only for very large waste shipments.

Hazardous wastes can be shipped in tank trucks made of steel or aluminum alloy, with capacities up to about 34,000 liters (9,000 gallons). They also can be containerized and shipped in 200-litre (55-gallon) drums. Specifications and standards for cargo tank trucks and shipping containers are included in governmental regulations.

4.6.8.2.The manifest system

In the United States and other countries a key feature of regulations pertaining to waste transport is the "cradle-to-grave" manifest system, which monitors the journey of hazardous waste from its point of origin to the point of final disposal. The manifest system helps to eliminate the problem of midnight dumping. It also provides a means for determining the type and quantity of hazardous waste being generated, as well as the recommended emergency procedures in case of an accidental spill. A manifest is a record-keeping document that must be prepared by the generator of the hazardous waste, such as a chemical manufacturer. The generator has primary responsibility for the ultimate disposal of the waste and must give the manifest, along with the waste itself, to a licensed waste transporter. A copy of the manifest must be delivered by the transporter to the recipient of the waste at an authorized TSDF. Each time the waste changes hands, a copy of the manifest must be signed. Copies of the manifest are kept by each party involved, and additional copies are sent to appropriate environmental agencies.

In the event of a leak or accidental spill of hazardous waste during its transport, the transporter must take immediate and appropriate actions, including notifying local authorities of the discharge. An area may have to be diked to contain the wastes, and efforts must be undertaken to remove the wastes and reduce environmental or public health hazards.

4.6.8.3.Responsibilities of the Hazardous Waste Transporter

- Vehicle used for transportation shall be in accordance with the provisions under the Motor Vehicle Act, 1988, and rules made there under. He should also require obtaining requisite authorization from SPCB/PCC for transport of hazardous waste.

- Transporter shall possess requisite copies of the certificate (valid authorization obtained from the concerned SPCB/PCC for transportation of waste by the waste generator and operator of a facility) for transportation of hazardous waste.
- Transporter should have valid "Pollution under Control Certificate" (PUCC) during the transportation of hazardous waste and shall be properly displayed.
- Vehicle shall be painted preferably in blue colour with white strip of 15 to 30 cm width running centrally all over the body. This is to facilitate easy identification.
- Vehicle should be fitted with mechanical handling equipment as may be required for safe handling and transportation of the wastes.
- The words "HAZARDOUS WASTE" shall be displayed on all sides of the vehicle in Vernacular Language, Hindi and English.
- The trucks shall be dedicated for transportation of hazardous wastes and they shall not be used for any other purpose.
- Each vehicle shall carry first-aid kit, spill control equipment and fire extinguisher.
- Hazardous Waste transport vehicle shall run only at a speed specified under Motor Vehicle Act in order to avoid any eventuality during the transportation of hazardous waste.
- Educational qualification for the driver shall be minimum of 10th pass. Driver of the transport vehicle shall have valid driving license of heavy vehicles from the State Road Transport Authority and shall have experience in transporting the chemicals.
- Driver (s) shall be properly trained for handling the emergency situations and safety aspects involved in the transportation of hazardous wastes.
- Transporting the wastes in closed container at all time.
- Cleanup in case of contamination.
- Cleaning of vehicles shall be carried out at designated places as authorized by SPCB/PCC

4.6.10Treatment of hazardous waste

Hazardous waste refers to any waste that poses a threat to human health or the environment. Proper treatment of hazardous waste is essential to prevent the release of harmful substances into the environment and to protect public health. Here are some common methods used for the treatment of hazardous waste. Hazardous waste can be treated by chemical, thermal, biological, and physical methods. Chemical methods include ion exchange, precipitation, oxidation and reduction, and neutralization. Among thermal methods is high-temperature incineration, which not only can detoxify certain organic wastes but also can destroy them.

4.6.10.1Physical treatment

Physical treatment of hazardous waste involves the use of physical processes to reduce the volume or toxicity of the waste. Some common physical treatment methods include:

- **Solidification/Stabilization:** This involves mixing hazardous waste with a binding agent, such as cement or lime, to create a solid, less hazardous material that is easier to handle and dispose of.
- **Filtration:** This involves passing the hazardous waste through filters to remove contaminants.
- **Evaporation:** This involves heating the hazardous waste to evaporate the liquid components, leaving behind a concentrated, less hazardous solid material.
- **Separation:** This involves separating the hazardous waste into its component parts, such as metals or organic compounds, for individual treatment or disposal.

Physical treatment methods may be used alone or in combination with other treatment methods, depending on the specific characteristics of the hazardous waste and the desired treatment outcome. It is important to note that the treatment of hazardous waste should only be performed by licensed professionals who have the expertise and equipment necessary to safely handle hazardous materials.

4.6.10.2Thermal treatment:

Thermal treatment is also called as incineration. Incineration is a physical treatment method that can also be considered a chemical treatment method, as it involves burning the hazardous waste at high temperatures to break down the hazardous components into less harmful materials. Special types of thermal equipment are used for burning waste in either solid, liquid, or sludge form. These include the fluidized-bed incinerator, multiple-hearth furnace, rotary kiln, and liquid-injection incinerator. One problem posed by hazardous-waste incineration is the potential for air pollution.

4.6.10.3Chemical treatment

Chemical treatment of hazardous waste involves the use of chemical reactions to neutralize or transform the hazardous waste into less harmful substances. Here are some common chemical treatment methods:

- **Neutralization:** This involves adding chemicals to the hazardous waste to neutralize its acidity or alkalinity, which can reduce its corrosive properties.
- **Oxidation/Reduction:** This involves using chemicals such as hydrogen peroxide or sodium hypochlorite to react with the hazardous waste and convert it into less harmful substances.
- **Precipitation:** This involves adding chemicals to the hazardous waste to cause certain components to form solids or precipitates that can be removed from the waste.
- **Chemical stabilization:** This involves adding chemicals to the hazardous waste to reduce its reactivity or prevent it from leaching into the environment.

Chemical treatment methods can be highly effective in reducing the toxicity of hazardous waste, but they require careful planning and execution to ensure that the chemicals used do not create additional hazards or contaminate the environment. Chemical treatment should only be performed by licensed professionals who have the expertise and equipment necessary to safely handle hazardous materials.

4.6.10.4Biological treatment of hazardous waste

Biological treatment of hazardous waste involves the use of microorganisms to break down and detoxify the hazardous waste. Biological treatment of certain organic wastes, such as those from the petroleum industry, is also an option. One method used to treat hazardous waste biologically is called land farming. In this technique the waste is carefully mixed with surface soil on a suitable tract of land. Microbes that can metabolize the waste may be added, along with nutrients. In some cases a genetically engineered species of bacteria is used. Food or forage crops are not grown on the same site. Microbes can also be used for stabilizing hazardous wastes on previously contaminated sites; in that case the process is called bioremediation. Here are some common biological treatment methods:

- **Bioremediation:** Bioremediation involves the use of naturally occurring or specially selected microorganisms to degrade hazardous substances into less toxic materials. This can be done either in situ (at the site of the hazardous waste) or ex situ (in a bioreactor or other controlled environment).
- **Composting:** Composting involves the use of microorganisms to break down organic waste, such as food or yard waste, into a nutrient-rich soil amendment. This method can be used to treat hazardous waste that contains organic materials.

- **Phytoremediation:** Phytoremediation involves the use of plants to absorb and detoxify hazardous substances from the soil or water. The plants can either break down the hazardous substances themselves or store them in their tissues for later removal.

Biological treatment methods can be effective in reducing the toxicity of hazardous waste and are often considered more environmentally friendly than other treatment methods. However, they may be slower and less predictable than other treatment methods, and their effectiveness depends on factors such as the type of microorganisms or plants used and the environmental conditions. Biological treatment should only be performed by licensed professionals who have the expertise and equipment necessary to safely handle hazardous materials.

The chemical, thermal, and biological treatment methods outlined above change the molecular form of the waste material. Physical treatment, on the other hand, concentrates, solidifies, or reduces the volume of the waste. Yet another process is solidification, which is achieved by encapsulating the waste in concrete, asphalt, or plastic. Encapsulation produces a solid mass of material that is resistant to leaching. Waste can also be mixed with lime, fly ash, and water to form a solid, cement like product.

4.6.11Surface storage and land disposal

Hazardous wastes that are not destroyed by incineration or other chemical processes need to be disposed of properly. For most such wastes, land disposal is the ultimate destination, although it is not an attractive practice, because of the inherent environmental risks involved. Two basic methods of land disposal include land filling and underground injection. Prior to land disposal, surface storage or containment systems are often employed as a temporary method.

Temporary on-site waste storage facilities include open waste piles and ponds or lagoons. New waste piles must be carefully constructed over an impervious base and must comply with regulatory requirements similar to those for landfills. The piles must be protected from wind dispersion or erosion. If leachate is generated, monitoring and control systems must be provided. Only non-containerized solid, no flowing waste material can be stored in a new waste pile, and the material must be land filled when the size of the pile becomes unmanageable.

A common type of temporary storage impoundment for hazardous liquid waste is an open pit or holding pond, called a lagoon. New lagoons must be lined with impervious clay soils and flexible membrane liners in order to protect groundwater. Leachate collection systems must be installed between the liners, and groundwater monitoring wells are required. Except for some sedimentation, evaporation of volatile organics, and possibly some surface aeration, open lagoons provide no treatment of the waste. Accumulated sludge must be removed periodically and subjected to further handling as a hazardous waste.

Many older, unlined waste piles and lagoons are located above aquifers used for public water supply, thus posing significant risks to public health and environmental quality. A large number of these old sites have been identified and scheduled for cleanup, or remediation, around the world.

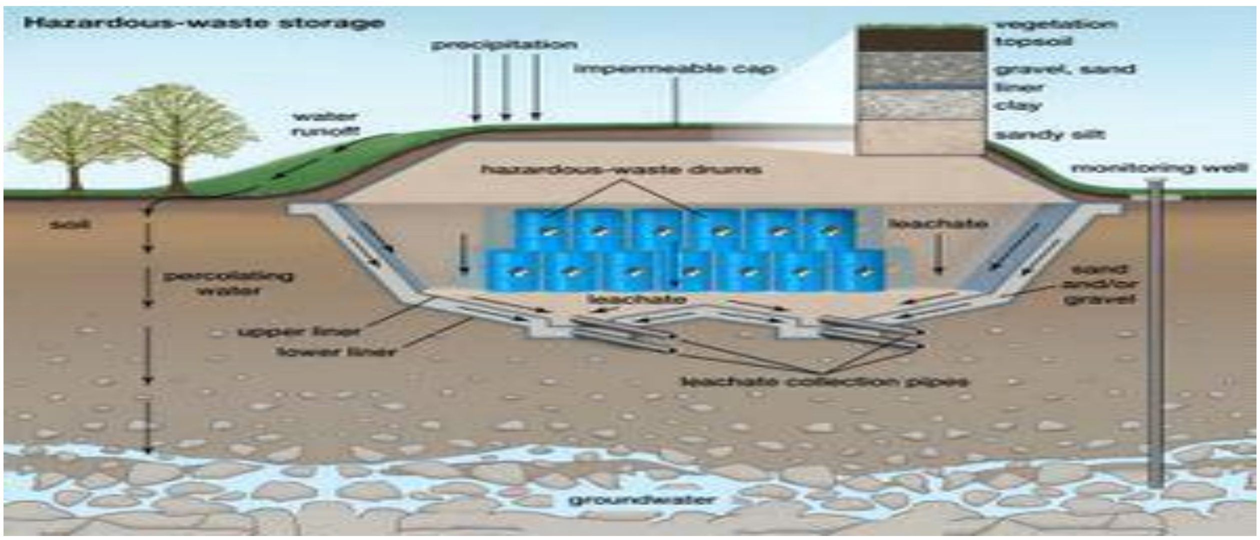


Figure 4: Secure landfills

4.6.12.Hazardous-Waste Landfill

Land filling of hazardous solid or containerized waste is regulated more stringently than land filling of municipal solid waste. Hazardous wastes must be deposited in so-called secure landfills, which provide at least 3 meters (10 feet) of separation between the bottom of the landfill and the underlying bedrock or groundwater table. A secure hazardous-waste landfill must have two impermeable liners and leachate collection systems. The double leachate collection system consists of a network of perforated pipes placed above each liner. The upper system prevents the accumulation of leachate trapped in the fill, and the lower serves as a backup. Collected leachate is pumped to a treatment plant. In order to reduce the amount of leachate in the fill and minimize the potential for environmental damage, an impermeable cap or cover is placed over a finished landfill. A groundwater monitoring system that includes a series of deep wells drilled in and around the site is also required. The wells allow a routine program of sampling and testing to detect any leaks or groundwater contamination. If a leak does occur, the wells can be pumped to intercept the polluted water and bring it to the surface for treatment.

4.6.13Deep well disposal

Another alternative disposal of liquid industrial waste is injection into deep well as shown in the Figure 4 . Deep well injection is a liquid waste disposal technology. This alternative uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers. In order to force the liquid into the pores and fissures of the rock, high pressures are applied. The rock unit selected are of porous and permeable (commonly, sandstone or fractured limestone), and must be separated by low permeability layers (for example, shale) above and below. Deep-well injection is a cost effective and requires little or no pretreatment of the waste, but it poses a danger of leaking hazardous waste and eventually polluting underground water resources.

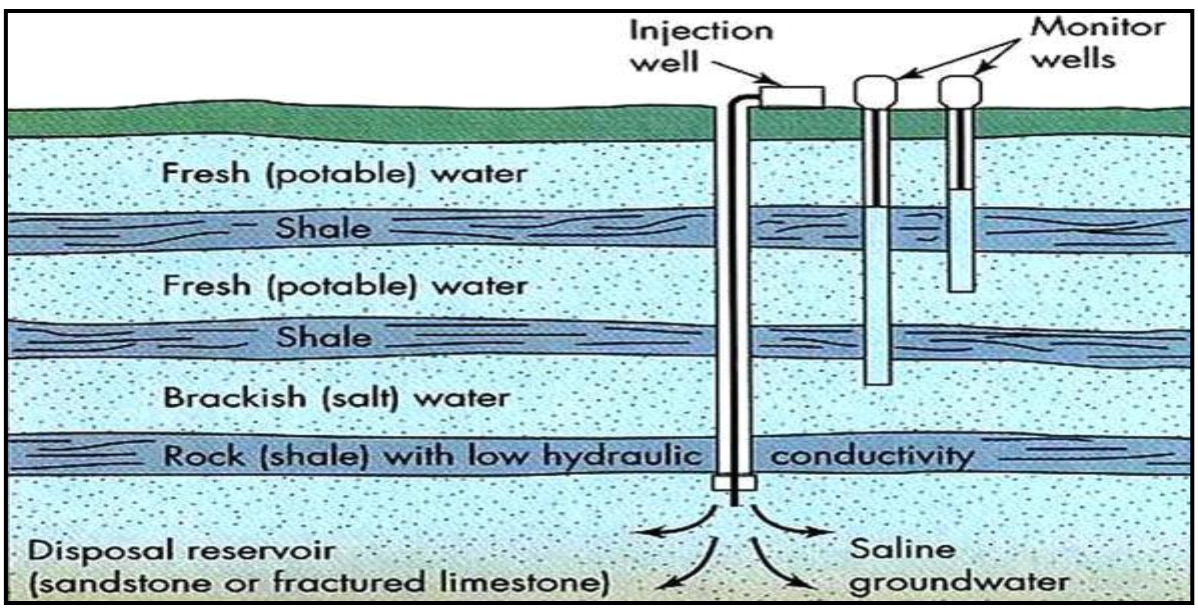


Figure 5: Deep well disposal method.

4.6.14. Bedrock disposal

Bedrock disposal is mainly meant for solid hazardous waste and a variety of bed rock types are being investigated as host rocks. The design of a bedrock disposal site or repository for hazardous wastes is shown in Figure 5 . It is based on the multiple barrier (or multi barrier) concept: surrounding solid hazardous waste sealed with several different types of materials to prevent waste leakage or invasion by ground water. A major concern is the nature of the host rock as well as some potential drawbacks. The method is widely used for high-level radioactive wastes. Sealed into stainless steel canisters, or spent fuel rods encapsulated in corrosion resistant metals such as copper or stainless steel and buried in stable rock structures deep underground. Many geological formations such as granite, volcanic tuff, salt, thick basalts such as the Columbia River plateau basalt or shale will be suitable.

Figure 6: Bedrock disposal method.

4.7Remedial action

Disposal of hazardous waste in unlined pits, ponds, or lagoons poses a threat to human health and environmental quality. Many such uncontrolled disposal sites were used in the past and have been abandoned. Depending on a determination of the level of risk, it may be necessary to remediate those sites. In some cases, the risk may require emergency action. In other instances, engineering studies may be required to assess the situation thoroughly before remedial action is undertaken.

One option for remediation is to completely remove all the waste material from the site and transport it to another location for treatment and proper disposal. This so-called off-site solution is usually the most expensive option. An alternative is on-site remediation, which reduces the production of leachate and lessens the chance of groundwater contamination. On-site remediation may include temporary removal of the hazardous waste, construction of a secure landfill on the same site, and proper replacement of the waste. It may also include treatment of any contaminated soil or groundwater. Treated soil may be replaced on-site and treated groundwater returned to the aquifer by deep-well injection.

A less costly alternative is full containment of the waste. This is done by placing an impermeable cover over the hazardous-waste site and by blocking the lateral flow of groundwater with subsurface cutoff walls. It is possible to use cutoff walls for this purpose when there is a natural layer of impervious soil or rock below the site. The walls are constructed around the perimeter of the site, deep enough to penetrate to the impervious layer. They can be excavated as trenches around the site without moving or disturbing the waste material. The trenches are filled with a bentonite clay slurry to prevent their collapse during construction, and they are backfilled with a mixture of soil and cement that solidifies to form an impermeable barrier. Cutoff walls thus serve as vertical barriers to the flow of water, and the impervious layer serves as a barrier at the bottom.

4.8.Summary

The main prospective of hazardous waste management program is to change the way of managing hazardous waste so that they can be stored, transported and dispose in an environmentally safe manner. The focus of managing hazardous waste comes in an effort to address potential threats to public health and environment. Hazardous waste management must have an initiative beyond disposing directly into the land surface. Industries are encouraged to generate less amount of hazardous waste as a part of manufacturing process. Because the toxic wastes cannot be completely eliminated and only possible way is to minimizing, recycling, and treating wastes. So steps should be taken to use the modern technology without causing any threat to environment. Minimizing, recycling, and treating wastes.

4.9.Terminal Questions

Q.1: Define hazardous waste. What are the characteristics of hazardous waste?

Answer:---

Q.2: What are the sources of hazardous waste? Give its classification.

Answer:---

Q.3: . Discuss various steps involved in hazardous waste management.

Answer:---

Q.4: Give in detail treatment and disposal of hazardous waste.

Answer:---

Q.5: How the hazardous waste is transported? Give in detail responsibilities of a transporter.

Answer:---

Q.6: What is a manifest system?

Answer:---

4.10Suggested Readings

1. Areivala, S.J. 1971. *Solid Wastes Disposal in India*, Central/Public Health Engineering Institute. Nagpur.
2. Asian Productivity Council, 2001. Hazardous waste Management: Policies and Practices in Asian Countries, Asian Productivity Council, Tokyo.
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Unit- 5: Hazardous waste Treatment methods

5.1 Introduction

Improper disposal of hazardous wastes is an increasing problem in many developing countries. Typically, but not ideally, the first stages of pollution control focus on discharges into air and water, leaving a wide range of other materials that are poorly controlled. These materials include substances that pose serious threats to public health and the environment and that are considered hazardous under almost any definition. Examples include sludges from chemical plants, clinical wastes, contaminated oils, and metal-bearing wastes. Materials of particular concern are those that do not degrade quickly in the environment, such as metals and persistent chemicals, and that can pose a threat for long periods into the future. Proper management and disposal of hazardous wastes is expensive, and therefore illegal dumping is common in many areas. The consequences include not only environmental degradation but also the undermining of legitimate waste management system. Where the production of the hazardous waste cannot be eliminated, action should be taken to reduce the hazardous characteristics by treatment or immobilization.

Objectives

- To study various methods of physical treatment of hazardous waste
- To understand the chemical methods of hazardous waste treatment to convert it in to non-hazardous waste.
- To study the possible biological measures to treat hazardous waste.
- To study the thermal treatment of hazardous waste.

5.2Treatment of hazardous waste

Processing is mainly done to recover useful products and to prepare waste for disposal. But prior to disposal, hazardous wastes need appropriate treatment, depending on the type of waste. All the waste products whether from manufacturing process or treatment facility must be treated for the impurities hazardous to the nature to render them harmless to the environment. The various options for hazardous waste treatment can be categorized under following categories:

- **Physical treatment**
- **Chemical treatment**
- **Thermal treatment**
- **Biological treatment**

5.2.1Physical Treatment

Physical treatment processes are important to most integrated waste treatment systems regardless of the nature of the waste materials or the ultimate technologies used for treatment or destruction.This includes processes that separate components of a waste stream or change the physical form of the waste without altering the chemical structure of the constituent materials. Physical treatment techniques are often used to separate the materials within the waste stream so that they can be reused or detoxified by chemical or biological treatment or destroyed by high-temperature incineration.These processes are very useful for separating hazardous materials from an otherwise non-hazardous waste stream so that they may be treated in a more concentrated form, separating various hazardous components for different treatment processes, and preparing a waste stream for ultimate destruction in a biological or thermal treatment process.The physical processes that are commonly used in waste treatment operations are as follows:

5.2.1.1Screening

Screening is a process for removing particles from waste streams, and it is used to protect downstream pre-treatment processes. Physical screening of wastewater is a process that involves the use of physical barriers or mechanical equipment to remove large, non-biodegradable materials from the wastewater. This step is important in the treatment of wastewater because it helps to prevent clogging and damage to the downstream treatment equipment and facilities.

Physical screening of wastewater can be done using various methods, including:

- **Bar screens:** These are mechanical screens that are used to remove large objects, such as branches, sticks, plastics, and rags, from the wastewater. The screens are typically made of stainless steel bars, and the wastewater is forced through the bars, allowing only the water and smaller particles to pass through while retaining the larger solids.
- **Gravel and sand filters:** These are physical filters that are used to remove suspended solids and organic matter from wastewater. The wastewater is passed through a bed of sand or gravel, which traps the particles and allows only the water to pass through.
- **Grit chambers:** These are tanks or chambers that are designed to remove heavy, inorganic materials, such as sand, grit, and gravel, from the wastewater. The wastewater is allowed to settle in the chamber, and the heavier materials settle to the bottom, where they can be removed.

5.2.1.1 Screens with rotating brushes:

These screens are similar to bar screens, but they have rotating brushes that sweep the bars to prevent clogging and improve the efficiency of the screening process.

Physical screening of wastewater is usually the first step in the treatment process and is followed by other treatment methods such as sedimentation, filtration, and disinfection.

5.2.1.2Sedimentation

- Sedimentation is the process by which suspended particles are removed from the water by means of gravity or separation
- In the sedimentation process, the water passes through a relatively quiet and still basin.
- Sedimentation involves one or more basins, called “clarifiers.” Clarifiers are relatively large open tanks that are either circular or rectangular in shape.
- The velocity of the water is reduced in the sedimentation tank.
- Sedimentation may remove suspended solids and reduce turbidity by about 50 to 90 percent
- This technique has been widely used in the removal of heavy metals from iron and steel industry waste water; removal of fluoride from aluminium production waste water; and removal of heavy metals from waste water from copper smelting and from metal finishing industry and waste water stream from organic chemicals.

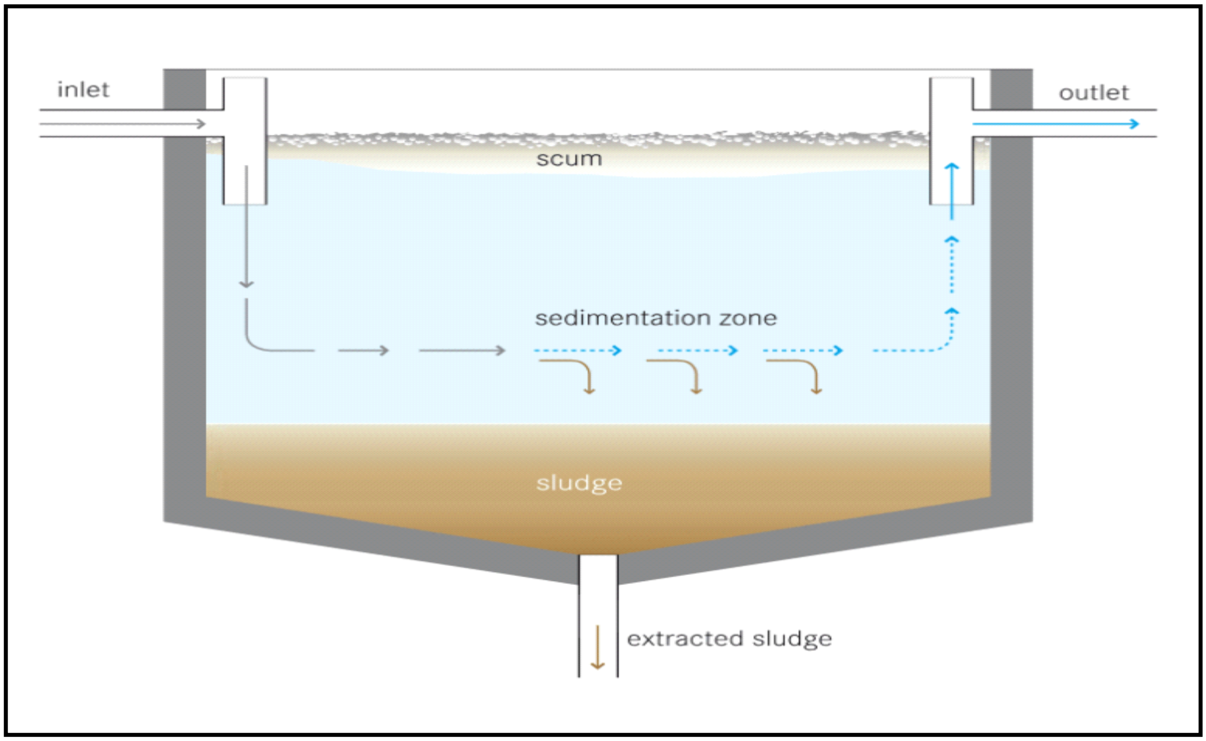

Figure 1: Process of sedimentation

https://images.app.goo.gl/2pjA3b9woHRykmgm8

5.2.1.3 Flotation

Flotation is useful for removing particles too small to be removed by sedimentation. Flotation is a physical-chemical wastewater treatment process that is used to remove suspended solids, oil and grease, and other contaminants from wastewater. The process uses air bubbles to lift the contaminants to the surface of the water, where they form a froth or scum that can be easily skimmed off.

Flotation works by introducing air into the wastewater under pressure, which creates small air bubbles that attach to the particles and lift them to the surface. The air bubbles rise to the surface of the water, carrying the contaminants with them, where they can be skimmed off using a skimmer or scraper.

There are two main types of flotation processes:

- **Dissolved air flotation (DAF):** This process involves adding a coagulant or flocculant to the wastewater to form larger particles, which are then floated to the surface using air bubbles. The larger particles are more easily removed from the water, resulting in a higher quality effluent.
- **Induced gas flotation (IGF):** This process involves introducing gas into the wastewater under pressure, which creates small gas bubbles that attach to the particles and lift them to the surface. The gas bubbles are typically nitrogen or natural gas, and they are introduced into the wastewater using mechanical devices, such as pumps or impellers.

Flotation is commonly used in industries such as food and beverage processing, paper and pulp, and mining, as well as municipal wastewater treatment plants. It is effective in removing a wide range of contaminants, including suspended solids, oil and grease, and metals, and is often used as a pre-treatment step before other treatment processes such as biological treatment or disinfection.

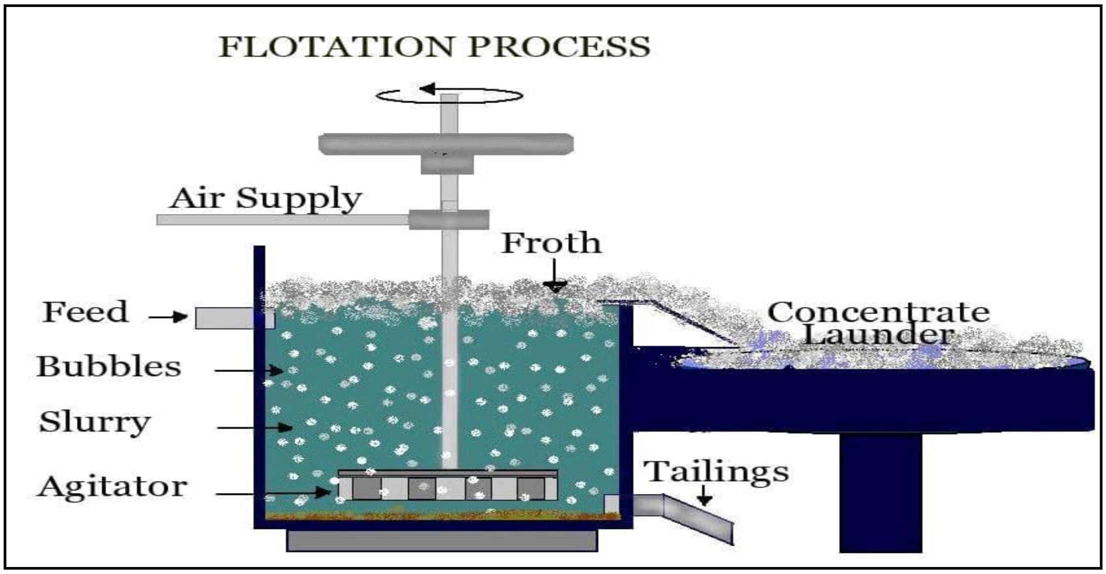

Figure 2: Flotation method

http://www.911metallurgist.com/blog/wp-content/uploads/2013/09/flotation-separators.jpg

5.2.1.4Filtration:

Filtration is a process for separating liquids and solids by using various types of porous materials.

- Filtration is a well-developed economical process used in the full scale treatment of many industrial waste waters and waste sludges. Energy requirements are relatively low, and operational parameters are well defined.
- Filtration is the process of passing water through material to remove particulates and other impurities, including floc, from the water being treated.
- Impurities like suspended particles (fine silts and clays), biological matter (bacteria, plankton, spores, cysts or other matter) and floc. There are many types of filters designed to achieve various levels of separation, Such as

➢ **Sand filters:** These are the most common type of filters used in wastewater treatment. They consist of a bed of sand or other granular material through which the wastewater is passed. The suspended solids are trapped in the sand bed, while the filtered water passes through.

➢ **Activated carbon filters:** These filters use activated carbon as the filter medium, which removes organic contaminants and odor-causing compounds from the wastewater.

➢ **Diatomaceous earth filters:** These filters use a fine powder made from the fossilized remains of diatoms as the filter medium, which can remove particles as small as 0.2 microns.

Filtration is an effective method of treating wastewater to remove suspended solids, pathogens, and other contaminants. It is often used in conjunction with other treatment processes, such as disinfection or biological treatment, to achieve the desired level of treatment.

5.2.1.5Centrifugation

Centrifugation is a physical separation process used in wastewater treatment to separate solid particles from the liquid phase by applying a centrifugal force. It is a high-speed process that uses a centrifuge to spin the wastewater rapidly and force the solids to settle at the bottom of the centrifuge, where they can be easily removed.

Centrifugation works on the principle of sedimentation, where the centrifugal force is used to enhance the sedimentation of particles in the wastewater. The force generated by the centrifuge is many times greater than the force of gravity, which accelerates the sedimentation of the particles.

The process involves the following steps:

- Wastewater is fed into the centrifuge through a feed pipe.
- The centrifuge spins at high speed, typically between 1000 and 4000 RPM, depending on the size and type of the centrifuge.
- The centrifugal force causes the solid particles in the wastewater to settle at the bottom of the centrifuge.
- The separated solids are discharged through a solids discharge port, while the clarified water is discharged through a liquid discharge port.

Centrifugation is a highly efficient method of separating solids from liquids and is used in a wide range of wastewater treatment applications, including municipal wastewater treatment, industrial wastewater treatment, and sludge dewatering. It is particularly useful for separating fine particles, such as those found in biological sludge or industrial wastewater, which are difficult to separate using other methods.

5.2.1.6 Dialysis

Dialysis is a process for separating components in a liquid stream by using a membrane. Components of a liquid stream will diffuse through the membrane if a stream with a greater concentration of the component is on the other side of the membrane. Dialysis is used to extract pure process solutions from mixed waste streams.

5.2.1.7Electrodialysis

Electrodialysis is an extension of dialysis. Electrodialysis is a separation process that uses an electric field to separate ions from a solution. It is commonly used in water treatment and desalination processes, as well as in the food and pharmaceutical industries.

The process involves passing a solution through a series of membranes, each with a specific charge (either positive or negative). As the solution passes through the membranes, the ions are attracted to and repelled by the charges, causing them to move toward or away from the membrane.

The result is that the ions are separated from the solution and concentrated in a separate stream. For example, in desalination, electrodialysis can be used to remove salt from seawater by separating the sodium and chloride ions.

One advantage of electrodialysis is that it is an energy-efficient process compared to other separation methods. However, it can be limited by the types of ions that can be effectively separated and the complexity of the equipment required for larger-scale operations.

5.2.1.8 Reverse osmosis

Reverse osmosis separates components in a liquid stream by applying external pressure to one side of a membrane so that solvent will flow in the opposite direction.Reverse osmosis, also known as RO, is a membrane technology that uses a semipermeable medium to remove certain ions and particles from a liquid stream. RO removes contaminants based on their particle size and charge—generally anything that is 0.0001 µm or larger, including:

- Bacteria
- Calcium
- Colloidal particles
- Fluoride
- Iron
- Manganese
- Organic material
- Pyrogens
- Salt
- Viruses

Because of its filtration properties, RO is often used to:

- Clean wastewater to acceptable effluent standards or for reuse concentrate solvents used in the food and beverage industry, such as whey create ultrapure process water streams, such as required in the microelectronics industry desalinate seawater or other brine solutions generate potable drinking water
- RO is also the reverse process of osmosis, a phenomenon that occurs naturally when a lower-solute stream (with a higher water concentration) migrates toward a higher-solute stream (with a lower-water concentration) through a semipermeable membrane to achieve concentrated equilibrium.

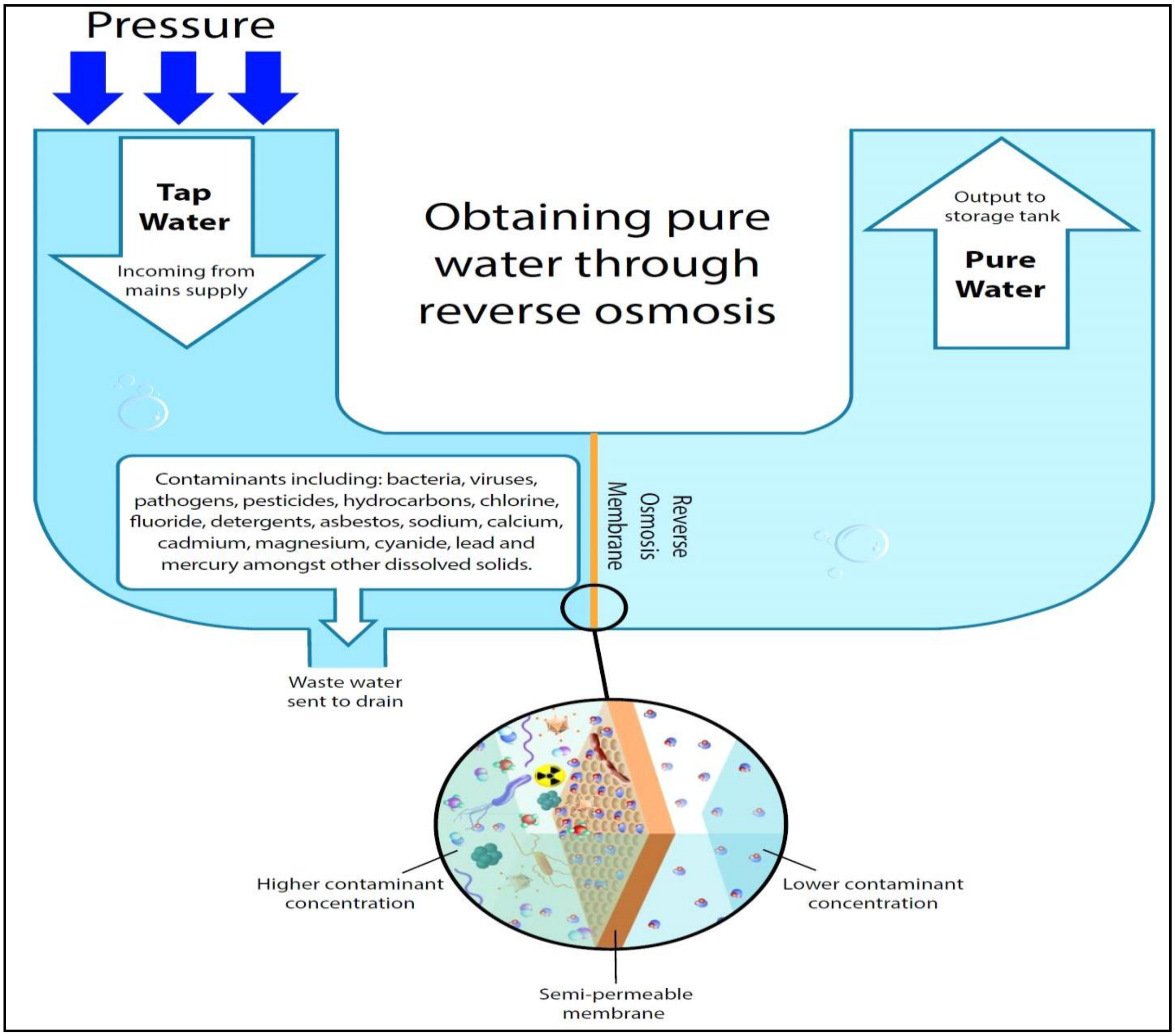

Figure 3: Process of reverse osmosis

https://andrewswater.co.uk/blog/what-is-a-reverse-osmosis-system/

5.2.1.9Ultrafiltration

Ultrafiltration is similar to reverse osmosis, but the separation begins at higher molecular weights. Ultrafiltration is a type of filtration that uses a membrane to separate particles and solutes from a solution based on their size and molecular weight. It is commonly used in various industrial, medical, and biotechnological applications.

The process involves passing a solution through a semipermeable membrane that has pores or holes of a specific size. The membrane allows smaller particles such as water and dissolved ions to pass through while blocking larger particles such as proteins, bacteria, and viruses.

The driving force for the ultrafiltration process is typically pressure, which is applied to the solution to force it through the membrane. As the solution passes through the membrane, the retained particles and solutes accumulate on the surface of the membrane, forming a concentrated solution known as the retentate.

The permeate, or the filtrate that passes through the membrane, is typically much cleaner and free of particles and solutes that were retained in the retentate. Ultrafiltration is commonly used in water treatment processes to remove bacteria and viruses, as well as in the dairy industry to concentrate milk proteins for cheese making.

Ultrafiltration is also commonly used in medical applications, such as blood purification and renal replacement therapy for patients with kidney failure.

5.2.1.10Distillation

Distillation is a process for separating liquids with different boiling points. The mixed-liquid stream is exposed to increasing amounts of heat, and the various components of the mixture are vapourised and recovered. The vapour may be recovered and re-boiled several times to effect a complete separation of components.

- Distillation is expensive and energy intensive and can probably be justified only in cases where valuable product recovery is feasible (e.g., solvent recovery). This technique has only limited application in the treatment of dilute aqueous hazardous wastes.
- Distillation refers to the selective boiling and subsequent condensation of a component in a liquid mixture. It is a separation technique that can be used to either increase the concentration of a particular component in the mixture or to obtain (almost) pure components from the mixture.

- It is important to note that distillation is not a chemical reaction but it can be considered as a physical separation process.

5.2.1.11Extraction

Extraction is a process used to separate or isolate a specific component or compound from a mixture using a solvent or other chemical agent. It is commonly used in various industries, including chemical, pharmaceutical, food, and natural products.

The process involves adding a solvent to the mixture, which selectively dissolves the desired compound while leaving the other components behind. The resulting mixture is then separated into two phases: the solvent phase and the residual phase. The solvent phase containing the desired compound is then further purified, and the solvent is typically evaporated to isolate the pure compound.

Extraction can be performed using various solvents, depending on the specific application and the properties of the desired compound. Some common solvents include water, ethanol, hexane, and chloroform.

One common extraction method is **liquid-liquid extraction**, also known as solvent extraction, which involves mixing the solvent with the mixture and separating the two phases. Another common method is **Solid-phase extraction**, which uses a solid-phase material to selectively adsorb the desired compound.

Extraction is a powerful tool for separating and purifying compounds and is used extensively in many fields. However, it can also be complex and time-consuming, requiring careful selection of the solvent and optimization of the extraction conditions to achieve the desired outcome.

5.2.1.12 Evaporation

Evaporation is a process for concentrating non-volatile solids in a solution by boiling off the liquid portion of the waste stream. Evaporation units are often operated under some degree of vacuum to lower the heat required to boil the solution.

5.2.1.13Carbon Adsorption

Adsorption is a process for removing low concentrations of organic materials on the surface of a porous material, usually activated carbon. Activated carbon is a highly porous material with a large surface area, which makes it an effective adsorbent for a wide range of compounds.

The process involves passing the gas or liquid stream through a bed of activated carbon, which adsorbs the impurities and contaminants onto its surface.

The carbon is replaced and regenerated with heat or a suitable solvent when its capacity to attract organic substances is reduce

- The principal use of vapour phase activated carbon in the environmental field is for the removal of volatile organic compounds such as hydrocarbons, solvents, toxic gases and organic based odours.
- In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen sulphide, mercury, or radon.
- In the industrial area, the most common applications of activated carbon are for process off-gases, tank vent emissions, work area air purification, and odour control, either within the plant or related to plant exhausts.
- Additionally, activated carbon is used in the hazardous waste remediation area to treat off-gases from air strippers and from soil vapour extraction remediation projects.

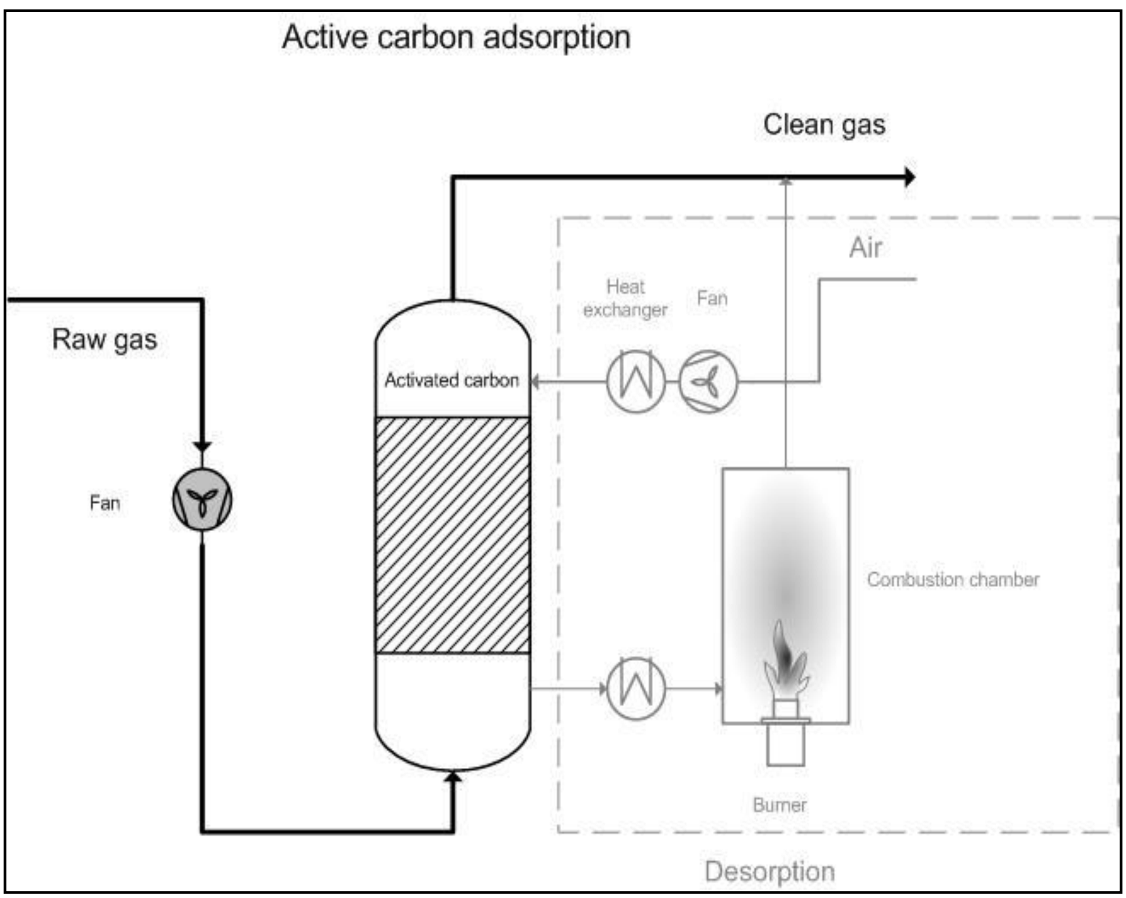

Figure 4: Process of Carbon adsorption

https://emis.vito.be/en/bat/tools-overview/sheets/activated-carbon-adsorption

5.2.1.14Flocculation

Flocculation is a process used in water treatment to remove suspended particles from a liquid by causing them to clump together, or coagulate, into larger masses known as flocs. This makes it easier to remove the particles from the water through sedimentation or filtration.

The process involves adding a chemical flocculant, such as alum or polyacrylamide, to the water. The flocculant neutralizes the electrical charges on the suspended particles, allowing them to come together and form flocs. The flocs can then be removed from the water through sedimentation or filtration.

Flocculation is commonly used in water treatment processes, such as in municipal drinking water and wastewater treatment facilities. It is also used in industrial processes, such as in the production of paper, where it is used to remove impurities from pulp.

One advantage of flocculation is that it is a simple and effective process for removing suspended particles from water. It can also be used in conjunction with other water treatment processes, such as sedimentation and filtration, to further improve water quality.

However, one potential drawback of flocculation is that it requires the use of chemical flocculants, which can add to the cost and complexity of the water treatment process. Additionally, if not properly treated or disposed of, the flocs themselves can become a source of environmental pollution.

Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs.

Chemicals used for flocculation include alum, lime, ferric chloride, ferrous sulphate and polyelectrolytes. Poly electrolytes consist of long chain, water soluble polymers such as polyacrylamides.

Inorganic flocculants such as alum, upon mixing with water, the slightly higher pH of water causes them to hydrolyse to form gelatinous precipitates of aluminium hydroxide.

5.2.2Chemical Treatment

Chemical treatment processes alter the chemical structure of the constituents of the waste to produce either an innocuous or a less hazardous material. Chemical processes are attractive because they produce minimal air emissions, they can often be carried out on the site of the waste generator, and some processes can be designed and constructed as mobile units.

- Chemical treatment transforms waste into less hazardous substances using such techniques as pH neutralization, oxidation or reduction, and precipitation.
- These procedures involve the use of chemical reactions with the help of various chemicals to convert hazardous waste into less hazardous substances.
- The chemical treatment produces useful by- products and some-times residual effluent that are environmentally acceptable.
- Chemical reactions, either reduce the volume of the waste or convert the wastes to a less hazardous form.

Chemical treatment process

- Solubility
- Neutralization
- Precipitation
- Coagulation and flocculation
- Oxidation and reduction
- Ion exchange methods

5.2.2.1Solubility

- Hazardous waste may be organic and inorganic containing various chemical elements and with various structural configurations.
- Water, known as the universal solvent, will dissolve many of these substances, while others have only limited water solubility.
- Solubility of various salts inorganic and organic is utilized as a means of treatment of hazardous waste when waste water treatment facilities are available and land fill options are limited

5.2.2.2Neutralization

- Neutralization can be defined as the treatment of industrial waste so that it is neither too acidic nor too alkaline for safe discharge
- There are several possible reasons that an industry neutralized its wastewater

- Neutralization of acids and alkaline waste streams is an example of the use of chemical treatment to mitigate waste characterized as corrosive.
- Neutralization of an acid or base is easily determined by measuring its pH. Acid based reactions are the most common chemical process used in hazardous waste treatment.
- Neutralization prior to landfill will be necessary so that inter reactions are avoided in landfill.

5.2.2.3 Precipitation

Precipitation is a process for removing soluble compounds contained in a waste stream. A specific chemical is added to produce a precipitate. This type of treatment is applicable to streams containing heavy metals.

- Often undesirable heavy metals are present in liquid and solid wastes which are in slurry form. Simple precipitation.
- The usual method of removal of organic heavy metals is chemical precipitation.
- Metals precipitate at varying pH levels depending on the metal ion, resulting in the formation of an insoluble salt.
- Hence neutralization of an acidic waste stream can cause precipitation of heavy metals.
- Hydroxides of heavy metals are usually insoluble so lime or caustic is commonly used to precipitate them.

5.2.2.4 Ion exchange

Ion exchange is used to remove from solution ions derived from inorganic materials. The solution is passed over a resin bed, which exchanges ions for the inorganic substances to be removed. When the bed loses its capacity to remove the component, it can be regenerated with a caustic solution.

- Ion exchange is reversible exchange of ions between liquid and solid phases.
- Ions held by electrostatic forces to charged functional groups on the surface of an insoluble solids are replaced by ions of similar charge in a solution Ion exchange is stoichiometric, reversible and selective removal of dissolved ionic species.

5.2.2.5Dechlorination

Dechlorination is the process of removing chlorine or chlorine compounds from a substance, typically water. Chlorine is often added to water as a disinfectant to kill bacteria and viruses, but it can also have negative effects on the environment and human health.

Dechlorination can be accomplished through various methods, including chemical, physical and biological processes. Some common methods include the use of activated carbon, sulfite compounds, and ultraviolet light.

One common method of dechlorination is the use of sulfur dioxide or sodium sulfite compounds, which react with the chlorine to form a non-toxic salt compound. Another method involves the use of activated carbon, which adsorbs the chlorine and other contaminants from the water.Dechlorination is commonly used in water treatment processes, such as in the treatment of municipal drinking water and wastewater. It is also used in various industrial processes, such as in the production of food and beverages, where it is used to remove chlorine from processing water.

One advantage of dechlorination is that it can help to reduce the negative effects of chlorine on the environment and human health. It can also help to improve the taste and odor of the water. However, one potential drawback of dechlorination is that it requires additional processing steps, which can add to the cost and complexity of the water treatment process.

5.2.2.6Oxidation and reductions

Oxidation-reduction is a process for detoxifying toxic wastes in which the chemical bonds are broken by the passage of electronics from one reactant to another. Oxidation-reduction, also known as redox, is a chemical process that involves the transfer of electrons between reactants. While it can be used to detoxify some toxic wastes, it is not a universal solution and depends on the specific waste and the conditions under which the reaction occurs.

In the context of toxic waste treatment, redox reactions are often used to convert toxic substances into less harmful or non-toxic forms. For example, some heavy metals can be converted into less toxic forms by oxidizing them to higher oxidation states or by reducing them to lower oxidation states.

One common application of redox reactions in toxic waste treatment is the use of activated carbon to promote the reduction of certain pollutants, such as chlorinated solvents, to less harmful forms. This process, known as reductive dechlorination, involves the transfer of electrons from the activated carbon to the chlorinated solvents, which causes them to break down into non-toxic compounds.

While redox reactions can be an effective method for detoxifying some toxic wastes, they are not universally applicable and may not be effective for all types of waste. The success of the process also depends on various factors, such as the specific reactants involved, the pH of the solution, and the presence of other chemicals that may interfere with the reaction.

