UNIT – 14 WASTE MANAGEMENT – MUDA

Structure

14.1 INTRODUCTION

Waste management (or **waste disposal**) is one of the major challenges of materials management because waste is also a kind of materials and its management includes the activities and actions required to manage from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process and waste-related laws, technologies, economic mechanisms.

Objective

After studying this unit, you should be able to understand

- What is waste and its logistics
- The waste management hierarchy
- The waste management strategies
- MUDA and seven wastes in industry

14.2 HISTORY

Throughout the history, the amount of waste generated by humans has been insignificant, perhaps due to low levels of population density and exploitation of natural resources. The common waste produced during pre-modern times could be chiefly ashes and human