Furthermore, the use of redox reactions for toxic waste treatment can be complex and requires careful monitoring and control to ensure that the reaction proceeds as intended and does not produce additional hazardous byproducts.

Heavy metals wastes are subjected to a reduction process to precipitate to safer compounds of heavy metals. Example is Hexavalent chromium is precipitated into trivalent chromic hydroxide. Similarly alkaline chlorination of cyanide neutralizes highly toxic cyanide wastes.

5.2.3Thermal treatments

Thermal treatment is any waste treatment technology that involves high temperatures in processing the waste feedstock. Thermal treatment is a solution for treating non-recyclable and non-reusable waste in an environmentally and economically friendly way. Thermal treatment reduces the volume and mass of the waste and inserts the hazardous components while at the same time generating thermal or electrical energy and minimizing pollutant emissions to air and water.

Thermal treatment involves the application of heat to treat and decompose waste materials through different approaches. Open burning is the primary method of thermal waste treatment but is considered an environmentally invasive process. No pollution controlling devices are engaged in open burning, allowing pollutants to escape into the environment. This method is practiced in most countries since it provides a cheaper solution for solid waste treatment.

5.2.3.1Thermal treatment methods ofhazardous waste

Thermal waste treatment refers to heat processes to treat waste materials. Following are some of the most commonly used thermal waste treatment techniques:

i. **Open burning**It is a legacy thermal waste treatment that is environmentally harmful. The incinerators used in such a process have no pollution control devices. They release hexachlorobenzene, dioxins, carbon monoxide, particulate matter, volatile organic compounds, polycyclic aromatic compounds, and ash.

ii. **Incineration**Incineration is one of the most common waste treatments, and this approach involves the combustion of waste material in the presence of oxygen.Waste incineration involves converting waste materials into ash, flue gas, and heat. The ash mainly consists of non-organic components of waste and can be in the shape of solid lumps or particulates carried by the flue gas. The flue gases are cleaned of particulate and gaseous contaminants before being released into the air.

In waste incineration, the most common technique is called "mass burn." This general process consists of 5 steps.

- **Waste preparation:** Oversized items are removed, and particular recyclables like metals are recovered.
- **Combustion:** Waste is burned in an oxygenated single combustion chamber.
- **Energy recovery:** The gases released during combustion are cooled with water.
- **Environmental control:** The cooled gas is treated by scrubbers, precipitators, and filters to remove pollutants.
- **Environmental release:** The treated gas is released into the atmosphere.

Advantages and disadvantages of waste incineration

Incinerators also have their downsides. Some of the most common advantages and disadvantages are listed below.

Advantages

- Decreased quantity of waste
- Efficient waste management
- Production of heat and power
- Reduction of pollution
- Saves on transportation of waste
- It prevents the production of methane gas

Disadvantages

- Expensive
- Pollutes the environment
- Harms public health

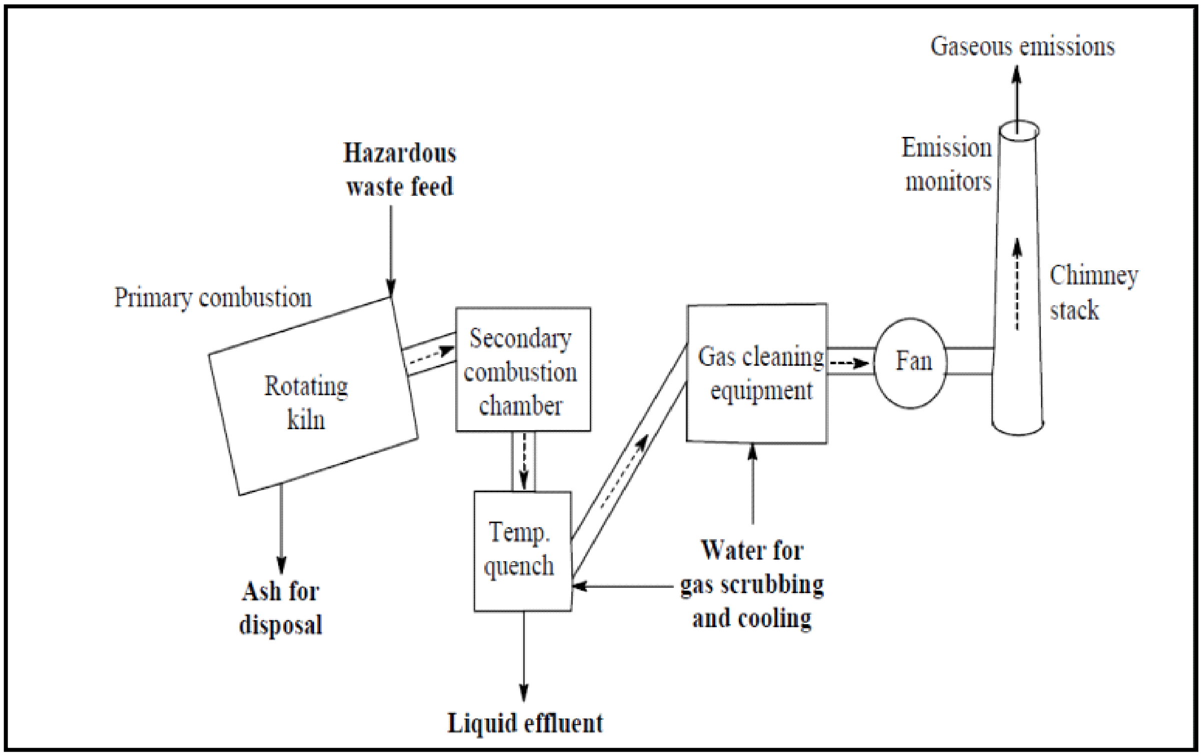

Figure 5: High Temperature Incineration System

iii. **Pyrolysis** The process of heating organic material, such as biomass, in the absence of oxygen. Because no oxygen is present, the material does not combust, but the chemical compounds, such as cellulose and lignin, make up that material thermally decompose into combustible gases and charcoal. These combustible gases can be condensed into a flammable liquid, called pyrolysis oil.

The pyrolysis process is used heavily in the chemical industry, for example, to produce ethylene, many forms of carbon, and other chemicals from petroleum, coal, and even wood, to make coke from coal. It is also used to convert natural gas into non-polluting hydrogen gas and non-polluting solid carbon char, initiating production in industrial volume.

Variables that can alter the pyrolysis process

- Treated material composition: each of the significant constituents of biomass and waste features different thermal decomposition temperatures.
- The temperature of the process: Higher pyrolysis temperatures provide a greater quantity of non-condensable gases, while lower temperatures favor the production of high-quality solid products.
- The residence time of material in the pyrolysis chamber: influences the degree of thermal conversion of the received solid product and the residence time of the vapor.
- Particle size and physical structure: influences the speed at which material is subjected to pyrolysis.

iv. **Gasification** Gasification is a process that converts biomass- or fossil fuel-based materials into gases. This is achieved by reacting the material at high temperatures without combustion via controlling the amount of oxygen and steam present in the reaction. An advantage of Gasification is that syngas can be more efficient than direct combustion of the original feedstock material because it can be combusted at higher temperatures.

Gasification is similar to combustion, but it's different in the amount of oxygen used in the process. Combustion uses abundant oxygen to produce heat and light by burning, and Gasification uses only a tiny amount of oxygen, combined with steam and cooked under intense pressure.

v. **Plasma gasification**Plasma is a very high temperature, highly ionized gas capable of conducting electrical current. Examples of plasma in nature include lightning and gas at the sun's surface.

Plasma gasification is a waste-treatment technology that uses a combination of electricity and high temperatures to turn municipal waste into usable by-products without combustion. Although the technology is sometimes confused with incineration, plasma gasification does not combust the waste as incinerators do. Instead, it converts the organic waste into a gas containing all its chemical and heat energy and converts the inorganic waste into an inert vitrified glass called slag. The process can reduce waste sent to landfills and generate electricity.

vi. Waste drying

Waste drying is the drying of materials that have been contaminated with hazardous chemical waste, and this waste must be handled, stored, and disposed of properly. Dry waste comprises a mix of timber, metals, plastics, cardboard, paper, and small amounts of concrete, bricks, and rubble.

Examples of dry waste

- Contaminated soils
- Extremely hazardous waste containers
- Debris that is contaminated
- Dried chemicals that are in scrapable amounts

Waste drying benefits

- Considerably reduce transport costs
- To transform a final waste aimed to a landfill into a waste-to-energy process
- Households refuse transformation into a solid recovered fuel
- Dried grains commercialization for animal feed
- Coproducts value from the forest industry into densified sticks, granules
- To control the activities environmental impact

5.2.4 Biological treatment

On the basis of the fact that hazardous materials are toxic to living beings, it is not uncommon for some to assume that biological treatment is not possible for hazardous wastes. This assumption is untenable, and, in fact, we must aggressively seek biological treatment in order to exploit the full potential of hazardous wastes in terms of removal efficiency and cost (Freeman, et al., 1988). Against this background, let us now list some of the techniques used for biological treatment of hazardous waste:

A. Bioremediation:

Bioremediation is a process that uses microorganisms to break down or transform hazardous waste contaminants into less harmful substances. The process can be applied to both solid and liquid waste, and can be carried out in situ (at the site of the waste) or ex situ (in a separate treatment facility). There are two types of bioremediation: aerobic and anaerobic. Aerobic bioremediation uses oxygen-dependent microorganisms to break down organic contaminants such as petroleum products, pesticides, and solvents. Anaerobic bioremediation, on the other hand, uses microorganisms that do not require oxygen to break down organic contaminants.

Bioremediation can be enhanced by adding nutrients to the waste material to stimulate microbial growth. This is called biostimulation. Alternatively, microorganisms can be added to the waste material to enhance the bioremediation process. This is called bioaugmentation. One of the benefits of bioremediation is that it is a relatively low-cost and environmentally friendly method of hazardous waste treatment. However, the effectiveness of the process depends on factors such as the type and concentration of contaminants, the availability of nutrients and oxygen, and the temperature and pH of the waste material. Bioremediation can be a useful method for managing a variety of hazardous wastes, including petroleum products, pesticides, solvents, and other organic contaminants. However, it is important to carefully evaluate the specific conditions and requirements of the waste material before implementing bioremediation as a treatment method.

B. Composting:

Composting can be an effective method for treating some types of hazardous waste, but it is not suitable for all hazardous wastes. Composting works by providing the right conditions for microorganisms to break down organic matter. Organic hazardous wastes, such as food waste, paper waste, and yard waste, can be composted. However, hazardous wastes that contain toxic chemicals, heavy metals, or pathogens cannot be composted using traditional methods.

If hazardous waste is to be composted, it must first be treated to remove or reduce the hazardous components. This can be done using physical, chemical, or biological methods. For example, hazardous waste containing heavy metals may be treated using chemical precipitation to remove the metals before composting. Composting of hazardous waste must also be carried out under carefully controlled conditions to ensure the safety of workers and the environment. The composting process must be carefully monitored to ensure that the temperature, moisture, and oxygen levels are within the optimal range for the microorganisms to function effectively. The final compost product must be tested to ensure that it meets regulatory standards for safety and quality.

C. Phytoremediation:

Composting can be an effective method for treating some types of hazardous waste, but it is not suitable for all hazardous wastes. Composting works by providing the right conditions for microorganisms to break down organic matter. Organic hazardous wastes, such as food waste, paper waste, and yard waste, can be composted. However, hazardous wastes that contain toxic chemicals, heavy metals, or pathogens cannot be composted using traditionalmethods.If hazardous waste is to be composted, it must first be treated to remove or reduce the hazardous components. This can be done using physical, chemical, or biological methods. For example, hazardous waste containing heavy metals may be treated using chemical precipitation to remove the metals before composting. Composting of hazardous waste must also be carried out under carefully controlled conditions to ensure the safety of workers and the environment. The composting process must be carefully monitored to ensure that the temperature, moisture, and oxygen levels are within the optimal range for the microorganisms to function effectively. The final compost product must be tested to ensure that it meets regulatory standards for safety and quality.

D. Phytoremediation

Phytoremediation is a process that uses plants to remove, contain, or detoxify hazardous contaminants in soil, water, or air. It is an environmentally friendly and cost-effective method for managing contaminated sites. Plants used in phytoremediation can accumulate contaminants in their tissues, which can then be harvested and disposed of safely. Some plants have the ability to break down or transform contaminants into less harmful compounds. This process can be enhanced by adding certain microorganisms to the soil, such as bacteria or fungi, that work in symbiosis with the plants to degrade contaminants. Phytoremediation can be used to treat a variety of contaminants, including heavy metals, petroleum hydrocarbons, pesticides, and solvents. However, the effectiveness of phytoremediation depends on several factors, such as the type and concentration of contaminants, soil conditions, and the type of plants used. Phytoremediation can be carried out in situ, which means the plants are grown directly in the contaminated soil or water. This method is often less expensive and less disruptive than traditional methods of remediation. Ex situ phytoremediation involves growing plants in a separate location and then transferring them to the contaminated site after they have accumulated the contaminants. This method is useful when the contaminated site is difficult to access or when the contamination is too severe to allow for in situ phytoremediation.

E. Vermicomposting: Vermicomposting is a type of composting where worms are used to decompose organic waste. Worms consume organic matter and excrete nutrient-rich castings, which can be used as a soil amendment. Vermicomposting is an effective method for treating food waste, paper waste, and yard waste. Overall, biological treatment methods offer a cost-effective and environmentally friendly approach to hazardous waste management. However, the effectiveness of these methods depends on the type and concentration of contaminants, as well as the conditions in which the treatment is carried out.

5.3. Summary

The treatability of the waste depends upon the susceptibility of the hydrocarbon content to anaerobic biological degradation, and on the ability of the organisms to resist detrimental effects of biologically recalcitrant and toxic organic and inorganic chemicals. The metabolic interactions among the various groups of organisms are essential for the successful and complete mineralisation of the organic molecules. Various parameters such as the influent quality, the biological activity of the reactor and the quality of the reactor environment are monitored to maintain efficient operating conditions within the reactor.

Though the Hazardous Wastes (Management & Handling) Rules were notified in 1989, the implementation on the ground has left a lot to be desired. Lack of proper infrastructure and strict enforcement mechanism has led to hazardous waste still remaining a grave problem. New emerging wastes and loopholes in the current legislation have also contributed to this. There are still problems of hazardous waste not being managed in sound environmental conditions, improper dumping and lack of proper treatment and disposal facilities.

5.4Terminal questions

Q.1: What are the various methods of physical treatment of hazardous waste? Describe in detail.

Answer:---

Q.2: Give in detail chemical methods of hazardous waste treatment.

Answer:---

Q.3: What is incineration? Write about the factors affecting incineration.

Answer:---

Q.4: What is bioremediation? How can we achieve effective bioremediation of hazardous waste?

Answer:--

Q.5: Describe various methods of hazardous waste treatment.

Answer:--

5.5Suggested readings

6. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.

7. E-waste: Implications, regulations and management in India and Current global best practices, TERI press, Johri, Rakesh.

8. Bio- medical waste management, Sahai, Sushma, APH Publishing.

9. Electronic waste management,design, analysis and application, R E Hester ,Cambridge Royal Society of Chemistry

10. Solid and Hazardous Waste Management, Rao, M.N. and Sultana ,BS Publications, Hyderabad

Unit-6: Biomedical Wastes

6.1. Introduction

Bio medical waste (BMW) may be defined as any solid, fluid or liquid waste material including its container and any other intermediate products which is generated during short term and long term care consisting of observational, diagnostic, therapeutic and rehabilitative services for a person suffering or suspected to be suffering from disease or injury or during research pertaining to production & testing of biologicals during immunization of human beings. From total quantity of waste generated by health care activities almost 80-90% is general waste comparable to domestic waste. This comes from the administrative and housekeeping functions of Hospital and laboratories. The balance 10-20% of waste is considered hazardous and / or infectious. This lesson discusses about biomedical waste management.

Objectives

- To study about bio medical waste and its sources
- To study the effects of biomedical waste
- To explain steps of bio medical waste management

- ➢ To segregate and dispose waste materials appropriately

6.2. Definition of Biomedical Waste

Bio-medical waste means "any solid and/or liquid waste produced during diagnosis, treatment or vaccination of human beings or animals. Biomedical waste creates hazard due to two principal reasons: infectivity and toxicity. According to the Bio Medical Waste (Management and Handling) Rules 1998, it is the duty of every "occupier" i.e. a person who has the control over the institution or its premises, to take all steps to ensure that waste generated is handled without any adverse effect to human health and environment.

6.3. Sources of biomedical waste

Hospital waste, also known as healthcare waste or biomedical waste, is generated from various sources within healthcare facilities such as hospitals, clinics, and laboratories. Here are some examples of the sources of hospital waste:

- **Patient care areas:** This includes patient rooms, operating rooms, emergency rooms, and outpatient clinics, where waste such as used gloves, gowns, masks, and other disposable items are generated.
- **Laboratories:** This includes pathological laboratories and research laboratories, where biological and chemical waste is generated.
- **Radiology departments:** This includes areas where imaging equipment is used, such as X-rays, CT scans, and MRIs, which may generate radioactive waste.
- **Pharmacy:** This includes areas where expired, unused, or contaminated pharmaceuticals are disposed off.
- **Kitchen and cafeteria:** This includes areas where food waste and packaging are generated.
- **Administrative areas:** This includes areas such as offices, conference rooms, and reception areas where waste such as paper, plastic, and glass is generated.

Major Sources	Minor Sources
Hospitals	Institutions
Labs	Clinics
Research Centers	Dental clinics
Animal research	Home care

Blood Banks	Cosmetic clinics
Nursing homes	Paramedics
Mortuaries	Funeral Centers
Autopsy Centers	Psychiatric hospitals
Obstetrics and maternity clinics	Disabled person’s institutions

Table 1: Major and minor sources of Biomedical waste

6.4. Types of biomedical waste

Biomedical waste can be of following types

Infectious waste

It is suspected to contain pathogenic organisms i.e. bacteria, viruses, parasites or fungi in sufficient concentration or quantity to cause disease in susceptible hosts. This category includes the following wastes:

- Cultured and stocks of infectious agents from clinical laboratories.
- Wastes from surgery and autopsies done on patients suffering from infectious diseases (e.g. tissues, materials or equipment that have been in contact with blood or other body fluids).
- Excreta, dressing from infected/ surgical wounds, clothes heavily soiled with human blood or other body fluids from infected patients in insolation wards.
- Dialysis equipment such as tubing and filters, gown, aprons, gloves, disposable tower and laboratory coats which have been in contact with infected patients undergoing hemodialysis.
- Infected research animals from laboratories.
- Any other instruments or materials that have been in contact with infected persons or animals.
- Cultures and stocks of highly infectious organisms, waste from autopsies, animal bodies other waste items inoculated, infected, or in contact with such agents are called highly infectious wastes.

Pathological waste

It consists of tissues, organs, body parts, human fetuses and animal carcasses, blood and body fluids.

- ❖ Anatomical waste i.e. recognizable human or animal body parts also comes under this category.
- ❖ Even-though this category may include healthy body parts, it should be considered as a subcategory of infectious waste.

Sharps

Sharps are items that could cause cuts or puncture wounds including needles, hypodermic needles, scalpel and other blades, knives, infusion sets, saws, broken glass and nails irrespective of the associated infection potential, such items are usually considered as highly hazardous healthcare waste.

Pharmaceutical waste

It includes expired, unused, spilt and contaminated pharmaceutical products, drugs, vaccines and sera that are no longer required and require appropriate disposal also included are the discarded items used in the handling of pharmaceuticals such as bottles or boxes with residues, gloves, masks, connecting tubing and drug vials.

Genotoxic waste

- ❖ It is highly hazardous and it may have mutagenic, teratogenic or carcinogenic properties.it poses serious safety threats, both inside hospitals and after disposal.
- ❖ It includes certain cytostatic drugs, feces, urine or vomit from patients treated with cytostatic drugs, chemicals and radioactive materials.
- ❖ The principal substances in this category, cytotoxic or antineoplastic drugs, have the ability to kill or stop the growth of certain living cells.
- ❖ Due to this property, they are used in chemotherapy of cancer.
- ❖ Most common genotoxic products used in healthcare

A. Classified as carcinogenic

- ❖ Chemicals, Benzene
- ❖ Cytotoxic and other drugs

B. Classified as possibly or probably carcinogenic.

Chemical Waste

- ❖ It consists of discarded solids, liquids and gaseous chemicals, i.e. those generated from diagnostic and experimental work and from procedures like cleaning, housekeeping and disinfection.
- ❖ Chemical waste from healthcare may be **hazardous** and **non-hazardous.**

Properties of hazardous chemical waste

- Toxic
- Corrosive
- Flammable
- Reactive(explosive, water-reactive, shock-sensitive)
- Genotoxic (e.g. Cytostatic drugs)

Properties of non-hazardous chemical waste

- Sugars
- Amino acids
- Organic and inorganic salts
- Formaldehyde chemical used for cleaning and disinfectant of equipment, specimens, preservation, pathology, dialysis and nursing units.
- Solvents containing waste from various departments contain halogenated and nonhalogeneted compounds.

Photographic/Radiographic Chemicals

- The fixer and developer solutions used in X-ray departments contain hazardous chemicals.
- The fixer contains hydroquinone 5 to 10 percent, potassium hydroxide 5%, silver more than 1 % and acetic acid.

Organic Chemicals

- In hospitals, disinfecting and cleaning solutions (phenol, perchlorethylene)
- Vaccum-pump oils use engine oil from vehicles
- Insecticides and rodenticides. Inorganic Chemicals
- Waste inorganic chemicals consists of acids (e.g. sulfuric, hydrochloric, nitric and chromic acids)
- Alkalis (e.g. sodium hydroxide and ammonia solutions)
- Oxidants (e.g. potassium permanganate and potassium dichromate)
- Reducing agents (e.g. sodium sulfite and sodium bisulfite) Waste with high content of heavy metals.
- Mercury, cadmium, lead, arsenic are highly toxic.
- Mercury volume of the waste is decreased with the substitution of equipment with solidstate electronic sensing instruments (e.g. thermometers, blood pressure, gauges).
- Cadmium waste enters the waste stream mainly from discarded batteries

- Lead containing reinforced wood panels are used as protection against X-rays and diagnostic departments.
- Arsenic compounds used in pharmaceutical purposes. Pressurized containers
- Gases used in healthcare are often stored in pressurized cylinders, cartridges and aerosol cans.
- It may explode if incinerated or accidently punctured.
- Commonly used gases in health care are Anesthetic gases, Ethylene oxide, Oxygen etc

Radioactive waste

It includes solids, liquids and gaseous wastes contaminated with radionuclides from nuclear medical diagnostic and therapeutic procedures.Disposal of such waste require special techniques in sealed sources and unsealed sources.

Categories and Classification of Biomedical Waste P13

Categories of biomedical waste

Option	Waste category	Treatment and disposal
Category 1	Human anatomical waste	Incineration /deep burials
Category 2	Animal waste	Incineration /deep burials
Category 3	Microbiology and Biotechnology waste	Localautoclaving/microwaving incineration
Category 4	Waste Sharps	Disinfection
Category 5	Discarded medicines and Cytotoxic drugs	Incineration/destruction and drugs disposal in ecuredlandfills
Category 6	Solid waste (ContaminatedWith Blood)	Incinerationautoclaving/microwaving
Category 7	Solid waste (disposable items waste)	Disinfection by chemical treatment,microwaving, mutilation/shredding.
Category 8	Liquid waste (lab waste, housekeeping, cleaning)	Disinfection by chemicaltreatment, microwaving,mutilation/shredding.

Category 9	Incineration ash	Disposal in municipal landfill
Category 10	Chemical waste	Chemical discharge into drains for liquids and securedLandfill for solids.

6.5. Classification of Biomedical waste

Methods used by various agencies for the classification of biomedical waste

WHO Classification for developing countries

- General nonhazardous waste
- Infected waste (not containing sharps)
- Sharps
- Chemical and pharmaceutical wastes
- Other hazardous waste-cytoxic and radioactive

Classification based on nature of waste – Medical waste can classified in to two

- **Hazardous waste**
- **Non hazardous waste**

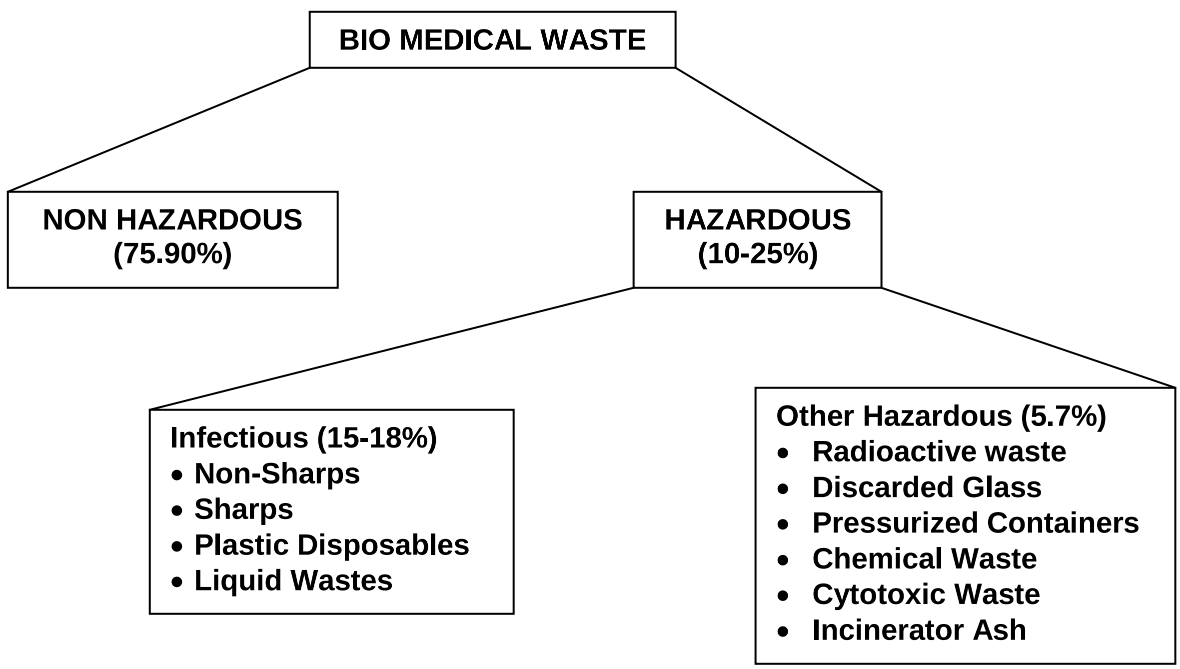

Figure 1 : Classification of Biomedical waste

Hazardous waste

- **Potentially infectious waste**
- Potentially infected material such as excised tumors and organs, placenta removed during surgery.
- Potentially infected animals which are used in diagnostic and research studies.
- Laboratory waste such as lab culture stocks of infectious agents.
- Dressings and swabs contaminated with blood, pups and body fluids.
- Blood and blood products.
- Sharps including blades, needle, syringes.
- **Potentially toxic waste**
- **Radioactive waste**

It means waste contaminated with radio-nuclides in the form of solid, liquids or gaseous waste. These wastes are generated during in vitro analysis of body fluids and tissue, therapeutic procedures and in vitro imaging.

- **Chemical waste**

It includes disinfectants (sodium hypochlorlite, glutaraldehyde, phenolic derivatives, and alcohol-based preparations), X-ray processing solutions.

- **Pharmaceutical waste**

  It includes antibiotics, anesthetics, analgesics, analgesics, sedatives, etc.

- **Nonhazardous waste**

It constitutes about 85% of the waste generated in most healthcare establishments. This includes waste comprising of food remnants, fruit peels, waste paper, packaging material.

6.6. Hazards of Biomedical Waste

- Waste from healthcare establishments should be collected and segregated for proper treatment in a hygienic manner.
- But, municipalities collect this waste and dispose it off in outskirts of cities and towns.
- Thus, biomedical waste emits foul smell during the rainy season and spreads various diseases such as dengue, HIV infections and remains dormant in human body for many years like hepatitis B, C and cancer.

6.7.1 Types of Hazards

The exposure to hazardous healthcare waste can result into:

- Infection
- Physical injuries
- Chemical injuries
- Radioactivity hazards
- Genotoxicity and cytotoxicity
- Public sensitivity

Infection

Portal of entry of the infectious agent into the body may be:

- Through a puncture, abrasion or cut in the skin
- Through mucous membranes
- ion and ingestion
- Most common infections, which can result from mishandling of hospital/healthcare waste are:
- Gastroenteric infections through feces or vomit.
- Respiratory infections through inhaled secretions, saliva
- Genital infections
- Ocular infections through eye secretions
- Skin infection through pus
- AIDS through blood and sexual secretions
- Meningitis through cerebrospinal fluid
- Septicemia and bacteremia through blood
- Viral hepatitis B and C through blood and body fluids
- Hemorrhagic fevers through body fluids

Physical injuries

- Can be attributed to sharps, chemicals and explosive agents.

Chemical injuries

- Various chemicals and pharmaceutical drugs which are used in hospitals for different purposes have potentially harmful effects.
- These effects may be due to the physical properties and chemical nature of these products.

- They may result in toxicity by both acute or chronic exposure and injuries like burns.

Radioactivity hazards

The exposure to radioactive waste may cause headache, dizziness, vomiting, tissue damage, genotoxicity, etc.

Genotoxicity and cytotoxicity

- Most cytotoxic drugs are extremely irritant.
- Their direct contact with skin and eyes also produces harmful local effects.
- Many pharmaceutical drugs are carcinogenic and mutagenic, secondary neoplasia is known to be associated with chemotherapy.
- **Public sensitivity**
- Every individual who is exposed to hazardous healthcare waste is potentially at risk, including those within healthcare establishments that generate hazardous waste, and those outside these sources who either handle such waste or are exposed to it as a consequence of careless management.
- The main groups at risks are the following:
    - Doctors, dentists, nurses, healthcare assistants and hospital maintenance personnel.
    - Patients in healthcare establishments or receiving home care and visitors at these sites.
    - Workers in allied support services to healthcare establishments such as laundries, waste handling and transportation.
    - Workers in waste disposal facilities (such as landfills or incinerators) including scavengers.

Hazards from Infectious Waste and Sharps

- Transmission of human immune deficiency virus (HIV) and Hepatitis viruses B and C via healthcare waste has emerged as a serious threat to public.
- These viruses are generally transmitted through injuries from sharps contaminated with human blood.
- The practice of reusing the syringes/ needles is still going on in rural India. Hence, putting an innumerable and recorded number of persons at risk.
- The evolution and spread of bacteria resistant to antibiotics and chemical disinfectants may also be related to poorly managed healthcare waste.

- FOR EG, plasmids from laboratory strains contained in healthcare waste can be transferred to indigenous bacteria via the waste disposal system.

Contaminated sharps (Particularly hypodermic needles) are probably the most acute potential hazards to health because:

- Sharps, if they are contaminated with pathogens, may not only cause cuts and punctures, but also infect these wounds.
- The infections that amy be transmitted by subcutaneous introduction of the causative agent.eg, viral blood infections as hypodermic needles are often contaminated with patient's blood.

Impacts Of Infectious Waste And Sharps

- A part from spreading serious infections such as HIV/AIDS, HBV AND HCV to healthcare workers (especially nurses), contaminated sharps (particularly hypodermic needles) can put at risk other hospital workers, waste management operators outside hospitals and scavengers on waste disposal sites.
- Certain infectious may spread through other media or caused by more resistance strains/agents. Such infectious may pose a significant risk to hospital's patients and to the general public.
- So another impact is spread of epidemics due to uncontrolled discharge of sewage from hospital down the drains to municipal sanitary sewer.

Hazards from Chemical and Pharmaceutical Waste

- Most of the chemicals and pharmaceutical used in healthcare establishments are hazardous (e.g. toxic, genotoxic, corrosive, flammable, reactive, explosive, shock-sensitive).
- Their intoxication can occur either by acute or by chronic exposure.
- The intoxication and injuries (including burns) are potential hazards.
- Intoxication can result from Inhalation, Ingestion, Absorption of a chemical or pharmaceutical through the skin or the mucous membranes.
- Contact with flammable, corrosive or reactive chemicals (e.g. formaldehyde and other volatile substances) can cause injuries to the skin, eyes or the mucous membranes of the airways, the most commons injuries being the chemical burns
- These substances are commonly present in small quantities in healthcare waste, larger quantities in unwanted or outdated chemicals and pharmaceuticals are disposed off.

- Disinfectants are used in large quantities and often corrosive.
- When their chemicals residues are discharged into the sewage system, they may affect the operation of biological sewage treatment plants adversely and have toxic effects on the natural ecosystems of receiving waters.
- Pharmaceutical residues, including antibiotics and other drugs, heavy metals such as mercury, phenols and its derivatives, disinfectants and antiseptics may pose similar challenges.

Impacts of Chemical and Pharmaceuticals Waste

- Although chemicals or pharmaceuticals waste from hospitals has not been related to widespread illness among the general public, extensive intoxication caused industrial chemical waste is a well known fact.
- Fish in Sutlej river in Punjab die in masses due to discharge of untreated industrial waste into the river which has raised many eyebrows.

Hazards from genotoxic waste

The severity of the hazards of genotoxic waste is governed by a combination of two factors:

- Substance toxicity itself
- The extent and duration of exposure.

Exposure to genotoxic substances in healthcare occurs during:

- The preparation of particular drug/chemicals.
- Treatment with particular drugs or chemicals
- Handling and disposal

The main pathways of exposure are:

- Inhalation: Inhalation of dust or aerosols
- Ingestion of food accidently contaminated with cytotoxic drugs, chemicals or waste.
- Ingestion as a result of bad practice such as mouth pipetting.

Impacts from genotoxic waste

- An increased risk of absorption and increased urinary levels of mutagenic compounds were noted in workers who handled these antineoplastic drugs.
- The exposure of personnel cleaning hospital urinals is found to be more than that of nurses and pharmacists because these individuals were less aware of the danger and take fewer precautions.

Hazards from radioactive waste

- The type and extent of exposure determines the type of diseases caused by radioactive waste. It can range from minor symptoms like headache, dizziness and vomit to more serious problems.
- Because radioactive waste is genotoxic, it may affect genetic material. Handling of highly active sources may cause more severe injuries such as destruction of tissues, necessitating amputation of body parts.
- The exposure surfaces to low-activity waste any arise from contaminated of external surfaces of containers or improper mode or duration of waste storage.
- Healthcare workers or waste-handling or cleaning personnel exposed to his radioactivity are at potential risk.

  Impacts of radio active waste

- Improper disposal of nuclear therapeutic materials have led to several accidents in history. A large number of persons are presently suffering from the results of exposure while many of the go unreported.
- The others sources of accidental exposure to ionizing radiations in healthcare settings have resulted from unsafe operation of X-ray apparatus, improper handling of radiotherapy solutions or inadequate control of radioactive waste in New Delhi in april 2010 eft five persons critically.

Public sensitivity

- The general public is very sensitive about the visual impact of anatomical waste, which is recognizable human body parts, including fetuses.
- It is unacceptable to dipose of this anatomical waste such as on a landfill where it is visible to public or to stray animals.
- In Asia, according to the religious beliefs, the human bodies are buried in cemeteries as well as keeping in coffins.

Need for disposal of biomedical waste

Effective and efficient methods of biomedical waste disposal should be employed to prevent such harms.

This requires huge investment in terms of money, material, material and machinery.

Health Reasons

- Injuries may lead to infectious to healthcare workers and waste handlers.

- Hospital acquired infection can spread due to poor practices of infection control and waste management.
- Risk of infection for waste handlers, scavengers and general public in the vicinity of hospitals.
- Risks due to drugs and hazardous chemicals to persons handling waste at each level.
- Disposable items being repacked and marketed by unscrupulous elements without any disinfectants.
- Repacking and resale of discarded drugs.
- Risk of air, water and soil pollution due to waste itself or its defective disposal.
- Tubercle bacilli spores remain suspended in the air and can spread tuberculosis.
- Soil may be polluted by tetanus spores.
- Pollution of water and food by biological agents results in alimentary infections like typhoid, cholera, infective hepatitis, polio, dysentery, ascariasis and hookworm diesaeas.
- Various vectors of disease transmission such as worms and pests breed on the waste.

  e.g. mosquitoes transmit malaria and filarial.
- Hospital acquired infections like AIDS, hepatitis b,c.

Ethical aspects

- It is the morale duty of healthcare workers to prevent hospitals from becoming centers of disease rather than center of cure.
- The rationale of biomedical waste management includes:
- Raising awareness on public health and environmental hazards associated with
- inappropriate segregation, collection, storage, transport, handling, treatment and disposal of healthcare waste.
- Providing information on hazards and sound management practices of healthcare waste for the policy making, development and improvement of legislation and technical guidelines.
- Identifying safe, efficient, sustainable, economic and culturally acceptable waste management practices and technologies and enabling the participants to identify the systems according to their particular needs.
- Enabling managers of healthcare establishments to develop their waste management plans

- Enabling course participants to develop training programs.

6.7. Environmental pollution through biomedical waste

Biomedical waste can cause air, water and soil pollution. Although pollution cannot be eliminated completely, efforts can be done to minimize it

Air pollution It is of three types

1. Biological
2. Chemical
3. Radioactive

Biological

A) Air Pollution Inside The Premises

- Pathogens or their spores can enter and remain suspended in the air building of the healthcare establishments for a prolonged period.
- This can result in nosocomial infections or occupational hazards.
- This puts healthcare workers, patient's as well as their attendants at risk of contracting airborne infections.

Indoor air pollution can be attributed to:

- Poor ventilation: improper planning and faculty air conditioning results in poor circulation of air within the rooms.so design of the buildings has an important role to play in maintaining proper ventilation.
- Use of chemicals: disinfectants, fumigants release acidic or hazardous gases or vapors into the air.

Outdoor Air Pollution

- When untreated waste is transported outside the healthcare establishments, dumped openly, pathogens in the waste can contaminate drinking water, foodstuff, soil.
- These may also remain in the ambient air and cause airborne diseases in animals and human beings.

Chemicals pollutants

Chemicals pollutants arise in two major sources

A) Open burning, Incinerators

- ➢ Open burning of biomedical waste is most harmful practice.
- ➢ The plastics and hazardous materials present in the waste generate oxides of sulfur and nitrogen, $CO_{2,}$ dioxin, furans, suspended particulate matter.

- When inhaled, these harmful chemicals can cause respiratory diseases.
- Out of these, dioxin and furans are carcinogenic.

Radioactive emissions

- Small quantities of radioactive gas are generated durning research and radioimmunoassay activities.
- The clinical application of Kr and Xe are the principal sources of gaseous radioactive waste.

Water pollution

- Improper disposal of biomedical waste for eg dumping in low-lying areas, into lakes and water bodies can lead to severe water pollution.
- Water can be polluted by biological, chemicals or radioactive substances.
- The pathogens and harmful chemicals present in the waste can leach out and contaminate the ground water or surface water.

Eutrophication

- Algal brooms over surface of water bodies. This occurs mainly because of excess nutrient leachates e.g. nitrates and phosphates from landfills.
- Water pollution can alter parameters such as Ph, biological Oxygen Demand (BOD). Dioxins have been reported from water body from the air.
- Radioactive effluents also pollute water.

Land pollution

- As all types of biomedical waste is finally disposed off on the land, land pollution is inevitable. Even liquid effluent after treatment is spread on land.
- However, if treated in a proper way, pollution can be minimized to a large extent.
- The main sources of soil pollution from biomedical waste are infectious waste, discarded medicines, chemicals waste and other waste generated during treatment processes.
- Heavy metals present in the waste such as cadmium, lead, mercury will get absorbed by plants and can then enter the food chain.
- Excessive amounts of trace nutrient elements and heavy metals in soil are harmful to crops, animals and human beings.
- Open dumping of biomedical waste is the greatest cause for land pollution and landfilling is also not a totally safe method.

6.8. Biomedical Waste Management

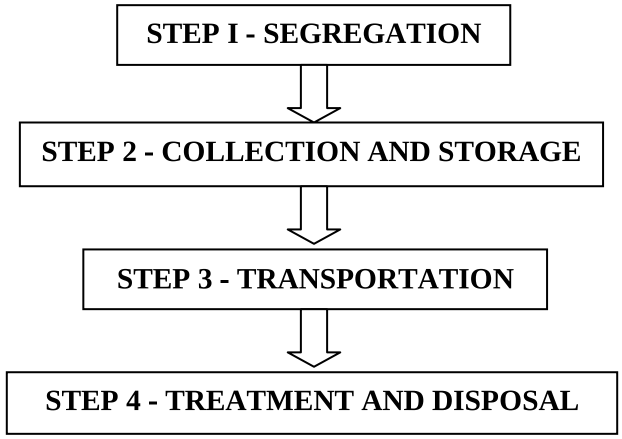

Figure 2 : Steps of Biomedical waste management

6.9. Waste Minimization

Waste minimization is the process and policy of reducing the amount of waste produced by a person or a society.

Need for waste minimization

- A huge stock of waste is generated when hazardous and non-hazardous biomedical waste is mixed which carries a increased environmental hazards, increased risk to the person in direct, indirect contact with waste, increased cost of handling and disposal.
- To overcome such challenges, it is advised to minimize the waste as much as possible.
- It is the duty of the hospital authorities to identify and quantify the waste generated.
- Effective measures should be taken to reduce the amount of waste by controlling demand/inventory and recycling of certain wastes such as paper, glassware, plastic material.
- Healthcare establishments encourages the purchase of reusable items made up of glass. Substitute PVC (Polyvinyl chloride).

Advantages of waste minimization

- Reduced potential for exposures of employees, patients, visitors and waste management personnel to hazards associated with wastes in term of health and safety.
- Reduced volume and toxicity of unavoidable waste.
- Improved transportation, storage, treatment and disposal of waste.

- Proper containment of hazardous materials.
- Prompt removal of hazardous materials from the workplace.
- Long-term economic benefit.

How to do waste minimization?

Apart from protecting people and the environment, waste minimization can save hospitals a great deal of money in the long run. Waste can be minimized by various methods:

Sources reduction:

- The amount of waste generated at the source itself can be minimized through product substitution, technology change and good operating practices.
- By changing the purchasing policies and product substitution, toxicity of the waste generated can be also reduced. The methods that can be adopted are:
- Prevent wastage of products in nursing and cleaning activities.
- Prefer physical cleaning methods over chemicals ones.
- Select supplies that are less wasteful or less hazardous.
- Centralize the purchasing of hazardous chemicals at hospital level.

Resource recovery and recycling

- The majority of waste from healthcare facilities is same as that of an office, e.g. paper, cardboard and food wastes.
- Healthcare establishments can implement very simple programs that divert these materials from the solid waste stream, lowering disposal costs.
- Wherever applicable, recycling should be adopted as a method of disposal and recycling should be bought and used.

Waste disposal

- For those things that cannot be reduced, reuse or recycled, we ensure that they are disposed in safer manner without affecting environment.
- E.g: Safer disposal of mobiles and batteries.

Significance

- Cost savings that go directly to the bottom line
- Reduced impact on the environment
- Improved public perceptions
- Development of new and more sustainable processes

- Development of new products.

6.10. Waste segregation

Waste segregation refers to the separation of wet waste and dry waste, the purpose is to recycle dry waste easily and to use wet waste as compost.

Persons responsible for Segregation

Duty of Care

- A duty of care on any person who produces imports, carries, keeps, treats or disposes of controlled waste or, as a broker, has control of such waste.
- These are individually called the waste holders.

Those subject to the Duty of Care must try to achieve the following:

- To prevent any other person committing any of the offences under s.33 of the Act, namely, disposing of controlled waste or treating or storing it.
- Without an environmental permit; or
- Breaking the conditions of a permit; or in a manner likely to cause pollution of the environment or harm to human health.
- To prevent the escape of waste
- To ensure that, if the waste is transferred, it goes only to an 'authorized person' or to a person for `authorized transport purposes';
- When waste is transferred, to make sure that there is also transferred a written description of the waste, which is sufficient to enable each person receiving it.

Procedure for segregation

What is waste segregation?

- Waste segregation refers to the separation of wet waste and dry waste, the purpose is to recycle dry waste easily and to use wet waste as compost.

Why should we segregate waste?

- When we segregate waste, there is reduction of waste that gets landfilled and occupies space, air and water pollution rates are considerably lowered.
- Segregating waste also makes it easier to apply different processes - composting, recycling and incineration can be applied to different kinds of waste.

Steps to manage and segregate waste:

- Keep separate containers for dry and wet waste in the kitchen.

- Keep two bags for dry waste collection- paper and plastic, for the rest of the household waste
- Keep plastic from the kitchen clean and dry and drop into the dry waste bin.
- Keep glass/plastic containers rinsed of food matter.
- Send wet waste out of your home daily.
- Store and send dry waste out of the home, once a week.
- Keep a paper bag for throwing the sanitary waste.

Rules for segregation

Keeping wet and dry wastes separately, so that dry can be recycled and wet can be composted.

Dry waste

It does the compost process.e.g. Coconut Shells, Vegetable Waste, Bones, Dust etc

Wet waste

It does the reuse and recycle processe.g. Paper, Plastic, Metal, Glass, Rexineetc

Advantages of segregation

- 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 medicine waste like plastics after proper and through disinfection.
- Recycling helps to reduce energy usage, reduce the consumption of fresh materials, reduce air pollution and water pollution.
- Reduces the greenhouse emissions.
- Building more space in landfills which takes up valuable space.

6.11. Containers For Waste Collection

- Waste must be safely contained during handling and to the point of its disposal.The packaging must remain intact throughout handling, storage, transportation, and treatment.
- When selecting packaging, the following factors should be considered: the type of waste being contained; appropriate colour-coding and labelling (see color coding section);

special transportation requirements; the method of disposal; transport requirements; and requirements of the disposal facility.

- To simplify their selection and use, waste containers should be classified as reusable or single-use/disposable.

Reusable Containers:

- Reusable waste containers made of metal or rigid plastic and able to withstand exposure to common cleaning agents.
- They must be colour-coded according to the type of waste for which they are intended ; and labelled with the biohazard symbol.
- Reusable waste containers should be inspected for holes or leaks each time they are emptied and their colour coding and labelling renewed if necessary.
- Holes or leaks must be repaired or the waste container replaced.
- Reusable waste containers must be cleaned regularly to prevent odours and as soon as possible if waste materials leak or spill within the containers.

SEGREGATION OF WASTE IN COLOR CODED BAGS

YELLOW BAGS	RED BAGS	BLUE BAGS	BLACK CARBOY
Infectious waste, bandages, any other objects in human bodygauze,cotton or contact with body fluids,parts,placentaetc.	Plastic waste Injection syringes tubing's.. bottles	All types of glass bottels catheters inject and broken glass articles. outdated & discarded medicines	Needles without syringes blades, sharps and all metal articals

Color Coding and Type Of Container for Disposal of Biomedical Wastes

Color coding	Container type	Waste category	Treatment options
Yellow	Plastic bag	Cat1, 2, 3, 6	Incineration/deep burial
Red	Disinfectedcontainer/ plastic bag	Cat3, 6, 7	Autoclaving/microwaving/chemicl treatment
Blue/White Translucent	Plastic bag/puncture proof container	Cat 4, 7	Autoclaving/microwaving/chemicl treatment/destruction/shredding.
Black	Plastic bag	Cat5,9, 10(solid)	Disposal in secured landfill

Single-use Containers

- Single-use waste containers should be classified as one of the following types: sharps container; waste-holding plastic bag; or cardboard container.

Sharps Containers

- The critical characteristic of any sharps container is that it be sturdy enough to resist puncture under conditions of use and to the point of disposal.
- Until a method is devised to determine this objectively, sharps containers should be tested and evaluated under actual conditions of use.

Category	Type of Waste	Type of Bag or Container to be used	Treatment and Disposal options
RED	a) Contaminated Waste (Recyclable)	non-chlorinated plastic bags or containers	Autoclaving or micro-waving followed by shredding or mutilation
White Translucent	Waste sharps including Metals	Puncture proof, Leak proof, tamper proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation
Blue	a) Glassware b) Metallic Body Implants	Cardboard boxes with blue colored marking	Disinfection (by soaking the washed glass waste in Sodium Hypochlorite) or through autoclaving or microwaving and then sent for recycling

Pickup containers

- This includes moving medical/biohazardous waste more than a few feet within a room.
- Wear and use personal protective equipment (PPE) appropriately when handling medical/biohazardous waste.
- Wear PPE (e.g., lab coat, gloves, safety glasses) to prevent potential contact with and exposure to infectious material.

In addition, prevent the spread of infectious material by:

- Changing gloves that have been used or may be contaminated,
- Not touching doorknobs or other “clean” surfaces with gloved hands, and
- Washing hands after removing gloves.

Seal the biohazard bag closed (tape, rubber band, etc.).

- The bio hazard bag must be secondarily contained during transport in a labeled biohazard container with a lid.
- Remove the biohazard bag and deposit it into the pickup container.
- The pickup container must be lined with a red biohazard bag.
- Close the lid on the pickup container after adding the waste.

6.12. Labeling P17

- Proper labeling of hazardous chemical and waste is extremely important to reduce exposure, prevent accidents and extra disposal costs

- OSHA’s Hazard Communications Program (HazCom) covers the labeling of hazardous chemicals in use.
- Once the chemical becomes a hazardous waste, a different set of labeling rules apply under EPA’s RCRA program (provide link).
- To add to the challenge of labeling all hazardous materials, to prepare hazardous waste for shipment, another set of rules apply under the Department of Transportation (DOT).
- HazCom requires that all containers of hazardous chemicals must be labeled, tagged, or marked with the identity of the material and appropriate hazard warnings.
- Chemical manufacturers, importers, and distributors must ensure that every container of hazardous chemicals they ship is appropriately labeled with such information and with the name and address of the producer or other responsible party.
- The primary information to be obtained from an OSHA-required label is the identity for the material and appropriate hazard warnings.
- The identity is any term which appears on the label, the MSDS, and the list of chemicals, and thus links these three sources of information.
- The identity used by the supplier may be a common or trade name ("Black Magic Floor Cleaner"), or a chemical name (1, 1, 1 - trichloroethane).
- The hazard warning is a brief statement of the hazardous effects of the chemical ("flammable," "causes lung damage").
- Labels frequently contain other information, such as precautionary measures ("do not use near open flame") but this information is provided voluntarily and is not required by the rule.
- Labels must be legible and prominently displayed. There are no specific requirements for size or color or any specified test.
- Proper labeling is extremely important to prevent accidents and extra disposal costs
- Ensure proper labeling of all incoming materials as they are received (Include product name, weight, concentration, lot number, date, hazard class and any other information useful in tracking material location, quality, age or use.)
- Always label hazardous waste at its point of generation where it can still be easily identified (Testing later to determine the contents is expensive.)
- Label all areas in the plant, including stationary tanks, pipelines, etc. containing hazardous materials or wastes

- If a chemical was in a labeled container and is subsequently transferred to another container, the employer must label the new container.
- Shelving the chemical stored may be labeled with additional labeling if when the chemical is removed from the labeled shelf, it will be used in its entirety. If not, it will require an additional label.
- Specifically, HazCom requires the following types of information to ensure that labeling is properly implemented in your facility:
- Designation of person(s) responsible for labeling system implemented throughout the facility;
- Designation of person(s) responsible for ensuring labeling of all containers in each department/area
- Designation of person(s) responsible for ensuring re-labeling of hazardous waste or to prepare waste for shipping
- Description of labeling system(s) used and comprehensive training program
- Description of written alternatives to labeling of containers (if used)

Procedures to review and update label information when necessary.

6.13. Waste handling and disposal

- It is an activity associated with the handling of solid waste until they are placed in containers.
- Waste handling depends on type of waste materials separated for reuse and recycling.
- Also it an activity to move the loaded containers to the collection point and to return containers to the point where they are stored between collectors.
- Hospital waste handlers bear the responsibility of keeping waste tightly contained upon receipt.
- Unfortunately, awareness of the need for safety and caution among staff members who routinely handle hospital waste may decrease over time, increasing the possibility for contamination or injury.
- All staff members handling waste products should receive periodic reminders and refresher training that includes information on the techniques and risks associated with the handling of waste, procedures for dealing with spillages and other accidents and instructions on the use of protective clothing.

- Additionally, staff should be required to demonstrate the procedure of proper waste handling to confirm their compliance.

6.14. Waste treatment and disposal

Several methods are used for treatment and disposal of waste. They are

- Composting
- Incineration
- Landfilling
- Pyrolysis
- Recycling

Composting

- It is a process in which organic matter of solid waste is decomposed and converted to humus and mineral compounds.
- Compost is the end product of composting, which used as fertilizer.
- Three methods of composting
- Composting by trenching
- Open window composting
- Mechanical composting

Composting by trenching

- Trenches 3-12m long, 2-3m wide and 1-2m deep with spacing 2m.
- Dry waste are filled up in 15cm.on top of each layer 5cm thick sandwiching layer of animal drugs is sprayed in semi liquid form.
- Biological action starts in 2-3 days and decomposition starts.
- Solid waste stabilize in 4-6 months and changed into brown colored odour less powdery form known as humus.

Open window trenching

- Large materials like broken glass, stone, plastic articles are removed.
- Remaining solid wastes is dumped on ground in form of piles of 0.6-1m height.
- Temperature increases in side pile.
- After pile for turned for cooling and aeration to avoid anaerobic decomposition.
- The complete process may take 4-6 week.

Mechanical composting

- It require small are compare to trenching and open window composting.

- The stabilization of waste takes 3-6 days.
- The operation involved are
- Reception of refuse
- Segregration
- Shredding
- Stabilization
- Marketing the humus.

Incineration

- Incineration is the waste treatment process that involves the combustion of organic substances contained in waste materials
- Incineration and other high temperature waste treatment systems are described as thermal treatment.4incineration of waste materials converts the waste into ash, flue gas,etc..

Advantages

- Less space required.
- Most hygienic method
- Heat generated can be used for steam powder.

Disadvantages

- Large initial expense.
- Large number of vehicles are required for transportation.

Landfilling

- It is site for the disposal of waste materials by burial nd is the oldest form of waste treatment.
- The dumping is done with layers of 1-2 m.
- The layer is covered with soil of 20cm in thickness.

Advantages

- Simple method
- Separation is not required
- unused lands can be used

Disadvantage

- Large land is required
- Odor problem.

- Green house gas problem

Pyrolysis

- Heating of the solid waste at very high temperature is absence of air.
- Carried out at temp between 500c – 1000c.
- Gas, liquid and chars are the by products.

Recycling

- Recycling is the process used materials into new products.
- It reduce the consumption of fresh raw materials,reduce air pollution and water pollution.
- Recycling is the key component of modern waste reduction and it is third component of the reduce, reuse and recycle waste hierarchy.

6.15. Rules for Biomedical waste management

The first legislation for biomedical waste management came under the Bio-Medical Waste (Management and Handling) Rules, 1998, which provided a regulatory framework for management of BMW generated in the country. This was amended as Bio-Medical Waste Management Rules, 2016 and again as Bio- Medical Waste Management (Amendment) Rules, 2018.

According to rules Biomedical waste comprises human & animal anatomical waste, treatment apparatus like needles, syringes and other materials used in health care facilities in the process of treatment and research. This waste is generated during diagnosis, treatment or immunisation in hospitals, nursing homes, pathological laboratories, blood bank, etc. Total bio-medical waste generation in the country is 484 TPD from 1,68,869 healthcare facilities (HCF), out of which 447 TPD is treated.

Scientific disposal of Biomedical Waste through segregation, collection and treatment in an environmentally sound manner minimises the adverse impact on health workers and on the environment. The hospitals are required to put in place the mechanisms for effective disposal either directly or through common biomedical waste treatment and disposal facilities. The hospitals servicing 1000 patients or more per month are required to obtain authorisation and segregate biomedical waste in to 10 categories, pack five colour backs for disposal. There are 198 common bio-medical waste treatment facilities (CBMWF) in operation and 28 are under construction. 21,870 HCFs have their own treatment facilities and 1,31,837 HCFs are using the CBMWFs.

The quantum of waste generated in India is estimated to be 1-2 kg per bed per day in a hospital and 600 gm per day per bed in a clinic. 85% of the hospital waste is non-hazardous, 15% is infectious/hazardous. Mixing of hazardous results in to contamination and makes the entire waste hazardous. Hence there is necessity to segregate and treat. Improper disposal increases risk of infection; encourages recycling of prohibited disposables and disposed drugs; and develops resistant microorganisms.

The new bio-medical waste management rules has hence been notified to efficiently manage the generated biowaste in the country.

Salient features of BMW Management Rules, 2016

- The ambit of the rules has been expanded to include vaccination camps, blood donation camps, surgical camps or any other healthcare activity;
- Phase-out the use of chlorinated plastic bags, gloves and blood bags within two years;
- Pre-treatment of the laboratory waste, microbiological waste, blood samples and blood bags through disinfection orsterilisation on-site in the manner as prescribed by WHOor NACO;
- Provide training to all its health care workers and immunise all health workers regularly;
- Establish a Bar-Code System for bags or containers containing bio-medical waste for disposal;
- Report major accidents; (g) Existing incinerators to achieve the standards for retention time in secondary chamber and Dioxin and Furans within two years;
- Bio-medical waste has been classified in to 4 categories instead 10 to improve the segregation of waste at source;
- Procedure to get authorisation simplified. Automatic authorisation for bedded hospitals. The validity of authorization synchronised with validity of consent orders for Bedded HCFs. One time Authorisation for Non-bedded HCFs;
- The new rules prescribe more stringent standards for incinerator to reduce the emission of pollutants in environment;
- Inclusion of emissions limits for Dioxin and furans;
- State Government to provide land for setting up common bio-medical waste treatment and disposal facility;
- No occupier shall establish on-site treatment and disposal facility, if a service of `common bio-medical waste treatment facility is available at a distance of seventy-five kilometer.

- Operator of a common bio-medical waste treatment and disposal facility to ensure the timely collection of bio-medical waste from the HCFs and assist the HCFs in conduct of training .

Amendments in Bio-Medical Waste Management Rules, 2016 Rules

Bio-Medical Waste Management Rules, 2016 Rules have been amended to improve compliance and strengthen the implementation of environmentally sound management of biomedical waste in India.

The amended rules stipulate that generators of bio-medical waste such as hospitals, nursing homes, clinics, and dispensaries etc will not use chlorinated plastic bags and gloves beyond March 27, 2019 in medical applications to save the environment. Blood bags have been exempted for phase-out, as per the amended BMW rules, 2018.

Salient features of Bio-Medical Waste Management (Amendment) Rules, 2018 are as follows:

- Bio-medical waste generators including hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks, health care facilities, and clinical establishments will have to phase out chlorinated plastic bags (excluding blood bags) and gloves by March 27, 2019.
- All healthcare facilities shall make available the annual report on its website within a period of two years from the date of publication of the Bio-Medical Waste Management (Amendment) Rules, 2018.
- Operators of common bio-medical waste treatment and disposal facilities shall establish bar coding and global positioning system for handling of bio-medical waste in accordance with guidelines issued by the Central Pollution Control Board by March 27, 2019.
- The State Pollution Control Boards/ Pollution Control Committees have to compile, review and analyze the information received and send this information to the Central Pollution Control Board in a new Form (Form IV A), which seeks detailed information regarding district-wise bio-medical waste generation, information on Health Care Facilities having captive treatment facilities, information on common bio-medical waste treatment and disposal facilities.
- Every occupier, i.e. a person having administrative control over the institution and the premises generating biomedical waste shall pre-treat the laboratory waste, microbiological

waste, blood samples, and blood bags through disinfection or sterilization on-site in the manner as prescribed by the World Health Organization (WHO) or guidelines on safe management of wastes from health care activities and WHO Blue Book 2014 and then sent to the Common bio-medical waste treatment facility for final disposal.

- These amendments have been made vide Notification G.S.R. 234(E) dated March 16, 2018.

6.16. Summary

Biomedical waste creates hazard due to two principal reasons: infectivity and toxicity. According to the Bio Medical Waste (Management and Handling) Rules 1998. Wastes from surgery and autopsies done on patients suffering from infectious diseases (e.g. tissues, materials or equipment that have been in contact with blood or other body fluids).Excreta, dressing from infected/ surgical wounds, clothes heavily soiled with human blood or other body fluids from infected patients in insolation wards. Certain infectious may spread through other media or caused by more resistance strains/agents. Such infectious may pose a significant risk to hospital's patients and to the general public.So another impact is spread of epidemics due to uncontrolled discharge of sewage from hospital down the drains to municipal sanitary sewer. The others sources of accidental exposure to ionizing radiations in healthcare settings have resulted from unsafe operation of X-ray apparatus, improper handling of radiotherapy solutions or inadequate control of radioactive waste in New Delhi in april 2010 eft five persons critically.

6.17. Terminal Question

Q.1: What is biomedical waste? Define it sources and classification.

Answer: ---

Q.2: Discuss the contamination occurs by biomedical waste.

Answer: ---

Q.3: Discuss the biomedical waste collection and segregation.

Answer: ---

Q.4: Discuss the Biomedical waste management.

Answer: ---

Q.5: Discuss treatment and waste disposal.

Answer: ---

Q.6: Handling and management of biomedical waste.

Answer: ---

6.18. Further suggested Readings

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Solid and Hazardous Waste Management

Block- 3

Radioactive Waste and Waste Recycling

UNIT -7

Radioactive and Plastic Wastes

UNIT-8

E-Waste

UNIT-9

Resource Recovery

PGEVS-108N

Rajarshi Tandon Open University, Prayagraj

Solid and Hazardous Waste Management

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Unit-07: Radioactive and plastic wastes

7.1. Introduction
Objectives
7.2. Radioactive waste overview
7.3. Sources of Radioactive waste
7.4. Fuel composition and long term radioactivity
7.5. Nuclear weapons decommissioning
7.6. Coal
7.7. Oil and gas
7.8. Natural radioactivity
7.9. Types of Radioactive waste

7.1. Introduction

This chapter covers all types of radioactive waste and plastic waste and waste management. Waste is a product or substance which is no longer suited for its intended use. Radioactive waste is a hazardous waste and micro plastic is also very dangerous for health.In this chapter we are studying the classification of radioactive waste and plastic waste. Radioactive waste is classified into three types: low -level waste (LLW), intermediate- level waste (ILW),and high- level waste (HLW), also studying about sources of radioactive waste and how to pollute the environment and how hazardous for human health.Radioactive waste comes from many different sources and also learns how to store and segregate radioactive waste.

The nuclear fuel cycle front end waste is usually alpha-emitting waste from the extraction of uranium and in the nuclear fuel cycle back end mostly spent fuel rods, taken fission products that emit gamma and beta radiation. After that we can also learn in this chapter Nuclear weapons decommissioning and some green techniques of radioactive waste and plastic waste management like recycling and also study the benefits of recycling based reduce and reuse based disposal and what is the micro plastic waste management and source of waste. And in this way we have learnt the segregation process and techniques and type benefits and drawbacks also. At last we can study the importance of 4R: reduce reuse, recycle and recover and land filling.

Objective

- To understand the radioactive waste and plastic waste.
- To study radioactive waste in plastic waste management.
- To understand disposal of waste and source point of waste.
- To understand micro plastic waste and its type.
- To understand the importance of reduce, reuse, recycle, recovery, and landfilling .
- To study plastic based on their use.
- To understand the possible recycled products of plastic.

7.2. Radioactive waste overview

Radioactive waste is a hazardouswaste that contains radioactive material. Radioactive waste is an outcome of many activities, including nuclear research, nuclear medicine, nuclear power generation, rare-earth mining, and nuclear weapons reclaiming. Government agencies regulate the storage and disposal of radioactive waste in order to protect human health and environment.

Figure: 1 Thailand Institute of Nuclear Technology (TINT) low-level radioactive waste barrels

Radioactive waste is classified into low-level waste (LLW), intermediate- level waste (ILW) and high-level waste (HLW). low- level waste ,such as paper, tools,rags, clothing, these things contain slight amount of mostly short-lived radioactivity, intermediate-level waste (ILW), which contains large amounts of radioactivity and requires some shielding, and high-level waste (HLW), which is highly radioactive and blazing due to decay heat, so requires cooling and shielding.

About 96% of spent nuclear fuel is recycled back into Uranium-based and mixed-oxide fuels in nuclear reprocessing plants.The remaining 4% is minor actinides and fission products the latter of which are a mixture of stable and quickly decaying (most likely already having decayed in the spent fuel pool) elements, such as Strontium-90 and Caesium-137 are medium lived fission product and finally seven long-lived fission products with half lives in the hundreds of thousands to millions of years. The minor actinides till then are heavy elements other than neutron capture that created the uranium and plutonium. Their half lives range from years to millions of years and as alpha emitters they are commonly radiotoxic. Although there are proposed - and to a much minor extent current - uses of all those elements, marketable scale reprocessing using the PUREX-process disposes of them as waste together with the fission products. The waste is thereafter converted into a glass-like ceramic for storage in a deep geological repository.

The storage time of radioactive waste must depend on the type of waste and radioactive isotopes it contains. Segregation and storage on the surface or near surface have been short term approaches to radioactive waste storage. Burial in a deep geological depository is a blessed solution for long-term storage of high-level waste, Although reuse and transformation are favored solutions for decreasing the HLW inventory. If chemical separation processes cannot achieve a very high purity then spent nuclear fuel recycling boundaries are regulatory and economic as well as the issue of radioactive contamination. Besides, elements may be present in both favorable and problematic isotopes, which would require pricey and energy demanding isotope splitting for their use, at present it is an uneconomic possibility.

An overview of the amounts of radioactive waste and management approaches for most developed countries is presented and The International Atomic Energy Agency (IAEA)'s Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management as part of the joint review periodically.

7.3. Sources of Radioactive waste

Radioactive waste comes from many different sources. In countries with nuclear power plants, nuclear fuel treatment plants or nuclear armament, the larger part of waste originates from the nuclear weapons reprocessing and nuclear fuel cycle. Other sources include industrial wastes and medical wastes, as well as naturally occurring radioactive materials (NORM) that can be concentrated as a consequence of the processing or consumption of coal, gas, and oil, and some minerals, as discussed below.

i. Front end

The nuclear fuel cycle front end waste is usually alpha-emitting waste from the extraction of uranium. It repeatedly contains radium and its decay products.

Uranium dioxide (UO2) intensified from mining is a thousand or eventually as radioactive as the granite used in buildings. It is purified from yellowcake (U3O8), then converted to uranium hexafluoride gas (UF6). As a gas, it witnesses enrichment to increase the U-235 content from 0.7% to about 4.4% (LEU). It is then converted into a hard ceramic oxide (UO2) for gathering as reactor fuel elements.

The main by-product of enhancement is depleted uranium (DU), basically the U-238 isotope, with a U-235 essence of ~0.3%. It is reserved, either as UF6 or as U3O8.

Some are used in applications where its excessively high density makes it invaluable such as anti-tank shells, and at least one event even a sailboat keel. It is also used with plutonium for making mixed oxide fuel (MOX) and to dilute, or downblend, highly heighten uranium from weapons stockpiles which is now being sidetracked to become reactor fuel.

ii. Back end

In the nuclear fuel cycle back end mostly spent fuel rods, taken fission products that emit gamma and beta radiation, and actinides that emit alpha particles, such as uranium-234 (half-life 245 thousand years), neptunium-237 (2.144 million years), plutonium-238 (87.7 years) and americium-241 (432 years), and even many times some neutron emitters like as californium (half-life of 898 years for californium-251). Nuclear reactors form these isotopes.

It is important to discriminate the processing of uranium to make fuel from the process again of used fuel. Used fuel takes the extremely radioactive products of fission. Many of these are neutron buffers, called neutron poisons in this situation. These ultimately build up to a level where they absorb so many neutrons that the chain reaction stops, despite the control rods completely removed. At that point, the fuel has to be replaced in the reactor with fresh fuel, even though there is still a significant quantity of uranium-235 and plutonium on offer.

iii. Nuclear weapons decommissioning

Waste from nuclear weapons decommissioning is objectionable to contain much beta or gamma activity other than tritium and americium. It is more likely to contain alpha-emitting actinides like Pu-239 whichever is a fissile material used in bombs, plus some material with much higher-end specific activities, such as Pu-238 or Po.

In the past the neutron stimulus for an atomic bomb tended to be beryllium and a higher activity alpha emitter such as polonium; an alternative to polonium is Pu-238. Some designs contain a radioisotope thermoelectric generator using Pu-238 to provide a durable source of electrical power for the electronics in the device.

It is like as that the fissile material of an old bomb which is due for modifying will contain decay products of the plutonium isotopes used in it, these are likewise to include U-236 from Pu-240 impurities, plus some U-235 from decay of the Pu-239; due to the relatively long half-life of these Pu isotopes, these wastes from radioactive decay of bomb core material would be very smallest, and in any case, far less dangerously (even in terms of simple radioactivity) than the Pu-239 itself.

iv. **Medicine**

Radioactive medical waste tends to contain beta particles and gamma ray emitters. It can be divided into two main classes. In diagnostic nuclear medicine a number of short-lived gamma emitters such as technetium-99m are used. Many of these can be disposed of by leaving it to decay for a short time before disposal as normal waste. Other isotopes used in medicine, with half-lives in parentheses, include:

- Y-90, used for treating lymphoma (2.7 days)
- I-131, used for thyroid function tests and for treating thyroid cancer (8.0 days)
- Sr-89, used for treating bone cancer, intravenous injection (52 days)
- Ir-192, used for brachytherapy (74 days)
- Co-60, used for brachytherapy and external radiotherapy (5.3 years)
- Cs-137, used for brachytherapy and external radiotherapy (30 years)
- Tc-99, product of the decay of Technetium-99m (221,000 years)

v. **Industry**

Industrial source waste can contain alpha, beta, neutron or gamma emitters. Gamma emitters are used in radiography at the same time neutron emitting sources are used in a range of applications, such as oil well logging.

vi. **Naturally occurring radioactive material**

vii. Natural radioactivityrefers to the radioactivity of materials found in nature. These materials are present in uranium and thorium ores, nature's nuclear fuels. Wastes from mining, ore milling, and fuel fabrication therefore contain this natural radioactivity, which consists primarily of the natural radioisotopes of uranium, thorium, radon (a gas), and radium. Most mines are in dry formations, but some must be kept dry by pumping out hundreds of gallons of water per minute. This water contains only traces of radioisotopes and poses no significant health hazard. In uranium ore-concentrating mills, liquid wastes are discharged to ponds or lagoons at a rate of 300 to 500 gallons per minute (for an average mill processing 1000 tons of ore per day). There are over 20 such mills in the United States. Radium is the principal radioisotope in mill wastes and is in-corporated in the solid residues, called "tailings", in an insoluble form.

a) **Coal**Coal contains a small amount of radioactive uranium, barium, thorium, and potassium but in the case of pure coal, this is significantly less than the moderate concentration of those elements in the Earth's crust. The surrounding circumstances, if shale or mudstone, often contain slightly more than average and this may also be reflected in the ash content of 'dirty' coals. The more active ash minerals become concentrated in the fly ash precisely because they do not burn well.The radioactivity of fly ash is about the same as black shale and is less than phosphate rocks, but is more of a concern because a small amount of the fly ash ends up in the atmosphere where it can be inhaled. According to the U.S. National Council on Radiation Protection and Measurements (NCRP) reports, population exposure from 1000-MWe power plants amounts to 490 person-rem/year for coal power plants, 100 times as great as nuclear power plants (4.8 person-rem/year). The exposure from the complete nuclear fuel cycle from mining to waste disposal is 136 person-rem/year; the corresponding value for coal use from mining to waste disposal is "probably unknown".

b) Oil and gas

Residues from the oil and gas industry often contain radium and its decay products. The sulfate scale from an oil well can be very radium rich, while the water, oil, and gas from a well often contain radon. The radon decays to form solid radioisotopes which form coatings on the inside of pipework. In an oil processing plant, the area of the plant where propane is processed is often one of the more contaminated areas of the plant as radon has a similar boiling point to propane.

Radioactive elements are an industrial trouble in some oil wells where workers working in direct contact with the crude oil and brine can be actually exposed to doses having negative health effects. Due to the relatively high concentration of these elements in the brine, its disposal is also a technological challenge. In the United States, the brine is furthermore liberated from the dangerous waste regulations and can be disposed of unconcerned of radioactive or toxic substances content since the 1980s.

c) Rare-earth mining

Due to natural occurrence of radioactive elements such as thorium and radium in rare-earth ore, mining operations also result in production of waste and mineral deposits that are slightly radioactive.

Radioactive wastes are created wherever radioactive material is used. By far the greatest source of wastes is the nuclear fuel cycle: The mining, milling, and preparation of fuel for reactors and weapons produce wastes containing natural radioisotopes; and fuel irradiation and subsequent processors produce wastes rich in fission products. Additional wastes are produced by irradiation of nonfuel materials in and around reactors. Let us consider these sources.

7.4. Proliferation concerns

Therefore uranium and plutonium are nuclear weapons materials, there have been proliferation concerns. Generally (in spent nuclear fuel), plutonium is reactor-grade plutonium. In addition to plutonium-239, which is extremely appropriate for building nuclear weapons, it contains larger amounts of inadmissible contaminants: plutonium-238, plutonium-240, and plutonium-241. These isotopes are highly difficult to separated, and high commercial ways procure fissile material existing (e.g., uranium enrichment or dedicated plutonium production reactors).

High-level waste is full of intense radioactive fission products, largely of which are consequently short-term. This is a solicitude since if the waste is stored in deep geological storage, over many years the fission products decay, decreasing the radioactivity of the waste and making the plutonium easier to access. The undesirable contaminant Pu-240 decays faster than the Pu-239, and thus the quality of the bomb material increases with time (although its quantity decreases during that time as well). Thus, some have quarrel, as time passes, these deep storage areas have the potential to grow into "plutonium mines", from which material for nuclear weapons can be collected with nearly little difficulty. Critics of the latter idea have pointed out the difficulty of recovering useful material from sealed deep storage areas makes other methods preferable. Specifically, high radioactivity and heat (80 °C in surrounding rock) greatly increase the difficulty of mining a storage area, and the enrichment methods required have high capital costs.

Pu-239 decays to U-235 which is appropriate for weapons and which has a very long half-life (roughly 109 years). Accordingly plutonium may decay and leave uranium-235. Besides, modern reactors are only moderately ameliorated with U-235 relative to U-238, so the U-238 continues to serve as a denaturation agent for any U-235 produced by plutonium decay.

One solution to this problem is to recycle the plutonium and use it as a fuel e.g. in fast reactors. In hydrometallurgical fast reactors, the separated plutonium and uranium are contaminated by actinides and are unable to be used for nuclear weapons.

7.5. Types of Radioactive waste

Radioactive waste includes any material that is either intrinsically radioactive, or has been contaminated by radioactivity, and that is deemed to have no further use. Government policy dictates whether certain materials such as used nuclear fuel and plutonium are categorized as waste.Every radionuclide has a half-life: the time taken for half of its atoms to decay, and thus for it to lose half of its radioactivity. Radionuclides with long half-lives tend to be alpha and beta emitters making their handling easier while those with short half-lives tend to emit the more penetrating gamma rays. Eventually all radioactive waste decays into non-radioactive elements. The more radioactive an isotope is, the faster it decays. Radioactive waste is typically classified as either low-level (LLW), intermediate-level (ILW), or high-level (HLW), dependent, primarily, on its level of radioactivity.

i. Low-level Waste:

Low-level Waste (LLW) has a radioactivecontent not exceeding four gigabecquerels per tonne (GBq/t) of alpha activity or 12 GBq/t beta-gamma activity. LLW does not require shielding during handling and transport, and is suitable for disposal in near surface facilities.LLW is generated from hospitals and industry, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters, etc., which contain small amounts of mostly short-lived radioactivity. To reduce its volume, LLW is often compacted or incinerated before disposal. LLW comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste.

ii. Intermediate-level waste:

Intermediate-level waste (ILW) is more radioactive than LLW, but the heat it generates (<2 kW/m3) is not sufficient to be taken into account in the design or selection of storage and disposal facilities. Due to its higher levels of radioactivity, ILW requires some shielding.ILW typically comprises resins, chemical sludges, and metal fuel cladding, as well as contaminated materials from reactor decommissioning. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. It makes up some 7% of the volume and has 4% of the radioactivity of all radioactive waste.

iii. High-level waste:

High-level waste (HLW) is sufficiently radioactive for its decay heat (>2kW/m3) to increase its temperature, and the temperature of its surroundings, significantly. As a result, HLW requires cooling and shielding.HLW arises from the 'burning' of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core. HLW accounts for just 3% of the volume, but 95% of the total radioactivity of produced waste. There are two distinct kinds of HLW:

- Used fuel that has been designated as waste.
- Separated waste from reprocessing of used fuel.

HLW has both long-lived and short-lived components, depending on the length of time it will take for the radioactivity of particular radionuclides to decrease to levels that are considered non-hazardous for people and the surrounding environment. If generally short-lived fission products can be separated from long-lived actinides, this distinction becomes important in management and disposal of HLW.HLW is the focus of significant attention regarding nuclear power, and is managed accordingly.

iv. Very low-level waste:

Exempt waste and very low-level waste (VLLW) contains radioactive materials at a level which is not considered harmful to people or the surrounding environment. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping, etc.) produced during rehabilitation or dismantling operations on nuclear industrial sites. Other industries, such as food processing, chemical, steel, etc., also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes (see also information page on Naturally-Occurring Radioactive Materials). The waste is therefore disposed of with domestic refuse, although countries such as France are currently developing specifically designed VLLW disposal facilities.

7.6. Effects of radioactive waste:

Radioactive waste can have a range of harmful effects on human health and the environment. The severity of these effects depends on the type and amount of radiation emitted, the duration of exposure, and the pathway of exposure. Here are some of the effects of radioactive waste in more detail:

Cancer: Exposure to ionizing radiation, such as that emitted by radioactive waste, can increase the risk of cancer. Radiation can damage DNA and other cellular components, leading to mutations that can trigger the development of cancerous cells.

Genetic Damage: Exposure to high levels of radiation can damage DNA in reproductive cells, leading to mutations that can be passed on to future generations. This can increase the risk of birth defects and genetic disorders.

Radiation Sickness: High levels of exposure to ionizing radiation can cause radiation sickness, which includes symptoms such as nausea, vomiting, diarrhea, and skin burns. In severe cases, radiation sickness can be fatal.

Environmental Damage: Radioactive waste can contaminate soil, water, and air, leading to environmental damage. It can harm plants and animals, disrupt ecosystems, and damage the food chain.

Long-Term Health Effects: Some types of radioactive waste can remain radioactive for thousands of years, which means they can continue to pose a risk to human health and the environment for a long time. This can create a long-term burden on future generations.

Economic Costs: Managing and disposing of radioactive waste can be expensive, which can have economic impacts on communities and governments. In addition, the risk of radioactive contamination can have negative impacts on property values and economic development.

In summary, radioactive waste can have a range of harmful effects on human health and the environment. It's essential to manage and dispose of radioactive waste safely to minimize these risks. Proper disposal methods include storing the waste in secure facilities, transporting it in specialized containers, and burying it in geologically stable formations

7.11. Radioactive waste management

Nuclear waste requires sophisticated treatment and management to successfully isolate it from interacting with the biosphere. This usually necessitates treatment, followed by a long-term management strategy involving storage, disposal or transformation of the waste into a non-toxic form. Governments around the world are considering a range of waste management and disposal options, though there has been limited progress toward long-term waste management solutions.

In the second half of the 20th century, several methods of disposal of radioactive waste were investigated by nuclear nations, which are :

- "Long-term above-ground storage", not implemented.
- "Disposal in outer space" (for instance, inside the Sun), not implemented as it would be currently too expensive.
- "Deep borehole disposal", not implemented.
- "Rock melting", not implemented.
- "Disposal at subduction zones", not implemented.
- Ocean disposal, by the USSR, the United Kingdom,Switzerland, the United States, Belgium, France, the Netherlands, Japan, Sweden, Russia, Germany, Italy and South Korea (1954–93). This is no longer permitted by international agreements.
- "Sub-seabed disposal", not implemented, not permitted by international agreements.
- "Disposal in ice sheets", rejected in Antarctic Treaty
- "Deep well injection", by the USSR and USA.
- Nuclear transmutation, using lasers to cause beta decay to convert the unstable atoms to those with shorter half-lives.

In the United States, waste management policy completely broke down with the ending of work on the incomplete Yucca Mountain Repository. At present there are 70 nuclear power plant sites where spent fuel is stored. A Blue Ribbon Commission was appointed by President Obama to look into future options for this and future waste.

7.12. Disposal and treatment of radioactive waste

Initial treatment

Verification

Long-term storage of radioactive waste requires the stabilization of the waste into a form that will neither react nor degrade for extended periods. It is theorized that one way to do this might be through verification. Currently at Sell afield the high-level waste (PUREX first cycle caffeinate) is mixed with sugar and then calcined. Calcination involves passing the waste through a heated, rotating tube. The purposes of calcination are to evaporate the water from the waste and de-nitrate the fission products to assist the stability of the glass produced.

The 'calcine' generated is fed continuously into an induction heated furnace with fragmented glass.The resulting glass is a new substance in which the waste products are bonded into the glass matrix when it solidifies. As a melt, this product is poured into stainless steel cylindrical containers ("cylinders") in a batch process. When cooled, the fluid solidifies ("vitrifies") into the glass. After being formed, the glass is highly resistant to water.

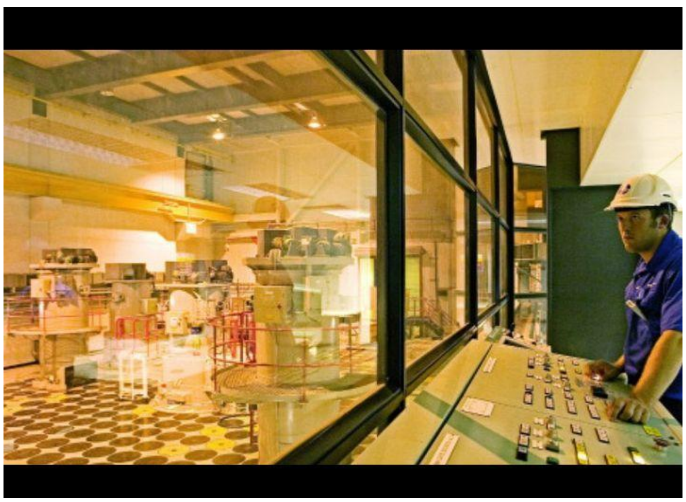

Figure: The Waste Verification Plant at Sell afield

After filling a cylinder, a seal is welded onto the cylinder head. The cylinder is then washed. After being inspected for external contamination, the steel cylinder is stored, usually in an underground repository. In this form, the waste products are expected to be immobilized for thousands of years.

The glass inside a cylinder is usually a black glossy substance. All this work (in the United Kingdom) is done using hot cell systems. Sugar is added to control the ruthenium chemistry and to stop the formation of the volatile RuO4 containing radioactive ruthenium isotopes. In the West, the glass is normally a borosilicate glass (similar to Pyrex), while in the former Soviet Union it is normal to use a phosphate glass. The amount of fission products in the glass must be limited because some (palladium, the other Pt group metals, and tellurium) tend to form metallic phases which separate from the glass. Bulk vitrification uses electrodes to melt soil and wastes, which are then buried underground. In Germany a vitrification plant is in use; this is treating the waste from a small demonstration reprocessing plant which has since been closed down.

Phosphate Ceramics

Vitrification is not the only way to stabilize the waste into a form that will not react or degrade for extended periods. Immobilization via direct incorporation into a phosphate-based crystalline ceramic host is also used. The diverse chemistry of phosphate ceramics under various conditions demonstrates a versatile material that can withstand chemical, thermal, and radioactive degradation over time. The properties of phosphates, particularly ceramic phosphates, of stability over a wide pH range, low porosity, and minimization of secondary waste introduces possibilities for new waste immobilization techniques.

Ion exchange

It is common for medium active wastes in the nuclear industry to be treated with ion exchange or other means to concentrate the radioactivity into a small volume. The much less radioactive bulk (after treatment) is often then discharged. For instance, it is possible to use a ferric hydroxide floc to remove radioactive metals from aqueous mixtures. After the radioisotopes are absorbed onto the ferric hydroxide, the resulting sludge can be placed in a metal drum before being mixed with cement to form a solid waste form. In order to get better long-term performance (mechanical stability) from such forms, they may be made from a mixture of fly ash, or blast furnace slag, and Portland cement, instead of normal concrete (made with Portland cement, gravel and sand).

Synroc

The Australian Synroc (synthetic rock) is a more sophisticated way to immobilize such waste, and this process may eventually come into commercial use for civil wastes (it is currently being developed for U.S. military wastes). Synroc was invented by Prof Ted Ringwood (a geochemist) at the Australian National University. The Synroc contains pyrochlore and cryptomelane type minerals. The original form of Synroc (Synroc C) was designed for the liquid high-level waste (PUREX raffinate) from a light-water reactor. The main minerals in this Synroc are hollandite ($BaAl_2Ti_6O_{16}$), zirconolite ($CaZrTi_2O_7$) and perovskite ($CaTiO_3$). The zirconolite and perovskite are hosts for the actinides. The strontium and barium will be fixed in the perovskite. The caesium will be fixed in the hollandite. A Synroc waste treatment facility began construction in 2018 at ANSTO

Long-term management

The time frame in question when dealing with radioactive waste ranges from 10,000 to 1,000,000 years, according to studies based on the effect of estimated radiation doses.Researchers suggest that forecasts of health detriment for such periods should be examined critically. Practical studies only consider up to 100 years as far as effective planning and cost evaluations are concerned. Long term behavior of radioactive wastes remains a subject for ongoing research projects in geo forecasting.

Remediation

Algae has shown differentiation for strontium in studies, where most plants used in bioremediation have not shown selectivity between calcium and strontium, often becoming saturated with calcium, which is present in greater quantities in nuclear waste. Strontium-90 with a half life around 30 years, is classified as high-level waste.

Researchers have peeted at the bioaccumulation of strontium by Scenedesmusspinosus (algae) in simulated wastewater. The study claims a highly selective biosorption capacity for strontium of S. spinosus, suggesting that it may be appropriate for use of nuclear wastewater. A study of the pond alga Closteriummoniliferum using non-radioactive strontium found that varying the ratio of barium to strontium in water improved strontium selectivity.

Above-ground disposal

Dry cask storage typically involves taking waste from a spent fuel pool and sealing it (along with an inert gas) in a steel cylinder, which is placed in a concrete cylinder which acts as a radiation shield. It is a relatively affordable method which can be done at a central facility or adjacent to the source reactor. The waste can be easily retrieved for reprocessing.

Geologic disposal.

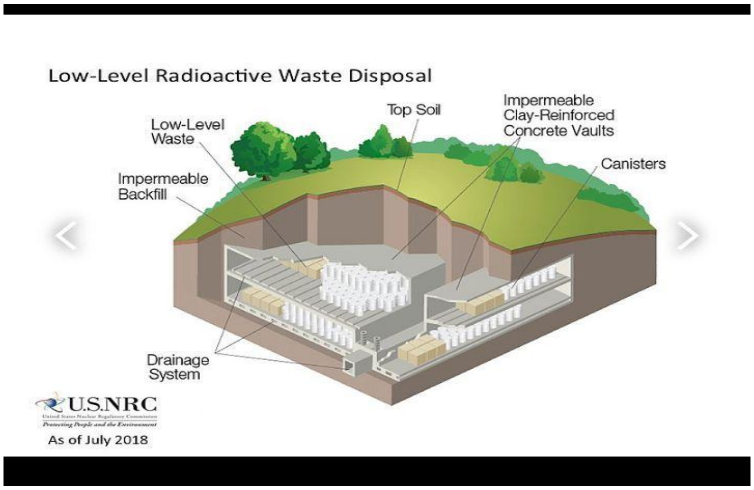

Diagram of an underground low-level radioactive waste disposal site

On Feb. 14, 2014, radioactive materials at the Waste Isolation Pilot Plant leaked from a damaged storage drum due to the use of incorrect packing material. Analysis showed the lack of a "safety culture" at the plant since its successful operation for 15 years had bred complacency.

The process of selecting appropriate deep final repositories for high-level waste and spent fuel is now underway in several countries with the first expected to be commissioned sometime after 2010. The basic concept is to locate a large, stable geologic formation and use mining technology to excavate a tunnel, or large-bore tunnel boring machines (similar to those used to drill the Channel Tunnel from England to France) to drill a shaft 500 meters (1,600 ft) to 1,000 meters (3,300 ft) below the surface where rooms or vaults can be excavated for disposal of high-level radioactive waste. The goal is to permanently isolate nuclear waste from the human environment. Many people remain uncomfortable with the immediate stewardship cessation of this disposal system, suggesting perpetual management and monitoring would be more prudent.

Because some radioactive species have half-lives longer than one million years, even very low container leakage and radionuclide migration rates must be taken into account.Moreover, it may require more than one half-life until some nuclear materials lose enough radioactivity to cease being lethal to living things. A 1983 review of the Swedish radioactive waste disposal program by the National Academy of Sciences found that the country's estimate of several hundred thousand years, perhaps up to one million years, being necessary for waste isolation was "fully justified."

Ocean floor disposal of radioactive waste has been suggested by the finding that deep waters in the North Atlantic Ocean do not present an exchange with shallow waters for about 140 years based on oxygen content data recorded over a period of 25 years. They include burial beneath a stable abyssal plain, burial in a subduction zone that would slowly carry the waste downward into the Earth's mantle, and burial beneath a remote natural or human-made island. While these approaches all have merit and would facilitate an international solution to the problem of disposal of radioactive waste, they would require an amendment of the Law of the Sea.

Article 1 (Definitions), 7., of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, (the London Dumping Convention) states:

""Sea" means all marine waters other than the internal waters of States, as well as the seabed and the subsoil thereof; it does not include sub-seabed repositories accessed only from land."

The proposed land-based subductive waste disposal method disposes of nuclear waste in a subduction zone accessed from land and therefore is not prohibited by international agreement. This method has been described as the most viable means of disposing of radioactive waste,and as the state-of-the-art as of 2001 in nuclear waste disposal technology. Another approach termed Remix & Return would blend high-level waste with uranium mine and mill tailings down to the level of the original radioactivity of the uranium ore, then replace it in inactive uranium mines. This approach has the merits of providing jobs for miners who would double as disposal staff, and of facilitating a cradle-to-grave cycle for radioactive materials, but would be inappropriate for spent reactor fuel in the absence of reprocessing, due to the presence of highly toxic radioactive elements such as plutonium within it.

Deep borehole disposal is the concept of disposing of high-level radioactive waste from nuclear reactors in extremely deep boreholes. Deep borehole disposal seeks to place the waste as much as 5 kilometers (3.1 mi) beneath the surface of the Earth and relies primarily on the immense natural geological barrier to confine the waste safely and permanently so that it should never pose a threat to the environment. The Earth's crust contains 120 trillion tons of thorium and 40 trillion tons of uranium (primarily at relatively trace concentrations of parts per million each adding up over the crust's 3 × 1019 ton mass), among other natural radioisotopes. Since the fraction of nuclides decaying per unit of time is inversely proportional to an isotope's half-life, the relative radioactivity of the lesser amount of human-produced radioisotopes (thousands of tons instead of trillions of tons) would diminish once the isotopes with far shorter half-lives than the bulk of natural radioisotopes decayed.

In January 2013, Cumbria county council rejected UK central government proposals to start work on an underground storage dump for nuclear waste near to the Lake District National Park. "For any host community, there will be a substantial community benefits package and worth hundreds of millions of pounds" said Ed Davey, Energy Secretary, but nonetheless, the local elected body voted 7–3 against research continuing, after hearing evidence from independent geologists that "the fractured strata of the county was impossible to entrust with such dangerous material and a hazard lasting millennia."

Horizontal drill hole disposal describes proposals to drill over one km vertically, and two km horizontally in the earth’s crust, for the purpose of disposing of high-level waste forms such as spent nuclear fuel, Caesium-137, or Strontium-90. After the emplacement and the retrievability period,[clarification needed] drill holes would be backfilled and sealed. A series of tests of the technology were carried out in November 2018 and then again publicly in January 2019 by a U.S. based private company.[104] The test demonstrated the emplacement of a test-canister in a horizontal drill hole and retrieval of the same canister. There was no actual high-level waste used in this test.

Transmutation

Main article: Nuclear transmutation

There have been proposals for reactors that consume nuclear waste and transmute it to other, less-harmful or shorter-lived, nuclear waste. In particular, the integral fast reactor was a proposed nuclear reactor with a nuclear fuel cycle that produced no transuranic waste and, in fact, could consume transuranic waste. It proceeded as far as large-scale tests but was eventually canceled by the U.S. Government. Another approach, considered safer but requiring more development, is to dedicate subcritical reactors to the transmutation of the left-over transuranic elements.

An isotope that is found in nuclear waste and that represents a concern in terms of proliferation is Pu-239. The large stock of plutonium is a result of its production inside uranium-fueled reactors and of the reprocessing of weapons-grade plutonium during the weapons program. An option for getting rid of this plutonium is to use it as a fuel in a traditional light-water reactor (LWR). Several fuel types with differing plutonium destruction efficiencies are under study.

Transmutation was banned in the United States in April 1977 by President Carter due to the danger of plutonium proliferation,[108] but President Reagan rescinded the ban in 1981. Due to economic losses and risks, the construction of reprocessing plants during this time did not resume. Due to high energy demand, work on the method has continued in the EU. This has resulted in a practical nuclear research reactor called Myrrha in which transmutation is possible. Additionally, a new research program called ACTINET has been started in the EU to make transmutation possible on a large, industrial scale. According to President Bush's Global Nuclear Energy Partnership

(GNEP) of 2007, the United States is actively promoting research on transmutation technologies needed to markedly reduce the problem of nuclear waste treatment.

There have also been theoretical studies involving the use of fusion reactors as so-called "actinide burners" where a fusion reactor plasma such as in a tokamak, could be "doped" with a small amount of the "minor" transuranic atoms which would be transmuted (meaning fissioned in the actinide case) to lighter elements upon their successive bombardment by the very high energy neutrons produced by the fusion of deuterium and tritium in the reactor. A study at MIT found that only 2 or 3 fusion reactors with parameters similar to that of the International Thermonuclear Experimental Reactor (ITER) could transmute the entire annual minor actinide production from all of the light-water reactors presently operating in the United States fleet while simultaneously generating approximately 1 gigawatt of power from each reactor.

Re-use

Main article: Nuclear reprocessing

Spent nuclear fuel contains abundant fertile uranium and traces of fissile materials. Methods such as the PUREX process can be used to remove useful actinides for the production of active nuclear fuel.

Another option is to find applications for the isotopes in nuclear waste so as to re-use them. Already, caesium-137, strontium-90 and a few other isotopes are extracted for certain industrial applications such as food irradiation and radioisotope thermoelectric generators. While re-use does not eliminate the need to manage radioisotopes, it can reduce the quantity of waste produced.

The Nuclear Assisted Hydrocarbon Production Method,Canadian patent application 2,659,302, is a method for the temporary or permanent storage of nuclear waste materials comprising the placing of waste materials into one or more repositories or boreholes constructed into an unconventional oil formation. The thermal flux of the waste materials fractures the formation and alters the chemical and/or physical properties of hydrocarbon material within the subterranean formation to allow removal of the altered material. A mixture of hydrocarbons, hydrogen, and/or other formation fluids is produced from the formation. The radioactivity of high-level radioactive waste affords proliferation resistance to plutonium placed in the periphery of the repository or the deepest portion of a borehole.

Breeder reactors can run on U-238 and transuranic elements, which comprise the majority of spent fuel radioactivity in the 1,000–100,000-year time span.

Space disposal

Space disposal is attractive because it removes nuclear waste from the planet. It has significant disadvantages, such as the potential for catastrophic failure of a launch vehicle, which could spread radioactive material into the atmosphere and around the world. A high number of launches would be required because no individual rocket would be able to carry very much of the material relative to the total amount that needs to be disposed of. This makes the proposal impractical economically and increases the risk of one or more launch failures. To further complicate matters, international agreements on the regulation of such a program would need to be established. Costs and imperfect reliability of modern rocket launch systems for space disposal has been one of the motives for interest in non-rocket space launch systems such as mass drivers, space elevators, and other proposals.

7.13. National management plans of radioactive waste

Anti-nuclear protest near nuclear waste disposal centre at Gorleben in northern Germany.Sweden and Finland are furthest along in committing to a particular disposal technology, while many others reprocess spent fuel or contract with France or Great Britain to do it, taking back the resulting plutonium and high-level waste. "An increasing backlog of plutonium from reprocessing is developing in many countries... It is doubtful that reprocessing makes economic sense in the present environment of cheap uranium.

In many European countries (e.g., Britain, Finland, the Netherlands, Sweden, and Switzerland) the risk or dose limit for a member of the public exposed to radiation from a future high-level nuclear waste facility is considerably more stringent than that suggested by the International Commission on Radiation Protection or proposed in the United States. European limits are often more stringent than the standard suggested in 1990 by the International Commission on Radiation Protection by a factor of 20, and more stringent by a factor of ten than the standard proposed by the U.S. Environmental Protection Agency (EPA) for Yucca Mountain nuclear waste repository for the first 10,000 years after closure.

The U.S. EPA's proposed standard for greater than 10,000 years is 250 times more permissive than the European limit.The U.S. EPA proposed a legal limit of a maximum of 3.5 millisieverts (350 millirem) each annually to local individuals after 10,000 years, which would be up to several percent of[vague] the exposure currently received by some populations in the highest natural background regions on Earth though the U.S. United States Department of Energy (DOE) predicted that received dose would be much below that limit. Over a timeframe of thousands of years, after the most active short half-life radioisotopes decayed, burying U.S. nuclear waste would increase the radioactivity in the top 2000 feet of rock and soil in the United States (10 million km2) by approximately 1 part in 10 million over the cumulatively amount of natural radioisotopes in such a volume, but the vicinity of the site would have a far higher concentration of artificial radioisotopes underground than such an average.

Mongolia

After serious opposition about plans and negotiations between Mongolia with Japan and the United States of America to build nuclear-waste facilities in Mongolia, Mongolia stopped all negotiations in September 2011. These negotiations had started after U.S. Deputy Secretary of Energy Daniel Poneman visited Mongolia in September 2010. Talks took place in Washington, D.C. between officials of Japan, the United States, and Mongolia in February 2011. After this the United Arab Emirates (UAE), which wanted to buy nuclear fuel from Mongolia, joined in the negotiations. The talks were kept secret and, although the Mainichi Daily News reported on them in May, Mongolia officially denied the existence of these negotiations. However, alarmed by this news, Mongolian citizens protested against the plans and demanded the government withdraw the plans and disclose information. The Mongolian President TsakhiagiinElbegdorj issued a presidential order on September 13 banning all negotiations with foreign governments or international organizations on nuclear-waste storage plans in Mongolia. The Mongolian government has accused the newspaper of distributing false claims around the world. After the presidential order, the Mongolian president fired the individual who was supposedly involved in these conversations.

Illegal dumping

Toxic waste dumping by the 'Ndrangheta

Authorities in Italy are investigating a 'Ndrangheta mafia clan accused of trafficking and illegally dumping nuclear waste. According to a whistleblower, a manager of Italy's state energy research agency Enea paid the clan to get rid of 600 drums of toxic and radioactive waste from Italy, Switzerland, France, Germany, and the United States, with Somalia as the destination, where the waste was buried after buying off local politicians. Former employees of Enea are suspected of paying the criminals to take waste off their hands in the 1980s and 1990s. Shipments to Somalia continued into the 1990s, while the 'Ndrangheta clan also blew up shiploads of waste, including radioactive hospital waste, sending them to the sea bed off the Calabrian coast. According to the environmental group Legambiente, former members of the 'Ndrangheta have said that they were paid to sink ships with radioactive material for the last 20 years.

7.14. Storage and Disposal of Radioactive Waste:

- Radioactive wastes are stored so as to avoid any chance of radiation exposure to people, or any pollution.
- The radioactivity of the wastes decays with time, providing a strong incentive to store high-level waste for about 50 years before disposal.
- Disposal of low-level waste is straightforward and can be undertaken safely almost anywhere.
- Storage of used fuel is normally under water for at least five years and then often in dry storage.
- Deep geological disposal is widely agreed to be the best solution for final disposal of the most radioactive waste produced.

Most low-level radioactive waste (LLW) is typically sent to land-based disposal immediately following its packaging for long-term management. This means that for the majority (~90% by volume) of all of the waste types produced by nuclear technologies, a satisfactory disposal means has been developed and is being implemented around the world.

For used fuel designated as high-level radioactive waste (HLW), the first step is storage to allow decay of radioactivity and heat, making handling much safer. Storage of used fuel may be in ponds or dry casks, either at reactor sites or centrally. Beyond storage, many options have been investigated which seek to provide publicly acceptable, safe, and environmentally sound solutions to the final management of radioactive waste. The most widely favoured solution is deep geological disposal. The focus is on how and where to construct such facilities.

Used fuel that is not intended for direct disposal may instead be reprocessed in order to recycle the uranium and plutonium it contains. Some separated liquid HLW arises during reprocessing; this is vitrified in glass and stored pending final disposal.

Intermediate-level radioactive waste (ILW) that contains long-lived radioisotopes is also stored pending disposal in a geological repository. In the USA, defence-related transuranic (TRU) waste – which has similar levels of radioactivity to some ILW – is disposed of in the Waste Isolation Pilot Plant (WIPP) deep geological repository in New Mexico. A number of countries dispose of ILW containing short-lived radioisotopes in near-surface disposal facilities, as used for LLW disposal.

Some countries are at the preliminary stages of their consideration of disposal for ILW and HLW, whilst others, such as Finland and Sweden, have made good progress. Finland's Onkalo repository is expected to start operating in 2023. It will be the first deep geological repository licensed for the disposal of used fuel from civil reactors.

The following table sets out the commonly accepted disposal options. When considering these, it should be noted that the suitability of an option or idea is dependent on the wasteform, volume, and radioactivity of the waste. As such, waste management options and ideas described in this section are not all applicable to different types of waste.

Commonly-accepted disposal options

Option	Suitable waste Type	Example
Near-surface disposal at ground level, or in caverns below ground level (at depths of tens of meters)	LLW and short-lived ILW	Implemented for LLW in many countries, including Czech Republic, Finland, France, Japan, Netherlands, Spain, Sweden, UK, and USA. Implemented in Finland and Sweden for LLW and short-lived ILW.
Deep geological disposal (at depths between 250m and 1000m for mined repositories, or 2000m to 5000m for boreholes)	Long-lived ILW and HLW (including used fuel)	Most countries have investigated deep geological disposal and it is the official policy in several countries. Implemented in the USA for defense-related transuranic waste at WIPP. Preferred sites selected in France, Sweden, and the USAa. Facility under construction and due to begin operations in 2023 in Finland. Geological repository site selection process commenced in the UK and Canada.

The world has over half a century's knowledge and experience on how to deal with nuclear waste. Good practices developed over the years are being used throughout the whole cycle of electricity production to help ensure the safety of people and the environment from possible effects of harmful radiation. The characteristics of nuclear waste are well known; a prerequisite for safe and secure disposal. The appropriate disposal option and the extent of safety measures depend on the length of time the waste remains hazardous – some waste remains radioactive for hundreds of thousands of years and other waste for tens of years or less.

Disposal of low and intermediate level radioactive wastes is already implemented in several countries. Usually these facilities are at, or near, the surface, but some intermediate level waste that contains long lived radioactivity requires disposal at greater depths, of the order of tens of meters to a few hundred meters.

High level radioactive waste is presently temporarily stored in storage facilities. Several options are being examined and research for implementing disposal is being conducted in many countries with nuclear power. In every option, deep geological disposal is the preferred final end point. The principle of geological disposal is to isolate the waste deep inside a suitable host formation, e.g. granite, salt or clay. The waste is placed in an underground facility or disposal facility, designed to ensure that a system of natural and multiple artificial barriers work together to prevent radioactivity from escaping.

In the nuclear energy sector, good waste management, resulting in safe disposal, also considers financial implications. The objective is to have enough funds to execute activities (waste disposal, decommissioning, human resources, etc.) required once electricity production of a facility has ceased. There are mechanisms for collecting money to cover all nuclear power production expenses. In terms of good practices of radioactive waste management, responsibility covers all the steps from ‘cradle to grave’, i.e. from uranium mining up to the disposal of the waste.

Accidents:

A few incidents have occurred when radioactive material was disposed of improperly, shielding during transport was defective, or when it was simply abandoned or even stolen from a waste store. In the Soviet Union, waste stored in Lake Karachay was blown over the area during a dust storm after the lake had partly dried out. At Maxey Flat, a low-level radioactive waste facility located in Kentucky, containment trenches covered with dirt, instead of steel or cement, collapsed under heavy rainfall into the trenches and filled with water. The water that invaded the trenches became radioactive and had to be disposed of at the Maxey Flat facility itself. In other cases of radioactive waste accidents, lakes or ponds with radioactive waste accidentally overflowed into the rivers during exceptional storms. In Italy, several radioactive waste deposits let material flow into river water, thus contaminating water for domestic use. In France in the summer of 2008, numerous incidents happened:in one, at the Areva plant in Tricastin, it was reported that, during a draining operation, liquid containing untreated uranium overflowed out of a faulty tank and about 75 kg of the radioactive material seeped into the ground and, from there, into two rivers nearby;in another case, over 100 staff were contaminated with low doses of radiation. There are ongoing concerns around the deterioration of the nuclear waste site on the Enewetak Atoll of the Marshall Islands and a potential radioactive spill.

Scavenging of abandoned radioactive material has been the cause of several other cases of radiation exposure, mostly in developing nations, which may have less regulation of dangerous substances (and sometimes less general education about radioactivity and its hazards) and a market for scavenged goods and scrap metal. The scavengers and those who buy the material are almost always unaware that the material is radioactive and it is selected for its aesthetics or scrap value.Irresponsibility on the part of the radioactive material's owners, usually a hospital, university, or military, and the absence of regulation concerning radioactive waste, or a lack of enforcement of such regulations, have been significant factors in radiation exposures. For an example of an accident involving radioactive scrap originating from a hospital see the Goiânia accident.

Transportation accidents involving spent nuclear fuel from power plants are unlikely to have serious consequences due to the strength of the spent nuclear fuel shipping casks.

On 15 December 2011, top government spokesman Osamu Fujimura of the Japanese government admitted that nuclear substances were found in the waste of Japanese nuclear facilities. Although Japan did commit itself in 1977 to these inspections in the safeguard agreement with the IAEA, the reports were kept secret for the inspectors of the International Atomic Energy Agency. Japan did start discussions with the IAEA about the large quantities of enriched uranium and plutonium that were discovered in nuclear waste cleared away by Japanese nuclear operators. At the press conference Fujimura said: "Based on investigations so far, most nuclear substances have been properly managed as waste, and from that perspective, there is no problem in safety management," But according to him, the matter was at that moment still being investigated.

Associated hazard warning signs:

The trefoil symbol used to indicate ionizing radiation.

2007 ISO radioactivity danger symbol intended for IAEA Category 1, 2 and 3 sources defined as dangerous sources capable of death or serious injury.

The dangerous goods transport classification sign for radioactive materials.

7.15. National Frameworks Set the Boundaries for Safe Operation:

In principle, the operators of the facilities which generate radioactive waste have prime responsibility for the safe management of the radioactive waste that they produce. Each operator has to ensure safety throughout the whole life cycle of the production chain: siting, design, construction, commissioning, operation, decommissioning, close-out or closure of its facilities, including remediation of any contaminated areas; and for activities in which radioactive material is used, transported or handled.However, the safety of nuclear facilities and sources of harmful radiation, radiation protection, the safe management of radioactive waste and the safe transport of radioactive material are of great importance to individuals, society and the environment. Therefore, each operator needs to demonstrate to the satisfaction of the national regulator that its responsibility has been, and will continue to be, fulfilled.

The sole purpose of the regulator is to protect the health and safety of people. The regulator carries out its function within the national legal framework, and the regulatory process continues throughout the life cycle of the facility or for the duration of an activity that produces radioactive waste. The day to day activities of a national regulator are related to authorization, review, assessment, inspection and enforcement.

The safety of facilities and activities is also of international concern.

Several international conventions are in force, where various aspects of safety related information are exchanged to fulfil safety obligations and to promote cooperation.**Addressing Safety Matters on a Global Scale**:

Among the many international organizations, the IAEA is the global focal point for nuclear cooperation. It is an independent, intergovernmental, science and technology based organization that works with its over 150 Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies. The mission of the IAEA is to:

• Assist its Member States, in the context of social and economic goals, in planning for and using nuclear science and technology for various peaceful purposes, including the generation of electricity, and facilitate the transfer of such technology and knowledge in a sustainable manner to developing Member States;

• Develop nuclear safety standards and, based on these standards, promote the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation;

• Verify, through its inspection system, that Member States comply with their commitments, under the Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.The only legal instrument to address the safety of spent fuel and radioactive waste management on a global scale is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.The Contracting Parties of the Joint Convention are committed to apply the Joint Convention's safety measures, and to demonstrate this, they prepare a National Report on the applied measures and submit this report for peer review by other Contracting Parties. The Review Meetings of the National Reports for the Joint Convention are held every three years and are organized by its Secretariat, the IAEA.The Joint Convention contributes to enhancing the safety of radioactive waste and spent fuel management in many ways, for example, by:

- Fostering an international approach to these areas and sharing expertise;
- Assuring the public that national arrangements for spent fuel and radioactive waste management conform to safety measures agreed internationally;and
- Highlighting the opportunities to receive assistance, in the case of a country having limited resources, to improve its infrastructure.

The Joint Convention is open for accession, not only to those States with nuclear power programmes, but also to those using radiation sources in medicine and industry.

The Things to Know about Radioactive Waste Generation

- All electricity generation forms produce waste. The most important waste from a nuclear power plant is radioactive nuclear waste.
- Radioactive waste is also produced by military activities and beneficial practices medicine, research and industry.
- The world has over half a century's experience in managing radioactive waste – the characteristics of the waste are well known and therefore it can be safely managed.
- The main objective of waste management is to protect people and the environment, now and in the future.
- As a term, nuclear waste management refers to practices and techniques used for all activities (administrative and operational) involving the handling, pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

- Only trained personnel are allowed to manage radioactive waste.
- There are over 440 nuclear power plant units in the world today producing three types of waste that are roughly categorized as low, intermediate and high level wastes.
- The criteria defining these three main types of waste are derived from the waste's radioactive content and half-life, i.e. the time taken to lose half of the radioactivity.
- The disposal of low and intermediate level wastes is well established in several countries.
- Long term safety determines the measures needed to protect people and the environment.
- A number of countries have made good progress towards implementing geological disposal of spent fuel, in particular Finland, France and Sweden.
- The mechanisms for collecting money in advance to cover waste management costs exist and have beensuccessfully implemented.

7.16. Plastic Waste Generation in India:

According to the reports for year 2017-18, Central Pollution Control Board (CPCB) has estimated that India generates approximately 9.4 Million tonnes per annum plastic waste, (which amounts to 26,000tones of waste per day), and out of this approximately 5.6 Million tones per annum plastic waste is recycled (i.e. 15,600 tonnes of waste per day) and 3.8 Million tonnes per annum plastic waste is left uncollected or littered (9,400 tones of waste per day). Out of the 60% of recycled plastic/

- 70% is recycled at registered facilities
- 20% is recycled by Unorganized Sector
- 10% of the plastic is recycled at home.

While these stats are 38% higher than the global average of 20%, there are no comprehensive methods in place for plastic waste management. Additionally, There is a constant increase in plastic 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.

Figure: Plastic waste recycled in India

Figure: Top 5 Plastic Waste producing States of India

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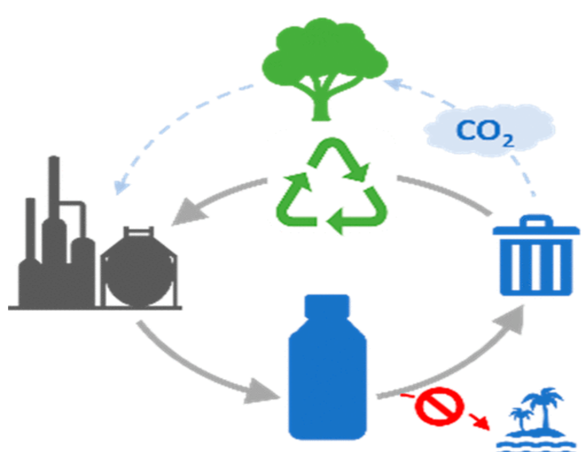
7.17. Plastic waste-source

Plastics are primarily made up of different kinds of material such as binders, plasticizers, pigments, llers, and other constituents. The binder provides the basic property of binding to plastic. They can be natural and artificial like cellulose derivatives and milk protein but most likely they are synthetic ones.



Plastic products have become an integral part of our daily life as a result of which the polymer is produced at a massive scale worldwide. 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.

It is estimated that approximately 70% of plastic packaging products are converted into plastic waste in a short span. Approximately 9.4 million TPA plastic waste is generated in the country, which amounts to 26,000 TPD2 .Of this, about 60% is recycled, most of it by the informal sector. While the recycling rate in India is considerably higher than the global average of 20%3, there is still over 9,400 tonnes of plastic waste which is either landfilled or ends up polluting streams or groundwater resources. While some kinds of plastic do not decompose at all, others could take up to 450 years to break down. The figure captures per capita plastic consumption in FY 2014-15. Plastics are not inherently bad, and they have many redeeming ecological features. Many of the techniques we utilize in our designs involve targeted use of plastic products. Their durability and low maintenance reduce material replacement; their light weight reduces shipping energy, their formulation into glue products allows for the creation of engineered lumber and sheet products from recycled wood, and their formulation into superior insulation and sealant products improves the energy performance of our structures.

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 remains 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. The recycling of a virgin plastic material can be done 2-3 times only, because after every recycling, the plastic material deteriorates due to thermal pressure and its life span is reduced. Hence recycling is not a safe and permanent solution for plastic waste disposal. It has been observed that disposal of plastic waste is a serious concern due to improper collection and segregation.Only 60% of the plastic produced is recycled, and 9400 Tonnes of plastic is left unattended in the environment causing land, air and water pollution.70% of Plastics packaging products are converted into plastic waste in a short span.

7.18. 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:

a) Polyethylene Terephthalate (PETE or PET)
b) High-Density Polyethylene (HDPE
c) Polyvinyl Chloride (PVC)
d) Low-Density Polyethylene (LDPE)
e) Polypropylene (PP)
f) Polystyrene or Styrofoam (PS)
g) Miscellaneous plastics (includes: polycarbonate,polylactide,acrylic,acrylonitrile butadiene, styrene, fiberglass, and nylon)

Plastics are generally categorized into two types

- **Thermoplastics:**Thermoplastics have properties of melting, molding and can be reheated and reshaped again which can be recycled easily while thermosets don't have such property due to their different kinds of chemical bonds and structural arrangements. Thermoplastics or Thermo-softening plastics are the plastics which soften on heating and can be molded into desired shape such as PET or PETE (polyethylene terephthalate). HDPE (high density polyethylene), LDPE(low density polyethylene), PP(polypropylene), PVC(polyvinyl -chloride), PS (polystyrene)etc.(Evode et al., 2021).

- **Thermosets**: Thermoset or thermosetting plastics strengthen on heating, but cannot be remolded or recycled such as Sheet Molding Compounds (SMC), Fiber Reinforced Plastic (FRP), Bakelite etc. are the examples of the same. Thermoset plastics pass through a series of physical and chemical transformations under specific conditions creating 3D linkage in bonding. This change is irreversible because, on heating, these arrangements.

  Nowadays, an alternative to petroleum-based plastic carry-bags/films has been introduced i.e. compostable plastics (100%bio-based)carry-bags/films conforming IS/ISO: 17088.The Plastic Waste Management (PWM) Rules 2016 also encourage the use of compostable carry-bags and products by exempting minimum thickness criteria of 50µm.Further, as per provision 4 (h) of PWM Rules, 2016, the manufacturers or sellers of compostable plastic carry bags shall obtain a certificate from the Central Pollution Control Board (CPCB) before marketing or selling their products. The manufacturers/sellers of compostable carry bags/products are required to apply to CPCB asper Standard Operating Procedure (SOP) available on CPCB's Website.

7.19. Plastic management strategies and disposal methods:

Plastic pollution is a serious concern around the world. It becomes an unavoidable part of our environment because of its usage from kitchen to industrial level. Overuse and improper disposal causing it to increase its generation at an exponential rate . In the current scenario, plastic waste management is the burning issue in front of scientists and researchers to manage it in a sustainable way. Number of methods such as biodegradation, incineration, recycling, construction of roads, landing generally employed to tackle the issue of safe disposal. Each and every method has its own pros and cons. In this chapter, each method is explained with its eciency and aws to combat the issue of plastic waste management.

Plastic carry bags are well popular with consumers and retailers as they are a cheap, hygienic, strong, lightweight alternative to carry out our food and other daily life products (MOHUA, 2019). These items after their usage go to landfills or can make garbage heaps, and some parts may be recycled. Once they are thrown in the open, they can make their way to our soil, streets, public places and into our drainage system and other water bodies. Plastic bags are the main part of plastic waste which create visual pollution problems and can affect aquatic and terrestrial animals. Plastic bags are particularly noticeable components of the lier and stream due to their size and can take a long time to fully break down. Plastic bags may be eaten by marine mammals and turtles that can be life threatening for them. In developed countries, billions of plastic bags are discarded every year, most of which are used only single time before their disposal. The main issue with plastic bags is that it takes about 500 years to decompose and remains as it is for a long duration. Most required hierarchy to manage plastic waste is shown in fig. 4. The top one (Reduce) strategy is the most preferable and last one (Landll) is least preferable choice to manage the plastic waste

Reduce

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Reuse

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Recycle

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Recovery

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Landfilling

Fig. 4: Strategic choice to manage the plastic waste

Reduce:

Plastic, because of its non-biodegradability, is highly problematic and therefore we have to skip plastic and use other non-plastic and biodegradable alternatives. Such initiatives at an individual level in daily life would help to keep the plastic from the waste stream. Some of these steps may include: Discourage the use of disposal plastics, minimizing the purchase of water bole, minimize the use of cutlery items, and prefer secondhand items and support tax and ban on plastic items.

Reuse:

Reuse is a reutilization of plastic items instead of discarding them. It stops the entry of new plastic items in the system and reduces the pressure on recycling facilities. The possible reusable items are plastic bags for vegetables, grocery, trash, and reusable plastic silverware and purchase of items that have the property of reutilization. Most people usuallyskip this step of reutilization and approach recycling directly but the fact is reutilization of plastics can reduce the demand for new plastics to be produced. For example, reliable plastic cans, rells and containers can 149 Plastic Waste Disposal Be reused for many times which reduces the substantial demand for new disposable plastic and decreases the use of materials and energy, which results in less utilization of resources and waste generation.

Recycle:

Recycling of plastics waste has a number of advantages. It reduces the demand of virgin materials and energy required to create new resources from nature, thus ultimately reducing carbon footprints. Only 10% of plastic waste is recycled all over the world . There are no. of benets of recycling plastic waste which includes reduction in environmental pollution due plastic waste, economic benefits, saves energy resources, decrease the demand for fresh and virgin polymer, reduces the load on landing, generates employment, save the fossil fuel reserves but recycling is also associated with some issues which includes diculty in separation of plastic from non-plastics (no 'magnet' equivalent), breakage in polymer chains on recycling, varied composition of plastic resins that make them incompatible for particular recycling, degradation of quality of recycled polymer than virgin polymer, low market value of thin plastic lm, identification of reuse and recycling opportunities, lacking in the infrastructure for recycling and low value of recovered plastics. In India, there is a lack and loopholes in the system so that waste is not segregated at sources. This is the crucial step in recycling of waste. Municipality infrastructure faces lack of facilities like mechanical recycling, plastic road construction, feedstock Recycling, plastic pavement blocks and recycling of multi-layered plastic. Mechanical recycling consists of the technology to segregate the waste by the techniques like air classier, air tabling, ballistic separator, dry and wet gravity separation, froth floatation, electrostatic precipitator and some other sensor based technologies such as plastic colour sorting, infrared radiation sorting etc. There is no ambiguity in the fact that recycling is an option for plastic waste management but due its expensive and advanced infrastructure, it becomes the main hurdle to do this task. Different types of plastic have different types of uses and can be recycled accordingly as shown in table 1. Table.

Table.1 plastic type with their used and possible recycled product.

1 PETE	PETE or PET	PET- Polyethylene Terephthalate used for many bottles application because they are inexpensive, lightweight, and shatter- resistant. (RECYCLED PRODUCTS: Mineral/ Drinking Water Bottles, Cosmetic Bottles)
2 HDPE	HDPE	HDPE- High Density Polyethylene used for in bottles, carry bags, milk pouches, recycle bins, etc. (RECYCLED PRODUCTS: Tubes, sewer pipes, pallets, boxes, buckets, toys, bottles for detergents, construction, cable insulation, packaging of food products etc.)
3 PVC	PVC	PVC- Polyvinyl Chloride used for pipes and fittings, Tarpaulins, Medical Apps., etc. (RECYCLED PRODUCTS: Sewer Pipes, Window frames, Construction, Flooring, Wallpaper, Bottles, Car Interiors, Medical products, Planks, etc.)
4 LDPE	LDPE	LDPE- Low Density Polyethylene used in Plastic bags, various containers, dispensing bottles, wash bottles, tubing, etc. (RECYCLED PRODUCTS: Flexible packaging, bin liners, carrier bags, tubes, agricultural mulch film, agricultural sheet, construction film, cling-film, heavy duty sacks, etc.)
5 PP	PP	PP- Polypropylene used in Auto parts, Industrial Fibers, Food containers, etc. (RECYCLED PRODUCTS: Pipes, pallets, boxes, furniture, car parts, pots of yoghurt, buckets, butter, margarine, fibers, milk crates, etc.)
6 PS	PS	PS- Polystyrene is used in food service packaging, disposable cups, tray pitchers, refrigerators, liners, etc. It may also be used as cushioning materials for fresh produce, electronic or appliance industries, etc. (RECYCLED PRODUCTS: Clothes Hangers, Park Benches, Flower Pots, Toys, Spoons, Cutlery, Picture Frames, Seeding containers, etc.)
7 Other	Others	Others (usually, Mixed Plastic Waste, used in Thermoset Plastics, Multilayer and laminates, Bakelite, Polycarbonate, etc.) (RECYCLED PRODUCTS: CDs, Pallets, Floors, Roofs, Furniture, Sheeting, Benches, Shoe soles, etc.)

Recovery

It is another strategy to recover fuel and material from waste plastic that means converting plastic waste into fuel for different purposes including power production in thermal plants and manufacturing processes to produce resources. Different technologies can transform and reprocess the plastic waste into fresh materials or energy resources. The concept of RDFs (Refuse Derived Fuels) provides fuels for sustainable development along with managing the waste. RDFs and co-processing use the plastic waste materials in industrial sectors mainly in cement and power plants and other large combustion plants. Co-processing is the energy recovery process that substitutes primary fuel and raw material by waste material. Waste materials, mainly plastic waste taken for co-processing, are known as alternative fuels or blended fuel. Co-processing of plastic waste oers advantages for these industries and municipalities responsible for waste management. On the other hand, by using the plastic waste, cement or power plants can conserve the fossil fuel resources and raw material stocks, making it more eco-efficient production along with managing the waste. In addition to this, it reduces the investment and resources required to manage the plastic waste such as landfilling.

Land filling

Plastic waste along with municipality solid waste in developing countries ended up in landfilling. As per the reports, approximate 65% plastic waste goes into landfills . The landlord plastic waste does not decompose for the years that ultimately cause soil, air and water pollution and make unsafe conditions for the inhabitants. As in case of unsecured landfills, the negative effects on environmental components of dumping the waste is serious. These impacts of landfilling could be minimized up to some extent by sanitary landfills. Oxygen deficient conditions cause slow and incomplete degradation of plastic in landfills .Landlord dumped plastic waste produces a lot of gases and leachates which cause soil, air and water pollution that ultimately affects the human’s life. The pollutants released from landfill waste are benzene, toluene, trimethylbenzenes, methylbenzenes, xylenes, and BisphenolA (BPA). It should be the least favored strategy for plastic waste management.

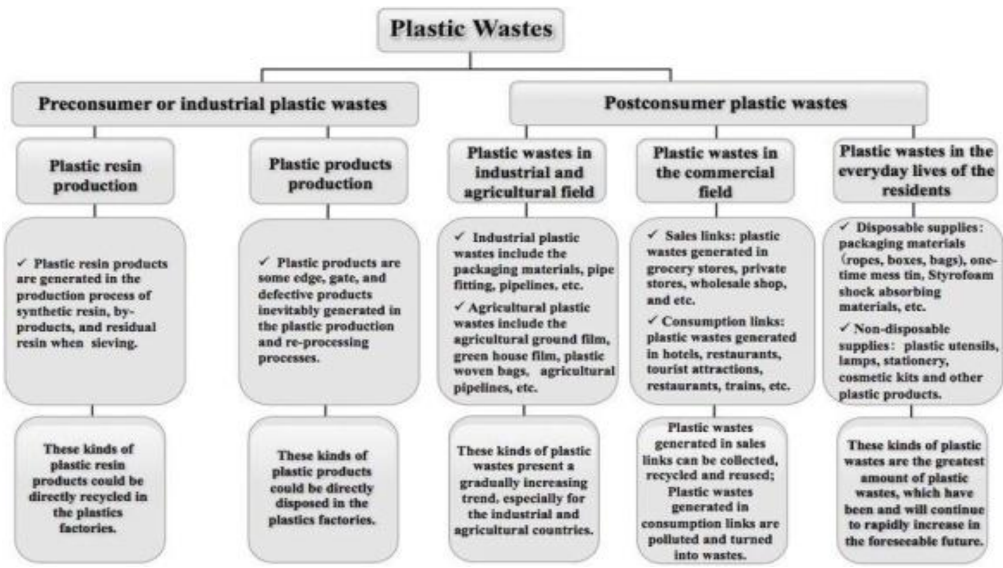
Incineration:

Incineration is used as the second best method to manage the plastic waste . It also can be called controlled burning, in turn a typical method employed to reduce the volume and size of municipal solid waste including plastic. However, this can be considered as a recovery method also because plastic could replace the application of energy resources such as fossil fuels or gases in thermals and other combustion plants. 25% of the discarded plastic is being burnt openly in the environment to reduce the pressure on landfills as these require a lot of space and also cause soil pollution. On the other hand, Incineration also causes air pollution by producing harmful gases such as carbon dioxide, Polycyclic aromatic hydrocarbons, heavy metals, Polychlorinated biphenyls (PCBs), furans, and dioxins (carcinogenic) emied in environment during the combustion . The toxic gases released on incineration of plastic waste causes no. health problems to the people residing near the incineration plant. So, this is not also an environmentally friendly method for the safe disposal of plastic waste. It causes various health ailments to the people living nearby to these incineration sites. Therefore, it compels us to think of some kind of different method. Recycling is considered the best choice over the incineration and landfills method of plastic waste management.

Bioremediation and biodegradation :

In this method, waste is decomposed using natural means such as bacteria, algae, fungi. Plastic polymers can be biodegraded and fragmented using heteroatomic molecules containing nitrogen, oxygen and double bonded carbon molecules. The enzymes which employed commonly for this task are microbial oxidoreductase, laccases, microbial oxygenase, peroxidases, microbial lignin peroxidases, hydrolases, and microbial manganese peroxidases, microbial lipase etc. Some polymers like PVC on treatment with natural agents like microbial enzymes convert into monomers of phthalates such as vinyl monomers, dioxins. Thus, bioremediation could be the most environmentally friendly and cost-effective method to manage the plastic waste but this needs to be explored using the contemporary tools of biotech and genetic engineering.

Management of plastic waste is the major concern all over the globe. Developed countries have managed this issue to great extent but developing countries need to take some strict measures and infrastructural and technical development to manage the plastic waste. Open dumping is the one of the most opted methods to dispose of waste in developing countries but it is not good in any way. This rate of waste generation and current method of its disposal is going to be an emergent concern in front of researchers, scientists and stakeholders. Current rate of plastic waste generation and its mismanaged and improper disposal would be going to cover land and water under heap of plastic waste in near future. As per an estimate, the present rate of plastic disposal in our ocean will lead to a situation where there will be more plastic waste in water than sheds. Some disposal methods are discussed with their pros and cons. Incineration and landfilling are not environmentally good and sustainable methods of plastic waste disposal. Some important strategies are discussed to manage it individually such as refuse and reduce. For industrial and commercial scale, recycle and recovery can be employed up to some extent. But there is a need of hour to invest in research and development of plastic waste management using natural ways. Therefore, bioremediation and biodegradation could be a promising tool to combat this issue to a great extent in near future.



Sources of plastic wastes and strategies for the management of plastic wastes

7.20 Micro plastic:

Micro plastics, small pieces of plastic, less than 5 mm (0.2 inch) in length, that occur in the environment as a consequence of plastic pollution. Micro plastics are present in a variety of products, from cosmetics to synthetic clothing to plastic bags and bottles. Many of these products readily enter the environment in wastes.

Properties:

Microplastics consist of carbon and hydrogen atoms bound together in polymer chains. Other chemicals, such as phthalates, polybrominateddiphenyl ethers (PBDEs), and tetrabromobisphenol A (TBBPA), are typically also present in microplastics, and many of these chemical additives leach out of the plastics after entering the environment.

Primary and secondary microplastics:

Microplastics are divided into two types: primary and secondary. Examples of primary microplastics include microbeads found in personal care products, plastic pellets (or nurdles) used in industrial manufacturing, and plastic fibres used in synthetic textiles (e.g., nylon). Primary microplastics enter the environment directly through any of various channels—for example, product use (e.g., personal care products being washed into wastewater systems from households), unintentional loss from spills during manufacturing or transport, or abrasion during washing (e.g., laundering of clothing made with synthetic textiles). Secondary microplastics form from the breakdown of larger plastics; this typically happens when larger plastics undergo weathering, through exposure to, for example, wave action, wind abrasion, and ultraviolet radiation from sunlight.

Environmental and health impacts:

Microplastics are not biodegradable. Thus, once in the environment, primary and secondary microplastics accumulate and persist. Microplastics have been found in a variety of environments, including oceans and freshwater ecosystems. In oceans alone, annual plastic pollution, from all types of plastics, was estimated at 4 million to 14 million tons in the early 21st century. Microplastics also are a source of air pollution, occurring in dust and airborne fibrous particles. The health effects of microplastics inhalation are unknown.

By 2018, in marine and freshwater ecosystems combined, microplastics had been found in more than 114 aquatic species. Microplastics have been found lodged in the digestive tracts and tissues of various invertebrate sea animals, including crustaceans such as crabs. Fish and birds are likely to ingest microplastics floating on the water surface, mistaking the plastic bits for food. The ingestion of microplastics can cause aquatic species to consume less food and therefore to have less energy to carry out life functions, and it can result in neurological and reproductive toxicity. Microplastics are suspected of working their way up the marine food chains, from zooplankton and small fish to large marine predators.

Microplastics have been detected in drinking water, beer, and food products, including seafood and table salt. In a pilot study involving eight individuals from eight different countries, microplastics were recovered from stool samples of every participant. Scientists have also detected microplastics in human tissues and organs. The implications of these findings for human health were uncertain.

Reducing microplastics pollution:

In 1950 and 2015, some 6,300 million metric tons of plastic waste were generated. The majority of this waste, about 4,900 million metric tons, ended up in landfills and the environment. On the basis of trends from that period, researchers estimated that by 2050 the amount of plastic waste in landfills and the environment would reach 12,000 million metric tons. Nonetheless, the potential dangers of escalating plastics pollution, especially pollution from microplastics, remained largely ignored by governments and policy makers.

To help overcome this obstacle, organizations such as the United Nations Expert Panel of the United Nations Environmental Programme engaged more than 100 countries in educational campaigns aimed at raising awareness of plastics pollution and encouraging reuse and recycling of plastics. Other international cooperative programs were established to address marine wastes, including microplastics pollution. In 2015 the United States passed the Microbead-Free Waters Act, which prohibits the manufacture and distribution of rinse-off cosmetics products that contain plastic microbeads. Many other countries also placed bans on microbeads.

Remediation of microplastics already in the environment is another key component of reducing microplastics pollution. Strategies under investigation included the use of microorganisms capable of breaking down synthetic microplastic polymers. A number of bacterial and fungal species possess biodegradation capabilities, breaking down chemicals such as polystyrene, polyester polyurethane, and polyethylene. Such microorganisms potentially can be applied to sewage wastewater and other contaminated environments.

7.21. Summary

Radioactive waste is classified into low-level waste (LLW) , intermediate- level waste (ILW) and high-level waste (HLW). low- level waste ,such as paper, tools,rags, clothing, these things contain slight amount of mostly short-lived radioactivity, intermediate-level waste (ILW), which contains large amounts of radioactivity and requires some shielding, and high-level waste (HLW), which is highly radioactive and blazing due to decay heat, so requires cooling and shielding.

Radioactive waste is a hazardous waste and micro plastic is also very dangerous for health.In this chapter we are studying the classification of radioactive waste and plastic waste.High-level waste is full of intense radioactive fission products, largely of which are consequently short-term. This is a solicitude since if the waste is stored,mayhaps in deep geological storage, over many years the fission products decay, decreasing the radioactivity of the waste and making the plutonium easier to access. The undesirable contaminant Pu-240 decays faster than the Pu-239, and thus the quality of the bomb material increases with time (although its quantity decreases during that time as well).Residues from the oil and gas industry often contain radium and its decay products. The sulfate scale from an oil well can be very radium rich, while the water, oil, and gas from a well often contain radon.

7.22. Terminal questions

Q.1: Explain what radioactive waste is? It type and also explain the source of waste.

Answer:---

Q.2: Describe in detail about radioactive waste management?

Answer:---

Q.3: What is the difference between low- level waste and intermediate -level waste and high -level waste of radioactive waste?

Answer:---

Q.4: Explain reduce reuse, recycle recovery and land filling?

Answer:---

Q.5: Definition of microplastic waste and also explain the source of microplastic waste?

Answer:---

Q.6: What is plastic waste? its type and source and disposal method?

Answer:---

Q.7: How to store radioactive waste and what type of radioactive isotope it contains?

Answer:---

7.23. Further suggested readings

1. Waste treatment and disposal, Williams, Paul T. John Wiley Publishers, 2013.
2. Radioactive Waste Management and Contaminated Site Clean-Up: Processes, Technologies and International Experience by William E. Lee and Michael I. Ojovan (Elsevier)
3. Radioactive Waste Management, Second Edition by Patrick J. McLaughlin (CRC Press)
4. Radioactive Waste Engineering and Management: An Advanced Course in Nuclear Engineering by J.H. Crocker (Springer)
5. Radioactive Waste Management: Second International Conference, Proceedings of ICORWM-2, 1989 by Institution of Civil Engineers (Thomas Telford)
6. Handbook of Radioactive Waste Management, Second Edition by Mohammad Modarres, William E. Kennedy, and Michael J. Zigler (CRC Press
7. "Plastic Waste Management: A Sustainable Approach" by Richard M. Lerner and Stephen R. Poliakoff, published by CRC Press.
8. "Plastics Waste Management: Processing and Disposal" by David Jones, published by Wiley.

Unit-8: E-Waste

Contents

8.1. Introduction

This chapter introduces the E-waste .Firstly; this chapter describes the concepts and objectives of E-waste management. Types of e-waste items and major E-waste problem are also covered in this chapter .Other topics included sources, composition and management of E-waste are covered in this chapter.

Objectives

- To understand the E-waste and its types
- To study the sources of E-waste.
- To understand the composition of E-waste.
- To study the collection and treatment of E-waste in other countries.
- To describe recycling of E-waste.
- To understand the reduction,reuse and repair of E-waste.
- To understand the E-waste management of India and other countries.

8.2. Concept of E-Waste

Any electrical or electronic devices that's been discarded is known as E waste Working and broken items that are discarded in the garbage or donated to a charity reseller like Goodwill is included in E waste. Because of toxic chemicals that naturally extract from the metals inside when buried waste is particularly very dangerous.

E-waste refers to electronic products that are no longer wanted or useful, such as computers, Smartphone's, televisions, and other electronic devices. These items can contain hazardous materials like lead, mercury, and cadmium, which can be harmful to the environment and human health if not disposed of properly. Recycling and proper disposal of e-waste are important to reduce the environmental impact and potential health risks associated with these materials.

Different forms of electric and electronic appliances that have ceased to be of value to their users or no longer satisfy their original purpose are termed as Electronic waste. Electronic waste (e-waste) products have exhausted their utility value through redundancy, replacement, or breakage and include both "white goods" such as refrigerators, washing machines, and microwaves and "brown goods" such as televisions, radios, computers, and cell phones. Given that the information and technology revolution has exponentially increased the use of new electronic equipment, it has also produced growing volumes of obsolete products; e-waste is one of the fastest-growing waste streams. Although e-waste contains complex combinations of highly toxic substances that pose a danger to health and the environment, many of the products also contain recoverable precious materials, making it a different kind of waste compared with traditional municipal waste.

Globally, e-waste constitutes more than 5 percent of all municipal solid waste and is increasing with the rise of sales of electronic products in developing countries. The majority of the world's e-waste is recycled in developing countries, where informal and hazardous setups for the extraction and sale of metals are common. Recycling companies in developed countries face strict environmental regulatory regimes and an increasing cost of waste disposal and thus may find exportation to small traders in developing countries more profitable than recycling in their own countries. There is also significant illegal transboundary movement of e-waste in the form of donations and charity from rich industrialized nations to developing countries.

8.3. Categories of E-Waste

E-waste can be broadly categorized into three main types, including:

1. Consumer electronics: This includes electronic devices used in households, such as TVs, laptops, Smartphone's, gaming consoles, and home appliances.
2. Information technology (IT) equipment: This includes electronic devices used in offices or businesses, such as desktop computers, servers, printers, and network devices.
3. Electrical and electronic equipment (EEE): This includes electronic devices used in industrial and commercial settings, such as medical equipment, telecommunication equipment, and industrial machinery.

E-waste can also be categorized based on its potential impact on the environment and human health, such as hazardous or non-hazardous waste, and based on the nature of the materials used in the devices, such as metals, plastics, and glass. Proper handling and disposal of e-waste are crucial to mitigate their impact on the environment and human health

8.4. Types of e-waste

Common items of electrical and electronic waste are

a. Large household appliances (refrigerators/freezers, washing machines, dishwashers)
b. Small household appliances (toasters, coffee makers, irons, hairdryers)
c. Information technology (IT) and telecommunications equipment (personal computers, telephones, mobile phones, laptops, printers, scanners, photocopiers)
d. Consumer equipment (televisions, stereo equipment, electric toothbrushes)
e. Lighting equipment (fluorescent lamps)
f. Electrical and electronic tools (handheld drills, saws, screwdrivers)
g. Toys, leisure and sports equipment
h. Medical equipment systems (with the exception of all implanted and infected products)
i. Monitoring and control instruments
j. Automatic dispensers

Fig: 8.1. Types of E-Waste

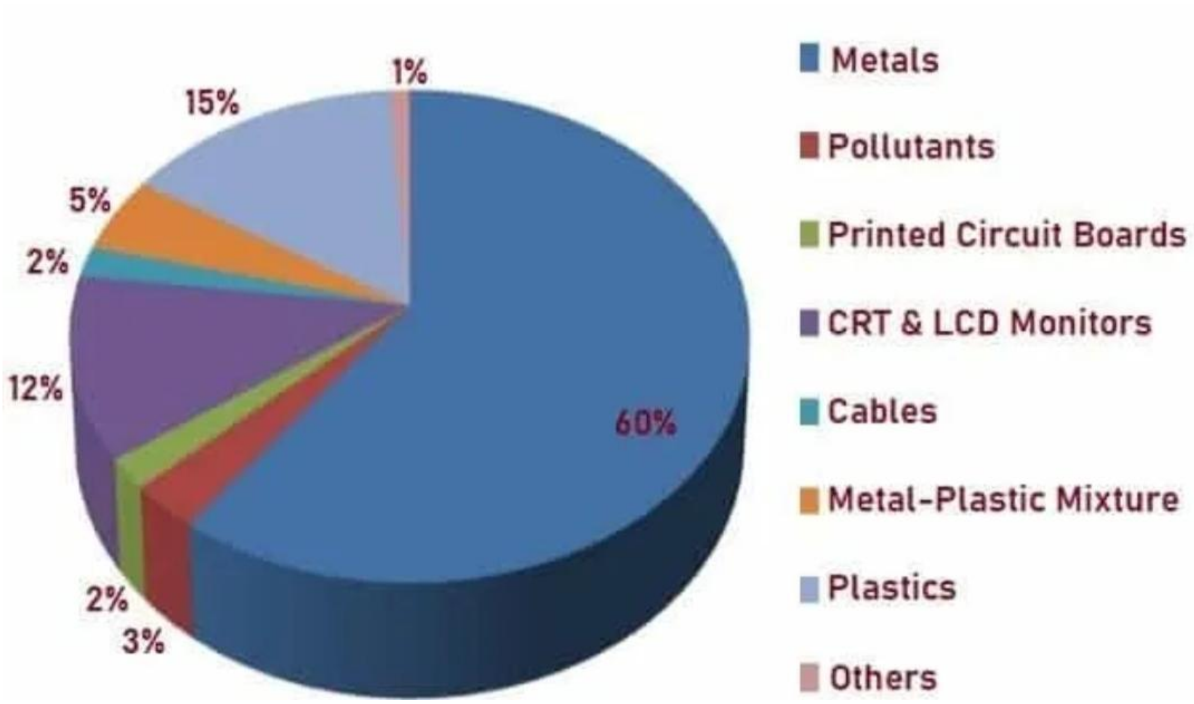
8.5. Sources of E-Waste

Any appliance that runs on electricity has the potential to cause damage to the environment if it is not disposed of properly. Common things of electrical and electronic waste are:

a. Large household appliances like refrigerators/freezers, washing machines, dishwashers, televisions.

b. Small household appliances which include toasters, coffee makers, irons, hairdryers.

c. Information Technology (IT) and Telecommunications equipment namely personal computers, telephones, mobile phones, laptops, printers, scanners, photocopiers etc.
d. Lighting equipment such as fluorescent lamps.
e. Electronic or Electrical tools i.e. handheld drills, saws, screwdrivers etc.
f. Toys, leisure and sports equipment.
g. Monitoring and control instruments.



h. Automatic dispensers.
i. Waste generated from the products used for data processing such as computers, computer devices like monitors, speakers, keyboards, printers etc.
j. Electronic devices used for entertainment like TV, DVDs, and CD players.
k. Equipment or devices used for communication like phones, landline phones, fax etc.
l. Household equipments like vacuum cleaner, microwave ovens, washing machines, air conditioners etc.
m. Audio, visual components such as VCRs, Stereo equipment etc.

8.6. Objectives of E-Waste Management:

The objectives of e-waste management are to:

1. **Reduce the environmental and health hazards associated with e-waste**: This involves minimizing the release of toxic substances such as lead, mercury, and cadmium into the environment, which can cause soil and water pollution, and pose health risks to humans and wildlife.
2. **Promote resource conservation:** E-waste contains valuable materials such as gold, silver, copper, and rare earth metals, which can be recovered and reused. E-waste management aims to recover these materials and reduce the demand for virgin resources.
3. **Encourage proper disposal of e-waste:** Proper disposal of e-waste reduces the risk of illegal dumping or disposal in landfills, which can lead to environmental pollution and health risks.
4. **Increase awareness and promote education on e-waste management:** Raising awareness about e-waste management practices among stakeholders, including consumers, manufacturers, and policymakers, can promote sustainable practices and enhance the understanding of the importance of e-waste management.

Overall, e-waste management seeks to address the challenges posed by the rapidly growing volume of e-waste and to promote sustainable practices in the management of electronic waste.

E-waste can contain a wide variety of materials, including:

Metals: E-waste can contain valuable metals such as gold, silver, copper, aluminum, and rare earth metals, which can be recovered and reused.

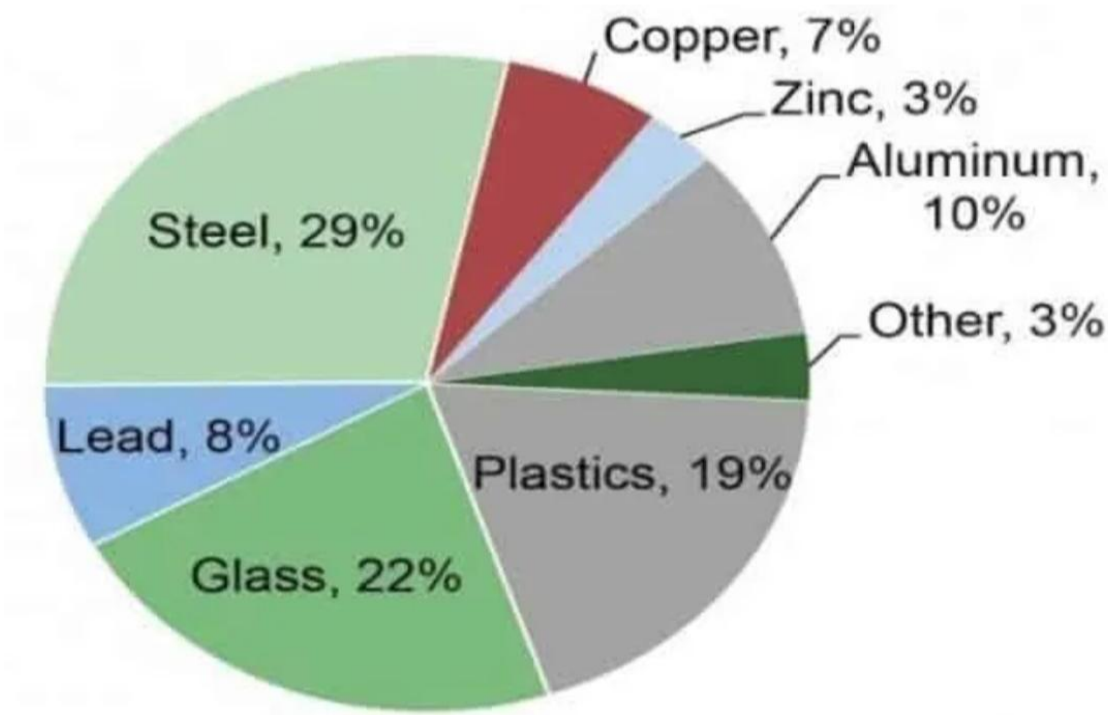
Plastics: E-waste can contain different types of plastics, including PVC, ABS, and polycarbonate, which can be recycled.

Glass: E-waste can contain glass components such as CRT tubes, which require proper handling and disposal to minimize their impact on the environment.

Hazardous substances: E-waste can also contain hazardous materials, such as lead, mercury, cadmium, and brominates flame retardants, which require special handling and disposal to prevent environmental and health risks.

Batteries: E-waste can contain different types of batteries, such as lead-acid, nickel-cadmium, and lithium-ion, which can pose a risk if not handled and disposed of properly.

The composition of e-waste can vary depending on the type and age of the device, as well as the manufacturer and design. Proper management and disposal of e-waste are crucial to minimize the environmental and health impacts of these materials.



8.7. Recycling of E waste

E-waste recycling refers to the reprocessing and re-use of the electronic wastes. It is a process that seeks to recover material from electronic waste. This way, you can use them in new electronic products.

These electronic wastes may be in the form of home appliances like your air conditioners, televisions, electric cookers, air conditioners, heater, DVDs, fans, microwaves, and radios. They may also be in the form of information tech equipment like your computers, laptops, mobile phones, batteries, hard disks, circuit boards, monitors.

E-waste recycling is one of the most talked-about issues in the world today due to its potentials to reduce environmental hazards and pollution. There is also the fact that it can protect our lives as humans and other life forms existing in our world. E-waste recycling is the reuse and reprocessing of electrical and electronic equipment of any type that has been discarded or regarded as obsolete

Recycling of e-waste is a growing trend and was initiated to protect human and environmental health mainly due to the widespread environmental pollution impacts of e-waste.Even more, millions of electronics are in use daily. Then, when they reach the tail of their lifespan, they mostly waste away in landfills. Only 12.5% of e-waste is recycled.

Components of E-waste that Can be Recycled

Some of the common materials that can be recycled are as follows:

Plastic

Plastic materials may be retrieved and sent for recycling. The recyclers can then use the plastic materials to manufacture items like plastic sleepers, vineyard stakes, fence posts, plastic trays, insulators, equipment holders, and much more.

Metal

Metals can also be retrieved and recycled to manufacture newer steel products and metals.

Glass

You can extract glass from CRTs (Cathode Ray Tubes) of computer monitors and televisions. But there's a little problem here. CRTS contains several hazardous substances, such as lead. And this is dangerous to both human health and the immediate environment. This makes it difficult to retrieve a glass from CRTs.

However, there are certain steps you may take to ensure safer CRT recycling.

First, separate the CRT from the monitor or television. Then shred the CRT into small pieces. Remove the metals with overband magnets. This helps you remove ferrous and even non-ferrous objects from that glass.

After this, use washing lines to clear phosphors and oxides from that glass. The last step is called glass sorting. This is where you separate non-leaded from leaded gas.

Mercury

Devices containing mercury may be sent to recycling facilities using specialized technology to eliminate mercury. The end product of this elimination includes metric instruments, dental amalgams, and fluorescent lighting.

Circuit Boards

There are accredited and specialized companies smelting and recovering resources like tin, gold, silver, copper, palladium, and valuable metals.

Hard Disk

When shredded and processed, you can recover aluminum ingots from hard disks. These are particularly useful for automobiles.

Toner and Ink Cartridges

Recyclers in various manufacturing industries that remanufacture them take these toners and ink cartridges for recycling. They then use retrieved plastic and metals as raw materials for other products.

Batteries

Scrap batteries can be used torecover cadmium, steel, nickel, and cobalt for re-use in new batteries. They are also useful for fabricating stainless steel.

Apart from the listed objects, there is an endless list of other objects. But, overall, there's kind of hack to recycling any item or component. And no, e-waste recycling is not a one size fits all approach. However, there is a general way to go about it.

Step-by-Step Process of E-waste Recycling

Recycling electronics is an often challenging activity. This is because e-scraps are typically sophisticated and manufactured from diverse elements such as metals, plastics, and glass. While this process often varies, there is a general process.

Step 1: Collecting and Transporting

This is the first stage of recycling e-waste. Here, recyclers place take-back booths or collection bins in specific places. When these bins get filled, the recyclers then transport the e-wastes to recycling facilities and plants.

Step 2: Shredding and Sorting

After collecting and transporting, the next step is to shred and sort the e-waste. The success of subsequent separation relies on shredding. And this is why efficiency is essential at this stage.Shredding involves breaking e-waste into smaller pieces for proper sorting. With the use of hands, these tiny prices get sorted and then manually dismantled. This is typically labour-intensive as waste items are, at this stage, separated to retrieve different parts.

After this, the materials get categorized into core materials and components. Then, these items get sorted into various categories. Typically, this category includes items that you can re-use as they are and those that require further recycling processes.

In any case, e-wastes are often manually sorted, while compounds such as fluorescent light, batteries, UPS batteries, and toner cartridges should not be crushed or shredded by hand.

Step 3: Dust Extraction

The tiny waste particles get smoothly spread via a shaking process on the conveyor belt. The smoothly spread e-waste pieces then get broken down even further. At this point, the dust gets extracted and discarded in an environmentally compliant manner. This way, there is no environmental degradation.

Step 4: Magnetic Separation

After this, a strong overhead magnet helps you separate steel and iron from other wastes. This way, you have successfully recycled the steel from the waste stream.

However, some mechanical processes may sometimes be required to separate circuit board, copper, and aluminium from other wastes particles. And this is especially where they are mostly plastic.

Step 5: Water Separation

After this, water separation tech becomes relevant to separate the glass from the plastic. It can be then send glass to smelters to use in the production of batteries, x-ray tubes, and new CRTs.

Step 6: Purification of Waste Stream

The next thing is locating and extracting leftover metals from plastics to purify the waste stream further.

Step 7: Preparing Recycled Materials for Sale

The final stage is preparing recycled materials for sale. Here, the materials separated during SSS get prepared for sale as raw materials to produce new electronics.

Benefits of E-waste Recycling

There are several benefits that you can derive from e-waste recycling

1. Resource conservation: E-waste recycling helps to conserve valuable natural resources, such as metals, plastics, and rare earth materials, by recovering and reusing them in the production of new electronic products.
2. Environmental protection: E-waste recycling helps to reduce the environmental impact of electronic waste by minimizing the release of toxic substances, such as lead, mercury, and cadmium, into the environment.
3. Energy savings: E-waste recycling can save energy by reducing the need to extract, process, and manufacture new raw materials, which require significant amounts of energy.
4. Job creation: E-waste recycling can create jobs in the waste management and recycling industries, which can contribute to economic growth and development.
5. Cost savings: E-waste recycling can be more cost-effective than the disposal of e-waste in landfills, which can be expensive and may pose long-term environmental and health risks.

Overall, e-waste recycling offers several benefits, including environmental protection, resource conservation, energy savings, job creation, and cost savings. Proper handling and management of e-waste are crucial to maximize the benefits of e-waste recycling.

8.8. Reduce of E waste

Here are some ways to reduce e-waste:

1. **Reduce consumption:** Consider whether you really need to buy a new electronic device before purchasing it. If possible, repair and upgrade your existing devices.
2. **Donate or recycle:** Instead of throwing away old electronics, donate them to charities or recycle them properly. Many electronics manufacturers and retailers offer recycling programs.
3. **Buy sustainable products:** Look for electronic devices that are designed to last longer, have replaceable parts, and are made from sustainable materials.
4. **Avoid disposables:** Use rechargeable batteries and avoid disposable electronics like disposable cameras and printers.
5. **Proper disposal:** If you must dispose of electronic waste, make sure to do so properly. Find a certified e-waste recycler who can safely dispose of the waste.

8.9. Reuse of E –waste

Here are some ways to reuse e-waste:

1. **Repurpose old electronics:** Old electronics can be used in creative ways, such as turning an old computer monitor into a fish tank or using an old smartphone as a security camera.
2. **Donate or sell:** If your old electronics are still in good condition, consider donating or selling them to someone who can use them.
3. **Use parts for repairs:** Salvage parts from old electronics to repair other devices. For example, you could use the screen from a broken laptop to repair another laptop.
4. **Create art:** Old electronics can be used to create unique pieces of art, such as sculptures or mosaics.
5. **Make DIY projects:** There are many DIY projects that can be made using e-waste, such as building a robot using old electronic parts.

8.10. E-waste Problems

Here are some of the problems associated with e-waste:

1. **Environmental pollution:** Improper disposal of e-waste can lead to toxic chemicals like lead, mercury, and cadmium leaching into the soil and groundwater, causing environmental pollution.
2. **Health hazards:** Exposure to toxic chemicals from e-waste can lead to a range of health problems, including respiratory problems, skin irritation, and damage to the nervous system.
3. **Resource depletion:** Electronic devices contain valuable resources such as rare earth metals and precious metals, and their disposal can lead to the depletion of these resources.
4. **Data security risks:** E-waste can contain sensitive data, and if not disposed of properly, can lead to data security risks.
5. **Global inequality:** E-waste disposal is often outsourced to developing countries, where workers may lack proper safety equipment and are exposed to hazardous chemicals, leading to health hazards and social inequality.

8.11. Treatment of E-Waste

1. Treatment in Europe

In Europe, e-waste treatment typically involves a combination of manual and mechanical processes. The first step is usually to manually sort the waste into different categories, such as batteries, plastics, and metals. After sorting, the waste is then processed using various mechanical methods, such as shredding, crushing, and melting.

The resulting materials are then further refined and processed to recover valuable metals and other materials, such as gold, silver, copper, and aluminum. These materials can then be reused in the production of new electronic devices, reducing the need for new resources and contributing to a circular economy.

In Europe, e-waste treatment is highly regulated, and strict standards are in place to ensure that waste is processed in an environmentally responsible and safe manner. This includes requirements for the safe handling and disposal of hazardous substances, as well as regulations around the export of e-waste to developing countries.

Some challenges in the future will be to level the standards for technology as well as for monitoring in the EU member states. As a directive, like the European WEEE II Directive it sets only a framework. National implementation will vary and produce unfair competition, favouring low-cost technology with lower material yields.

2. **Treatment in China**

In China, e-waste treatment has historically been characterized by informal and often unsafe practices. Due to the high demand for recycling and the lack of effective regulation and enforcement, many unlicensed and informal e-waste recycling operations have emerged.

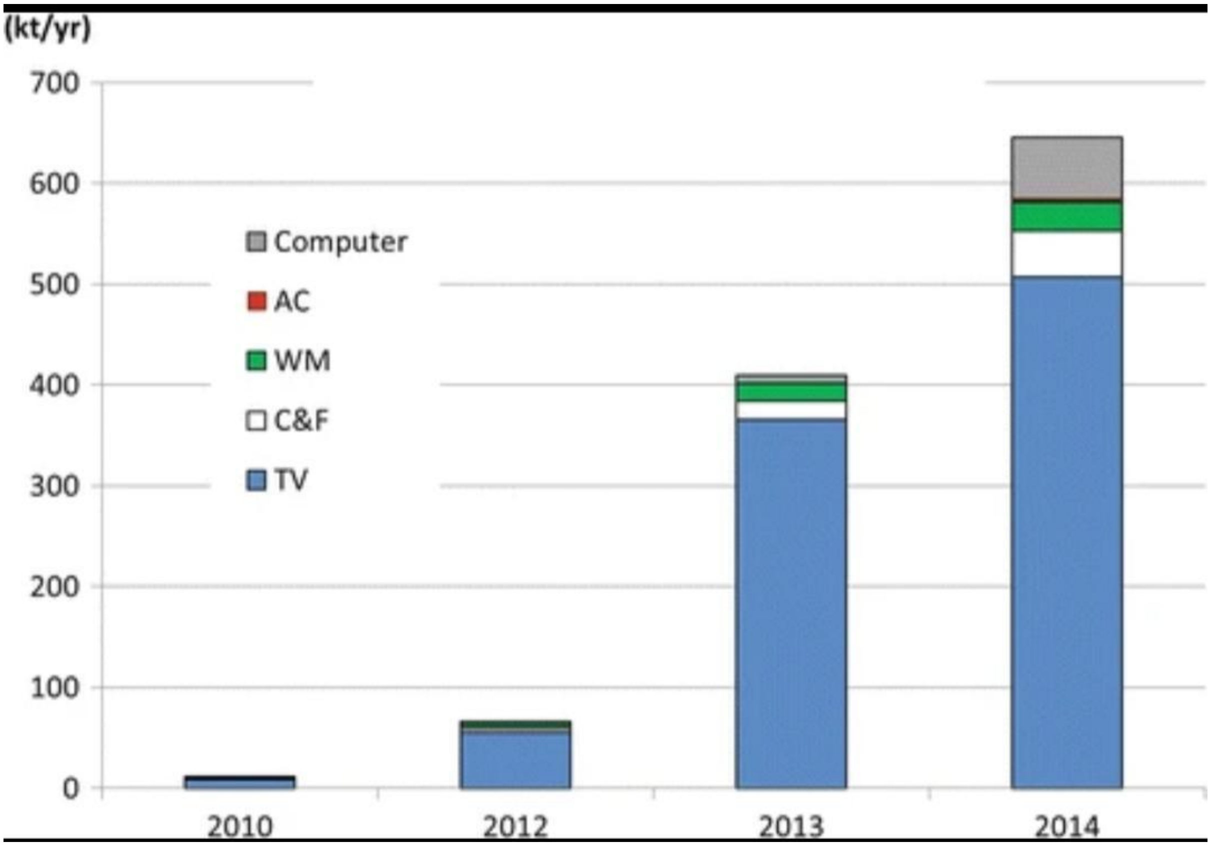
These informal operations often involve manual dismantling of electronic devices, without proper safety equipment, which can expose workers to hazardous chemicals and metals. The recovered materials are then sold to middlemen, who sell them to downstream processing facilities.

However, in recent years, the Chinese government has taken steps to regulate and improve e-waste treatment. The country has implemented a series of laws and regulations to improve the management of e-waste and reduce environmental pollution, including a ban on the import of certain types of e-waste.

In addition, the government has invested in the development of advanced e-waste treatment technologies, such as automated dismantling and sorting systems, to improve the safety and efficiency of e-waste treatment. While significant challenges remain, these efforts have helped to improve the safety and sustainability of e-waste treatment in China.

Plastics from dismantling are partly sorted into plastic types and partly fragmentize to reduce the volume for transport into specialised plastic recyclers. No separation of plastics with brominated flame retardants was observed in the plants visited. Some e-waste recyclers use plastics from dismantling directly for the production of wood plastic compounds.

Figure, shows the input into recycling facilities in five provinces (Beijing, Hubei, Zhejiang, Jiangsu and Guangdong), where the above-mentioned recycling plants are located and which were visited as part of the REWIN project. The figure shows the quick increase in treatment capacities from 2010 to 2014 and, secondly, the large proportion of TV sets (80–90% of the mass input) compared to other types of appliances. It is obvious that TV sets are less attractive for informal recyclers compared to product types like PCs, refrigerators or air conditioners, as the latter have a higher share of ferrous, non-ferrous or – for PCs – precious metals.



The main challenge for the treatment of e-waste in China is the variable and partly lacking supply of input material for recycling facilities. Comparing e-waste generation and input to formal recycling facilities makes clear that a larger part of the e-waste still does not end up in the formal recycling industry but probably undergoes informal treatment practices. For the established formal recycling facilities, the processing of PCBs and plastics poses challenges, as PCBs are mainly processed mechanically, leading to a loss of precious metals, and plastics are typically not separated into materials containing (brominated) flame retardant and those free of flame retardants

3. Treatment in Vietnam

In Vietnam, e-waste treatment is still in its early stages, and the majority of e-waste is treated through informal channels. Much like China, informal e-waste recycling in Vietnam often involves manual dismantling and processing of electronic devices, without proper safety equipment, which can expose workers to hazardous chemicals and metals.

However, the Vietnamese government has taken some steps to address e-waste management. In 2020, the country passed a new law on environmental protection that includes regulations on e-waste management. The law requires e-waste to be collected, transported, and treated by licensed organizations, and prohibits the disposal of e-waste in landfills.

In addition, the government has established a pilot program for e-waste management in Ho Chi Minh City and has invested in the development of e-waste recycling facilities. These facilities use advanced technologies to safely and efficiently recover valuable materials from e-waste, such as gold, copper, and aluminium, while minimizing the environmental impact.

While there is still much work to be done to improve e-waste management in Vietnam, these efforts represent important steps towards more sustainable and responsible e-waste treatment in the country

The current situation of e-waste treatment has led to many serious risks related to the environment and human health, not only of the workers at those workshops but also for residents living close to workshops. The analysis of accumulation of polychlorinated biphenyls and brominates flame retardants in breast milk from women living in e-waste recycling sites (Bui Dau in Hung Yen province) at very high levels of polybrominateddiphenyl ethers and hexabromocyclododecane. It is difficult to estimate, monitor and record how much e-waste is transported to and processed at craft villages in Vietnam. The data on e-waste is rough, and based on estimates from interviews with people from craft villages, experts and traders in the field, it is impossible to clarify the situation with certainty.

8.12. E-Waste management in India

India is one of the fastest-growing economies in the world and is rapidly increasing its usage of electronic gadgets, making e-waste management a critical issue for the country. E-waste management in India has been a topic of concern for a long time, and the Indian government has implemented several measures to address the issue. Here are some key points about e-waste management in India:

1. E-waste refers to all electronic items that are discarded, including old cell phones, computers, televisions, refrigerators, and other electronic devices.
2. According to a report by the Central Pollution Control Board (CPCB), India generated 3.2 million metric tonnes of e-waste in 2019. This figure is expected to increase to 5.2 million metric tonnes by 2025.
3. The government of India has implemented the E-Waste (Management) Rules, 2016, which requires all producers of electronic products to be responsible for the collection and recycling of e-waste. The rules also lay down guidelines for the management and handling of e-waste.
4. In addition, the government has launched various programs to encourage the proper disposal of e-waste. One such program is the Swachh Bharat Abhiyan, which aims to clean up the country and raise awareness about the need for proper waste management.
5. Various e-waste management companies have also emerged in India in recent years, offering services such as collection, transportation, dismantling, and recycling of e-waste.
6. Despite these measures, the implementation of e-waste management in India faces several challenges. One of the biggest challenges is the lack of awareness and understanding of the issue among the general public.
7. Another challenge is the lack of proper infrastructure for e-waste management. Most of the e-waste generated in India is handled by the informal sector, which often uses crude methods that can be harmful to the environment and human health.

Overall, while e-waste management in India is still a work in progress, the government and various stakeholders are taking steps to address the issue and ensure a sustainable future for the country.

E-Waste Legislation in India:

E-waste legislation in India has evolved over the years to address the growing concern of electronic waste generated in the country. The key legislation governing e-waste management in India is the E-Waste (Management) Rules, 2016, which replaced the earlier E-Waste (Management and Handling) Rules, 2011. Here are some key provisions of the E-Waste (Management) Rules, 2016:

1. Extended Producer Responsibility (EPR): The EPR concept makes producers and brand owners responsible for the entire life cycle of their products, including proper disposal of e-waste. The rules require producers to collect a certain amount of e-waste annually based on their sales of electronic and electrical equipment.
2. Authorization and registration: The rules require producers, dismantlers, and recyclers of e-waste to obtain authorization and registration from the State Pollution Control Boards.
3. Collection and channelization: The rules mandate that producers have to establish collection mechanisms for e-waste, which includes setting up collection centers and tie-ups with authorized e-waste collectors or recyclers.
4. Environmentally Sound Management Practices (ESMPs): The rules lay down guidelines for environmentally sound dismantling and recycling of e-waste to ensure that it does not harm the environment and public health.
5. Penalties: The rules also stipulate penalties for violations, which include fines and imprisonment.
6. In addition to the E-Waste (Management) Rules, 2016, there are other laws and regulations that address e-waste management in India. These include the Hazardous Waste (Management, Handling, and Transboundary Movement) Rules, 2016, the Plastic Waste Management Rules, 2016, and the Biomedical Waste Management Rules, 2016.

Despite the existence of these laws and regulations, the implementation of e-waste management in India remains a challenge. However, with the growing awareness about the issue, the Indian government and stakeholders are taking steps to ensure a sustainable and responsible approach to e-waste management.

For effective implementation of the E-Waste Rules, the producers have to take responsibility for their products. A synchronized endeavour by the industries and the pollution control boards and local authorities is crucial to cope up with the problem of e-waste in India. The relaxation in the EPR Plan by reduction in the e-waste collection targets and overture of realistic collection targets will result in increased observance of the E-Waste Rules by organizations. Also, the requirement of PROs to register with CPCB would aid in the creation of an organized and legitimate industry and would pave way for effective and improved e-waste management in India.

8.13. Summary

In this chapter you have learned that Any electrical or electronic devices that's been discarded are known as E waste Working and broken items that are discarded in the garbage or donated to a charity reseller like Goodwill is included in E waste. we have studied different types of E- Waste and have understood the sources of E-waste and also known that what are the processes and techniques required to manage waste. Together we have also studied some methods of collection and treatment of E-waste and how can manage the E-waste in other countries .After this we have also studied the recycling process and benefits .and also studied the E-waste management in India.

8.14. Terminal Questions

Q.1: Explain what is E-waste? Its type and also explain the sources of E- waste?

Answer: --

Q.2: Write recycling process of E- Waste in detail and also explain the benefits of E-waste recycling?

Answer: --

Q.3: Describe components of E- Waste that can be recycled?

Answer: --

Q.4: Describe E- Waste management in detail?

Answer: --

Q.5: What is the collection and treatment of E-waste in different countries?

Answer: --

Q.6: Explain reduce, reuse and repair of E- Waste?

Answer: --

8.15.Suggested book readings

1. "E-Waste Management: From Waste to Resource" by Ravi Jain and S. K. Dhameja (Springer)
2. "E-Waste Management: Research, Technology and Applications" edited by MajetiNarasimhaVara Prasad (Elsevier)
3. "E-Waste Management and Recycling" by sDr. NnamdiAnyadike (CRC Press)
4. "Electronic Waste Management: Design, Analysis and Application" by Shahriar Khan and Kunal Pal (Wiley)
5. "E-waste Recycling and Management: Present Scenarios and Environmental Challenges" edited by Ram NareshBharagava and PankajChowdhary (Elsevier)

Unit-9: Resource Recovery

9.1. INTRODUCTION

This unit covers all type of waste and its management.Waste is a product or substance which is no longer suited for its intended use. Generally waste is classified on the basis of matter, feature, environmental impact and sources.In this chapter some green techniques of solid waste management like reduce, reuse, and recycling andthe benefits of recycling waste. Garbage disposals and solid waste management techniques such as composting process, anaerobic digestion process.Reductivedehalogenation structure and mechanism also study bioremediation in detail. At the last we can study of importance of 4r's reduce, reuse, recycle and recover.

Objectives:

- To understand the waste and it's type.
- To study solid waste management.
- To understand biological waste and management.
- To understand composting and its types and techniques.
- To study of anaerobic digestion and its process stages.
- To study of Reductive dehalogination and bioremediation.
- To understand importance of 4r's reduce, reuse, recycle and recover.

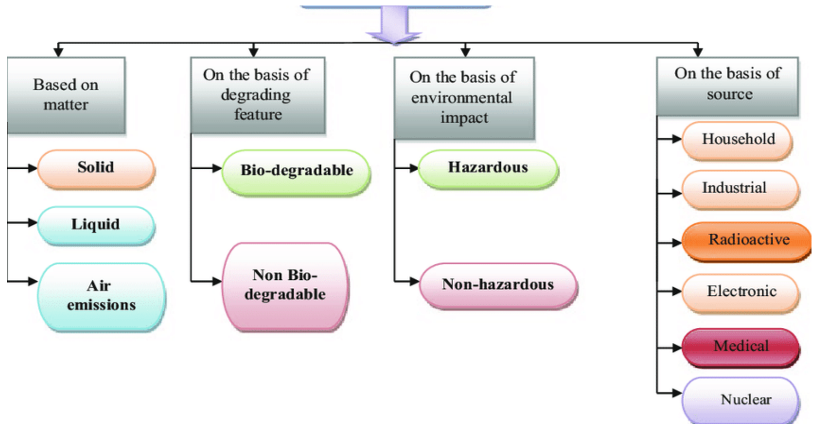
9.2. Overview of waste

Waste is defined as unwanted and unusable materials and is regarded as a substance which is of no use. Waste that we see in our surroundings is also known as garbage. Garbage is mainly considered as a solid waste that includes wastes from our houses (domestic waste), wastes from schools, offices, etc (municipal wastes) and wastes from industries and factories (industrial wastes).

Waste can have negative impacts on the environment, public health, and the economy if not properly managed. Proper waste management involves the reduction, reuse, recycling, and safe disposal of waste, in accordance with environmental and health regulations. The goal of waste management is to minimize the amount of waste generated and to prevent harm to the environment and human health.

9.3. Classification of waste

Waste can be classified on the following basis



1.On the basis of matter

a) solid waste

A "solid waste" is defined as any discarded material that is abandoned by being disposed of, burned or incinerated, recycled or considered "waste-like." A solid waste can physically be a solid, liquid, semi-solid, or container of gaseous material.

b) **liquid waste**

Liquid waste can be defined as such Liquids as wastewater, fats, oils or grease (FOG), used oil, liquids, solids, gases, or sludges and hazardous household liquids. These liquids that are hazardous or potentially harmful to human health or the environment

2.**On the basis of degrading features**

a) Biodegradable waste

These are the wastes that come from our kitchen and it includes food remains, garden waste, etc. Biodegradable waste is also known as moist waste. This can be composted to obtain manure. Biodegradable wastes decompose themselves over a period of time depending on the material.

b) Non-biodegradable waste

These are the wastes which include old newspapers, broken glass pieces, plastics, etc. Non-biodegradable waste is known as dry waste. Dry wastes can be recycled and can be reused. Non-biodegradable wastes do not decompose by themselves and hence are major pollutants.

3.On the basis of Environmental impacts

a) Hazardous waste

Hazardous waste is waste that has been identified as potentially causing harm to the environment and human health and therefore needs special, separate treatment and handling. Flammability, corrosiveness, toxicity, ecotoxicity and explosiveness are the main characteristics of hazardous waste.

(i)E-waste is waste from electric and electronic equipment such as end-of-life computers, phones and home appliances. E-waste is generally classified as hazardous because it contains toxic components (e.g. PCB and various metals).

(ii)Medical waste originates from the human and animal healthcare systems and usually consists of medicines, chemicals, pharmaceuticals, bandages, used medical equipment, bodily fluids and body parts. Medical waste can be infectious, toxic or radioactive or contain bacteria and harmful microorganisms (including those that are drug-resistant).

(iii)Radioactive waste contains radioactive materials. The management of radioactive waste differs significantly from that of other waste.

(iv)Household hazardous waste

As the name indicates, household hazardous wastes are hazardous solid wastes that are generated in small amounts by individual households across the nation. This category includes various household cleaners, paints, solvents and other chemicals. Some of the items in this category, such as batteries, light bulbs and pesticides, are also considered universal waste.

b) Non-hazardous waste

Non-hazardous wastes, which comprise the other category of solid waste, are solid wastes that do not meet the Resource Conservation and Recovery Act (RCRA) and are not subject to RCRA Subtitle C regulations. However, it is not safe to assume that waste classified as "non-hazardous" poses no risk. This category is further subdivided into municipal solid waste and industrial waste.

(i)Municipal solid waste

Municipal solid waste is a broad category of non-hazardous solid waste that includes animal carcasses as well as the typical garbage or trash.

(ii)Agricultural solid waste

Agricultural solid waste is a subcategory of municipal solid waste and is waste that is generated by the rearing of animals and the production or harvesting of crops or trees. This category includes animal waste and animal carcasses.

(iii)Industrial solid waste

Industrial solid waste is a second subcategory of non-hazardous solid waste and includes solid waste generated by industrial processes and manufacturing. This category also includes medical waste and regulated medical waste, which are particularly relevant for veterinarians.

(iv)Medical waste/Regulated medical waste

Medical waste is industrial solid waste "generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals" according to the Medical Waste Tracking Act of 1988. Depending on the situation, this category may include potentially infectious animal wastes, bedding, carcasses or tissues.

Regulated medical waste, more typically known as "biohazard" or "infectious" waste, includes

Equipment, instruments, utensils, and fomites (any substance that may harbor or transmit pathogenic organisms) and Laboratory wastes etc.

9.4. Sources of Waste

Sources of waste can be broadly classified into four types: Industrial, Commercial, House hold , and Agricultural.

a) **Industrial Waste**

These are the wastes created in factories and industries. Most industries dump their wastes in rivers and seas which cause a lot of pollution. Example: plastic, glass, etc.

b) **Commercial Waste**

Commercial wastes are produced in schools, colleges, shops, and offices.Example: plastic, paper, etc.

c) **Household Waste**

The different household wastes which are collected during household activities like cooking, cleaning, etc. are known as domestic or Household wastes.Example: leaves, vegetable peels, excreta, etc.

d) **Agricultural Waste**

Various wastes produced in the agricultural field are known as agricultural wastes.Example: cattle waste, weed, husk, etc.

9.5. Solid Waste Management

The term solid waste management mainly refers to the complete process of collecting, treating and disposing of solid wastes.

In the waste management process, the wastes are collected from different sources and are disposed of. This process includes collection, transportation, treatment, analysis and disposal of waste. It needs to be monitored so that strict regulations and guidelines are followed

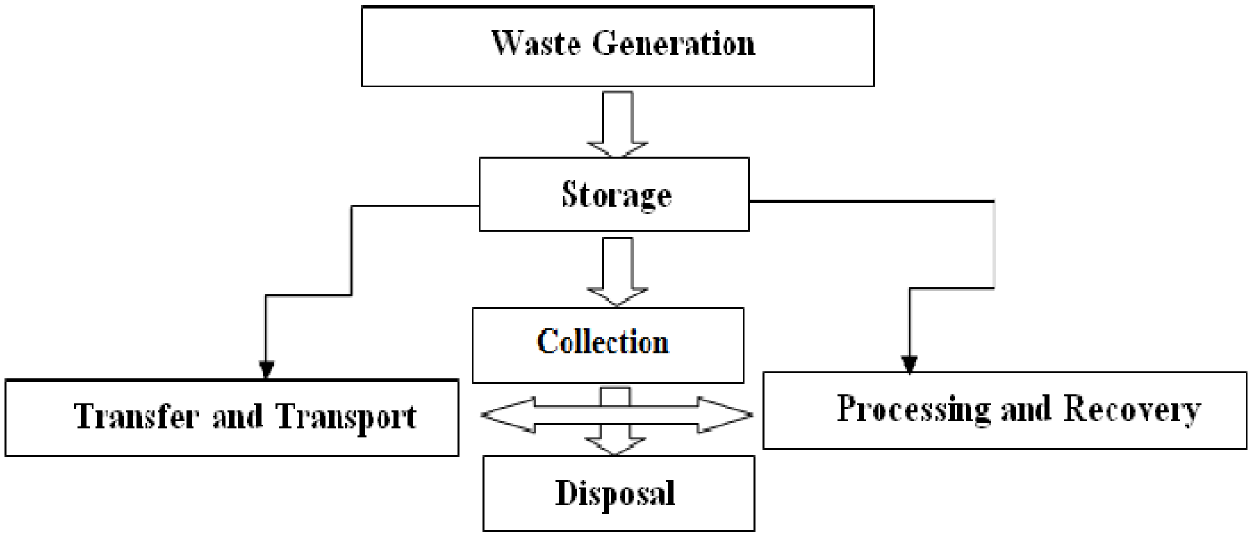


Figure: Solid Waste Management Diagram

9.5.1 Waste Management collection system

Steps of waste management

Essentially there are up to five basic alternatives for collection systems, depending upon the level of effort required from the waste generators. These are described below:

i. Community Bins

This is by far the most common collection method in all developing countries, particularly in Pakistan. The planning and organization of waste collection is greatly simplified by the use of large communal storage sites or bins. Although the use of large communal sites may seem to be a fairly inexpensive and simple solution, it may transfer much of the burden of waste collection onto the street cleaning service and actually increase total costs. This may be due to:

Indiscriminate dumping of waste in streets and drains by residents who have to walk too far to communal sites or those who refuse to cooperate;

Humans and animals scavenging from these sites may spread waste around the area of the site which then has to be swept and re-collected;

Waste may be scattered during unloading of bins and carts and during loading of larger secondary collection vehicles.

It is less expensive to collect waste directly from a residence or business than to sweep it up from the streets. The use of large, widely spaced communal storage sites generally fails because the demand placed on the waste generator goes beyond his willingness to cooperate. If communal storage sites are going to be used, the storage points should be at intervals convenient to the generators and should be designed so that waste is deposited into containers at that site to facilitate secondary collection. This is often a problem in densely constructed areas, where finding an optimal space for large communal bins could pose a problem.

ii. Block collection

This is essentially the same system as above with the exception that no community bins are provided. Instead, a collection vehicle travels a regular route at an agreed frequency (two to three times per week or daily, to a set schedule). The vehicle stops at all street intersections and a bell is rung. At this signal the residents of all the streets leading from that intersection bring their waste containers to the vehicle and hand them to the crew to be emptied. A number of variations to this scheme may be operated, but the common theme is that householders are requested to use waste containers (owner containers) which are kept in the house and brought out to the waste collectors at prearranged and scheduled times. In some cases, standardized owner containers are provided by the municipality, although the cost implications of this standardization need to be carefully considered.

iii. Curbside collection

This system of collection requires a regular service and a fairly precise schedule. Residents must place their containers (set-out containers) on the curb before the time of collection and remove the containers after they have been emptied. It is important that the containers are of a standard type. Observations in local areas revealed lack of use of any kind of containers, instead it is likely that wastes will be set out in any type of container such as plastic bags, baskets, cardboard boxes, or even in piles. Under these conditions the wastes may be scattered by animals and wind, thus making the collection process very inefficient. Some of the problems commonly encountered with curbside collection include spilling of the contents of the containers to allow sorting by waste pickers, the containers may either be stolen, overturned by animals, or left on the street for long periods of time.

iv. Door to door collection

In this system the householder does offer minimal participation in the collection process. The collector rings a bell or knocks at the door of each house and waits for an occupant to bring the waste to the door. Often the cart makes enough noise for the residents to be ready with their containers on arrival. The collector collects the waste container from each house, carries it to the vehicle, empties it and returns it to the house. This system is costly in terms of labour because of the high proportion of time spent walking from one dwelling to the next. However, in low-income countries where labour is relatively inexpensive, this may form a satisfactory system. This is, in some ways, a combination of several of the basic systems described above.

v. Contracted or Delegated Service

Residential societies or markets (or a union of shopkeepers in a market) hire firms (or municipalities with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private operators and may designate collection areas to encourage collection efficiencies, by creating a competition for efficient and economical solid waste collection.

9.5.2. Waste segregation

This is the separation of wet waste and dry waste. The purpose is to recycle dry waste easily and to use wet waste as compost. When segregating waste, the amount of waste that gets landfilled reduces considerably, resulting in lower levels of air and water pollution. Importantly, waste segregation should be based on the type of waste and the most appropriate treatment and disposal. This also makes it easier to apply different processes to the waste, like composting, recycling and incineration. It is important to practice waste management and segregation as a community. One way to practice waste management is to ensure there is awareness. The process of waste segregation should be explained to the community.

Segregated waste is also often cheaper to dispose of because it does not require as much manual sorting as mixed waste. There are a number of important reasons why waste segregation is important such as legal obligations, cost savings and protection of human health and the environment. Institutions should make it as easy as possible for their staff to correctly segregate their waste. This can include labelling, making sure there are enough accessible bins and clearly indicating why segregation is so important. Labeling is especially important when dealing with nuclear waste due to how much harm to human health the excess products of the nuclear cycle can cause.

9.5.3 Transportation of waste

The collection, transfer and disposal of solid waste requires a significant investment in waste management equipment and vehicles, as well as the infrastructure that allows this machinery to function effectively. Consequently, transportation of the waste itself takes up most of the total budget for solid waste management and can be a big financial commitment for many short-haul waste transporters.

From the dump trucks and front-end roll-off containers to wheel loaders, excavators and other heavy equipment, there are many ways to move and manage your solid waste. In this article, we'll discuss solid waste transportation methods you should incorporate into your waste management plan, including the types of transportation most commonly used to move solid waste, and solid waste transportation best practices.

Types of Solid Waste Transportation

Our customers use a variety of trucks, trailers, tanks and heavy-duty equipment to reliably manage their waste hauling operations. These are just a few of the most commonly used waste management vehicles and pieces of equipment.

i. Dump Trucks and Trailers

Perhaps the vehicle most commonly associated with the transportation of solid waste, dump trucks are used to collect waste and transport it to transfer stations, or directly to the landfills and recycling plants to be unloaded. The trailers are generally made from either aluminum or steel, and rely on hydraulic systems to unload waste from the trucks.

ii. Landfill Tippers

Using self-contained hydraulic power units to raise themselves, tippers can be coupled with a truck or trailer to unload solid waste at landfills. Not to be confused with dump trailers, tippers are separate units that connect to the trailers on the trucks. Dump trailers, on the other hand, are heavy duty chassis with open-body tops where the body can be tipped up to unload the waste.

iii. Storage and Treatment Tanks

Used to store large volumes of waste, tanks are durable and versatile, able to hold most waste types. Waste storage tanks must meet specific regulatory requirements to ensure structural integrity, and they must be well-maintained through inspections and leak tests to prevent corrosion, ruptures or other unit failures.

iv. Heavy Equipment

Heavy equipment consists of the robust waste loading equipment like steer loaders, wheel loaders and hydraulic excavators, as well as waste handling equipment, such as compactors and rollers, sifting machines, crushers, shredders and wheel dozers. All heavy equipment should be durable and able to handle a range of solid waste material types, from construction waste to municipal waste or hazardous waste.

v. Walking Floor Trailers

Also powered by hydraulic systems, walking floor trailers are great for collecting waste from those difficult-to-reach places like tunnels, building interiors and sites located on uneven ground. Once transported to the landfills, the waste can be “walked” off the back of the trailer using moving floor slats, saving you the time and effort of having to use bulky unloaded equipment.

vi. Bulk Pneumatic Tanker

Vacuum-sealed to prevent contamination by moisture, dirt or germs, pneumatic tankers are most often used to transport materials such as food, chemicals or even contaminated soil.

Solid Waste Transportation Best Practices

Just as there are best practices regarding the collection, storage, and disposal of municipal solid waste and other solid waste types, there are also best practices for the transportation of solid waste between waste management facilities. For short-haul waste transporters, vehicle route planning is critical. These are just a few tips to help you with the optimization of municipal solid waste collection and transportation routes:

- Whether you use micro-routing to create a specific path for your drivers to take every day, or you use macro-routing to better balance your collection and transportation routes, your waste hauling routes shouldn't overlap.
- The largest waste-producing sources should be given higher priority during waste collection than the smaller sources.
- To keep the driver and vehicle workloads the same, collection and transport time should be equal on each route.
- All vehicles and equipment should all have regular cleaning and maintenance schedules in order to prevent the build up of odors or infestation from rodents or insects.
- Minimize the number of left-hand turns to improve safety outcomes and increase fuel efficiency.

9.5.4.Waste disposal methods

In general, waste should undergo material recycling or thermal treatment. If this is not possible for technical reasons, or it is not economically viable, the waste is deposited in a landfill following suitable treatment.The standard waste disposal methods are given below

9.5.4.1. Recycling

Recycling refers to both the direct reuse of used products (e.g. used clothing and functioning parts removed from used vehicles) and material recycling, that is the recovery of raw materials from waste (e.g. production of new glass from fragments, the melting of scrap iron and the production of recycled building materials from construction waste). Downcycling refers to the transformation of waste to materials of lower quality than the initially used material.The waste management routes for different categories of materials are described below:

Recycled construction materials, like gravel sand, concrete granulate and mixed granulate from demolition waste, can be produced from mineral construction waste or sludges from street cleaning through the separation of the impurities, crushing and classification in defined particle sizes. Reclaimed asphalt paving with a high tar content must undergo thermal pre-treatment.

Green waste can be processed into compost following quality control or be fermented with other biogenic waste, e.g. used cooking oil, to produce biogas.

Metal waste like scrap iron and steel, but also other metals like aluminum and copper from industry and households, is collected separately and, following pre-sorting, processed into crude metals at steelworks or metal works.

Waste glass, paper and paperboard, plastic waste, waste wood, waste oil and solvents are generated during production or as a result of consumption and use. Following separate collection, they are processed and reintroduced into the materials cycle.

Undamaged and functioning tyres and textiles are sorted from separately collected waste and sold as second-hand goods.Objects and devices with complex structures like used vehicles, electrical and electronic devices, batteries and discarded chemicals undergo several treatment steps. The aim is to strip the waste of hazardous substances and separate the recoverable fractions.

9.5.4.2. Incineration

Combustible waste from households and waste wood that is not suitable for recycling undergo thermal treatment in waste incineration plants or waste wood furnaces. The heat released in the process is used to generate electricity and heat buildings. Waste with a high calorific value and low level of pollutant contamination can be used in industrial plants, e.g. cement plants, as an alternative to fossil fuels. Waste that is contaminated with organic pollutants undergoes separate thermal treatment (e.g. in hazardous waste incineration plants). Incinerators must have a flue gas treatment system. The requirements for flue gas treatment and the incineration system are based on the nature of the waste.

Specialised waste disposal companies treat the waste in accordance with the requirements of the incineration plant. This guarantees that the fuel will be of a high quality and reduces the accident risk. The companies ensure, for example, that no undesirable reactions occur when liquids are mixed. Waste materials that are used as substitute fuels in cement plants must be crushed in advance and set at a constant calorific value.

9.5.4.3. Landfills

Residues from waste incineration or waste that is not suitable for material recycling or thermal treatment are deposited in landfills that are compliant with the legal requirements. If the waste does not fulfil the requirements for landfilling, it must be pre-treated.

There are five types of landfill which are identified by the letters A to E, representing an ascending scale of increased risk potential of the waste deposited there. Crucial for the authorisation of a landfill deposit are the total pollutant content (mg/kg dry matter) and also the eluate levels (mg/L) of the waste.

Type A landfills are meant for waste such as, for example, excavation and quarrying material where the presence of pollution can be excluded, as listed in the appendix to the Ordinance on Waste .

In Type B landfills, individually identified waste and other mineral wastes are permitted, as long as the requirements for threshold values and elute levels can be shown to be fulfilled .

Type C landfills are designated for the deposit of inorganic and difficult to dissolve waste and waste containing metals. That is mainly dependent on their previous treatment, for example, heat treatment, and the aim is to largely eliminate organic pollution .

Incineration residues such as waste incineration slag are typical of the types of waste permitted in **Type D**landfills .

In Type E landfills, finally, the range of waste is larger, although there is a strict maximum total content for organic material that must be adhered to. The individually listed types of waste may be deposited. Other types of waste are also permitted as long as they adhere to the fixed threshold values .

The phases of a landfill, its construction, operation and its maintenance are regulated in the Ordinance on Waste . A landfill concern which as a disposal facility accepts special waste or other notifiable types of waste requires a licence in accordance with the Ordinance on the Movement of Waste

9.5.4.4. Composting process and techniques

Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting.

Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil:

(i) becomes more resistant to stresses such as drought, diseases and toxicity;

(ii) helps the crop in improved uptake of plant nutrients; and

(iii) possesses an active nutrient cycling capacity because of vigorous microbial activity. These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers.

Types of composting

Composting may be divided into two categories by the nature of the decomposition process. In anaerobic composting, decomposition occurs where oxygen (O) is absent or in limited supply. Under this method, anaerobic microorganisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. In the absence of O, these compounds accumulate and are not metabolized further. Many of these compounds have strong odours and some present phytotoxicity. As anaerobic composting is a low-temperature process, it leaves weed seeds and pathogens intact. Moreover, the process usually takes longer than aerobic composting. These drawbacks often offset the merits of this process, viz. little work involved and fewer nutrients lost during the process.

A. Aerobic composting

It takes place in the presence of ample Oxygen. In this process, aerobic microorganisms break down organic matter and produce carbon dioxide (CO2), ammonia, water, heat and humus, the relatively stable organic end product. Although aerobic composting may produce intermediate compounds such as organic acids, aerobic microorganisms decompose them further. The resultant compost, with its relatively unstable form of organic matter, has little risk of phytotoxicity. The heat generated accelerates the breakdown of proteins, fats and complex carbohydrates such as cellulose and hemi-cellulose. Hence, the processing time is shorter. Moreover, this process destroys many micro-organisms that are human or plant pathogens, as well as weed seeds, provided it undergoes sufficiently high temperature. Although more nutrients are lost from the materials by aerobic composting, it is considered more efficient and useful than anaerobic composting for agricultural production. Most of this publication focuses on aerobic composting.

Composting objectives may also be achieved through the enzymatic degradation of organic materials as they pass through the digestive system of earthworms. This process is termed vermicomposting.the composting process lends itself to accepting material with a wide range of pH, the pH level should not exceed eight. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere.

Techniques for effective aerobic composting

Simple replication of composting practices does not always give the right answer to potential composters. This is because composting takes place at various locations and under diverse climates, using different materials with dissimilar physical, chemical and biological properties. An understanding of the principles and technical options and their appropriate application may be helpful in providing the optimal environment to the compost pile.

Improved aeration

In order to obtain the end product of uniform quality, the whole of the pile should receive a sufficient amount of O so that aerobic microorganisms flourish uniformly. The methodologies deliberated in this publication made use of the techniques as presented below.

Pile size and porosity of the material

The size of the pile is of great significance and finds mention in the sections on passive composting of manure piles and turned wind-rows . Where the pile or wind-row is too large, anaerobic zones occur near its centre, which slows the process in these zones. On the other hand, piles or wind-rows that are too small lose heat quickly and may not achieve a temperature high enough to evaporate moisture and kill pathogens and weed seeds. The optimal size of the piles and wind-rows should also consider such parameters as the physical property (porosity) of the materials and the way of forming the pile. While more porous materials allow bigger piles, heavy weights should not be put on top and materials should be kept as loose as possible. Climate is also a factor. With a view to minimizing heat loss, larger piles are suitable for cold weather. However, in a warmer climate, the same piles may overheat and in some extreme cases (75 °C and above) catch fire.

Ventilation

Provision of ventilation complements efforts to optimize pile size. Ventilation methods are varied. The simplest method is to punch holes in the pile at several points. The high temperature compost method of Chinese rural composting involves inserting a number of bamboo poles deep into the pile and withdrawing them a day later, leaving the pile with ventilation holes. Aeration is improved by supplying more air to the base of the pile where O deficiency occurs most often. In addition to the above-mentioned vertical poles, Ecuador on-farm composting uses a lattice of old branches at the base to allow more pile surface to come into contact with the air, and the composting period is reduced to two to three months in warm seasons. This technique is also practised in the rapid composting method developed by the Institute of Biological Sciences (IBS) in the Philippines , where the platform should be 30 cm above the ground. The passively aerated wind-rows method uses a more sophisticated technique. It entails embedding perforated pipes throughout the pile. As the pipe ends are open, air flow is induced and O is supplied to the pile continuously. The aerated static pile method takes this aeration system a step further; a blower generates air flow to create negative pressure (suction) in the pile and fresh air is supplied from outside.

Turning

Once the pile is formed and decomposition starts, the only technique for improving aeration is turning. As Table 1 shows, frequency of turning is crucial for composting time. While the Indian Bangalore method requires six to eight months to mature, the Indian Coimbatore method (turning once) reduces the time to four months, and the Chinese rural composting pit method (turning three times) reduces the time to three months. An extreme example is the Berkley rapid composting method, which employs daily turning to complete the process in two weeks. In some cases, turning not only distributes air throughout the pile, it also prevents overheating as it kills all the microbes in the pile and terminates decomposition. However, turning too frequently might result in a lower temperature.

Inoculation

While some composters find improved aeration enough for enhanced microbial activities, others may need inoculation of microorganisms. Inoculum organisms utilized for composting are mainly fungi such as Trichoderma sp. (IBS rapid composting and composting weeds andPleurotus sp. (composting Coir Pith and composting weeds). This publication also features 'effective microorganisms' (EMs) (EM-based quick compost production process . The inoculums are an affordable choice for those with access to the market and also for resource-poor farmers. The production cost could be reduced by using inoculums taken from compost pits (pit method of the Indian Indore method , by purchasing the commercial product and multiplying it on the farm (EM-based quick compost production process), and by utilizing native inoculums derived from soils or plant leaves.(37).

Supplemental nutrition

The techniques mentioned above often need to be complemented by the provision of nutrients. One of the most common practices is to add inorganic fertilizers, particularly N, in order to modify a high C:N ratio. Similarly, P is sometimes applied as the C:P ratio of the material mix is also considered important (the ratio should be between 75:1 and 150:1). When microorganisms are inoculated, they require sugar and amino acids in order to boost their initial activities; molasses is often added for this purpose

Benefits and drawbacks of composting

Composting offers a variety of economic and environmental benefits. When considering the benefits of composting, it is important to distinguish between composting, the “process” and compost. Although the benefits are numerous, composting can be a major undertaking, with associated costs and drawbacks . One cannot simply dump leaves on a hillside or pile manure behind the barn and expect to have compost several weeks later. A successful composting operation deserves the same planning and commitment given to other functions, like crop production or landscape maintenance. Although it is often integral to the other operations, composting should be viewed as an enterprise in its own right. Like any enterprise, a composter needs to consider the labor, physical infrastructure, financial resources, and time available to compost properly.

The benefits of on-farm composting.

(1)Economic benefits of composting and compost

a).Revenue from processing or “gate” fees.

b).Revenue from compost sales.

c).Production of a usable product; reduced costs of substitute inputs.

d).Increase in crop yields and plant production and quality.

d).Generation of an animal bedding substitute.

e).Destruction of weed seeds; reduce herbicide costs.

f).Reduction in waste disposal costs.

g).Expansion of outlets for organic residuals.

(2)Environmental benefits of composting and compost

a) Improved soil health and plant vigor

b) Retention of soil nutrients.

c) Water conservation.

d) Plant disease suppression; reduction in pesticide use.

e) Erosion control.

f).Destruction of human, animal, and plant pathogens.

g).Decomposition of hormones, antibiotics, and pesticides.

g).Treatment of animal mortalities.

h).Lower environmental impacts from compost versus raw feedstocks.

i).Reduction of greenhouse gas emissions.

Drawbacks

- Upfront and sustained investments in time and money
- Land requirement (and possibly building space)
- Odor and other nuisance complaints
- Management in unfavorable weather
- Diversion of manure and crop residues from crops if compost is sold off-farm
- Potential loss of nitrogen and generation of methane under anaerobic conditions
- Slow release of plant nutrients in finished product

- Variable levels of plant-available nitrogen
- Zoning risk of being considered a commercial enterprise (rather than a farm)
- Need for environmental permits and adherence to regulations

B. Anaerobic Digestion

Anaerobic digestion is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste or to produce fuels. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion

Anaerobic digester system

Anaerobic digester system in Germany

Anaerobic digestion occurs naturally in some soils and in lake and oceanic basin sediments, where it is usually referred to as "anaerobic activity". This is the source of marsh gas methane as discovered by Alessandro Volta in 1776.

The digestion process begins with bacterial hydrolysis of the input materials. Insoluble organic polymers, such as carbohydrates, are broken down to soluble derivatives that become available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. In acetogenesis, bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide amongst other compounds. Finally, methanogens convert these products to methane and carbon dioxide. The methanogenicarchaea populations play an indispensable role in anaerobic wastewater treatments.

Anaerobic digestion is used as part of the process to treat biodegradable waste and sewage sludge. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.

Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide, and traces of other 'contaminant' gases. This biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas-quality biome thane. The nutrient-rich digestate also produced can be used as fertilizer.

With the re-use of waste as a resource and new technological approaches that have lowered capital costs, anaerobic digestion has in recent years received increased attention among governments in a number of countries, among these the United Kingdom and the United States.

Many microorganisms affect anaerobic digestion, including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). These organisms promote a number of chemical processes in converting the biomass to biogas.

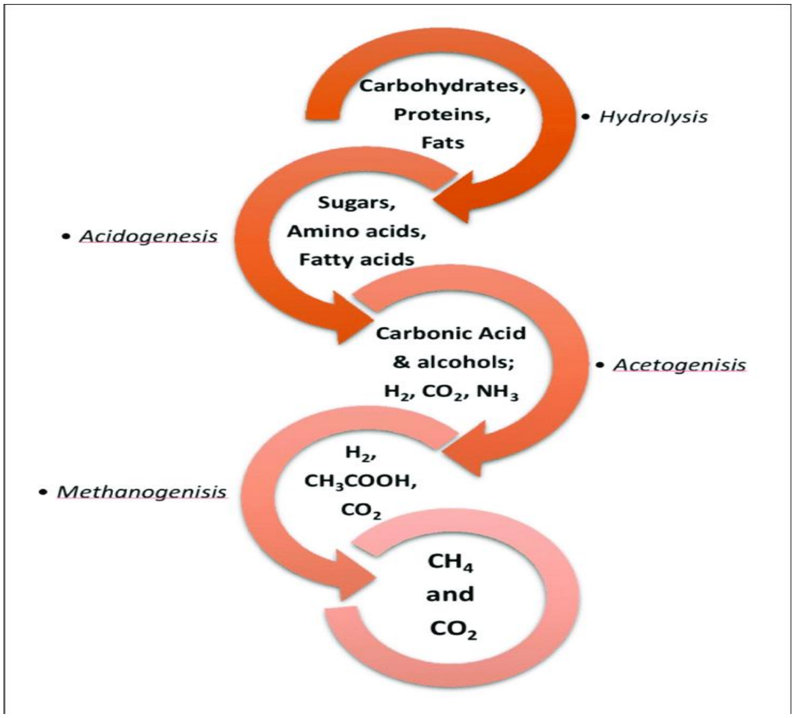
Gaseous oxygen is excluded from the reactions by physical containment. Anaerobes utilize electron acceptors from sources other than oxygen gas. These acceptors can be the organic material itself or may be supplied by inorganic oxides from within the input material. When the oxygen source in an anaerobic system is derived from the organic material itself, the 'intermediate' end products are primarily alcohols, aldehydes, and organic acids, plus carbon dioxide. In the presence of specialized methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide, and trace levels of hydrogen sulfide. In an anaerobic system, the majority of the chemical energy contained within the starting material is released by methanogenicarchaea as methane.

Populations of anaerobic microorganisms typically take a significant period of time to establish themselves to be fully effective. Therefore, common practice is to introduce anaerobic microorganisms from materials with existing populations, a process known as "seeding" the digesters, typically accomplished with the addition of sewage sludge or cattle slurry.

Process stages

The four key stages of anaerobic digestion involve hydrolysis, acidogenesis, acetogenesis and methanogenesis. The overall process can be described by the chemical reaction, where organic material such as glucose is biochemically digested into carbon dioxide (CO_2) and methane (CH_4) by the anaerobic microorganisms.

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$



Hydrolysis

In most cases, biomass is made up of large organic polymers. For the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts, or monomers, such as sugars, are readily available to other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis. Therefore, hydrolysis of these high-molecular-weight polymeric components is the necessary first step in anaerobic digestion. Through hydrolysis the complex organic molecules are broken down into simple sugars, amino acids, and fatty acids.

Acetate and hydrogen produced in the first stages can be used directly by methanogens. Other molecules, such as volatile fatty acids (VFAs) with a chain length greater than that of acetate must first be catabolized into compounds that can be directly used by methanogens.

Acidogenesis

The biological process of acidogenesis results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created, along with ammonia, carbon dioxide, and hydrogen sulfide, as well as other byproducts.The process of acidogenesis is similar to the way milk sours.

Acetogenesis

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as carbon dioxide and hydrogen.

Methanogenesis

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here, methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. These components make up the majority of the biogas emitted from the system. Methanogenesis is sensitive to both high and low pHs and occurs between pH 6.5 and pH 8. The remaining, indigestible material the microbes cannot use and any dead bacterial remains constitute the digestate.

9.6. Reductive dehalogenation

Reductive dehalogenases are a group of enzymes utilized in organohalide respiring bacteria. These enzymes are mostly attached to the periplasmic side of the cytoplasmic membrane and play a central role in the energy-conserving respiratory process for organohalide respiring bacteria by reducing organohalides. During such reductive dehalogenation reactions, organohalides are used as terminal electron acceptors. They catalyze the following general reactions:

$$R\text{-}X + 2\,e^- + 2\,H^+ \rightarrow R\text{-}H + H\text{-}X$$

$$X\text{-}RR\text{-}X + 2\,e^- + 2\,H^+ \rightarrow R{=}R + 2X^-$$

These membrane-associated enzymes have attracted great interest for the detoxification of organohalide pollutants. Organohalide pollution is a serious global environmental issue affecting soil and groundwater; and reductive dehalogenases offer a promising natural tool for bioremediation.

Structure and mechanism

Reductive dehalogenases are related to the cobamide (or vitamin B12) family of enzymes. They contain a cobalamin at its catalytic active site, where actual reductive reaction occurs. They also harbor iron− sulfur clusters that supply the reducing equivalents.[60][62] All membrane-associated dehalogenases harbor a N-terminal twin-arginine (TAT) signal sequence (RRXFXK), which is a conserved signal peptide for membrane protein translocation. Monomeric as well as dimeric forms were previously reported.

Enzymatic mechanism is still understudied; however, several studies reported various mechanisms involving an organocobalt adduct, a single-electron transfer, and a halogen–cobalt bond.

Common reductive dehalogenases studied

Reductive dehalogenases from Dehalobacter species

Chloroform reductive dehalogenases: TmrA and CfrA

Reductive dehalogenases from Dehalococcoides species

Vinyl chloride reducing VcrA

Hexachlorobenzene degrading CbrA

Reductive dehalogenases from Desulfitobacterium species

Perchloroethylene and trichloroethylene degrading PceA

Production methods

Native enzymes

The examples are those that can dechlorinatechloroform , PCE , TCE , and VC . Purification of such enzymes in native forms are reportedly difficult; however, a few such enzymes were purified to near homogeneity.Ultracentrifugation, membrane solubilization and a series of liquid chromatography are the commonly employed techniques to the isolation and purification. A chloroform reducing dehalogenase is the latest reductive dehalogenase that was successfully produced and purified

Heterologous expressions

The researchers in the field had turned their interest to heterologous expression of the same enzymes due to difficulties in obtaining these enzymes in the native form. Only recently have a few recombinant reductive dehalogenases been functionally expressed, bringing the dehalogenase research into next levels. Those successful efforts facilitate further investigations on their biochemical and structural properties.

The first membrane-associated respiratory reductive dehalogenase was heterologously expressed in a soluble and active form and purified using Bacillus megaterium.

Uses in bioremediation

In recent years, research on reductive dehalogenases have attracted great interest from both academic and industrial researchers for their potential application in bioremediation of organohalide contamination.

9.7. Mechanical Biological Treatment

A mechanical biological treatment (MBT) system is a type of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial wastes.

Process

The terms mechanical biological treatment or mechanical biological pretreatment relate to a group of solid waste treatment systems. These systems enable the recovery of materials contained within the mixed waste and facilitate the stabilisation of the biodegradable component of the material. Twenty two facilities in the UK have implemented MBT/BMT treatment processes.

The sorting component of the plants typically resemble a materials recovery facility. This component is either configured to recover the individual elements of the waste or produce a refuse-derived fuel that can be used for the generation of power.

The components of the mixed waste stream that can be recovered include:

Ferrous metal

Non-ferrous metal

Plastic

Glass

Terminology

MBT is also sometimes termed biological mechanical treatment (BMT), however this simply refers to the order of processing (i.e., the biological phase of the system precedes the mechanical sorting). MBT should not be confused with mechanical heat treatment (MHT).

Mechanical sorting

The "mechanical" element is usually an automated mechanical sorting stage. This either removes recyclable elements from a mixed waste stream (such as metals, plastics, glass, and paper) or processes them. It typically involves factory style conveyors, industrial magnets, eddy current separators, trommels, shredders, and other tailor made systems, or the sorting is done manually at hand picking stations. The mechanical element has a number of similarities to a materials recovery facility (MRF).

Some systems integrate a wet MRF to separate by density and flotation and to recover and wash the recyclable elements of the waste in a form that can be sent for recycling. MBT can alternatively process the waste to produce a high calorific fuel termed refuse derived fuel (RDF). RDF can be used in cement kilns or thermal combustion power plants and is generally made up from plastics and biodegradable organic waste. Systems which are configured to produce RDF include the Herhof and Ecodeco processes. It is a common misconception that all MBT processes produce RDF; this is not the case, and depends strictly on system configuration and suitable local markets for MBT outputs.

9.8. Bioremediation

Bioremediation is the process of removing or utilizing the pollutants from a particularly polluted area (like soil, municipal water tanks or sewage water, oil spills in water, or land) with the help of microorganisms like bacteria, fungi and also plants. It is a type of biotechnical waste management method which uses no harmful chemicals and, in order, protects the Earth and promotes a sustainable environment.

Bioremediation by keeping environmental pollution in mind. Pollution has grown rapidly in the past years due to rising anthropogenic activities. Our expert's team showcases bioremediation as an appealing and good technique for cleaning and removing toxic material from the contaminated environment has explained superbly how bioremediation is highly useful in eradicating, detoxifying, degrading, or immobilizing varied physical dangerous material or other chemical wastage from our surroundings using the actions of the microorganisms. In the next few paragraphs, it would be interesting for you to know how beautifully this entire process works for removing toxic elements from the atmosphere.

Process of Bioremediation

The microorganisms used in the Bioremediation process degrade the pollutants and convert them into a non-toxic substance or form. The process begins when microorganisms like bacteria, fungi, and small plants, which are used to extract the pollutants, come in contact with the contaminants like oil, etc. The microbes use the contaminants as food. To start the process of bioremediation, the microorganisms need a suitable environment to thrive and do their job. Ideal environment conditions consist of a balanced temperature, availability of moisture, proper levels of surface pH. After the microorganisms are comfortable in their surroundings, they use the contaminants as a source of food. To break down the food consumed, the microbes secrete enzymes, which degrade the contaminants into nutrients. The result of the process ends up with byproducts, which are water, carbon dioxide, and non-toxic acids.

The toxic elements do not singly affect the environment but it causes climate change in several ways. First of all, it traps heat, which contributes to the birth of several respiratory diseases due to air pollution and smog. Apart from this, disruptions in the food supply, extreme weather conditions, and increasing wildfires are the issues that are primarily happening due to greenhouse gases.

Types of Bioremediation

Microbial Remediation

This type of bioremediation process is done with the help of microorganisms which convert the organic contaminants or metallic contaminants into more chemically inactive forms. The microorganisms break down the compounds and metabolize them. Aerobic bacteria need an oxygen source, and the byproducts at the end of the process are typically water, salts, and carbon dioxide. Anaerobic processes of bioremediation are carried out in the absence of oxygen, and the byproducts of this process are typical, i.e., methane gas, sulfides, hydrogen gas, elemental sulfur.

Phytoremediation

Phytoremediation is another type of bioremediation that helps eliminate contaminants with the help of plants by repairing and regenerating the soil and ground and surface water. The plants used in the process disseminate the toxic material from the soil and hold on to them within their plant tissues and constrain them until they are broken down at the roots. The plants work by pulling up the contaminants with their roots, which accumulates in the stems. Plants take up the dangerous chemicals from the soil and release them into the air through transpiration and evaporation by the air. A few pollutants which the plants can clean up are metals, pesticides, chlorinated solvents, polychlorinated biphenyls, and petroleum hydrocarbons. Some plants which can be used for phytoremediation are Indian Mustard, Indian Grass, Brown mustard, Sunflower plants, Barley Grass, Pumpkin, Poplar trees, Pine trees, and White Willows. These have rejuvenating and revitalizing characteristics which help the process.

Mycoremediation

Fungi are known as nature's decomposers. They break down most of the Earth's plant and hard woody material, resulting in the regeneration of the soil. Fungi use their metabolic enzymes to decompose chemicals like metals and varied types of pesticides. Fungi acts as a catalyst for microorganisms and plants by breaking down the larger hydrocarbon chains into smaller pieces, thereby making their process easy. The fungi suck up the chemicals by breaking them down with the help of enzymes and then store the nutrients in the fleshy parts, which are known as mushrooms.

Bioremediation of Wastewater

The bioremediation of wastewater is an important part of bioremediation. The sewage water can be treated by the processes of bioaugmentation and intrinsic bioremediation. The process is done with the help of microorganisms, which can reach any parts of the contaminated places like municipal water tanks. The aerobic microbes are used in these processes, and the water is aerated to provide oxygen for the bacteria to thrive and grow. The bacteria consume the organic contaminants and mould the less soluble parts. The byproduct of this process is nitrogen gas, which is later released into the atmosphere.

It is up to the situation or the availability of the resources that which one fits well. All of them have their unique attributes. Along with these, people have also explored a few more methods such as incineration, landfill burial, treatment with the use of chemicals, managing solid waste, managing nuclear waste, and more.

If we talk about the pillars of bioremediation, then fungi and bacteria top the chart. Bacteria are said to be the most important microbes for executing this entire process as these help in breaking the waste material into organic and nutritional matters. Without this, it is considered that bioremediation will not be sufficient to kill pollutants completely. Similarly, bacteria can consume pollutants such as chlorinated pesticides.

Advantage and disadvantage

All bioremediation techniques have their own advantages and disadvantages because they have their own specific applications.

The advantage of bioremediation

It is a natural process; it takes a little time, as an adequate waste treatment process for contaminated material such as soil. Microbes able to degrade the contaminant, the biodegradative populations become reduced. The treatment products are commonly harmless including cell biomass, water and carbon dioxide.

It needs very little effort and can commonly be carried out on site, regularly without disturbing normal microbial activities. This also eradicates the transport amount of waste off site and the possible threats to human health and the environment.

It is functional in a cost effective process as compared to other conventional methods that are used for clean-up of toxic hazardous waste regularly for the treatment of oil contaminated sites. It also supports complete degradation of the pollutants; many of the toxic hazardous compounds can be transformed to less harmful products and disposal of contaminated material.

It does not use any dangerous chemicals. Nutrients, especially fertilizers, are added to make active and fast microbial growth. Because bioremediation changes harmful chemicals into water and harmless gases, the harmful chemicals are completely destroyed.

Simple, less labor intensive and cheap due to their natural role in the environment.

Contaminants are destroyed, not simply transferred to different environments.

Nonintrusive, possibly allowing for continued site use.

Current way of remediating the environment from large contaminates and acts as eco friendly sustainable opportunities.

The disadvantage of bioremediation

It is restricted for biodegradable compounds. Not all compounds are disposed of in a quick and complete degradation process.

There are particular new products of biodegradation that may be more toxic than the initial compounds and persist in the environment.

Biological processes are highly specific, eco-friendly which includes the presence of metabolically active microbial populations, suitable environmental growth conditions and availability of nutrients and contaminants.

It is demanding to encourage the process from bench and pilot-scale to large-scale field operations. Contaminants may be present as solids, liquids and gases. It often takes longer than other treatment preferences, such as excavation and removal of soil or incineration.

Research is needed to develop and engineer bioremediation technologies that are appropriate for sites with complex mixtures of contaminants that are not evenly dispersed in the environment.

9.9. Green techniques of solid waste management

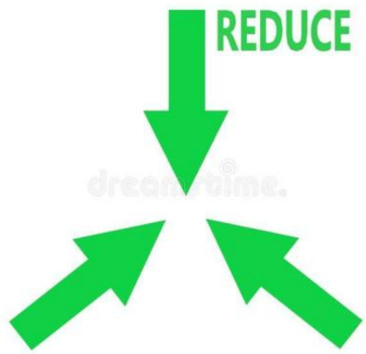
Solid waste management is a comprehensive discipline, including controlling the waste generation, storage, transfer, and disposal in the best way for public health. While the benefits of solid waste management have been realized all over the world, now it's time for eco-friendly methods to swell. Using these techniques, we can save our precious environment in many ways**4rs(importance of Reduce, Reuse, Recycle, and Recover)**

a. REDUCE

Out of all 3 priorities 'Reduce, Reuse & Recycle' the most effective and preferred method is the first step; which is to Reduce and avoid waste altogether. If we consider the energy required to produce products and the energy utilized in the recovery process, it is clear that the most efficient process in resource recovery is to 'avoid unnecessary consumption' as outlined by the Environmental Protection Authority (EPA).

An example of reduction and avoidance of waste can be experienced in supermarkets and retail outlets across Australia with the ban on single-use plastic bags being introduced. With a reported estimate of 1.5 billion bags prevented from landfill by December 2018 alone, it is evident that reduction and avoidance in the first place is the most powerful method of resource recovery.

Symbol of Reduce



https://www.dreamstime.com/computer-generated-illustration-image-reduce-symbol-representing-reduction-usage-new-materials-goods-green-image237908264

Reduce waste at the source

Reduction at the source is the simplest and least expensive method of reducing the amount of waste buried in Israel's landfills. Reducing waste refers to any action related to the design, manufacture, purchase or use of materials or products that can lead to a reduction in the amount of waste generated in the first place, and a reduction in the toxicity of that waste before it enters the system.

Reduction at-source is at the top of the waste treatment hierarchy, because from an environmental point of view, the best treatment for waste is its prevention.

How can we reduce the amount of waste generated?

Do not use disposable products

Be a proportionate and wise consumer

Buy products without unnecessary packaging, as much as possible

Repair and reuse products instead of throwing them out and buying new ones

Buy second-hand products and clothing

Manufacturers can make more products that are more durable and less toxic

The Plastic Bag Law has already prevented the unnecessary consumption and disposal (or in many cases, littering) of millions of tons of plastic bags

Challenges to reducing waste

Cost:

The main costs associated with reduction at the source are incurred from research, collection of data, management of waste systems, product design, passage of relevant legislation, education/raising awareness, and advocacy. These are much lower, however, than the costs of treating waste after it is generated.

Difficulty in quantifying results:

It is difficult to define and quantify something that has not yet been produced. Therefore, it is difficult to show the results of reduction at the source. It is much simpler to explain the benefits of recycling 30 tons of plastic – which can be seen – than to prevent the production of 30 tons of packaging material.

Difficulty in changing attitudes and behaviors: A reduction at-source system relies on a change in attitude and behavioral patterns. This change is required both from the citizens – who would have to purchase and consume fewer products – as well as at the level of decision makers, who could, for example, create legislation that would incentivize people to consume less, or manufacturers to produce less packaging.

Multitude of stakeholders:

Reduction-at-source requires the involvement of all stakeholders, including government, manufacturers, institutions, businesses, and private consumers.

b. REUSE

Reuse is the action or practice of using an item, whether for its original purpose (conventional reuse) or to fulfill a different function (creative reuse or repurposing). It should be distinguished from recycling, which is the breaking down of used items to make raw materials for the manufacture of new products. Reuse – by taking, but not reprocessing, previously used items – helps save time, money, energy and resources. In broader economic terms, it can make quality products available to people and organizations with limited means, while generating jobs and business activity that contribute to the economy.

https://www.alamy.com/green-reuse-symbol-image209980056.htm

Reusing tin cans as planters

Reusing tin cans as planters

Reuse refers to using products more than once, for the same purpose. Reusing products is a good way to reduce the amount of waste generated, and ultimately landfilled. It is also a good way to save money.

Examples of reuse of products:

Refilling beverage bottles Buying and selling or donating products from and to second-hand stores Taking books and other products out of libraries.

c.RECYCLING

Recycling is the process of converting waste materials into new materials and objects. The recovery of energy from waste materials is often included in this concept. The recyclability of a material depends on its ability to reacquire the properties it had in its original state.[33] It is an alternative to "conventional" waste disposal that can save material and help lower greenhouse gas emissions. It can also prevent the waste of potentially useful materials and reduce the consumption of fresh raw materials, reducing energy use, air pollution (from incineration) and water pollution (from landfilling**).**

https://ssrcoop.info/recycle-this-its-the-law/

d. RECOVERY

Recovery is the next best option when we can't apply the first 3 Rs of waste management in the waste hierarchy. For waste that we can't recycle, it may be possible to recover energy in the form of "waste to energy".Waste to energy is the process of incinerating non-recyclable waste to produce electricity. WtE helps reduce our reliance on fossil fuels and decreases carbon emissions.Composting is also a method we use when we can't recycle materials. Composting turns organic wastes into nutrient-rich food for plants.

9.10. Summary

In this chapter you have learned that, waste is defined as we see in our surroundings is also known as garbage is mainly considered as a solid waste that includes waste from our houses (domestic waste). Waste from schools, officemate. Municipal waste and waste from industries and factories are called industrial wastes. We have studied different types of waste and have understood how we can manage solid waste and biological waste, what are the processes and techniques required to manage waste.Together we have also studied some methods of waste disposal such as recycling, incineration, chemical, physical and biological treatment, land fill etc.After this, we have also studied composting, an important part of waste management, what is composting, its types, its advantages and disadvantages have also been explained. And also studied Anaerobic Digestion Bioremediation, Reductive dehalogenation.Finally we have understood the important role of reduce, reuse, recycle and recover. All of three priorities reuse , reduce , recycle the most effective and preferred method is the first step .which is to reduce and avoid waste altogether.

9.11. Terminal questions

Q.1: Explain what is waste? Its type and also explain the sources of waste?

Answer:---

Q.2: Describe in detail about solid waste management?

Answer:---

Q.3: What is the difference between Hazardous waste and municipal solid waste?

Answer:---

Q.4: What is composting? Its type and techniques and also explain the benefits of composting?**Answer:**---
----

Q.5: Explain 4 R's reduce,reuse, recycle and recover?

Answer:---

Q.6: Definition of bioremediation? And also explain the advantages and disadvantages of bioremediation?

Answer:---

9.12. Further suggested readings

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Rajarshi Tandon Open University, Prayagraj

Solid and Hazardous Waste Management

Block- 4

Waste Management Handling and Rules

UNIT -10

Solid Waste Management

UNIT-11

Hazardous and Medical Wastes Management

UNIT-12
E-Waste Management

PGEVS-108N

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Solid and Hazardous Waste Management

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Unit-10: Solid Waste Management

Contents

10.1. Introduction:

Solid waste refers to any discarded material or substance that is not liquid or gas. It includes a variety of materials generated by human activities, such as household garbage, construction debris, industrial waste, and hazardous waste. Solid waste management is the process of collecting, transporting, treating, and disposing of solid waste in a way that minimizes its negative impact on the environment and public health. Solid waste management rules and regulations in India are governed by the Ministry of Environment, Forest and Climate

Change (MoEFCC), which has set guidelines for the management of solid waste in the country. In India major rules and regulations related to solid waste management are Solid Waste Management Rules, 2016, Plastic Waste Management Rules, 2016, Bio-medical Waste Management Rules, 2016, E-waste Management Rules, 2016,Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016. In addition to these rules and regulations, the MoEFCC has also launched various initiatives to promote proper solid waste management in the country, such as the Swachh Bharat Abhiyan (Clean India Mission) and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT). These initiatives aim to improve the overall cleanliness and hygiene of the country, and promote sustainable solid waste management practices.

Objectives

- To study the Solid waste management rules 2016
- To understand the evolution of SWM rules in India
- To study the municipal solid wastes (management and handling) rules 2000,
- To study the criteria for waste to energy process
- To understand the plastic waste management rules 2016

10.2. Solid Waste Management overview

With increasing population and urbanization, the waste management has emerged as a huge challenge in the State. Not only the waste has increased in quantity, but the characteristics of waste have also changed tremendously over the period with the introduction of new products, gadgets and equipments. Scientific disposal of solid waste through segregation, collection, treatment and disposal in an environmentally sound manner minimises the adverse impact of waste on the environment. The urban local authorities are responsible for development of infrastructure for collection, storage, segregation, transportation, processing and disposal of MSW.

As many of the municipal authorities are still to develop in-house capabilities to independently govern their solid waste, the central and state governments continue to play a crucial role by formulating policies, programmes, and regulations and by providing technical and financial assistance for infrastructure development including management of municipal solid waste (MSW) in urban areas. Although municipal solid waste management (MSWM) is an essential service and a mandatory function of municipal authorities across the country, it is still being managed in an unplanned manner, giving rise to environmental degradation and serious health problems especially for women and children. This clearly underlines the need for preparing a strategic and detailed MSWM plan by the urban local bodies (ULBs). Every ULB should undertake the preparation of a MSWM plan, addressing short term and long term actions.

Concept of solid waste management

- Solid Waste includes solid or semi-solid domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from the surface drains, **horticulture** waste, **agriculture** and dairy waste, treated **biomedical waste** excluding industrial waste, bio-medical waste and **e-waste**, battery waste, radio-active waste etc.
- **India's Status of solid waste management**
- Urban India alone generates nearly **0.15 million tonnes per day** of Municipal Solid Waste.
- It is estimated that about **62 million tonnes of waste** are generated annually in the country, out of which 5.6 million is **plastic waste**, 0.17 million is biomedical waste.
- In addition, hazardous waste generation is 7.90 million tonnes per annum and 15 lakh tonnes is e-waste.
- The volume of waste is projected to reach 165 million tonnes by 2031 and 436 million tonnes by 2050.

Challenges in Waste Management:

Increasing urbanization in India has resulted in **hyper-consumerism**, resulting in more waste generation.

- **Organic farming** and composting are not economically attractive to the Indian farmer, as **chemical pesticides** are heavily subsidized, and the compost is not efficiently marketed.
- **Lack of financial resources** with Municipal Corporations/Urban Local Bodies, result in **poor collection, transportation and management of solid waste.**

Evolution of Solid Waste Management

Waste Management and sorting has been a matter of concern for decades and has been rapidly rising by the escalation in the population. This paper focusses on the evolution of various technological methods that emerged over the years to make this process more cost-effective and implementable. The techniques proposed were not necessarily implementable but provided some sought of advancement that helped in understanding what is feasible and in which area there is a necessity for improvement.The below events account of the major events that took place in the waste management history:

History of dumping waste

In 500 BC, the first-ever municipal dump program was initiated in Athens.[2] In 6,500 BC it was estimated that the increase in the use of products led the Native Americans in the present state of Colorado to produce about 5.3 pounds of waste per person per day. Dumping became so regular that in the year 1388, the English government banned waste disposal in waterways and ditches. Then in 1400 in Paris, it was observed that the garbage piles became so high that it interfered with the city's defence system.

The Beginning of the Recycling era

Although recycling is a very old phenomenon that can be traced to around 400 BC but was very insignificant. The first major attempt to minimize the waste was initiated by the Japanese in 1031 as the Paper Production moved from the hands of the state's control to the public due to the decline of the Japanese Imperial court in the Heian Period. Then the privates started setting up paper mills to meet the demand. Within a short period, recycling and re-pulping of the paper began to take place and was largely accepted by the locals.

Then again in 1690, a big step was taken in the history of recycling; the first paper mill in America was set up by the German-born William Rittenhouse (Wilhelm Rittenhausen) in Philadelphia. It used rags for the production of paper and was operational till the mid-18th century.

The sorting and detection of solid waste

It is often said that "need is the mother of invention"and this saying was proved in the late 1700s when the Americans were engaged in a war against the British for their independence, a dire need for supplies in the defense led to the sorting and recycling of metal. 42,088 bullets were made from melting and recycling the statue of King George III situated in

New York City, after the declaration of independence.In 1813 Benjamin Law laid the foundation of manufacturing recycled wool from old rags and clothes in Barley, West Yorkshire. For the production of yarn, he took the help of the 'tatters' which collected the old fabric from various industries. This whole process involved sorting of various fabric types then washing them with soap to remove dirt and grease, 'willeying', scribbling and carding, then even amounts of wool was rolled, milled, filled and then for finishing the wool was dyed.

The age of Sanitation

In England during the 1800s, daily the females collected waste from the households using movable bins and sorted manually. The materials like glass, metals, etc. were given back to the shopkeepers or manufacturers for reuse. Then in 1834, in Charleston, West Virginia, a law was legislated which outlawed huntsmen from hunting vultures that fed on garbage. This did not work for a long period; a report issued in 1842 claimed that a disease was spread due to the unsanitary environmental circumstances, which led to the beginning of the age of sanitation. This gained momentum in the year 1848 when the Public Health Act was imposed under which regulation of waste was done.

The Incineration

In 1874, in England's Nottingham, the process of incineration was introduced. The process was to convert the waste into heat/ash via combustion. For its implementation, a machine called 'The destructor' was used which prevented the release of methane in the air. This technology was again used for the first time in USA's Governor's Island in NY.

The North American Dilemma

With the exponential growth of waste, the lands started running insufficient for its proper disposal. One such major event was encountered in 1889 when Washington DC reported exhaustion of suitable land for refuse. To overcome this issue, in 1896, waste reduction plants were introduced, which aimed at the extraction of grease and oil from organic waste by compressing. But it was observed that this process emitted noxious fumes and had to be shut. In the same year, 760000 cubic yards of waste was dumped into the Atlantic, off the Virginia coast. Then in 1897, NY set up 'picking yards' were all the garbage was collected and sorted various types of papers, metals, etc to facilitate material recovery. The recovery was mainly done by either reusing or recycling. In the year 1898, in

New York, the first plant which generated energy though incineration was set up. With all these advancements, suspensions and implementations the century came to an end.

The First Two Decades

In 1900, piggeries were developed to eat fresh or cooked waste. The norms were not followed strictly and as a result, an outbreak of vesicular exanthema killed thousands of pigs a year later. Laws were passed to ensure that pigs will only be served cooked food.Manhattan residents were producing 1500 lbs of waste annually, 80% of which was ash from burning of coal and wood to incinerate waste. In the 1900s the reuse programs embraced the phase ‘Waste as wealth’ to describe the greens earned by recycling and reselling the waste. In 1904 the first major recycling plant was inaugurated in Cleveland and Chicago, simultaneously the waste was increasing exponentially. By 1911 the NYC citizens produced 4.6 pounds of refuse daily. BY 1914, 300 incinerators were working in the US for burning household waste. In 1916 due to massive shortages of raw materials during World War I, the Federal government creates the Waste Reclamation Service with the motto “Don’t Waste It – Save It”. In 1918, due to these complications violating the marine and harbor protection act 1888 the NYC resumed the dumping of waste at sea.

The Acts

As the cities grew and the industrialization gained momentum, the waste disposal became a big challenge for the government due to its adverse effect on the health and environment. The dumping of waste in the landfills and in the ocean became very common and led to a miserable condition of the aquatic life. Beaches became foul due to the waste that was pushed along with the tides. Then many laws were imposed, and much emphasis was given for the reuse and proper recycling of products was given much emphasis. There was a major initiative taken in Olympia Washington in 1954 when it announced to pay money for bringing empty aluminum cans back**.** Then in 1965, the US Government imposed the Solid Waste Disposal Act (SWDA). This law was aimed at improving the solid waste disposal methods and provides minimum safety guidelines for the landfills. But this act was amended in the year 1970 by The Resource Conservation and Recovery Act (RCRA).This act grew the engagement of the government in handling waste. Also, in the same year, the Environmental Protection Agency (EPA) was created and the first Earth Day was also celebrated.

The beverage industry innovation

In the latter half of the 20th century, the waste grew enormously. The majority of the beer producers shifted from using traditional glass bottles to metal cans and no-return bottles. The beverages at first continued to be sold particularly in refillable glass bottles requiring a deposit but later they also were sold in a ‘consumer-oriented, non-return, one-way’ cans or bottles. This resulted in the burst of beverage trash and to improve the situation, in 1971, Oregon passed the first bottle bill (also known as a deposit law) in the United States. According to this bill, the purchaser had to deposit a little sum of money on every beer and beverage container. By 1986, almost 10 States in the US imposed some sought of deposit on the purchase of the before-mentioned. These bills were not only meant to lessen the litter but also to raise the capital for recycling, preserving the natural resources and, reduce the quantity of solid waste running to the landfills. The percentage of beverage waste earlier reaching from 70-83 percent decreased to 30-47 percent.

In 1977, UK’s Glass Manufacturing Federation (GMF) established the first bottle bank in Barnsley used for recycling glass. It was also installed in South Yorkshire and Oxford the same day, and successfully collected 500 tonnes of glass in the first six months.

The 3 R’s

The 'Reduce, Re-use, and Recycle' slogan, which was used originally introduced on the first Earth Day in 1970 began to gain momentum. To promote this, the Blue Box Recycling System (BBRS) was initiated by the Canadian Municipalities in 1992. Under this system, the government collecting household waste, and the recyclable waste was sorted and kept separately in the blue bins. This made it easier to sort and recycle waste. In 1987, Ontario Multi Material Recycling Incorporated (OMMRI) promised 20 million dollars in funding over four years, which was equated by municipalities and the Ontario government to finance the Blue Box recycling program. This method was effective and is in use till date.

The new waste

Towards the end of the century, the use of electronic devices rose, and consequently, the difficulty in the disposal of e-waste also expanded. The e-waste management was of much need because of the environmental side-effects it had if not disposed of properly. They have toxic elements present which could be harmful to the environment as well as humans. So, in the year 1991, in Switzerland, the Swico recycling system began to recycle old refrigerators, free of cost for the consumer, and later started recycling all sought of e-waste. With this, the new century began and reforms regarding waste management were taken all over the world. India drafted a completely new set of rules in 2000 for the regulation of waste dumping. Several committees were formed all over the country to ensure proper implementation of the fore stated. While in 2003, the EU set up various revised directives as concrete laws for faster and effective waste dumping or incineration. In the same year law of providing every household, the facility of collection of recyclable material came into action. In the year 2006, the computer manufacturers offered provision for recycling its products which were considered a great initiative in America and many companies took inspiration from it and started the same policy.UK had multiple revisions of the directives of the EU and implemented its expanded variant. To discourage the use of single-use plastic bags England in 2015 charged an amount of five pence for use of single-use plastic bags throughout the shops of England. There was 80% dip in the use of plastic bags due to the same. Also, in the same year, California enacted the first-ever, state-wide ban on plastic bags in grocery and convenience stores. Cal Recycle, the agency tasked amidst administering and implementing California's laws related to waste management published an article highlighting the outcomes of a survey of thousands of shops and grocers. The investigation found that in the six months following the bag ban around 86 percent of customers brought their bags and didn't purchase a paper or reusable bag. As a result, there was an 85 percent decrease in the quantity of plastic bags and a 61 percent decline in the number of paper bags catered to customers.

The Further Advancements

In the year 2016, the Japanese scientist discovered an enzyme that feeds on plastic commonly used in drinking water bottles (PET). This created a possibility to reduce the waste. Earlier China used to import waste from other countries but in 2018 it banned the import due to the excessive cost and lesser outcome. At present the reaches are concentrating on improving the waste management by the use of artificial intelligence and advancement in machine learning, and the list goes on

10.3. Solid Waste Management Rules, 2000

Municipal Solid Wastes (Management and Handling) Rules, 2000 are being implemented by the municipal authorities as these authorities are responsible for management of municipal solid waste (MSW). The Rules are in force from September, 2000. Local bodies are required to ensure that solid waste generated in city/town is managed in accordance with the provisions of the Rule relating to collection, segregation, storage, transportation, processing and disposal.

The draft of the Municipal Solid Wastes (Management and Handling) Rules, 1999 were published under the notification of the Government of India in the Ministry of Environment and Forests number S.O. 783(E), dated, the 27th September, 1999 in the Gazette of India, Part II, Section 3, Sub-section (ii) of the same date inviting objections and suggestions from the persons likely to be affected thereby, before the expiry of the period of sixty days from the date on which the copies of the Gazette containing the said notification are made available to the public, and whereas copies of the said Gazette were made available to the public on the 5th October, 1999.

Now, therefore, in exercise of the powers conferred by section 3, 6 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government hereby makes the following rules to regulate the management and handling of the municipal solid wastes, namely:-

Short title and commencement: --

These rules may be called the Municipal Solid Wastes (Management and Handling) Rules, 2000.

Save as otherwise provided in these rules, they shall come into force on the date of their publication in the Official Gazette.

Application -These rules shall apply to every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes.

Definitions-- In these rules, unless the context otherwise requires,--

1 "anaerobic digestion" means a controlled process involving microbial decomposition of organic matter in the absence of oxygen;

2 "authorization" means the consent given by the Board or Committee to the "operator of a facility" ;

3 "biodegradable substance" means a substance that can be degraded by micro-organisms;

4 "biomethanation" means a process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas;

5 "collection" means lifting and removal of solid wastes from collection points or any other location;

6 "composting" means a controlled process involving microbial decomposition of organic matter;

7 "demolition and construction waste" means wastes from building materials debris and rubble resulting from construction, re-modeling, repair and demolition operation;

8 "disposal" means final disposal of municipal solid wastes in terms of the specified measures to prevent contamination of ground-water, surface water and ambient air quality;

9 "Form" means a Form appended to these rules;

10 "generator of wastes" means persons or establishments generating municipal solid wastes;

11 "land filling" means disposal of residual solid wastes on land in a facility designed with protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion;

12 "leachate" means liquid that seeps through solid wastes or other medium and has extracts of dissolved or suspended material from it;

13 "lysimeter" is a device used to measure rate of movement of water through or from a soil layer or is used to collect percolated water for quality analysis;

14 "municipal authority" means Municipal Corporation, Municipality, Nagar Palika, Nagar Nigam, Nagar Panchayat, Municipal Council including notified area committee (NAC) or any other local body constituted under the relevant statutes and, where the management and handling of municipal solid waste is entrusted to such agency;

15 "municipal solid waste" includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes;

16 "operator of a facility" means a person who owns or operates a facility for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes and also includes any other agency appointed as such by the municipal authority for the management and handling of municipal solid wastes in the respective areas;

17 "pelletisation" means a process whereby pellets are prepared which are small cubes or cylindrical pieces made out of solid wastes and includes fuel pellets which are also referred as refuse derived fuel;

18 "processing" means the process by which solid wastes are transformed into new or recycled products;

19 "recycling" means the process of transforming segregated solid wastes into raw materials for producing new products, which may or may not be similar to the original products;

20 "schedule" means a Schedule appended to these rules;"segregation" means to separate the municipal solid wastes into the groups of organic, inorganic, recyclables and hazardous wastes;

21 "State Board or the Committee" means the State Pollution Control Board of a State, or as the case may be, the Pollution Control Committee of a Union territory;

22 "storage" means the temporary containment of municipal solid wastes in a manner so as to prevent littering, attraction to vectors, stray animals and excessive foul odour;

23 "transportation " means conveyance of municipal solid wastes from place to place hygienically through specially designed transport system so as to prevent foul odour, littering, unsightly conditions and accessibility to vectors;

24 "vadose water" water which occurs between the ground, surface and the water table that is the unsaturated zone;

25 "vermicomposting" is a process of using earthworms for conversion of bio- degradable wastes into compost.

Responsibility of Municipal Authority

1 Every municipal authority shall, within the territorial area of the municipality, be responsible for the implementation of the provisions of these rules, and for any infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid wastes.

2 The municipal authority or an operator of a facility shall make an application in Form-

I, for grant of authorization for setting up waste processing and disposal facility including landfills from the State Board or the Committee in order to comply with the implementation programme laid down in Schedule I.

3 The municipal authority shall comply with these rules as per the implementation schedule laid down in Schedule I.

4 The municipal authority shall furnish its annual report in Form-II, -

a. to the Secretary-incharge of the Department of Urban Development of the concerned State or as the case may be of the Union territory, in case of a metropolitan city; or

b. To the District Magistrate or the Deputy Commissioner concerned in case of all other towns and cities, with a copy to the State Board or the Committee on or before the 30th day of June every year.

1. RESPONSIBILITY OF THE STATE GOVERNMENT AND THE UNION TERRITORY ADMINISTRATIONS: --

1) The Secretary-incharge of the Department of Urban Development of the concerned State or the Union territory, as the case may be, shall have the overall responsibility for the enforcement of the provisions of these rules in the metropolitan cities.

2) The District Magistrate or the Deputy Commissioner of the concerned district shall have the overall responsibility for the enforcement of the provisions of these rules within the territorial limits of their jurisdiction.

2. RESPONSIBILITY OF THE CENTRAL POLLUTION CONTROL BOARD AND THE STATE BOARD OR THE COMMITTEES: —

1) The State Board or the Committee shall monitor the compliance of the standards regarding ground water, ambient air, leachate quality and the compost quality including incineration standards as specified under Schedules II, III and IV.

2) The State Board or the Committee, after the receipt of application from the municipal authority or the operator of a facility in Form I, for grant of authorization for setting up waste processing and disposal facility including landfills, shall examine the proposal taking into consideration the views of other agencies like the State Urban Development Department, the Town and Country Planning Department, Air Port or Air Base Authority, the Ground Water Board or any such other agency prior to issuing the authorization.

3) The State Board or the Committee shall issue the authorization in Form-III to the municipal authority or an operator of a facility within forty-five days stipulating compliance criteria and standards as specified in Schedules II, III and IV including such other conditions, as may be necessary.
4) The authorization shall be valid for a given period and after the validity is over, a fresh authorization shall be required.
5) The Central Pollution Control Board shall co-ordinate with the State Boards and the Committees with particular reference to implementation and review of standards and guidelines and compilation of monitoring data.

Management of Municipal Solid Wastes

Any municipal solid waste generated in a city or a town, shall be managed and handled in accordance with the compliance criteria and the procedure laid down in Schedule-II.The waste processing and disposal facilities to be set up by the municipal authority on their own or through an operator of a facility shall meet the specifications and standards as specified in Schedules III and IV.

a. **ANNUAL REPORTS: —**

1 The State Boards and the Committees shall prepare and submit to the Central Pollution Control Board an annual report with regard to the implementation of these rules by the 15^{th} of September every year in Form-IV.

2 The Central Pollution Control Board shall prepare the consolidated annual review report on management of municipal solid wastes and forward it to the Central Government along with its recommendations before the 15^{th} of December every year.

b. **ACCIDENT REPORTING: --** When an accident occurs at any municipal solid wastes collection, segregation, storage, processing, treatment and disposal facility or landfill site or during the transportation of such wastes, the municipal authority shall forthwith report the accident in Form-V to the Secretary in-charge of the Urban Development Department in metropolitan cities, and to District Collector or Deputy Commissioner in all other cases.

Schedule –II

[Rules 6(1) and (3), 7(1)]

Management of Municipal Solid Wastes

S. No	Parameters	Compliance criteria
1.	Collection municipal wastes of solid	Littering of municipal solid waste shall be prohibited in cities, towns and in urban areas notified by the State Governments. To prohibit littering and facilitate compliance, the following steps shall be taken by the municipal authority, namely: -
		Organizing house-to-house collection of municipal solid wastes through any of the methods, like community bin collection (central bin), house-to-house collection, collection on regular pre-informed timings and scheduling by using bell ringing of musical vehicle (without exceeding permissible noise levels);
		Devising collection of waste from slums and squatter areas orlocalities including hotels, restaurants, office complexes and commercial areas;
		Wastes from slaughter houses, meat and fish markets, fruits and vegetable markets, which are biodegradable in nature, shall be managed to make use of such wastes;
		Bio-medical wastes and industrial wastes shall not be mixed with municipal solid wastes and such wastes shall follow the rules separately specified for the purpose;
		Collected waste from residential and other areas shall be transferred to community bin by hand-driven containerized carts or other small vehicles;
		Horticultural and construction or demolition wastes or debris shall be separately collected and disposed off following proper norms. Similarly, wastes generated at dairies shall be regulated in accordance with the State laws;
		Waste (garbage, dry leaves) shall not be burnt;
		Stray animals shall not be allowed to move around waste storage facilities or at any other place in the city or town and shall be managed in accordance with the State laws. The municipal authority shall notify waste collection schedule and the likely method to be adopted for public benefit in a city or town.
2.	Segregation of municipal solid wastes	It shall be the responsibility of generator of wastes to avoid littering and ensure delivery of wastes in accordance with the collection and segregation system to be notified by the municipal authority as per para 1(2) of this Schedule.
		In order to encourage the citizens, municipal authority shall organise awareness programmes for segregation of wastes and shall promote recycling or reuse of segregated materials. The municipal authority shall undertake phased programme to ensure community participation in waste segregation. For this purpose, the municipal authorities shall arrange regular meetings at quarterly intervals with representatives of local resident welfare associations and non-governmental organizations.

3.	Storage of municipal solid wastes	Municipal authorities shall establish and maintain storage facilities in such a manner as they do not create unhygienic and in sanitary conditions around it. Following criteria shall be taken into account while establishing and maintaining storage facilities, namely: - Storage facilities shall be created and established by taking into account quantities of waste generation in a given area and the population densities. A storage facility shall be so placed that it is accessible to users; Storage facilities to be set up by municipal authorities or any other agency shall be so designed that wastes stored are not exposed to open atmosphere and shall be aesthetically acceptable and user-friendly; Storage facilities or 'bins' shall have 'easy to operate' design for handling, transfer and transportation of waste. Bins for storage of bio-degradable wastes shall be painted green, those for storage of recyclable wastes shall be printed white and those for storage of other wastes shall be printed black; Manual handling of waste shall be prohibited. If unavoidable due to constraints, manual handling shall be carried out under proper precaution with due care for safety of workers.
4.	Transportation of municipal solid wastes	Vehicles used for transportation of wastes shall be covered. Waste should not be visible to public, nor exposed to open environment preventing their scattering. The following criteria shall be met, namely:- The storage facilities set up by municipal authorities shall be daily attended for clearing of wastes. The bins or containers wherever placed shall be cleaned before they start overflowing; Transportation vehicles shall be so designed that multiple handling of wastes, prior to final disposal, is avoided.
5	Processing of municipal solid wastes	Municipal authorities shall adopt suitable technology or combination of such technologies to make use of wastes so as to minimize burden on landfill. Following criteria shall be adopted, namely:-
6		The biodegradable wastes shall be processed by composting, vermicomposting, anaerobic digestion or any other appropriate biological processing for stabilization of wastes. It shall be ensured that compost or any other end product shall comply with standards as specified in Schedule-IV; Mixed waste containing recoverable resources shall follow the route of recycling. Incineration with or without energy recovery including pelletisation can also be used for processing wastes in specific cases. Municipal authority or the operator of a facility wishing to use other state-of-the-art technologies shall approach the Central Pollution Control Board to get the standards laid down before applying for grant of authorization.

7	Disposal of municipal solid wastes	Land filling shall be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing. Land filling shall also be carried out for residues of waste processing facilities as well as pre-processing rejects from waste processing facilities. Land filling of mixed waste shall be avoided unless the same is found unsuitable for waste processing. Under unavoidable circumstances or till installation of alternate facilities, land-filling shall be done following proper norms. Landfill sites shall meet the specifications as given in Schedule –III.

Schedule III

[rules 6(1) and (3), 7(2)]

Specifications for Landfill Sites

Site Selection

1. In areas falling under the jurisdiction of 'Development Authorities' it shall be the responsibility of such Development Authorities to identify the landfill sites and hand over the sites to the concerned municipal authority for development, operation and maintenance. Elsewhere, this responsibility shall lie with the concerned municipal authority.
2. Selection of landfill sites shall be based on examination of environmental issues. The Department of Urban Development of the State or the Union territory shall co-ordinate with the concerned organisations for obtaining the necessary approvals and clearances.
3. The landfill site shall be planned and designed with proper documentation of a phased construction plan as well as a closure plan.
4. He landfill sites shall be selected to make use of nearby wastes processing facility. Otherwise, wastes processing facility shall be planned as an integral part of the landfill site.
5. The existing landfill sites, which continue to be used for more than five years, shall be improved in accordance of the specifications given in this Schedule.
6. Biomedical wastes shall be disposed off in accordance with the Bio-medical Wastes

(Management and Handling) Rules, 1998 and hazardous wastes shall be managed in accordance with the Hazardous Wastes (Management and Handling) Rules, 1989, as amended from time to time.

7. The landfill site shall be large enough to last for 20-25 years.

8. The landfill site shall be away from habitation clusters, forest areas, water bodies monuments, National Parks, Wetlands and places of important cultural, historical or religious interest.

9. A buffer zone of no-development shall be maintained around landfill site and shall be incorporated in the Town Planning Department's land-use plans.

10. Landfill site shall be away from airport including airbase. Necessary approval of airport or airbase authorities prior to the setting up of the landfill site shall be obtained in cases where the site is to be located within 20 km of an airport or airbase.

Facilities at the Site

11. Landfill site shall be fenced or hedged and provided with proper gate to monitor incoming vehicles or other modes of transportation.

12. The landfill site shall be well protected to prevent entry of unauthorized persons and stray animals.

13. Approach and other internal roads for free movement of vehicles and other machinery shall exist at the landfill site.

14. The landfill site shall have wastes inspection facility to monitor wastes brought in for landfill, office facility for record keeping and shelter for keeping equipment and machinery including pollution monitoring equipments.

15. Provisions like weigh bridge to measure quantity of waste brought at landfill site, fire protection equipments and other facilities as may be required shall be provided.

16. Utilities such as drinking water (preferably bathing facilities for workers) and lighting arrangements for easy landfill operations when carried out in night hours shall be provided.

17. Safety provisions including health inspections of workers at landfill site shall be periodically made

Specifications for land filling

18. Wastes subjected to land filling shall be compacted in thin layers using landfill compactors to achieve high density of the wastes. In high rainfall areas where heavy compactors cannot be used alternative measures shall be adopted.

19. Wastes shall be covered immediately or at the end of each working day with minimum 10 cm of soil, inert debris or construction material till such time waste processing facilities for composting or recycling or energy recovery are set up as per Schedule I.

20. Prior to the commencement of monsoon season, an intermediate cover of 40- 65 cm thickness of soil shall be placed on the landfill with proper compaction and grading to prevent infiltration during monsoon. Proper drainage berms shall be constructed to divert run-off away from the active cell of the landfill.

After completion of landfill, a final cover shall be designed to minimize infiltration and erosion. The final cover shall meet the following specifications, namely: The final cover shall have a barrier soil layer comprising of 60 cms of clay or amended soil with permeability coefficient less that 1 x 10^{-7} cm/sec.

a. On top of the barrier soil layer there shall be a drainage layer of 15 cm.

b. On top of the drainage layer there shall be a vegetative layer of 45 cm to support natural plant growth and to minimize erosion.

Pollution prevention

In order to prevent pollution problems from landfill operations, the following provisions shall be made, namely:

Diversion of storm water drains to minimize leachate generation and prevent pollution of surface water and also for avoiding flooding and creation of marshy conditions. Construction of a non-permeable lining system at the base and walls of waste disposal area. For landfill receiving residues of waste processing facilities or mixed waste or waste having contamination of hazardous materials (such as aerosols, bleaches, polishes, batteries, waste oils, paint products and pesticides) minimum liner specifications shall be a composite barrier having 1.5 mm high density polyethylene (HDPE) geomembrane, or equivalent, overlying 90 cm of soil (clay or amended soil) having permeability coefficient not greater than 1 x 10^{-7} cm/sec. The highest level of water table shall be at least two meter below the base of clay or amended soil barrier layer;

Provisions for management of leachates collection and treatment shall be made. The treated leachates shall meet the standards specified in Schedule- IV; Prevention of run-off from landfill area entering any stream, river, lake or pond. Before establishing any landfill site, baseline data of ground water quality in the area shall be collected and kept in record for future reference. The ground water quality within 50 meters of the periphery of landfill site shall be periodically monitored to ensure that the ground water is not contaminated beyond acceptable limit as decided by the Ground Water Board or the State Board or the Committee. Such monitoring shall be carried out to cover different seasons in a year that is, summer, monsoon and post-monsoon period. Usage of groundwater in and around landfill sites for any purpose (including drinking and irrigation) is to be considered after ensuring its quality. The following specifications for drinking water quality shall apply for monitoring purpose, namely: -

S.No.	**Parameters**	**IS 10500:1991** **Desirable limit (mg/l except for pH)**
1.	Arsenic	0.05
2.	Cadmium	0.01
3.	Chromium	0.05
4.	Copper	0.05
5.	Cyanide	0.05
6.	Lead	0.05
7.	Mercury	0.001
8.	Nickel	-
9.	Nitrate as NO_3	45.0
10.	PH	6.5-8.5
11.	Iron	0.3
12.	Total hardness (as $CaCO_3$	300.0
13.	Chlorides	250
14.	Dissolved solids	500
15.	Phenolic compounds (as C_6H_5OH)	0.001

16.	Zinc	5.0
17.	Sulphate (as SO_4)	200

Ambient Air Quality Monitoring

1. Installation of landfill gas control system including gas collection system shall be made at landfill site to minimize odour generation, prevent off-site migration of gases and to protect vegetation planted on the rehabilitated landfill surface.
2. The concentration of methane gas generated at landfill site shall not exceed 25 per cent of the lower explosive limit (LEL).
3. The landfill gas from the collection facility at a landfill site shall be utilized for either direct thermal applications or power generation, as per viability. Otherwise, landfill gas shall be burnt (flared) and shall not be allowed to directly escape to the atmosphere or for illegal tapping. Passive venting shall be allowed if its utiliztion or flaring is not possible.
4. Ambient air quality at the landfill site and at the vicinity shall be monitored to meet the following specified standards, namely :-

S. No.	**Parameters**	**Acceptable levels**
i.	Sulphur dioxide	120µg/m3 (24 hours)
ii.	Suspended Particulate Matter	500µg/m3 (24 hours)
iii.	Methane	Not to exceed 25 per cent of the lower explosive limit (equivalent to 650 mg /m3) (24 hours)
iv.	Ammonia daily average	o.4mg/m3 (400 µg/m3)
v.	(sample duration 24 hrs) Carbon monoxide	1 hour average : 2 mg/m3 8 hour average : 1 mg/m3

1. The ambient air quality monitoring shall be carried out by the concerned authority as per the following schedule, namely:-

   Six times in a year for cities having population of more than fifty lakhs;

   a. Four times in a year for cities having population between ten and fifty lakhs;
   b. Two times in a year for town or cities having population between one and ten lakhs.

Plantation at Landfill Site

2. A vegetative cover shall be provided over the completed site in accordance with the and following specifications, namely: -
   - **a.** Selection of locally adopted non-edible perennial plants that are resistant to drought and extreme temperatures shall be allowed to grow;
   - **b.** The plants grown be such that their roots do not penetrate more than 30 cms. This condition shall apply till the landfill is stabilized;
   - **c.** Selected plants shall have ability to thrive on low-nutrient soil with minimum nutrient addition;
   - **d.** Plantation to be made in sufficient density to minimize soil erosion.

Closure of Landfill Site and Post-care

3. The post-closure care of landfill site shall be conducted for at least fifteen years and long term monitoring or care plan shall consist of the following, namely :-
   - **a.** Maintaining the integrity and effectiveness of final cover, making repairs and preventing run-on and run-off from eroding or otherwise damaging the final cover;
   - **b.** Monitoring leachates collection system in accordance with the requirement;
   - **c.** Monitoring of ground water in accordance with requirements and maintaining ground water quality;
   - **d.** Maintaining and operating the landfill gas collection system to meet the standards.

4. Use of closed landfill sites after fifteen years of post-closure monitoring can be considered for human settlement or otherwise only after ensuring that gaseous and leachates analysis comply with the specified standard

Special provisions for hilly area

Cities and towns located on hills shall have location-specific methods evolved for final disposal of solid wastes by the municipal authority with the approval of the concerned State Board or the Committee. The municipal authority shall set up processing facilities for utilization of biodegradable organic wastes. The inert and non-biodegradable waste shall be used for building roads or filling-up of appropriate areas on hills. Because of constraints in finding adequate land in hilly areas, wastes not suitable for road-laying or filling up shall be disposed of in specially designed landfills.

Schedule IV

[Rules 6(1) and (3), 7(2)]

Standards for Composting, Treated Leachates and Incineration

1. The waste processing or disposal facilities shall include composting, incineration, pelletisation, energy recovery or any other facility based on state- of-the-art technology duly approved by the Central Pollution Control Board
2. In case of engagement of private agency by the municipal authority, a specific agreement between the municipal authority and the private agency shall be made particularly, for supply of solid waste and other relevant terms and conditions.
3. In order to prevent pollution problems from compost plant and other processing facilities, the following shall be complied with, namely :-
4. The incoming wastes at site shall be maintained prior to further processing. To the extent possible, the waste storage area should be covered. If, such storage is done in an open area, it shall be provided with impermeable base with facility for collection of leachate and surface water run-off into lined drains leading to a leachate treatment and disposal facility;

i. Necessary precautions shall be taken to minimize nuisance of odour, flies, rodents, bird menace and fire hazard;

ii. In case of breakdown or maintenance of plant, waste intake shall be stopped and arrangements be worked out for diversion of wastes to the landfill site;

iii. Pre-process and post-process rejects shall be removed from the processing facility on regular basis and shall not be allowed to pile at the site. Recyclables shall be routed through appropriate vendors. The non-recyclables shall be sent for well designed landfill site(s).

iv. In case of compost plant, the windrow area shall be provided with impermeable base. Such a base shall be made of concrete or compacted clay, 50 cm thick, having permeability coefficient less than 10^{-7} cm/sec. The base shall be provided with 1 to 2 per cent slope and circled by lined drains for collection of leachate or surface run-off;

v. Ambient air quality monitoring shall be regularly carried out particularly for checking odour nuisance at down-wind direction on the boundary of processing plant.

vi. In order to ensure safe application of compost, the following specifications for compost quality shall be met, namely:-

Parameters	**Concentration not to exceed *(mg/kg dry basis, except pH value and C/N ratio)**
Arsenic	10.00
Cadmium	5.00
Chromium	50.00
Copper	300.00
Lead	100.00
Mercury	0.15
Nickel	50.00
Zinc	1000.00
C/N ratio	20-40
PH	5.5-8.5

* Compost (final product) exceeding the above stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops.

The disposal of treated leachates shall follow the following standards, namely:-

S.No	Parameter	Standards (Mode of Disposal)		
		Inland surface water	Public sewers	Land disposal
1	Suspended solids, mg/l, max	100	600	200
2	Dissolved solids (inorganic) mg/l, max.	2100	2100	2100
3	PH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
4	Ammonical nitrogen (as N), mg/l, max.	50	50	-
5	Total Kjeldahl nitrogen (as N), mg/l, max.	100	-	-
6	Biochemical oxygen demand (3 days at 27^0 C) max.(mg/l)	30	350	100
7	Chemical oxygen demand, mg/l, max.	250	-	-
8	Arsenic (as As), mg/l, max	0.2	0.2	0.2
9	Mercury (as Hg), mg/l, max	0.01	0.01	-
10	Lead (as Pb), mg/l, max	0.1	1.0	-
11	Cadmium (as Cd), mg/l, max	2.0	1.0	-
12	Total Chromium (as Cr), mg/l, max.	2.0	2.0	-
13	Copper (as Cu), mg/l, max.	3.0	3.0	-
14	Zinc (as Zn), mg/l, max.	5.0	15	-
15	Nickel (as Ni), mg/l, max	3.0	3.0	-
16	Cyanide (as CN), mg/l, max.	0.2	2.0	0.2

17	Chloride (as Cl), mg/l, max.	1000	10 00	600
18	Fluoride (as F), mg/l, max	2.0	1.5	-
19	Phenolic compounds (as C_6H_5OH) mg/l, max.	1.0	5.0	-

Note : While discharging treated leachates into inland surface waters, quantity of leachates being discharged and the quantity of dilution water available in the receiving water body shall be given due consideration.

The incinerators shall meet the following operating and emission standards, namely:

A. Operating Standards

The combustion efficiency (CE) shall be at least 99.00%.

B. Emission Standards

Parameters	**Concentration mg/Nm^3 at (12% CO_2 correction**
Particulate matter	450
Nitrogen Oxides	150
HCl	50

1. Minimum stack height shall be 30 meters above ground
2. Volatile organic compounds in ash shall not be more than 0.01%.

Note:

1. Suitably designed pollution control devices shall be installed or retrofitted with the incinerator to achieve the above emission limits, if necessary.
2. Wastes to be incinerated shall not be chemically treated with any chlorinated disinfectants
3. Chlorinated plastics shall not be incinerated.
4. Toxic metals in incineration ash shall be limited within the regulatory quantities as specified in the Hazardous Wastes (Management and Handling) Rules, 1989 as

amended from time to time.

5. Only low sulphur fuel like diesel shall be used as fuel in the incinerator.

10.4. Solid Waste Management Rules, 2016

Solid Waste Management Rules, 2016 replaced the Municipal Solid Wastes (Management and Handling) Rules, 2000. The Municipal Solid Waste (Management and Handling) Rules, 2000 were notified in the year 2000 and came into force on September 25, 2000. However, post the suggestions of the public, the set of rules were updated in the areas of plastic, e-waste, biomedical, hazardous and construction and demolition waste management rules. Later the Government notified Solid Waste Management Rules, 2016 in the year 2016.

The new set of rules are now not only applicable in Municipal Areas but have also included urban agglomerations, census towns, notified industrial townships, and also areas which fall under the control and direction of Indian Railways, Airports, Special economic zones, Places of Pilgrimage, Religious and Historical importance, and Organizations under the conduct of State and Central Government.

Waste and its management

The Municipal Solid Waste comprises household waste, Commercial and Institutional waste, Marketing and Catering waste, Street sweepings and silt from Drains, Horticulture and dairy waste, Slaughterhouse waste, and Treated Biomedical Waste. (The Construction and Demolition waste is no longer a part of municipal solid waste. Construction and Demolition Waste Management Rules 2016, Plastic Waste Management Rules 2016, E-Waste Management Rules 2016, Biomedical Waste Management Rules 2016, and Hazardous and Other Waste Management Rules, 2016 are separately notified). It may be further categorised through three ways-

- Emergence
- Contents
- Hazard potential

Solid Waste Management reduces or eliminates its hostile impact on the environment & human health. Its poor management causes Air pollution, Water and Soil contamination. This is the reason why a municipality includes a number of processes for effective waste management i.e. monitoring, collection, transport, processing, recycling and disposal of waste. The amount of waste generated in the area depends on various factors like different lifestyles of the people. However, the two overwhelming challenges facing urban local governments in putting an effective solid waste management system in place are:

- Environmental sustainability, and
- Financial sustainability.

Important Terms of Solid Waste Management Rules, 2016

1. "Biodegradable waste" – means any organic material that can be degraded into simpler stable compounds by microorganisms.
2. "Bio-methanation" – means a process which involves the organic matter to go under enzymatic decomposition by microbial action to produce methane.
3. "Combustible waste" – means a composition of non-biodegradable, non-recyclable, non-hazardous solid waste with a high calorific value of over 1500 kcal/kg, except plastic chlorinated materials and wood pulp, etc.
4. "Composting" – means a scientific process involving microbial decomposition of organic matter.
5. "Disposal" – means the disposal of post-processed residual solid waste and collected street sweepings and silt from the surface of drains to prevent contamination of groundwater, unpleasant odour and attraction of stray animals or birds.
6. "Domestic Hazardous waste" – means the remaining household products which given under certain circumstances can catch fire, react or explode, or are corrosive or toxic in nature.
7. "Inerts" – means wastes which are not biodegradable, recyclable or combustible in nature like dust and silt removed from the surface drains or street sweeping.
8. "Leachate" – means the solvent that trickles from the solid waste medium and has absorbed or contains dissolved products.
9. "Material recovery facility" – means a facility in which non-compostable solid waste may be deposited temporarily by a municipal agency in order to facilitate the aggregation, storage, and recycling, through waste recyclers, or by some other local body prior to collection of waste for its processing or disposal.
10. "Non-biodegradable waste" – means any waste which cannot be converted to simpler stable compounds by microorganisms.

11. "Recycling" – means a process of collecting and processing by which one can transform their old goods or the solid waste into a new product for use or raw material for the building of other goods or products.
12. "Refuse derived fuel" – means fuel generated from fractions of solid waste such as plastic, wood, pulp or organic waste, rather than chlorinated products, in the form of pellets or fluff formed by drying, shredding, dehydrating and compacting solid waste.
13. "Sanitary landfilling" – means that the safe and final disposal of the residual solid and inert wastes on land in a facility which is specially built with protective measures against contamination of groundwater, surface water and dust, wind-blown litter etc.
14. "Segregation" – means the collection and separate handling of different components of solid biodegradable waste, including agricultural and dairy waste; non-biodegradable waste, including recyclable waste, non-recyclable fuel waste, sanitary waste and non-recyclable toxic waste, household hazardous waste, and building and demolition waste.
15. "Solid waste" – means and involves solid or semi-solid waste, sanitary waste, industrial waste, administrative waste, hospitality and agricultural waste and other non-residential pollutants, street sweepings, surface water sludge, greenhouse waste, farm and livestock waste, municipal hazardous waste and other bodies.
16. "Vermicomposting" – means the process of conversion from with compost is obtained by earthworms out of biodegradable waste.
17. "Waste Generator" – means and includes all persons or groups, on residential and non-residential premises, including Indian Railways, defence facilities which produce solid waste.
18. "Waste Hierarchy" – means the priority order of management of solid waste by emphasizing prevention, reduction, reusability, recycling, recycling and waste disposal, prevention as the preferred choice, and its disposal at the landfills as the least possible.
19. "Waste Picker" – means an individual or groups informally engaged in the recovery of recycled and recyclable solid waste from waste streams, street bins, recycling facilities and recycling facilities for recyclers to gain their livelihood directly or by an intermediary.

Duties of waste generators

1. Each waste generator shall separate the waste that is generated and store it in three different parts which are biodegradable, non-biodegradable and household hazardous waste and store it differently. Subsequently, the collected waste shall be passed to the approved rag pickers or collectors.
2. The sanitary waste used, for example, diapers, sanitary pads etc., shall be securely wrapped in pouches provided or in a suitable wrapping material by the manufacturers of these items and placed in the bins intended for dry or non-biodegradable wastes.
3. Construction and demolition waste shall be treated separately and disposed of according to the Waste Management Rules 2016 for Building and Demolition.
4. The waste generated from the premises through horticulture or garden shall be stored separately and be disposed of as per the Rules.
5. The practice of burying, burning or throwing the solid waste generated by the individual in open public areas, on streets, drains or water bodies shall be stopped immediately.
6. As per the laws of the local authorities, the waste generators shall pay a fee for solid waste management.
7. Under no circumstances until the permission given by the local authority no event or gathering of more than 100 people shall be made at any unlicensed place and a permit should be taken at least three working days prior to the event. The segregation of the waste and handling of it over to the waste collector shall be monitored by the organiser.
8. Storage containers shall be kept by all the street vendors for keeping the waste generated such as food waste, disposable plates, cups, cans, wrappers, coconut shells, leftover food, vegetables, fruits etc. and shall be disposed of properly.

Duties of Ministry of Urban Development

National Policies and Strategies on Solid Waste Management including the policies on Waste to Energy shall be made. Promotion of research and development, technical guidelines and project finance shall be and reviewable of the measures taken by the States shall be done by the ministry.

Duties of Department of Fertilizers, Ministry of Chemicals and Fertilizers

The Ministry shall provide market development assistance on the city compost and promote co- marketing of compost with chemical fertilizers bags by the fertilizer companies.

Duties of Ministry of Agriculture, Government of India

The Ministry shall provide leniency in the Fertiliser Control Order for the production and sale of compost and shall promote its use of compost on agricultural land. They shall set up laboratories for testing the quality of compost produced by local authorities.

Duties of the Ministry of Power

The Ministry shall decide the charge of energy generated from waste to energy plants from the solid waste and ensure the mandatory purchase of energy generated from such waste to energy plants by DISCOMs.

Duties of Ministry of New and Renewable Energy Sources

The Ministry of New Renewable Energy Sources shall facilitate the creation of infrastructure for waste to energy plants and provide necessary incentives for such energy plants.

Duties of the Secretary–in charge, Urban Development in the States and Union Territories and of Village Panchayat or Rural Development Department in the State and Union Territory

1. All of them shall come together within a year to frame a state policy on solid waste management.
2. They shall make a plan to identify and allocate suitable land for setting up the processing and disposal facilities for solid wastes within one year and start incorporating them.
3. Separate areas shall be reserved for segregation, storage and decentralized treatment of solid waste as specified in the development plan for group housing or industrial, institutional or any other non-residential complex of more than 200 dwellings or having a plot area of more than 5,000 square meters.
4. They shall ensure that the developers of the Special Economic Zone, Industrial Estate, and Industrial Park have at least 5 percent of the total area of the plot or at least 5 plots/holes for recovery and recycling facilities.
5. Notifications shall be given to the buffer zone for solid waste treatment and disposal facilities of more than 5 tons per day in consultation with the State Pollution Control Board and a framework for the registration of waste pickers and waste dealers shall be created.

Duties of the Central Pollution Control Board

1. The coordination between the Central Pollution Control Board and the State Pollution Control Boards shall be maintained for the enactment of these rules and adherence to the standards prescribed by the ground authorities. Also, the formulation and review of the standards for groundwater, air, noise pollution, in respect of all solid waste processing and disposal facilities shall be done.
2. The proposals given by the state pollution control boards or pollution control committees on the use of any new technologies for processing, recycling and treatment of solid waste shall be reviewed.
3. Preparation of an Annual Report on the enactment of these rules and submission of it to the Ministry of Environment, Forest and Climate Change shall be done and the report shall also be put in the public domain.
4. Publish guidelines for the management of buffer zones that exclude any residential, industrial or other building operation from the outer boundary of waste treatment and disposal facilities for various facilities handling more than 5 tons of solid waste each day.
5. The publication of guidelines on the environmental aspects of the treatment and disposal of solid waste shall take place from time to time in order to enable local authorities to abide by the terms of the law and to provide assistance to States or Union Territories on the interstate movement of waste.

Duties and Responsibilities of local authorities and village Panchayat of census towns and urban agglomerations

1. Within six months, local authorities must draw up a comprehensive waste management strategy according to State policy.
2. Collection of segregated waste from door to door shall be arranged.
3. Within one year a user fee shall be prescribed to the waste generators and appropriate by laws for incorporating these rules shall also be created.
4. Guide waste generators to not dispense and separate waste at source and pass on separated waste to approved waste recyclers from the local authorities.
5. Create material recovery plants or secondary storage plants and provide easy access for the collection of recycled waste to waste pickers and recyclers.
6. Establish safe waste storage and transportation facilities for household hazardous waste to the hazardous wastes disposal facility.

7. Instruct road sweepers not to burn tree leaves gathered from street debris and store them individually and later, pass them to the waste collectors or to the local authority appointed agent.
8. Train waste collectors and waste collectors in solid waste management.
9. Promote the establishments in suitable locations on the markets, or near the markets, for decentralized compost plant or biomethanation plant, ensuring sanitary conditions.
10. Collect waste separately, depending on the populations, businesses, and locations, by streets, paths and by-lanes daily or in alternative days or twice a week.
11. Collect horticulture, gardening and parks waste separately and process as much as possible in parks and gardens itself.
12. Transportation of separated bio-degradable waste to processing plants such as compost, bio-methane plant, or any other faculty shall be done.
13. Non-bio-degradable waste should be transported to their respective processing facilities or material recycling (MRF) or secondary storage facilities.
14. According to the provisions present in the Construction and Demolition Waste Management Rules, 2016, the transportation of the waste generated at these sites shall be made.
15. Initiate community involvement in waste management and promotion of domestic composting, biogas production, decentralized waste processing at the community level subject to odor management and maintenance of sanitary conditions in the facility.
16. Phasing out of chemical fertilizer and using compost in all parks and gardens maintained by the local authorities and, where possible, elsewhere within the jurisdiction of the local authority, over the next two years. The informal waste recycling sector can provide incentives for recycling initiatives.
17. Facilitate constructing, operating and maintaining waste processing facilities such as bio-methanation, microbial composting, vermicomposting, anaerobic digestion or any other appropriate bio-stabilization method for bio-degradable waste; waste for energy processes like waste fuel for fuel fraction of waste or for feedstock to the solid waste-based power plant.
18. If the volume of waste reaches 5 metric tons per day, a proposal should be made for authorization to create a waste collection, processing and disposal facility.
19. Prepare and forward the annual report to the Commissioner, Controller, Municipal Administration or Appointed Officer by 30 April of the following year and send it to

the Secretary, Chair of the Department for State Urban Development or Village Panchayat or the Department for Country Development or the respective State Pollution Control Board or Pollution Control Committee on 31 May of the following year.

20. Contractors and door to door collection supervisors shall be directed to collect and transport non-mixed waste to processing or disposal sites, during primary and secondary transport.
21. The plant operator shall ensure that the facility provides personal safeguard equipment to all employees who handle solid waste, including uniform, fluorescent jackets, hand gloves, raincoats, suitable footwear and masks.
22. Ensure that guidelines are included in the building plan for creating centers to receive, segregate and store separated wastes when providing for building plans for the housing population or complex business group.
23. Identify bye- laws and administer spot fine requirements for persons who litter or refuse to comply, and delegate powers to officers and local authorities to levy spot fines under the by-laws specified. Stop the deposition or disposal of mixed waste immediately following the schedule stated in Rule 23 for the establishment and operation of sanitary waste.
24. Enable the inert and pre-processed refuse and waste from manufacturing facilities to be moved to sanitary sites including non-usable, non-recyclable, non-biodegradable, non-combustible and non-reactive materials.
25. Investigate and analyze all old open dumpsites and existing operational dumpsites for their potential of bio- mining and bio- remediation and wherever feasible, take necessary actions to bio- mine or bio- remediate the sites.
26. In absence of the potential of bio- mining and bio- remediation of the dumpsite, it shall be scientifically capped as per landfill capping norms to prevent further damage to the environment.

Duties of District Magistrate or District Collector or Deputy Commissioner according to Solid Waste Management Rules, 2016

At least once in a quarter, the District Officer or District Collector or Deputy Commissioner shall make it possible to identify and allocate appropriate land for the construction and disposal of solid waste, and to review the performance of local authorities.

Duties of the State Pollution Control Board or Pollution Control Committee according to the Solid Waste Management Rules, 2016

These laws shall be imposed in their respective states by the State Pollution Control Boards or the Commissions. The environmental quality shall be monitored by the commission and the request to grant authorization shall be considered; inter-state waste movement should be taken under control.

Duty of manufacturers or Brand owners of disposable products and sanitary napkins and diapers according to the Solid Waste Management Rules, 2016

1. The implementation of this waste management scheme shall be sponsored by all producers of disposable goods, such as tin, glass, plastics, packaging, etc. or the brand owners, who bring these items into the market.
2. All brand owners who are selling or distributing their goods in non-biodegradable packaging material must develop a system for recovering the packaging waste generated by their production.
3. Manufacturers or brand owners or companies that sell sanitary napkins or diapers shall explore the possibility to manufacture their products by using all recyclable materials or have a pouch for disposal, along with the packet of their sanitary items, of any fabric or fabric for each dress.
4. Education to the masses shall be given for the wrapping and disposal of their products by all the brand owners, companies or manufacturers.

Duties of the industrial units located within one hundred km from the RDF and Waste to Energy plants based on solid waste according to Solid Waste Management Rules, 2016

All fuel-using industrial plants located within 100 kilometers of an RDF solid waste plant must arrange for the replacement of at least 5 percent of its fuel requirement by RDF so provided within six months of the notification of those laws.

Criteria for setting up solid waste processing and treatment facilities.

1. The land allocation department must provide appropriate land for the construction of the processing and treatment plants for solid waste.
2. The facility operator shall obtain appropriate authorization and shall be responsible for the safe and environmentally friendly operations and/or process of solid waste in the facilities by the State Pollution Control Board or Pollution Control Committee.

3. An annual report shall be submitted to the State Pollution Control Board and Local Authority by 30th April by the operator of the solid waste collection and treatment facility.

Criteria and actions to be taken for solid waste management in hilly areas

1. Construction of landfill on the hill shall be avoided. A transfer station at a suitable enclosed location shall be set up to collect residual waste from the processing facility and inert waste. A suitable land shall be identified in the plain areas down the hill within 25 kilometers for setting up sanitary landfill. The residual waste from the transfer station shall be disposed of at this sanitary landfill.
2. Efforts shall be made to establish the regional sanitary wasteland for inert and residual waste in case of non-availability of such land.

Criteria for waste to energy process

1. Non-recyclable waste of 1500 kg/cal/kg or longer shall not be disposed of in dumps and only used as a feedstock for the preparation of waste-driven fuel, either by refuse-derived fuel, or by refuse-disposing it.
2. High calorific wastes shall be used for co- processing in cement or thermal power plants.

State Level Advisory Body

Within 6 months of the notification date of these laws, each of the departments in charge of the local bodies of the concerned State Government or Union Territory Administration shall constitute the State Level Advisory Body.

Time frame for implementation

The local authorities and other concerned authorities, as applicable, shall set up on their own initiative or by engaging agencies within the time limits laid down in the Rules the necessary infrastructure to enforce these regulations.

Create a solid waste disposal facility for all local authorities with 100,000 or more inhabitants within two years, create local authorities and census towns with a population of less than 1000, develop common or autonomous health sites by or for all local authorities with a population of 0.5 million or more, and set up a common or national sanity site for all local authorities and census towns with less than 0.5 million people.

Specifications for Sanitary Landfills

The regulations provide for site selection requirements, site development, landfill site development and site closure design, site closure, contamination control, old dump closure and restoration, and define the conditions for special provisions for hillock areas.

The rules also specify Standards of processing and treatment of solid waste, composting, treated leachates, incineration.

Monitoring

Overall oversight of the country's enforcement of these rules shall be conducted by the Ministry of the Environment, Forest and Climate Change. It shall constitute a Center for Monitoring, chaired by the Minister of Environment, Forest and Climate Change and comprising the Ministry of Urban Development, the Ministry of Rural Development, the Ministry of Climate Development, the Ministry of Agriculture, the Central Pollution Control Board and the Three-State Pollution Control Boards/ Pollution Control Boards and the urban planning and management boards, three Urban Local Bodies, Two census towns, FICCI, CII and Two subject experts.

This Committee shall meet at least once a year to track and review the compliance of the laws. If required, the Ministry can collaborate with other experts. Every three years, the Committee shall be renewed.

Important Provisions updated in the Solid Waste Management Rules, 2016

Segregation at source

The new rules include the segregation of the waste stream to collect, reuse and recycle waste. Waste generators will now need, before the waste being passed on to the collector, to sort waste into three fluxes-biodegradable, dry material (plastics, paper, metalworking, wood etc.) and domestically hazardous waste (diaper, serviettes, mosquito repellents, cleaning agents, etc.).

Institutional generators, business groups, event managers and hotels and restaurants were primarily responsible for the segregation and waste collection and control of waste in cooperation with local authorities. In the occurrence of an event or gathering in a place licensed/non-licensed of more than 100 people, the organizer shall guarantee the segregation of waste at the source and the distribution of separated waste, as stipulated by the local authority, to the waste collector or organization.

Collection and disposal of sanitary waste

The waste generators shall dispose of the waste of sanitary napkins generated in a pouch or wrapper for proper disposal which shall be provided by the manufacturer or the brand owner with the sanitary product as it is their responsibility.

Collect Back scheme for packaging waste

In accordance with the rules, a scheme to collect packaging waste from their manufacturing should be put in place for the brand owners who sell or market their products in a packaging material that is non-biodegradable.

User fees for collection

The new rules gave local authorities in India the authority to assess user charges. City authorities can charge usage fees from bulk generators for collection, disposal and distribution. According to the regulations, the generator must pay the "User Fee' to the waste collector and "Spot Fine" in the case of waste disposal and non-segregation, the quantum of which will be decided by the local bodies.

In addition, new rules have been referred to on incorporating the State government into the formal sector rag pickers, waste pickers and kabadiwalas from the informal sector.

Waste processing and treatment

In compliance with the new rules, it was advised that the biodegradable waste should be refined, treated and disposed of as far as possible by composting or bio-methanation at the facility as needed. Developers of the Special Economic Zone, industrial estate and industrial areas shall devote at least 5% of the total area of the property to the recovery and recycling facilities or at least 5 plots/sheds.

All local agencies with 1 million or more inhabitants within two years will have to establish waste processing facilities. The rules also require the bio-remediation or capping within five years of old and abandoned dump sites.

Promoting the use of compost

According to the regulations, the Fertilizer Department, the Chemicals Ministry and Fertilizers will provide city compost for business growth assistance and ensure co-commercialization with chemical fertilizers for the fertilizer companies, with a ratio of 3-4 bags to 6-7 bags as far as the composting sector is made accessible to the companies. In the

Fertilizer Control Order, the Ministry of Agriculture should also provide for the manufacture and sale of compost, the promotion of compost use on agricultural land and the establishment of compost quality testing laboratories manufactured by local authorities or their approved agencies.

Promotion of waste to energy

In a not-so-welcome move, the Solid Waste Management Rules, 2016 emphasise the promotion of waste to energy plants. The rules mandate all industrial units using fuel and located within 100 km from a solid waste-based Refuse-Derived Fuel (RDF) plant to make arrangements within six months from the date of notification of these rules to replace at least 5 percent of their fuel requirement by RDF so produced.

As per the rules, the Ministry of New and Renewable Energy Sources should facilitate infrastructure creation for Waste to Energy plants and provide appropriate subsidy or incentives for such Waste to Energy plants. The Ministry of Power should fix tariff or charges for the power generated from the Waste to Energy plants based on solid waste and ensure compulsory purchase of power generated from such Waste to Energy plants by DISCOMs.

Revision of parameters and existing standards

Under this new regulation, the deposit site is located 100 meters from the river, 200 meters from the ponds, 500, 200 meters from highways, homes, public parks and wells and 20 kilometers from airports. There are complete modifications to the emission standards including dioxin, furan and particulate matter reduction limits between 150 and 100 and now 50. The compost standards were also modified to comply with the Fertiliser Control Order.

Management of waste in hilly areas

The development of sites on hills is to be avoided according to the new guidelines. In plain areas within 25 kilometres, land for building sanitary sites in hilly areas will be listed. Transfer plants and processing plants in hilly areas shall however be operational.

Constitution of a Central Monitoring Committee

The Government also created the Central Monitoring Committee, chaired by the Secretary of the MoEF&CC, to monitor the overall enforcement of the laws. The Committee of the various stakeholders of the central and state governments will meet once a year to track the enforcement of these laws.

10.5. Implementation of Solid Waste Management Rules, 2016

The Solid Waste Management Rules has the ability to fully alter the waste management system in India. The rules sound too good to be true for a country with such colossal waste management. Unfortunately, the SWMR was not followed up with the correct mobilization of the agencies. There are a variety of other elements required for transformational change in location. Several people across the spectrum are willing to take the initiative to get involved. The policy structure, in particular SWMR, supports sustainable waste management through the steps set out above, with provisions that also encourage local authorities to impose user fees to cover their costs, etc.

However, the existing programs generate overflowing and over-exhausted landfill sites. Even if people are encouraged to segregate waste at the source, the non-compartmentalized transport and dumping equipment would discourage such responsible behaviour. The problem is that the organizations responsible for making such improvements are not geared and motivated. Community participation has not been withheld.

While the rest of the world evolves, local management mechanisms do not seem to be capable of handling this. Not because of some agency's deliberate mal intentions, but simply because we, as a state and community, have no idea as to how this and subsequent generations so desperately sought after the change agenda can be furthered.

Criteria for waste to energy process

Every year, millions of tons of solid waste is generated in households around the world and which is disposed of in council and municipal landfill sites, while at the same time, millions of units of energy from coal, oil and natural gas are burned daily to create the electrical power we need to run our homes and workplaces. Today, a new generation of Waste to Energy, (WTE) conversion technologies are emerging which hold the potential to create clean renewable energy from solid and liquid waste materials.

Waste to energy- The energy content available from combustion of solid waste represents a significant "alternative energy" supply to help reduce the use and our dependency on conventional fossil fuels. "Waste" by definition includes any waste materials other than liquids, gases and any non-usable by-product generated as a result of a process or production that is no longer deemed valuable, and are therefore normally discarded

Such waste materials typically originate from either the residential community as municipal solid waste or from commercial, light-industrial, and agricultural wastes.Traditionally the term “waste to energy” has generally referred to the practice of incineration of waste products either by burning the rubbish in the back yard or by large industrial incinerators to produce heat. The category of waste to energy broadly describes any of a number of processes or technologies in which a useful byproduct (energy) is recovered from an otherwise unusable source.

Waste to energy technologies- Physically convert waste matter into more useful forms of fuel that can be used to supply energy. This waste to energy processes includes thermal conversions such as combustion (incineration), pyrolysis, gasification, or biological treatments such as anaerobic digestion and fermentation, etc, and various combinations of the above.

The more common ways in which waste is converted in energy-

Combustion – This is by far the oldest, most common and well-proven thermal process using a wide variety of waste fuels. Municipal and household waste is directly combusted in large waste to energy incinerators as a fuel with minimal processing known as mass burning. The earliest waste combustion systems were simple incinerators which produced heat and carbon dioxide, along with a variety of other pollutants and had no energy recover capabilities. Today the heat energy generated from the combustion process is used to turn water into steam, which is then used to power steam-turbine generators to produce electricity. Most modern waste incinerators now incorporate heat recovery systems and air-pollution control systems. The mass burn process burns the waste virtually as it is received thereby eliminating the need to process the material prior to burning except for the removal of oversized items and obvious non-combustible metallic materials. The problem with this mass burn approach is that after combustion, the incinerators ash and other pollutants removal system must be capable of disposing of every bit of the size and capacity of the combusted material coming out the incinerator as it is going in.

1. **Gasification** – Gasification of waste materials is not the same as incineration. Incineration is the burning of waste fuels in an oxygen rich environment, where as gasification is the conversion of waste materials that takes place in the presence of limited amounts of oxygen. Gasification is a thermochemical process that converts solid wastes into a mixture of combustible gases. Steam or the oxygen in the air is reacted at high

temperature with the available carbon in the waste material to produce gases such as carbon monoxide, hydrogen and methane. The gasification process produces a syngas (hydrogen and carbon monoxide) which is used for generating electricity power. Whereas the incineration of waste to energy converts the fuel waste into energy directly on-site, thermal gasification of the waste materials allow the production of a gaseous fuel that can be easily collected and transported.

2. **Pyrolysis** – This is also a thermal process similar to gasification above which involves the thermal degradation of organic waste in the absence of free oxygen to produce combustible gases. In other words, pyrolysis uses heat to break down organic materials in the absence of oxygen. Materials suitable for pyrolysis processing include coal, animal and human waste, food scraps, paper, cardboard, plastics and rubber. The pyrolytic process produces oil which can be used as a synthetic bio-diesel fuel or refined to produce other useful products. Although pyrolysis technology has been around for a long time, its application to biomass and waste materials is a relatively recent development as pyrolytic products are more refined and therefore can be used with greater efficiency. A common byproduct of pyrolysis is a kind of fine-grained bio-charcoal called “biochar”, which retains most of the carbon and nutrients contained in biomass so can be used as a soil enhancement to increase soil productivity.
3. **Anaerobic Digestion** – Landfilling is still the primary method of disposal of municipal solid waste and if left undisturbed, landfill waste produces significant amounts of gaseous byproducts, consisting mainly of carbon dioxide (CO2) and methane (natural gas, CH4). This landfill gas or “biogas” is produced by the anaerobic (oxygen-free) digestion of organic matter. Anaerobic digestion to produce biogas can either occur naturally producing a landfill gas, or inside a controlled environment like a biogas digester. A digester is a warmed, sealed, airless container where bacteria ferment an organic material such as liquid and semi-liquid slurries, animal wastes and manures in oxygen-free conditions to produce biogas. The main advantage of anaerobic digestion for converting waste to energy fuel is that it deals with “wet waste” which normally may be difficult to dispose of. The amount of biogas produced is limited by the size of the digester tank, so is largely used as a fuel for small-scale operations, such as farms, where enough energy can be produced to run the farm. The biogas produced can be burned in a conventional gas boiler to produce heat or as fuel in a gas engine to generate electricity or fuel some of the farm vehicles.

4. **Fermentation** – Fermentation uses various microorganisms and yeasts to produce liquid ethanol, a type of alcohol, from biomass and biowaste materials. The conversion of waste to energy by fermentation requires a series of chemical reactions to produce the ethanol biofuel. The first reaction is called hydrolysis, which converts organic materials into sugars. The sugars are then fermented to make dilute ethanol, which is then further distilled to produce a biofuel grade ethanol, (ethyl alcohol). With increasing global consumerism and population growth leading to an increase in the levels of waste materials we produce, waste management technologies are now helping to find alternatives to landfills by converting as much of the mixed general waste back to be recycled or reused as possible in an attempt to turn waste into energy and waste into fuels. Converting Waste to Energy has many advantages too by not only reducing the amount of landfill dumping, but by reducing the amount of greenhouse-gas emissions and pollution we pump into the atmosphere each and every year as well as reducing our dependence on non-renewable fossil fuels. However, many waste to energy conversion technologies are designed to handle only one or a few types of waste and can be difficult to fully separate different types of waste materials. Advances in non-incineration conversion technologies and methods like pyrolysis and thermal gasification are providing ways of generating clean energy from waste materials that avoid many of the pollution concerns around conventional incineration and combustion.
5. Rather than sending residual wastes direct to landfill, advanced conversion technologies coupled with advanced pollution control systems can be employed to convert these calorific materials into clean energy. Advanced waste-to-energy technologies can be used to produce biogas (methane and carbon dioxide), syngas (hydrogen and carbon monoxide), liquid biofuels (ethanol and biodiesel), or pure hydrogen. Just as oil, coal and gas are used as fuels in a fossil fuel fired power stations, these alternative biofuels can also be converted into electricity. Today, we have the technologies and options available to us to separate the bio-waste which should be recycled, from the waste that can be used as a valuable and future energy source turning waste and other renewable waste fuels into clean energy.

10.6. Plastic Waste Management Rules, 2016

The draft rules, namely the Plastic Waste Management Rules, 2015 were published by the Government of India vide G.S.R. 423(E), dated the 25th May, 2015 in the Gazette of

India, inviting public objections and suggestions. The Plastic Waste Management Rules, 2016 aim to:

- Increase minimum thickness of plastic carry bags from 40 to 50 microns and stipulate minimum thickness of 50 micron for plastic sheets also to facilitate collection and recycle of plastic waste,
- Expand the jurisdiction of applicability from the municipal area to rural areas, because plastic has reached rural areas also;
- To bring in the responsibilities of producers and generators, both in plastic waste management system and to introduce collect back system of plastic waste by the producers/brand owners, as per extended producers responsibility;
- To introduce collection of plastic waste management fee through pre-registration of the producers, importers of plastic carry bags/multilayered packaging and vendors selling the same for establishing the waste management system;
- To promote use of plastic waste for road construction as per Indian Road Congress guidelines or energy recovery, or waste to oil etc. for gainful utilization of waste and also address the waste disposal issue; to entrust more responsibility on waste generators, namely payment of user charge as prescribed by local authority, collection and handing over of waste by the institutional generator, event organizers.

An eco-friendly product, which is a complete substitute of the plastic in all uses, has not been found till date. In the absence of a suitable alternative, it is impractical and undesirable to impose a blanket ban on the use of plastic all over the country. The real challenge is to improve plastic waste management systems.

In addition, the expected outcome from the new rules includes:

i. Increase in the thickness of carry bags and plastic sheets. Increasing the thickness of plastic carry bags from 40 to 50 micron and stipulation of 50 micron thickness for plastic sheets is likely to increase the cost by about 20 %. Hence, the tendency to provide free carry bags will come down and collection by the waste-pickers also increase to some extent.

ii. Collect back system

The producers, importers and brand owners who introduce the plastic carry bags, multi-layered plastic sachet, or pouches, or packaging in the market within a period of six months from the date of publication of these rules, need to establish a system for collecting back the plastic waste generated due to their products. They shall work out modalities for waste collection system based on Extended Producers Responsibility and involving State Urban Development Departments, either individually or collectively, through their own distribution channel or through the local body concerned. This plan of collection has to be submitted to the State Pollution Control Boards while applying for consent to Establish or Operate or Renewal. The producers / brand owners whose consent has been renewed before the notification of these rules shall submit such plan within one year from the date of notification of these rules and implement within two years thereafter.

The introduction of the collect back system of waste generated from various products by the producers/brand owners of those products will improve the collection of plastic waste, its reuse/ recycle.

iii. Phasing out of manufacture and use of non- recyclable multilayered plastic

Manufacture and use of non-recyclable multilayered plastic if any should be phased out in two years' time.

iv. Responsibility of waste generator

All institutional generators of plastic waste shall segregate and store the waste generated by them in accordance with the Solid Waste Management Rules, and handover segregated wastes to authorized waste processing or disposal facilities or deposition centers, either on its own or through the authorized waste collection agency.

All waste generators shall pay such user fee, or charge, as may be specified in the bye-laws of the local bodies for plastic waste management, such as waste collection, or operation of the facility thereof, etc.;

Every person responsible for organising an event in open space, which involves service of food stuff in plastic, or multilayered packaging, shall segregate and manage the waste generated during such events, in accordance with the Solid Waste Management Rules.

v. Responsibility of local bodies and Gram Panchayat

The local bodies shall be responsible for setting up, operationalisation and co-ordination of the waste management system and for performing associated functions.

vi. Responsibility of retailers and street vendors

Retailers or street vendors shall not sell, or provide commodities to consumers in carry bags, or plastic sheet, or multilayered packaging, which are not manufactured and labelled or marked, as prescribed under these rules.

Every retailer, or street vendor, selling or providing commodities in, plastic carry bags or multilayered packaging or plastic sheets, or like, or covers, made of plastic sheets which are not manufactured, or labelled, or marked, in accordance with these rules shall be liable to pay such fines, as specified under the bye-laws of the local bodies.

vii. Pre- registration fee

The shopkeepers and street vendors willing to provide plastic carry bags for dispensing any commodity shall register with local body. The local body shall, within a period of six months from the date of final publication of these rules on the Official Gazette of India notification of these rules, by notification, or an order under their appropriate state statute or byelaws shall make provisions for such registration on payment of plastic waste management fee of minimum Rs. 48, 000/- @ Rs. 4,000/- per month. The concerned local body may prescribe higher plastic waste management fee, depending upon the production, or sale capacity. The registered shopkeepers shall display at prominent place that plastic carry bags are given on payment.

Only the registered shopkeepers or street vendors shall be eligible to provide plastic carry bags for dispensing the commodities.

The local body shall utilize the amount paid by the customers for the carry bags exclusively for the sustainability of the waste management system within their jurisdictions.

The introduction of provision to collect fee from the producers, importers of plastic carry bags / multilayered packaging and vendors selling the same, will strengthen the financial status of local authorities and improve Plastic Waste Management System.

viii. Reuse of plastic waste

The options on reuse of plastic in various applications namely, road construction, waste to oil, waste to energy will enhance the recycling of plastic.

ix. Land for waste management facility

The responsibility to provide land for establishing waste management facility has been made to the Department with business allocation of land allotment in the State

Government. This would eliminate the issue of getting land for the waste management facility.

The Ministry had initially notified the Recycled Plastic Manufacture and Usage Rules in 1999, which was mainly on manufacturing and usage of Plastic carry bags. It is specified that the minimum thickness of plastic bags should be of 20 microns. The Plastic Waste (Management and Handling) Rules, 2011 laid down certain conditions for manufacturing, stocking, sale and use of plastic carry bags and sachets, which were required to be monitored and implemented by the State Pollution Control Boards/ Municipal Authorities. It specified that the minimum thickness of plastic bags should be of 40 microns. This was to facilitate its collection and recycle. However, the implementation of these rules was not so effective because the ambit of these rules was limited to notified municipal areas whereas today, the plastic has reached to our rural areas also. There were no provisions on responsibility of waste generators. The rules did not address the promotion of conversion of waste to useful resources. Though, it provided for Extended Producers Responsibility for the establishment of waste management system, pricing of carry bags etc. those were not exercised by the local authorities as it was simply left at the discretion of municipal authorities.

To implement these rules more effectively and to give thrust on plastic waste minimization, source segregation, recycling, involving waste pickers, recyclers and waste processors in collection of plastic waste and adopt polluter pays principle for the sustainability of the waste management system, the Central Government reviewed the existing rules and drafted revised rules. Stakeholders' consultation meets were organized in New Delhi, Mumbai and Kolkata wherein major Associations, industrial units, experts in various fields were invited. Consultative meetings with relevant State governments, State Pollution Control Boards were also held on these draft Rules. The suggestions / objections (238 in number) were received on these draft rules and have been examined by the Working Group. Based on the recommendations of the Working Group, now, the Plastic Waste Management Rules, 2016 have come into force.

Plastic has multiple uses and the physical and chemical properties lead to commercial success. However, the indiscriminate disposal of plastic has become a major threat to the environment. In particular, the plastic carry bags are the biggest contributors of littered waste and every year, millions of plastic bags end up in to the environment vis-a-vis soil, water bodies, water courses, etc and it takes an average of one thousand years to decompose completely. Therefore, to the address the issue of scientific plastic waste management, new regulations namely, the Plastic Waste (Management and Handling) Rules, 2011 were notified in 2011, which included plastic waste management.

10.7. Summary

Solid waste management refers to the collection, transportation, treatment, and disposal of waste in a way that is environmentally sustainable and socially responsible. The process of solid waste management involves several steps, including generation, collection, transport, processing or treatment, and disposal. Solid waste can be classified into various categories, such as municipal, industrial, hazardous, and biomedical waste. Municipal solid waste is generated from households, commercial establishments, and public places, while industrial waste is produced by factories and manufacturing units. The most common method of solid waste disposal is land filling, which involves burying the waste in a designated area. However, this method has several environmental concerns, such as the release of harmful gases and leachate into the environment. Other methods of solid waste disposal include incineration, which involves burning the waste at high temperatures, and recycling, which involves the conversion of waste materials into new products. These methods are generally more sustainable and environmentally friendly than land filling. Effective solid waste management requires a coordinated effort between government agencies, private organizations, and individuals. It involves the implementation of policies and regulations that encourage waste reduction, recycling, and proper disposal. Community education and awareness programs can also help promote responsible waste management practices.

10.8. Terminal question

Q.1. What is solid waste management? Discuss the municipal solid waste management.

Answer: --

Q.2. What are the criteria for solid waste management in hill area?

Answer: --

Q.3. Discuss the Responsibility of Municipal Authority.

Q.4. **Answer**: ---

Q.5. Discuss the Solid Waste Management Rules, 2016.

Answer: ---

Q.6. Discuss the Duties of the Central Pollution Control Board.

Answer: ---

Q.7. Waste processing and treatment of solid waste.

Answer: ---

Q.8. Implementation of Solid Waste Management Rules, 2016.

Answer: ---

10.8. Further suggested readings

1. "Waste Management Practices: Municipal, Hazardous, and Industrial" by John Pichtel - Wiley, 2018.
2. "Handbook of Solid Waste Management" by George Tchobanoglous and Frank Kreith - McGraw-Hill Education, 2019.
3. "Environmental Law Handbook" by Christopher L. Bell and Richard G. Stoll - Government Institutes, 2018.
4. "Introduction to Environmental Engineering and Science" by Gilbert M. Masters and Wendell P. Ela - Prentice Hall, 2019.
5. "Waste Management and Sustainable Development: Trends and Impacts" by SyedaAzeemUnnisa - Springer, 2021.

Unit-11: Hazardous and Medical Wastes Management

11.1 Introduction

In India, hazardous waste management is governed by the Hazardous Waste Management (HWM) Rules, which were first introduced in 1989 and have since undergone several amendments to keep up with changing times and technologies. The latest version of the HWM Rules was introduced in 2016.The HWM Rules provide guidelines and regulations for the handling, storage, transportation, and disposal of hazardous waste in India. The rules require that hazardous waste be treated and disposed of in an environmentally sound manner to protect human health and the environment. The Biomedical Waste Management and Handling Rules, 2016 is the primary legislation in India for the management and handling of biomedical waste. The rules were introduced by the Ministry of Environment, Forest and Climate Change, and they supersede the earlier Biomedical Waste (Management and Handling) Rules, 1998.

Objectives

- To study about hazardous waste
- To study the hazardous waste management and handling rules 1989
- To study hospital waste management
- to understand the bio-medical waste (management and handling) rules 199

11.2 Hazardous waste

Hazardous waste is any type of waste material that is potentially harmful or dangerous to human health and the environment. This can include materials that are toxic, flammable, corrosive, reactive, or infectious.

Examples of hazardous waste include chemicals, batteries, electronic waste, medical waste, pesticides, solvents, and radioactive materials. These types of waste require special handling, transportation, and disposal to ensure that they do not pose a threat to public health or the environment.Proper management of hazardous waste is essential to prevent contamination of soil, water, and air. Governments have regulations in place to govern the proper handling, transportation, and disposal of hazardous waste to minimize the risk of exposure to humans and the environment.The HWM Rules are enforced by the State Pollution Control Boards and the Central Pollution Control Board. Additionally, the Ministry of Environment, Forests, and Climate Change has established the Central Pollution Control Board to oversee hazardous waste management in the country.

Biomedical waste, also known as medical waste, is a type of hazardous waste that is generated from healthcare facilities such as hospitals, clinics, and research centers. This waste is generated during medical diagnosis, treatment, or research of humans or animals.Biomedical waste includes a variety of materials such as human tissues, body fluids, discarded sharps (needles, scalpels, and other sharp medical instruments), laboratory waste, cultures, stocks, and other waste generated from medical facilities.Improper disposal of biomedical waste can pose significant health risks to humans and the environment. It can spread infectious diseases like HIV, hepatitis B and C, and other viral and bacterial infections. It can also lead to contamination of soil, water, and air.

Therefore, it is essential to properly handle, transport, and dispose of biomedical waste. This includes segregating and properly labeling different types of biomedical waste, using proper personal protective equipment while handling them, and using proper disinfectants and treatment methods to dispose of them. Governments have regulations in place to govern the proper handling, transportation, and disposal of biomedical waste to minimize the risk of exposure to humans and the environment.

11.3 The hazardous wastes (management and handling) rules, 1989

[Notification No. SO 594(E), dated 28th. July, 1989][1]

In exercise of the powers conferred by sections 6, 8, and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government hereby makes the following rules, namely: -

1. Short title and commencement

(1) These rules may be called the Hazardous Wastes (Management and Handling) Rules, 1989.

(2) They shall come into force on the date of their publication in the Official Gazette.

2. Application

These rules shall apply to hazardous wastes as specified in the Schedule and shall not apply to-

a) waste water and exhaust gases as covered under the provisions of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974), and the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981), and rules made there under;

b) wastes arising out of the operation from ships beyond five kilometers as covered under the provisions of the Merchant Shipping Act, 1958 (44 of 1958), and the rules made there under;

c) Radioactive wastes as covered under the provisions of the Atomic Energy Act, 1962 (33 of 1962), and rules made there under.

3. Definitions

In these rules, unless the context otherwise requires-

a) "Act" means the Environment (Protection) Act, 1986 (29 of 1986);

b) "applicant" means a person or an organization that applies, in Form I, for granting of authorization to perform specific activities connected with handling of hazardous wastes;

c) "authorization" means permission for collection, reception, treatment, transport, storage and disposal of hazardous wastes, granted by the competent authority in Form 2;

d) "authorized person" means a person or an organization authorized by the competent authority to collect, treat, transport, store or dispose of hazardous wastes in accordance with the guidelines to be issued by the competent authority from time to time;

e) "export" with its grammatical variations and cognate expressions, means taking out of India to a place outside India;

f) "exporter" means any person under the jurisdiction of the exporting country who exports hazardous wastes and the exporting country itself, which exports hazardous wastes;

g) "facility" means any location wherein the processes incidental to the waste generation, collection, reception, treatment, storage and disposal are carried out;

h) "Form" means a Form appended to these rules;

i) "hazardous wastes" means categories of wastes specified in the Schedule;

j) "hazardous wastes site" means a place for collection, reception, treatment, storage and disposal of hazardous wastes which has been duly approved by the competent authority;

k) "import", with its grammatical variations and cognate expressions, means bringing into India from a place outside India;

l) "importer" means an occupier or any person who imports hazardous wastes;

m) "operator of a facility" means a person who owns or operates a facility for collection, reception, treatment, storage and disposal of hazardous wastes;

n) "Schedule" means the Schedule appended to these rules;

o) "State Pollution Control Board" means the Board appointed under sub-section (1) of section 4 of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) and under section 4 of the Air (Prevention and Control of, Pollution) Act, 1981 (14 of 1981);

p) "transboundary movement" means any movement of hazardous wastes or other wastes from an area under the national jurisdiction of one country to or through an area under the national jurisdiction of another country or to or through an area not under the national jurisdiction of any country, provided at least two countries are involved in the movement;

q) the words and expressions used in these rules and not defined but defined in the Act, shall have the meanings respectively assigned to them in the Act.

4. Responsibility of the occupier for handling of wastes

(1) The occupier generating hazardous wastes listed in column (2) of the schedule in quantities equal to or exceeding the limits given in column (3) of the said Schedule, shall take all practical steps to ensure that such wastes are properly handled and disposed of without any adverse effects which may result from such wastes and the occupier shall also be responsible for proper collection, reception, treatment, storage and disposal of these wastes either himself or through the operator of facility.

(2) The occupier or any other person acting on his behalf who intends to get his hazardous waste treated by the operator of a facility under sub-rule (1) shall give to the operator of a facility such information as may be specified by the [2][State Pollution Control Board or [3][Committee]].

5. Grant of authorization for handling hazardous wastes

(1) Hazardous wastes shall be collected, treated, stored and disposed of only in such facilities as may be authorized for this purpose.

(2) Every occupier generating hazardous wastes and having a facility for collection, reception, treatment, transport, storage and disposal of such wastes shall make an application in Form 1 to the [2][State Pollution Control Board or Committee] for the grant of authorization for any of the above activities:

PROVIDED that the occupier not having a facility for the collection, reception, treatment, transport, storage and disposal of hazardous wastes shall make an application to the State Pollution Control Board in Form 1 for the grant of authorization within a period of six months from the date of commencement of these rules.

(3) Any person who intends to be an operator of a facility for the collection, reception, treatment, transport, storage and disposal of hazardous wastes, shall make an application in Form 1 to the [2][State Pollution Control Board or Committee] for the grant of authorization for any of the above activities:

PROVIDED that the operator engaged in the business of collection, reception, treatment, transport, storage and disposal of hazardous wastes shall make an application to the State Pollution Control Board in Form 1 for the grant of authorization within a period of six months from the date of commencement of these rules.

(4) The [2][State Pollution Control Board or Committee] shall not issue an authorization unless it is satisfied that the operator of a facility or an occupier, as the case may be, possesses appropriate facilities, technical capabilities and equipment to handle hazardous wastes safely.

(5) The authorization to operate a facility shall be issued in Form 2 and shall be subject to conditions laid down therein.

(6) (i) An authorization granted under this rule shall, unless sooner suspended or cancelled, be in force for a period of two years from the date of issue or from the date of renewal.

(ii) An application for the renewal of an authorization shall be made in Form 1, before its expiry.

(iii) The authorization shall continue to be in force until it is renewed or revoked.

(7) The [2][State Pollution Control Board or Committee] may, after giving reasonable opportunity of being heard to the applicant, refuse to grant any authorization.

6. Power to suspend or cancel an authorization

(1) The [2][State Pollution Control Board or Committee] may cancel an authorization issued under these rules or suspend it for such period as it thinks fit if, in its opinion, the authorized person has failed to comply with any of the conditions of the authorization or with any provisions of the Act or these rules, after giving the authorized person an opportunity to show cause and after recording reasons therefore.

(2) Upon suspension or cancellation of the authorization and during the pendency of an appeal under rule 12, the [2][State Pollution Control Board or Committee] may give directions to the persons whose authorization has been suspended or cancelled for the safe storage of the hazardous wastes, and such person shall comply with such directions.

7. Packaging, labeling and transport of hazardous wastes

(1) Before any hazardous waste is delivered at the hazardous wastes site, the occupier or operator of a facility shall ensure that the hazardous waste is packaged in a manner suitable for storage and transport and the labeling and packaging shall be easily visible and be able to withstand physical conditions and climatic factors.

(2) Packaging, labeling and transport of hazardous wastes shall be in accordance with the provisions of the rules issued by the Central Government under the Motor Vehicles Act, 1988, and other guidelines issue from time to time.

8. Inventory of disposal sites

(1) The State Government or a person authorized by it shall undertake a continuing programme to identify the sites and compile and publish periodically an inventory of disposal sites within the State for the disposal of hazardous wastes.

(2) The State Government or a person authorized by it shall undertake an environmental impact study before identifying a site as waste disposal site in the State.

(3) The State Government or a person authorized by it shall undertake a continuing programme to compile and publish an inventory of sites within the State at which hazardous wastes have at any time been stored or disposed of and such inventory shall contain, besides the location and description, information relating to the amount, nature and toxicity of hazardous wastes at each such site as may be associated with such site.

9. Records and returns

(1) The occupier generating hazardous waste and operator of a facility for collection, reception, treatment, transport, storage and disposal of hazardous waste shall maintain records of such operations in Form 3.

(2) The occupier and operator of a facility shall send annual returns to the [2][State Pollution Control Board or Committee] in Form 4.

10. Accident reporting and follow-up

here an accident occurs at the facility or on a hazardous waste site or during transportation of hazardous wastes, the occupier or operator of a facility shall report immediately to the [2][State Pollution Control Board or Committee] about the accident in Form 5.

11. Import of hazardous wastes

(1) Import of hazardous wastes from any country to India shall not be permitted for dumping and disposal of such wastes. However, import of such wastes may be allowed for processing or reuse as raw material, after examining each case on merit by the [2][State Pollution Control Board or Committee] or by an officer authorised in this behalf.

(2) The exporting country or the exporter, as the case may be, of hazardous wastes shall communicate in Form 6 to the Central Government (the Ministry of Environment and Forests) of the proposed transboundary movement of hazardous wastes.

(3) The Central Government shall, after examining the communication received under sub-ruleand on being satisfied that the import of such hazardous wastes is to be used for processing or reuse as raw material, grant permission for the import of such wastes subject to such conditions as the Central Government may specify in this behalf and if, however, the Central Government is not satisfied with the communication received under sub-rule (2), it may refuse permission to import such hazardous wastes.

(4) Any importer importing hazardous wastes shall provide necessary information as to the type of hazardous wastes he is to import, in Form 6, to the concerned [2][State Pollution Control Board or Committee] the Central Pollution Control Board in the case of Union Territories.

(5) The [2][State Pollution Control Board or Committee] shall examine the information received under sub-rule (4) and issue such instructions to the importer as it considers necessary.

(6) The Central Government or the [2][State Pollution Control Board or Committee I, as the case may be, shall inform the concerned Port Authority to take appropriate steps regarding the safe handling of the hazardous wastes at the time of off-loading the same.

(7) Any person importing hazardous wastes shall maintain the records of the hazardous wastes imported as specified in Form 7 and the records so maintained shall be open for inspection by the [2][State Pollution Control Board or Committee]/ the Ministry of Environment and Forests/the Central Pollution Control Boards in the case of Union

Territories or an officer appointed by them in this behalf.

12. Appeal

1. An appeal shall lie against any order of suspension or cancellation or refusal of an authorization by the [2][State Pollution Control Board to the State Government or Committee to the Union Territory] and to the Ministry of Environment and Forests in the case of the Central Pollution Control Board.
2. Every appeal shall be in writing and shall be accompanied by a copy of the order appealed against and shall be presented within thirty days of the order passed.

SCHEDULE: CATEGORIES OF HAZARDOUS WASTES

[Rules 3(i), 3(n) and 4]

Waste categories	Types of Wastes	Regulatory quantities
(1)	**(2)**	**(3)**
Waste Category No. 1	Cyanide wastes	1 kilogram me per year Calculated as cyanide.
Waste category No. 2	Metal finishing wastes	10 kilograms per year the sum of the specified substance Calculated as pure metal.
Waste Category No. 3	Waste containing water soluble chemical compounds of lead, copper, Zinc, Chromium, nickel, selenium, Barium and antimony	10 kilograms per year the sum of the specified substance calculated as pure metal.
Waste Category No. 4	Mercury, arsenic, thallium and cadmium bearing wastes	5 kilogrammes per year the sum of the specified substance calculated as pure metal.
Waste Category No. 5	Non-halogenated hydrocarbons including solvents	200 kilogrammes per year calculated as non-halogenated hydrocarbons.
Waste Category No. 6	Halogenated hydrocarbons including solvents	50 kilogram's per year calculated as halogenated hydrocarbons.
Waste Category No. 7	Wastes from paints, pigments glue, varnish and printing ink	250 kilogram's per year calculated as oil or oil

		emulsions.
Waste Category No. 8	Wastes from dyes and dye intermediates containing inorganic chemical compounds	200 kilogrammes per year calculated as inorganic chemicals.
Waste category No. 9	Wastes from dyes and dye intermediates containing organic chemical compounds	50 kilogrammes per year calculated as organic chemicals.
Waste category No. 10	Waste oil and oil emulsions	1000 kilogrammes per year calculated as oil and oil emulsions.
Waste category No. 11	Tarry wastes from refining and tar residues from distillation or pyrolytic treatment	200 kilogrammes per year calculated as tar.
Waste category No. 12	Sludges arising from treatment of waste waters containing heavy metals, toxic organics,oils, emulsions and spent chemicals and incineration ash	Irrespective of any quantity.
Waste Category No. 13	Phenols	5 kilogrammes per year calculated as phenols.
Waste category No. 14	Asbestos	200 kilogrammes per year calculated as asbestos.
Waste Category No.15	Wastes from manufacturing of pesticides and harbicides and residues from pesticides and herbicides formulation units	5 kilogrammes per year calculated as pesticides and their intermediate products
Waste category No. 16	Acid/ alkaline/ slurry wastes	700 kilogrammes per year calculated as acids/ alkalies.
Waste category No. 17	Off-specification and discarded products	Irrespective of any quantity.

Waste category No. 18	Discarded container and container liners of hazardous and toxic chemicals and wastes	Irrespective of any quantity.

11.4 Summary of the Hazardous Wastes (Management and Handling) Rules, 1989

Hazardous waste is a complicated issue since it endangers both the environment and human health. Hazardous Waste (Management and Handling) Rules, 1989 were published by the Ministry of Environment, Forest and Climate Change (MoEF& CC), formerly known as the Ministry of Environment and Forest (MoEF), in accordance with the provisions of the Environment Protection Act, 1986. The Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008, which supersede previous notifications, were finalized in 2008 after being updated in the years 2000, 2003, and 1989. The Rules provide matching obligations for various authorities.

What is the meaning of Waste?

"Waste" refers to resources that are not products or by-products and have no further use for manufacturing, transformation, or consumption by the generator. The word "waste" refers to materials that may be produced during the extraction of raw materials, the processing of those materials into intermediate and final products, the consumption of those goods, and other human activities, but does not include residuals that are recycled or reused at the site of creation. A byproduct is a substance that is not meant to be generated but is created during the manufacturing process of the intended product and used as such.

What is the meaning of Hazardous Waste?

The fundamental goal of a hazardous waste definition is to assist stakeholders in determining whether waste is dangerous or potentially harmful. According to the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, "hazardous waste" is defined as any waste that, due to characteristics such as physical, chemical, biological, reactive, poisonous, combustible, explosive, or corrosive, causes or is likely to cause risk to health or the environment, whether alone or in interaction with other waste or substances.

Object of the Rules

The Rules aim is to regulate the production, collection, processing, treatment, importation, storage, and management of hazardous waste.

Scope and Applicability of the Rule

The regulations for managing hazardous and other wastes as listed in the schedules to these rules are also applicable across all of India and are governed by this Act. The rules are not applicable in the following circumstances −

Provisions under the Rule

The rule consists of 21 sections and 8 schedules. The important provisions are −

Section	**Content**
Section 1	Short Title and Commencement
Section 2	Application
Section 3	Definitions
Section 4	Responsibility of the Occupier and Operator of a facility for handling of the wastes
Section 5	Grant of authorization for handling hazardous wastes.
Section 6	Power to suspend or cancel an authorization.
Section 7	Packaging, labelling and transport of hazardous wastes.
Section 8	Disposal sites
Section 9	Records and returns
Section 10	Accident reporting and follow-up
Section 11	Import and export of hazardous wastes for dumping and disposal
Section 12	Import and export of hazardous wastes for recycling and reuse
Section 13	Import of hazardous waste.
Section 14	Export of hazardous waste.
Section 15	Illegal traffic.
Section 16	Liability of the occupier, transporter and operator of a facility.

Section 17	Transitional provisions
Section 18	Appeal.
Section 19	Procedure for registration and renewal of registration of recyclers and re-refiners.
Section 20	Responsibility of waste generator.
Section 21	Technology and standards for re-refining or recycling.

Schedules

In addition to this, there are 8 schedules.

The given table illustrates the major points of these schedules −

Schedule	**Content**
Schedule 1	List of processes generating hazardous wastes.
Schedule 2	List of waste constituents with concentration limits.
Schedule 3	List of Hazardous Wastes applicable for import and export.
Schedule 4	List of the commonly recyclable wastes.
Schedule 5	Specification of used oil suitable for recycling and specification of fuel derived from waste oil.
Schedule 6	List of Hazardous and other wastes prohibited for import.
Schedule 7	List of authorities and corresponding duties.
Schedule 8	List of documents for verification by customized for import of certain wastes.

How to Identify Hazardous Waste under the Rule?

Hazardous wastes represent current or potential threats to human health or living creatures because they are −

Non-biodegradable or persistent in nature;

Can be biologically amplified; and

Are very poisonous and even fatal at very low quantities.

A substance must also fulfill the requirements given in the regulation definition of solid waste in order to be categorized as a hazardous waste.

For the identification of Hazardous Waste it must determine if a waste is dangerous, we can use one or both of the following criteria −

The list of substances that government organizations have designated as harmful.

Features of the compound, such as ignitability, corrosively, reactivity, and toxicity

Conclusion

Waste that poses serious or prospective risks to the environment or public health is referred to as hazardous waste. Dangerous products include hazardous trash. The following hazardous characteristics are typically present in them: ignitability, reactivity, corrosivity, and toxicity. Listed hazardous wastes are substances that are expressly identified by regulatory authorities as hazardous wastes and come from a variety of sources, including chemical goods that have been abandoned or specified source.

11.5 Bio-medical waste (management and handling) rules, 1998

The Biomedical Waste Management & Handling) Rules, 1998 came into force on 1998. In exercise of the powers conferred by section 6,8&25 of EP Act, 1986, the Central Govt. notified these rules for the management and Handling of biomedical wastes generated from Hospitals, clinics, other institutions for scientific management of Biomedical Waste.

Shorttitleandcommencement:

TheserulesmaybecalledtheBio-MedicalWaste(ManagementandHandling)Rules, 1998.Theyshallcomeintoforceonthe dateoftherepublicationintheofficialGazette.

APPLICATION:

These rules apply toall persons whogenerate,collect, receive,store, transport, treat, dispose,or handlebio medical waste in anyform.

DEFINITIONS: Intheserulesunlessthecontexton therise requires

"Act “meanstheEnvironment(Protection)Act,1986(29of1986);

"Animal House" means a place where animals are reared/kept for experiments or testingpurposes;

"Authorization" means permission granted by the prescribed authority for the generation,collection,reception, storage,transportation,treatment,disposaland/or anyotherformofhandlingofbio-medicalwasteinaccordancewiththeserulesandanyguidelinesissued by the Central Government.

Authorized person" means an occupier or operator authorized by the prescribed authority to generate, collect, receive, store, transport, treat, dispose and/or handle bio-medical waste inaccordancewiththeserulesandanyguidelinesissuedbytheCentralGovernment;

"Bio-medical waste" means any waste, which is generated during the diagnosis, treatment orimmunization of human beings or animals or in research activities pertaining thereto or in theproductionortestingofbiological,andincludingcategoriesmentionedinScheduleI;

"Biologicals" means any preparation made from organisms or micro-organisms or product ofmetabolism and biochemical reactions intended for use in the diagnosis, immunization or thetreatmentofhumanbeingsoranimals orinresearchactivities pertainingthereto;

"Bio-medical waste treatment facility" means any facility wherein treatment. disposal ofbio-medical waste or processes incidental to such treatment or disposal is carried out (andincludes common treatment facilities).Added by Rule2(1) of the Bio-Medicalwaste (M&H)(Second Amendment) Rules,2000 notified vide notification No.S.O.545 (E), dated 2-06-2000andcameintoforcew.e.f2-6-2000.(7(a)FormmeansFormappendedtotheseRules)

"Occupier"in relation to any institutiongenerating bio-medical waste,which includesahospital, nursing home, clinic dispensary, veterinary institution, animal house, pathologicallaboratory, blood bank by whatever name called, means a person who has control over thatinstitution and/or its premises;

"Operatorof abio-medicalwastefacility"meansapersonwhoownsorcontrolsoroperates a facility for the collection, reception, storage, transport, treatment, disposal or anyotherformof handlingof bio-medicalwaste;

"Schedule “meansscheduleappendedtotheserules;

Dutyofoccupier:

It shall be the duty of every occupier of an institution generating bio-medical waste which includes ahospital, nursing home, clinic, dispensary, veterinary institution, animal house, pathological laboratory,blood bank by whatever name called to take all steps to ensure that such waste is handled without anyadverseeffectto humanhealthand theenvironment.

Treatmentanddisposal

Bio-medical waste shall be treated and disposed of in accordance with Schedule I, and incompliance withthestandardsprescribedinSchedule V.

Every occupier, where required, shall set up in accordance with the time-schedule in ScheduleVI, requisitebiomedicalwastetreatmentfacilitieslikeincinerator,autoclave,microwavesystem for the treatment of waste, or, ensure requisite treatment of waste at a common wastetreatment facilityoranyotherwastetreatmentfacility.

Segregation,packaging, transportationandstorage

Bio-medicalwasteshallnotbemixedwithotherwastes.Bio-medicalwasteshallbesegregatedintocontainers/bagsatthepointofgenerationinaccordance with Schedule II prior to its storage, transportation, treatment and disposal. Thecontainers shallbelabeled accordingtoSchedule III.If a container is transported from the premises where bio-medical waste is generated to anywastetreatmentfacility outside thepremises,thecontainershall,apartfromthelabelprescribedinScheduleIII,alsocarryinformation prescribedinScheduleIV.Notwithstanding anything contained in the Motor Vehicles Act, 1988, or rules there under,untreated biomedical waste shall be transported only in such vehicle as may be authorized forthepurposebythecompetentauthorityasspecifiedbythegovernment.Nountreatedbio-medicalwasteshallbe keptstoredbeyondaperiodof48hoursProvided thatany reason it becomes necessary tostore the waste beyond suchperiod,the authorized personmusttakepermissionoftheprescribedauthorityandtakemeasurestoensurethatthewastedoes notadverselyaffecthumanhealthandtheenvironment.

[(6) The Municipal body of the area shall continue to pick up and transport segregated non bio-medical solid waste generated in hospitals and nursing homes, as well as duly treated bio-medical wastes for disposal at municipal dump site.Inserted by Rules 3 of the Bio-MedicalWaste(Management&Handling)(SecondAmendment)Rules,2000videnotificationS.O. 545(E),dated2-6-2000.

Prescribedauthority

Save as otherwise provide, the prescribed authority for enforcement) of the provisions of these rules shall be the State Pollution Control Boards in respect of States and the PollutionControlCommitteesinrespectoftheUnionTerritoriesandallpendingcases with a prescribed authority appointed earlier shall stand transferred to the concerned State PollutionControlBoard,orasthecasemaybe,thePollutionControlCommittees).The prescribed authority for enforcement of the provisions of these rules in respect of all healthcareestablishmentsincludinghospitals,nursinghomes,clinics,dispensaries,veterinaryinstitutions, Animal houses, pathological laboratories and blood banks of the Armed ForcesundertheMinistryofDefenseshallbetheDirectorGeneral,ArmedForcesMedicalServices.

The prescribed authority shall function under the supervision and control of the respectiveGovernment ofthe Stateor UnionTerritory.

The prescribed authority may cancel or suspend an authorization, if for reasons, to be recordedin writing, the occupier/operator has failed to comply with any provision of the Act or these rules:Providedthatno authorization shallbecancelledorsuspendedwithoutgivingreasonableopportunity tothe occupier/operatorof being heard.

AUTHORISATION

Everyoccupierofaninstitutiongenerating,collecting,receiving,storing,transporting,treating,disposingand/orhandlingbio-medicalwasteinanyothermanner,exceptsuch occupierofclinics,dispensaries,pathologicallaboratories,bloodbankprovidingtreatment/servicetolessthan1000(one thousand)patientspermonth,shallmakean applicationinForm1totheprescribedauthorityforgrantofauthorization.

Everyoperatorofabio-medicalwastefacilityshallmakeanapplicationinForm1totheprescribed authorityforgrant toauthorization.

EveryapplicationinForm1forgrantof authorization shallbeaccompaniedbyafeeasmaybeprescribedbytheGovernmentoftheStateorUnionTerritory.Theauthorizationtooperateafacilityshallbeissuedin Form-IV,subjecttoconditionslaidthereinandsuchothercondition,astheprescribedauthority,mayconsiderit necessary.

ANNUALREPORT

Everyoccupier/operatorshallsubmitanannualreporttotheprescribedauthorityinForm11by31 January every year, to include information about the categories and quantities of bio-medicalwasteshandledduringtheprecedingyear.Theprescribedauthorityshallsendthisinformationinacompiledformtothe CentralPollutionControlBoardby31Marcheveryyear.

MAINTENANCEOFRECORDS

Every authorized personshallmaintainrecordsrelatedtothegeneration,collection,reception, storage, transportation,treatment, disposaland/orany form of handling of bio-medicalwasteinaccordancewiththeserulesandanyguidelinesissued.

All records shall be subject to inspection and verification by the prescribed authority at anytime.

ACCIDENTREPORTING

Whenanyaccidentoccursatanyinstitutionorfacilityoranyothersitewherebio-medicalwasteishandledorduringtransportationofsuchwaste,the authorized personshallreporttheaccident in to the prescribedauthority forthwith.

COMMONDISPOSAL/INCINERATIONSITES

Withoutprejudice to rule 5 of these rules, the Municipal Corporations, Municipal Boards orUrban Local Bodies, as the case may be, shall be responsible for providing suitable commondisposal/incineration sites for the biomedical wastes generated in the area under their jurisdictionand in areas outside the jurisdiction of any municipal body, it shall be the responsibility of theoccupiergeneratingbio-medicalwaste/operatorofabio-medicalwastetreatmentfacilityto arrangeforsuitablesitesindividuallyorinassociation,soastocomplywiththeprovisionsoftheserules].

11.6. BIO-MEDICAL WASTE (MANAGEMENT AND HANDLING)RULES, 1998 as amended in 2016

Introduction

Hospitals and various other laboratories engender a wide range and a significant quantity of wastes (including biomedical or infectious waste) that has the ability to give rise to various health problems and environmental hazards. Generally in India, 1-2 kg waste per bed per day in a hospital and 600 gm waste per day per bed in a clinic is generated, out of which more than 15% is hazardous or infectious and this hazardous waste is mixed with remaining waste which results into the contamination of the entire waste. This is why proper, effective, and efficient rules and regulations are needed for segregation and disposal of waste. The sustainable management of these wastes is the social and legal responsibility of the government as well as the public at large. So these wastes have to be properly collected, transported, and disposed of in order to safeguard the environment, and to streamline these activities various guidelines and rules were published by the Government of India in 1998 known as the Biomedical Waste (Management and Handling) Rules, 1998.

These rules are continuously monitored, altered, and updated from time to time as effective management is necessary for a cleaner and greener environment. In 2016, the Government of India decided to publish a new set of rules, Biomedical Waste Management Rules, 2016, supervening the old one with various changes and additions in order to improve the collection, segregation, treatment, and disposal facilities of these biomedical waste produced by the hospitals and laboratories to mitigate the environmental pollution. The treatment technologies identified include incineration, microwaving, autoclaving, and chemical treatment.

Biomedical waste

Biomedical waste (hereinafter BMW) is defined under the rules as any waste produced during the diagnosis, treatment, or immunization of human or animal research activities pertaining thereto or in the production or testing of biological or in health camps.

In simple words, these wastes include animal anatomical waste, human waste, medical apparatus like syringes, needles, and other materials used in hospitals and other laboratories(research center, nursing homes, blood bank, pathological laboratories, etc) in the process of research and treatment.

Biomedical wastes are divided into four color category:

Yellow: In this category, eight types of waste are categorized- Human anatomical waste, animal anatomical waste, soiled waste, expired or discarded waste, chemical waste, chemical liquid waste(separate collection system leading to effluent treatment system), discarded linen, mattresses, beddings contaminated with blood or body fluid, and microbiology, biotechnology, and other clinical laboratory waste.

Red: It includes contaminated waste that is recyclable like waste generated from disposable items such as tubing, bottles, intravenous tubes and sets, urine bags, syringes, and gloves.

White(Translucent): It includes waste sharps including metals (includes used, contaminated and discarded metal sharps)

Blue: It includes broken or contaminated or discarded glass and metallic body implants.

Objective

The main objective of these rules is based on the concept of 3Rs, namely, reduce, recycle, and reuse. It aims to delimit the waste, recover or reuse it as much as possible, and avoid disposing of it. The waste should be tackled at the origin or at source rather than the "end of pipe approach".

These guidelines mainly focus on the application and implementation of rules and regulations for the betterment of the environment as well as the people. In these rules, it was explicitly mentioned that these guidelines don't apply to hazardous chemicals, municipal solid waste, radioactive waste, lead-acid batteries, e-waste, genetically engineered organisms, and cells, and hazardous microorganisms which are governed under other rules. The important elements of the rules are training to workers, health checkups, immunization, and occupation safety of the workers.

As per the Indian government data, the total biomedical waste generated is 484 tonnes per day from 1,68,869 health care facilities in the country but only 447 tonnes per day is treated. There are only 198 common biomedical waste treatment facilities in operation. The number of healthcare facilities using common biomedical waste treatment facilities is 1,31,837 and approximately 21870 health care facilities have their own treatment facilities on-site. To overcome this problem, these stringent rules have been notified by the government and to ensure no pilferage of recyclables items occurs.

Main provisions

These rules have been modified completely to ensure the management of regulation of biomedical waste in the country. The term 'handling' is also being removed from the name which gives more clarity about the management and implications of the rules. Some of the updated and salient features of the rules are as follows:

- Now the wastes from vaccination camps, blood donation camps, and surgical camps are also included, thus expanding the scope of the rules.
- Duties of both occupiers (one who has administrative control over the health care facilities that is generating biomedical wastes) and operators (one who controls the facilities of collection, reception, transportation, treatment, and disposal of biomedical wastes) are unambiguously specified under these rules.
- Setting up of a barcode system for biomedical waste that is to be sent for treatment or disposal.

- Maintenance of biomedical waste register daily and monthly updates on the website either by the operator or occupier and also the maintenance of all the records for operation of hydroclaving/incineration/autoclaving for a period of 5 years.
- The method i.e. segregation, packaging, transportation, and storage of biomedical wastes has been improved and the waste has been classified into four categories instead of ten for efficacious management.
- There should be a distance of seventy-five kilometers of common biomedical waste treatment facility and onsite treatment or disposal facility. State governments should also provide the land for the establishment of a common biomedical waste treatment facility and disposal facility.
- The use of chlorinated plastic gloves, bags, blood bags, etc. should be gradually stopped.
- Compulsory pretreatment of the laboratory, microbiological waste, and blood bags on-site before disposal either at Common biomedical waste treatment facility or on-site. The method of sterilization/disinfection should be in accordance with the World Health Organisation or the National AIDS Control Organization (NACO).
- Standards for emission from incinerators have been modified to be more environmentally friendly.
- Residence time in the secondary chamber of the incinerator – two seconds; standard for dioxin and furans – 0.1 ng TEQ/Nm^3 are the permissible limit for SPM-50 mg/nm^3.
- The Ministry of Environment, Forest, and Climate change will monitor the implementation of rules yearly. The responsibility of each state to check for compliance will be done by setting up a district-level committee under the chairpersonship of District Collector or District Magistrate or Additional District Magistrate. In addition, every 6 months, this committee shall submit its report to the State Pollution Control Board.

Reforms and suggestions

Biomedical waste Management Rules, 2016 was also altered and updated to improve compliance and strengthen the implementation for a better environment. In 2018, the Government of India published the Bio-Medical Waste Management (Amendment) Rules, 2018. Some of the major reforms in 2018 rules are:

- Complete phasing out of chlorinated plastic items such as bags and gloves from the bio-medical waste generators including hospitals, dispensaries, animal houses, clinics, nursing homes, blood banks, etc.
- Within two years of the publication of these rules, all institutions have to publish an annual report on its site.
- In accordance with the guidelines issued by the Central Pollution Control Board, all the operators of common bio-medical waste treatment and disposal facilities have to establish a global positioning system and as well as a barcoding system for handling of bio-medical waste.
- The State Pollution Control Board has to compile, review and analyze the information received by the operators and also have to send these reports to the Central Pollution Control Board, which keeps detailed information regarding district-wise waste generation.
- One of the major challenges that will be faced by the healthcare facilities and hospitals in implementing these rules and guidelines is Lack of funds- as to phase out chlorinated plastic bags and to establish a global positioning and a barcode system for biomedical waste, a huge cost will be incurred and the time span for the same is very short i.e. two years.

Another major challenge is the use of incinerators and the hazards it causes. After implementing the first rules in 1998, India saw a boom in the installation of incinerators. It is the system that is based on the high temperature that kills the pathogen and in the process, it also destroys the material in which the microbes reside. But the limitation of this system is that it produces a number of toxins during the process such as products of incomplete combustion and dioxins. These products of incomplete combustion are the particles that are formed during incineration and dissociation of waste components. By this method, metals are not destroyed but dispersed into the environment causing serious health problems. These toxins have a tendency to accumulate in fatty acids and travel up the food chain. This damages the immune and endocrine system of humans. In foreign countries like the Philippines and Denmark, the construction and use of incinerators are banned, similar steps should be taken by the Government of India to mitigate these toxins from the environment.

The major technology used for disposal of biomedical waste is incineration, microwaving, autoclaving, and chemical treatment, but apart from these some new technologies have also been developed or are still under research such as thermal processes, biological processes, irradiative processes, and chemical processes. In the thermal processes mostly waste including cultures, soft waste (gauze, bandages, and gowns), human waste, laboratory waste, and sharp medical instruments are sterilized. These thermal processes are divided into three groups- low heat technologies (operating between 93 C and 177 C) which include microwaves and autoclaves, medium heat technologies(operating between 177 C and 540 C) which include reverse polymerization and thermal depolymerization, and high heat technologies (operating between 540C and 8300C) which include plasma, induction, lase oxidation based pyrolysis. In biological processes, bio converter and biodegradable plastic systems are used for the disposal of biomedical waste.

Conclusion

Article 21 of the Indian Constitution gives us the right to live in a clean and safe environment. To protect this right, efficient and effective biomedical waste management should be done not only by the government but also by the people themselves. The Biomedical Waste Management Rules, 2016 are improved in terms of the facilities like segregation, collection, transportation, and disposal methods to mitigate environmental pollution and safeguard human health. These rules serve as the checklist to accomplish the goal of biomedical waste management for the operator occupier, the regulatory authority, and other authorities. The pillar of these rules is the segregation of waste and the concept of 3Rs on which it is based, namely, reduce, recycle, and reuse. Eco-friendly systems, development of newer novel technologies for disposal of biomedical wastes should be encouraged rather than using the methods which harm the environment such as the incineration process. All representatives involved in the process of biomedical waste management should take a pledge to guarantee a cleaner and greener environment.

Summary

The main objective of the rules is to regulate the handling, generation, segregation, transportation, treatment, and disposal of all the hazardous and medical waste to prevent its adverse impact on human health and the environment.Under the rules, hazardous waste is defined as any waste that is dangerous, toxic, flammable, explosive, or corrosive in nature. This includes waste generated by industrial activities, healthcare facilities, research laboratories, and households.The rules mandate that all generators of waste, including industries and healthcare facilities, must obtain authorization from the State Pollution Control Board (SPCB) or Pollution Control Committee (PCC) to generate, store, transport, treat and dispose of hazardous waste.The rules require that all hazardous waste be segregated at the point of generation and stored in designated containers and areas. The waste must then be transported by authorized personnel and vehicles to treatment and disposal facilities.

The rules also specify the treatment and disposal methods for different categories of hazardous waste. Treatment methods include physical, chemical, and biological treatment, among others. Disposal methods include incineration, deep burial, and landfills.Additionally, the rules mandate that hazardous and medical waste management facilities maintain records of hazardous waste management and submit annual reports to the SPCB or PCC.Overall, the Hazardous Waste Management and Handling Rules play a critical role in protecting public health and the environment by ensuring safe and proper handling, treatment, and disposal of hazardous waste. The rules are enforced by the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs) to ensure compliance and prevent any adverse impact on human health and the environment.

10.7. Terminal questions

Q.9. What is biomedical waste? How it is segregated according to rule.

Answer: --

Q.10. Discuss the Biomedical Waste Management and Handling Rules, 1998.

Answer: --

Q.11. Give the amendmentsmade in BiomedicalWaste Management and Handling Rules, 1998 in 2016

Answer: --

Q.12. Discuss the Hazardous Waste Management and Handling Rules, 1989.

Answer: --

Q.13. What are the characteristics of hazardous waste? Give the provisions made for management of hazardous waste according to rule.

Answer: --

Q.14. Describe the important terms and definitions given in Biomedical Waste Management Rules, 1998.

Answer: --

10.8. Further suggested readings

1. Biomedical Waste Management and Handling Rules, 2016: An Overview by Harshit Sharma and Preeti Agrawal. Publication: LAP Lambert Academic Publishing, 2017.
2. Hazardous Waste Management: An Introduction by Clifford F. Gray and Erik R. Johnson. Publication: CRC Press, 2015.
3. Handbook of Hazardous Waste Management for Small Quantity Generators by World Health Organization. Publication: World Health Organization, 2016.
4. Biomedical Waste Management and Disposal: A Guide to Best Practices by Ramesh C. Gupta. Publication: Academic Press, 2019.
5. Hazardous Waste Compliance by Barbara Liang. Publication: Jones & Bartlett Learning, 2012.
6. Biomedical Waste Management: Principles, Challenges and Issues by Utkarshini Jaimini. Publication: Springer, 2021.

Unit-12: E-Waste Management Introduction

Contents

12.1. Introduction

The Government of India (GoI) introduced the E-Waste Management Rules in 2016. The rules apply to businesses that are generating electronic waste items. The rules specify that businesses should make arrangements for the safe disposal of scrapped electronic items. The rules are administered by the Ministry of Environment, Forest and Climate Change. As the decomposition of electronic items will take a more prolonged and different methodology, the companies are asked to separate the wastes at source. To address the issue, the Government of India has introduced the Extended Producer Responsibility Plan as part of the E-

Waste Management Rules. Under the plan, companies should undertake the responsibility to recycle a minimum percentage of the electronic products manufactured. The E-Waste Management Rules mention the ceiling limit for hazardous chemicals that are used in manufacturing electronic products. The rules also specify the procedure to obtain authorization from the pollution control for handling e waste

Objectives

- To study the management of e waste
- To understand the procedure for storage of e-waste
- To study the e-waste management rules 2016
- To study about the e-waste regulation in India,
- To understand the state government for the management of waste
- To study the procedure for authorization for management of e-waste

12.2. Electronic waste (e-waste)

Electronic waste (e-waste) is defined as waste in the form of electrical or electronic equipment, devices or things (or materials or parts of such equipment, devices or things), the operation of which is dependent on, or designed for the generation, transfer or measurement of, an electric current or electromagnetic field. This means any device that has a plug, battery or power cord that is no longer working or wanted. It includes a range of items we use and discarded from home and business

- Television
- Computers
- mobile phones
- kitchen appliances
- batteries (including rechargeable batteries)
- photovoltaic panels

12.3. Need for management of e waste

The poor management of e-waste poses a hazard to the environment, particularly from:

- air emissions
- dust
- ground contamination from e-waste liquid components
- fire

Risky e-waste stockpiling may also result in the increased likelihood of fire and soil contamination. As some persistent organic pollutants, dioxins and polycyclic aromatic hydrocarbons (PAHs) are released as combustion by-products of e-waste, the consequences of fires at e-waste reprocessing facilities could be substantial.

Steps to be taken for management of e waste

Following steps should be taken for management of e-waste:

- understand the risks of harm to human health and the environment posed by e-waste and communicate this to staff
- store, transport and handle e-waste to eliminate or reduce risk of harm to human health and environment, including fire
- separate and store e-waste away from other waste
- provide e-waste to an appropriate collector or re-processor that complies with the Waste Management Policy (E-waste)
- keep records of e-waste movement to the primary re-processor
- prevent breakage or spoilage of e-waste that might limit its suitability for reprocessing
- only store e-waste for the purposes of transfer, recycling and reprocessing
- take all reasonable steps to minimize how long e-waste under their control or in their possession is stored.

Storing and transporting e-waste

Where there is a risk, storing e-waste on an impermeable surface and protected from the weather, can help control dust particles and runoff being released that could contaminate land, surface water and groundwater.

Specified e-waste must be stored on an impermeable surface and protected from the weather.

According to the Environment Protection (Scheduled Premises) Regulations 2017, ‘specified electronic waste’ means:

- rechargeable batteries
- cathode ray tube monitors and televisions
- flat panel monitors and televisions
- information technology and telecommunications equipment
- lighting
- Photovoltaic panels.

All e-waste streams at the site should be assessed for risks to determine any necessary controls. For example, we may identify that bunding is required to manage the risk of ground contamination from e-waste liquid components, including heating and cooling equipment or batteries. At a minimum, we need to ensure that e-waste loads are secure before transporting. We must also minimise damage or breakage. There are additional requirements for packing and transporting lithium batteries.

Storage duration and managing stockpiles

E-waste should be transported to a compliant facility as soon as reasonably practicable. As an e-waste service provider, we must only store e-waste for the purpose of transfer, recycling or reprocessing. We can demonstrate that we have taken reasonable steps to limit the time we have stored e-waste through, for example, receipts/invoices/certificates of destruction from a compliant e-waste recovery service or a contract with a compliant e-waste recovery service which shows the frequency of collection.

Keeping appropriate records

Good record keeping is important because it means we can track resource recovery from site and better manage on-site volumes being stored. Good record keeping for storing e-waste includes:

Origin

Name of e-waste generator/source.

Address of e-waste generator/source.

Transport

- Name of transporter.
- Address of transporter.
- Vehicle registration numbers.
- E-waste
- Description of the waste type(s).
- Amount of waste(s).
- Determine hazards of e-waste for transport, and if required specify:
- hazard category
- contaminant(s)
- dangerous goods class
- packaging group number.

Specified e-waste

Specified e-waste poses greater risk to human health and the environment. For any specified e-waste transported, we must record:

- date the specified e-waste is transported
- name and address of the premises from and to which the specified e-waste is transported
- description of the specified e-waste
- Quantity of the specified e-waste.
- All required records must be kept for a minimum of five years.

There is a number of additional record keeping requirements for e-waste reprocessors

Controlling hazards and risks

Any person who is responsible for e-waste must assess the risks of harm to human health and the environment and take steps to eliminate or manage the risks.

Assessing and controlling risk in a structured way will help ensure that storage, transport and/or reprocessing of e-waste prevents harm to human health and the environment and meets community expectations.

There are four basic stepsthat needs to follow to control hazards and risks present in the storage of e-waste:

Identify and understand risks, including:

- types of e-waste managed – does any of the e-waste we are managing contain hazardous substances?
- e-waste components – are any hazardous parts to the types of e-waste we are receiving?
- storage and handling practices – are they being stored or handled in a way that could contaminate soil, or water, or cause a fire risk?
- fire risks and potential impacts of fire management – have we considered whether the types of e-waste could pose a fire risk with how they are being stored (e.g. batteries)
- site design, access and drainage – does the site have adequate ways of containing any potential soils or water contaminants?
- consideration of what is around the site, for example, houses or a waterway – could the environment or people be harmed if any contaminants were released or a fire started at site?

Step 2: Assessment of risks

- ➢ Understand and assess the level or severity of risk, based on consequence and likelihood. For example, a fire hazard can result in:
- runoff of firewater, combustion products and firefighting chemicals into local creeks and waterways, poor air quality and pollution due to emittance of toxic smoke
- harm to employees, visitors, contractors, emergency service personnel and others on site
- harm to surrounding residents and businesses and the broader community such as exposure to toxic smoke, asbestos or other reactive dusts.
- ➢ Some typical questions to ask to identify the consequences of a fire include:
- Are there adequate distances between storage piles?
- Is there adequate access to/around the site for firefighting authorities?
- Have the minimum site access requirements stipulated by the firefighting authorities been adapted onsite?
- How could firewater runoff enter the environment?
- How far away is the nearest waterway?

Step 3: Implement controls

- ➢ What measures are suitable and available to the business to eliminate or reduce the risk?
- ➢ Reduce risks by implementing controls, for example:
- do not accept types of e-waste that cannot be appropriately managed or stored
- have appropriate infrastructure to store e-waste, such as an impermeable surface and coverage to ensure the e-waste doesn't get wet
- avoid risky activities such as e-waste compaction or crushing
- isolate areas where risky activities occur
- install engineering controls to capture dust, vapours or liquids generated from e-waste processing or handling
- transport in a manner that avoids breakage or prevents dust escape
- train staff to appropriately handle types of e-waste
- provide relevant signs and instruction.

<u>Step 4: Check controls</u>

- Review the controls to ensure they are effective
- Regularly monitor and review the controls we have put in place for their effectiveness and take action to resolve any issues. Ensure controls continue to eliminate and/or minimise harm

12.4. Procedure for storage of e waste

Proper storage of e-waste is crucial to ensure safe disposal and prevent environmental pollution. Below are the steps for storing e-waste:

Segregate the e-waste: Segregate the e-waste into different categories based on their type and potential hazards. For instance, separate batteries, fluorescent lamps, and circuit boards from other electronic devices.

Identify hazardous materials: Identify the hazardous materials present in each type of e-waste. Use Material Safety Data Sheets (MSDS) or other resources to determine the potential risks.

Label the e-waste: Label the e-waste with the name of the device, date of disposal, and any hazardous materials present.

Store the e-waste in a secure location: Store the e-waste in a secure location that is locked and only accessible to authorized personnel. The storage location should be well-ventilated and dry to prevent moisture from damaging the e-waste.

Use appropriate storage containers: Use appropriate storage containers such as boxes, bags, or containers that are made of materials that can withstand the e-waste's weight and size. Use containers that are labeled for e-waste storage and disposal.

Store e-waste away from heat sources: Store the e-waste away from heat sources such as direct sunlight, heaters, and boilers.

Keep the storage area clean: Keep the storage area clean and free of debris. Regularly inspect the storage area for leaks, spills, and other hazards.

Consider using a certified e-waste recycler: Consider using a certified e-waste recycler to ensure safe and environmentally responsible disposal of e-waste.

12.5. E- Waste regulation in India

The Government has taken a number of steps to formalise the e-waste recycling sector of the country. The E-Waste (Management) Rules, 2016 provide for compulsory authorisation of the dismantling and recycling units from the concerned State Pollution Control Boards (SPCBs)/ Pollution Control Committees (PCCs). CPCB has issued guidelines/SOP for processing of e-waste. The CPCB and SPCBs have been monitoring the units and necessary steps have been taken to mainstream and modernise the recycling industry with the help of Ministry of Electronics and Information Technology.

Following steps have been taken by the government in the direction of finding out solution to the problems related to E-Waste:

i. The management of e-waste is being carried out under the frame work of E-Waste (Management) Rules, 2016 and amendments there off. The Rules, are effective from 1st October, 2016. The rules provide for followings:

- Applicable to every manufacturer, producer, consumer, bulk consumer, collection centres, dealers, e-retailer, refurbisher, dismantler and recycler.
- Under the EPR regime, producers have to obtain EPR Authorization from CPCB for implementing their EPR and details of their dismantlers/recyclers.
- Notified EEE are twenty-one (21) and listed in Schedule – I of the above said Rules.
- Under EPR regime, producers of notified EEE have been given annual E-Waste collection targets based on the generation from the previously sold EEE or based on sales of EEE as the case may be.

ii. Ministry has notified the E-Waste (Management) Rules, 2022 on 2nd November, 2022. These rules will replace E-waste (Management) Rules, 2016 and will be effective from 1st April, 2023. These rules will launch a new Extended Producer Responsibility (EPR) regime for e-waste recycling. The salient feature of new rules is as under:

- Applicable to every manufacturer, producer, refurbished, dismantler and recycler.

- All the manufacturer, producer, refurbisher and recycler are required to register on portal developed by CPCB.
- No entity shall carry out any business without registration and also not deal with any unregistered entity.
- Authorization has now been replaced by Registration through online portal and only manufacturer, producer, refurbished and recycler require Registration.
- Schedule I expanded and now 106 EEE has been include under EPR regime.
- Producers of notified EEE, have been given annual E-Waste Recycling targets based on the generation from the previously sold EEE or based on sales of EEE as the case may be. Target may be made stable for 2 years and starting from 60% for the year 2023-2024 and 2024-25; 70% for the year 2025-26 and 2026-27 and 80% for the year 2027-28 and 2028-29 and onwards.
- Management of solar PV modules /panels/ cells added in new rules.
- The quantity recycled will be computed on the basis of end products, so as to avoid any false claim.
- Provision for generation and transaction of EPR Certificate has been introduced.
- Provisions for environment compensation and verification & audit has been introduced.
- Provision for constitution of Steering Committee to oversee the overall implementation of these rules.

Under the E-Waste Management Rules, provision for reduction of hazardous substances in manufacturing of Electrical and Electronic Equipment (EEE) has been provided. It mandates that every producer of EEE and their components shall ensure that their products do not contain lead, mercury and other hazardous substances beyond the maximum prescribed concentration.

The E-Waste (Management) Rules also provide for recognition and registration, skill development, monitoring and ensuring safety and health, of workers involved in dismantling and recycling of e-waste.

12.6. Role of State Government in management of waste

State governments have a critical role to play in the management of waste, as they are responsible for developing and implementing policies and regulations that govern waste management practices within their jurisdiction. Some key ways in which state governments can manage waste include:

I. **Developing waste management plans**: State governments can develop comprehensive waste management plans that outline the strategies and programs that will be used to manage different types of waste in their state. These plans can include targets for waste reduction, recycling, and diversion from landfills.

II. **Regulating waste management practices:** State governments can also establish regulations that govern the collection, transport, storage, and disposal of waste. These regulations can help ensure that waste is managed safely and responsibly, and can help prevent environmental damage and public health risks.

III. **Supporting recycling and waste reduction:** State governments can provide funding and incentives to support recycling programs and waste reduction initiatives. For example, they may offer grants to local governments or businesses that implement recycling programs, or establish bottle deposit programs to encourage the recycling of beverage containers.

IV. **Enforcing waste management laws:** State governments can also enforce waste management laws and regulations by conducting inspections, issuing fines or penalties for non-compliance, and taking legal action against violators.

Overall, effective waste management requires a coordinated effort between state governments, local governments, businesses, and individuals. State governments have a critical role to play in providing leadership and guidance to ensure that waste is managed in a safe, responsible, and sustainable manner.

Procedure for authorization for management of e waste

The process for authorization for management of e-waste can vary depending on the country or region, but here are some general steps that may apply:

i. **Research and identify the relevant laws and regulations:** Find out what laws and regulations apply to the management of e-waste in your country or region. This will help you understand what requirements you need to meet to obtain authorization.

ii. **Obtain necessary permits and licenses:** Depending on the regulations in your country or region, you may need to obtain permits or licenses to handle e-waste. Check with your local authorities to find out what permits or licenses are required.

iii. **Develop a management plan:** Create a plan for how you will manage e-waste, including how you will collect, transport, store, and dispose of it. This plan should address any requirements outlined in the regulations and demonstrate that you have the necessary resources and expertise to manage e-waste safely.

iv. **Implement the management plan**: Once your plan is developed, put it into action. Ensure that your staff is trained on how to handle e-waste safely and that all necessary equipment and resources are available.

v. **Monitor and evaluate:** Regularly monitor and evaluate your e-waste management practices to ensure that they remain compliant with regulations and are effective in protecting the environment and public health.

vi. **Obtain authorization:** Once you have met all the requirements outlined in the regulations, submit an application for authorization to manage e-waste to the relevant authorities. The process for obtaining authorization will vary depending on the country or region, but typically involves an application review, site inspections, and verification of compliance with regulations.

vii. **Maintain authorization:** Once you have obtained authorization, make sure to maintain compliance with regulations to avoid the risk of losing your authorization. This may involve regular reporting, inspections, or audits to demonstrate ongoing compliance.

12.7. E-Waste (Management) Rules, 2016

The E-Waste (Management) Rules, 2016 is a set of regulations introduced by the Ministry of Environment, Forest and Climate Change in India to manage the handling, collection, and disposal of electronic waste. Here are the key details of the E-Waste (Management) Rules, 2016:

Applicability: The rules apply to all producers, consumers, and bulk consumers of electronic goods, as well as manufacturers, refurbishers, dismantlers, and recyclers of electronic waste.

Collection targets: The rules require manufacturers to collect e-waste equivalent to 30% of the quantity of electronic goods they sell in the previous year. Bulk consumers must ensure that e-waste generated by them is collected by authorized collection centers.

Extended Producer Responsibility (EPR): The EPR principle requires producers to take responsibility for the entire life cycle of their products, including collection and disposal. The rules make it mandatory for manufacturers to apply for EPR authorization from the Central Pollution Control Board.

Authorization for dismantlers and recyclers: The rules mandate that all dismantlers, recyclers, and refurbishers of electronic waste must obtain authorization from the State Pollution Control Board. The authorization process involves meeting specific criteria, such as having adequate infrastructure for collection and treatment, complying with safety standards, and maintaining proper records.

Responsibilities of stakeholders: The rules define the responsibilities of stakeholders, such as manufacturers, bulk consumers, consumers, and dismantlers/recyclers, in the management of e-waste. For instance, manufacturers must label their products to indicate that they contain hazardous substances and provide information on how to dispose of them safely.

Penalties for non-compliance: The rules impose penalties for non-compliance with the provisions of the rules, including fines and imprisonment. The State Pollution Control Boards have the authority to initiate legal proceedings against violators.

Salient features ofE-Waste (Management) Rules, 2016

1. Manufacturer, dealer, refurbisher and Producer Responsibility Organization (PRO) have been introduced as additional stakeholders in the rules.
2. The applicability of the rules has been extended to components, consumables, spares and parts of EEE in addition to equipment as listed in Schedule I.
3. Compact Fluorescent Lamp (CFL) and other mercury containing lamp brought under the purview of rules.
4. Collection mechanism based approach has been adopted to include collection centre, collection point, take back system etc for collection of e - waste by Producers under Extended Producer Responsibility (EPR).

5. Option has been given for setting up of PRO , e - waste exchange , e - retailer, Deposit Refund Scheme as additional channel for implementation of EPR by Producers to ensure efficient channelization of e - waste.
6. Provision for Pan India EPR Authorization by CPCB has been introduced replacing the state wise EPR authorization.
7. Collection and channelisation of e - waste in Extended Producer Responsibility - Authorisation shall be i n line with the targets prescribed in Schedule III of the Rules. The phase wise Collection Target for e - waste, which can be either in number or Weight shall be 30% of the quantity of waste generation as indicated in EPR Plan during first two year of implementation of rules followed by 40% during third and fourth years, 50% during fifth and sixth years and 70% during seventh year onwards.
8. Deposit Refund Scheme has been introduced as an additional economic instrument wherein the producer charges an additional amount as a deposit at the time of sale of the electrical and electronic equipment and returns it to the consumer along with interest when the end - of - life electrical and electronic equipment is returned.
9. The e - waste exchange as an option has been provided in the rules as an independent market instrument offering assistance or independent electronic systems offering services for sale and purchase of e - waste generated from end - of - life electrical and electronic equipment between agencies or organizations authorised under these rules.
10. The manufacturer is also now responsible to collect e - waste generated during the manufacture of any electrical and electronic equipment and channelise it for recycling or disposal and seek authorization from SPCB.
11. The dealer, if has been given the responsibility of collection on behalf of the producer, need to collect the e - waste by providing the consumer a box and channelize it to Producer.
12. Dealer or retailer or e - retailer shall refund the amount as per take back system or De posit Refund Scheme of the producer to the depositor of e - waste.
13. Refurbisher need collect e - waste generated during the process of refurbishing and channelise the waste to authorised dismantler or recycler through its collection centre and seek one time authorization from SPCB.
14. The roles of the State Government has been also introduced in the Rules in order to ensure safety, health and skill development of the workers involved in the dismantling and recycling operations.

15. Department of Industry in State or any other government agency authorised in this regard by the State Government is to ensure earmarking or allocation of industrial space or shed for e - waste dismantling and recycling in the existing and upcoming industrial park, estate and industrial clusters.
16. Department of Labour in the State or any other government agency authorised in this regard by the State Government need to ensure recognition and registration of workers involved in dismantling and recycling; assist formation of groups of such workers to facilitate setting up dismantling facilities; undertake industrial skill development activities for the workers involved in dismantling and recycling; and undertake annual monitoring and to ensure safety & health of workers involved in dismantling and recycling.
17. State Government to prepare integrated plan for effective implementation of these provisions, and to submit annual report to Ministry of Environment, Forest and Climate Change.
18. The transportation of e - waste shall be carried out as per the manifest system whereby the transporter shall be required to carry a document (three copies) prepared by the sender, giving the details.
19. Liability for damages caused to the environment or third party due to improper management of e - waste including provision for levying financial penalty for violation of provisions of the Rules has also been introduced.
20. Urban Local Bodies (Municipal Committee/Council/Corporation) has been assign the duty to collect and channelized the orphan products to authorized dismantler or recycler.

12.8. Amendments in E-Waste Management Rules 2016

The E-Waste Management Rules 2016 have been amended vide notification G.S.R. 261(E), dated March 22, 2018.

The amendment in rules has been done with the objective of channelizing the E-waste generated in the country towards authorized dismantlers and recyclers in order to formalize the e-waste recycling sector. The collection targets under the provision of Extended Producer Responsibility (EPR) in the Rules have been revised and targets have been introduced for new producers who have started their sales operations recently.

Some of the salient features of the E-waste (Management) Amendment Rules, 2018 are as follows:

1. The e-waste collection targets under EPR have been revised and will be applicable from 1 October 2017. The phase-wise collection targets for e-waste in weight shall be 10% of the quantity of waste generation as indicated in the EPR Plan during 2017-18, with a 10% increase every year until 2023. After 2023 onwards, the target has been made 70% of the quantity of waste generation as indicated in the EPR Plan.
2. The quantity of e-waste collected by producers from the 1 October 2016 to 30 September 2017 shall be accounted for in the revised EPR targets until March 2018.
3. Separate e-waste collection targets have been drafted for new producers, i.e. those producers whose number of years of sales operation is less than the average lives of their products. The average lives of the products will be as per the guidelines issued by CPCB from time to time.
4. Producer Responsibility Organizations (PROs) shall apply to the Central Pollution Control board (CPCB) for registration to undertake activities prescribed in the Rules.
5. Under the Reduction of Hazardous Substances (RoHS) provisions, cost for sampling and testing shall be borne by the government for conducting the RoHS test. If the product does not comply with RoHS provisions, then the cost of the test will be borne by the Producers.

12.9. Highlights of E-waste (Management) Rules, 2022

Background and scope:

The growing problem of e-waste required greater emphasis on recycling of the e-waste and better e-waste management. In the light of above, the Ministry of Environment, Forest & Climate Change ('**MOEFCC**') on 2 November 2022, has notified E-waste (Management) Rules, 2022 ('**2022 Rules**') which has replaced the E-waste (Management) Rules, 2016 ('**2016 Rules**').

2022 Rules will come into force on 1 April 2023 and has introduced recycling targets in the extended producer responsibility (‘**EPR**’) plan of the producers of e-waste.

EPR is a policy-based approach wherein responsibility is casted over the producers of specific category of waste for the treatment and safe disposal of such waste. EPR mechanism under the 2016 Rules focused more on the producer’s responsibility to collect back the e-waste introduced in the market and provided collection targets, whereas the EPR regime under 2022 Rules provides an annual e-waste recycling targets to the producers.

Scope and definitions:

Scope of applicability of 2022 Rules has been restricted to manufacturer, producer, refurbishers, dismantlers and recycler of e-waste (‘**MPRDR**’), unlike 2016 Rules wherein dealer, consumer, bulk consumer and collection centres were also covered.

- The definition of term ‘*e-waste*’ has been widened to include solar photo-voltaic modules or panels or cells, which are discarded as waste and the term ‘*bulk consumer*’ has been widened and simplified. Now, any entity which has used at least one thousand units of electrical and electronic equipment listed in Schedule I of 2022 Rule, at any point of time in the particular financial year including the e-retailer, will be considered as bulk consumers of e-waste.
- The term EPR has been redefined to mean responsibility of any producer of electrical or electronic equipment as given in Schedule-I **for meeting recycling targets as per Schedule-III and Schedule-IV, only through registered recyclers of e-waste** to ensure environmentally sound management of such waste. Further, the definition of term ‘producer’ has also been widened.

Registration requirement:

Unlike 2016 Rules which mandates manufacturer, producer, refurbishers and recycler of e-waste (‘**MPRR**’) to obtain authorization from concerned State Pollution Control Board, 2022 Rules mandates MPRR of e-waste to obtain registration on the portal (‘**Portal**’) to be developed by Central Pollution Control Board (‘**CPCB**’). Further, 2022 Rules bars MPRR to operate its business without obtaining aforesaid registration and/or to deal with any unregistered MPRR.

Reducing compliances on 'bulk consumers':

In general parlance, private and public companies and multi-national organizations are considered as 'bulk consumers' for the purpose of 2016 Rules. The requirement of (i) filing annual return and (ii) maintaining record of e-waste generated, by the bulk consumer under 2016 Rules has been done away with under Rule 2022.

Introduction of recycling certificate:

The concept of obtaining EPR recycling certificate has been introduced by 2022 Rules for facilitating the fulfilment of EPR targets. Producers can purchase online EPR recycling certificate from registered recyclers for fulfilling its recycling target under 2022 Rules. However, such recycling certificate issued by CPCB will be valid for two years from the end of the financial year in which the same was generated.

Introduction of refurbishing certificate and deferred liability:

The concept of deferred liability has also been incorporated in 2022 Rules. Now, refurbisher will be issued a refurbishing certificate for a particular quantity of refurbished product whereby the life of such product has been extended. Producers can purchase refurbishing certificate from refurbishers to defer their EPR vis-à-vis corresponding quantity of e-waste in a particular year and same shall be added to the EPR target of the year in which the extended life of the refurbished product is expired.

Incorporation of penal provisions and widened scope:

Unlike 2016 Rules, 2022 Rules expressly introduced provisions related to environment compensation and prosecution under section 15 of the Environment (Protection) Act, 1986 ('**EPA**'). Further, the environment compensation can also be imposed on an entity which aids or abets the violation of 2022 Rules. This widens the scope of imposing environment compensation.

Conclusion

As per statistics available in public domain, India is the third largest generator of e-waste after China and USA. Expanding the definition of e-waste and electronic equipment, specifying the recycling target with proper implementation mechanism and clearly specifying the penalties for violation of Rule2022 will assist in better implementation of the collection, processing and recycling of e-waste.

For creating vibrant recycling market, the possibility of regulating the role of e-waste collection centres, producer responsibility organization and dealers under Rule 2022 may also have been explored since they also, play a significant role.

12.9. Summary

Electronic waste, also known as e-waste, is one of the fastest-growing waste streams in India. The country is the fifth largest producer of e-waste in the world, generating over 2 million tonnes of e-waste per year.

The Indian government has taken several measures to manage e-waste, including the implementation of the E-waste (Management and Handling) Rules, 2011. The rules require producers to take responsibility for the collection and disposal of e-waste, and establish a system for the collection and recycling of e-waste.

The Central Pollution Control Board (CPCB) has also established e-waste management facilities across the country to handle the growing volume of e-waste. These facilities are equipped with state-of-the-art technology and are managed by trained professionals to ensure the safe and environmentally sound disposal of e-waste.

Despite these efforts, the management of e-waste in India remains a challenge. Many consumers are unaware of the proper methods of e-waste disposal, and there is a lack of awareness and infrastructure to manage the growing volume of e-waste.

In recent years, several private companies have entered the e-waste management market in India, providing collection, recycling, and disposal services to consumers and businesses. These companies have helped to increase awareness of e-waste management and have established a network of collection and recycling facilities across the country.

12.10. Terminal questions

Q.1: What is the e-waste? Define the e-waste briefly.

Answer………………………………………………………………………………………

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Q.2: What are the e-waste management and its handling?

Answer………………………………………………………………………………

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Q.3: Discuss the disposal and treatment of e-waste.

Answer………………………………………………………………………………

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Q.4: Discuss the e waste management and handling rules 2016

Answer………………………………………………………………………………

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Q.5: Highlights the E-waste (Management) Rules, 2022

Answer…………………………………………………………………………

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12.11. Further suggested readings

1. E-Waste Management: From Waste to Resource" by Sadhan Kumar Ghosh, CRC Press
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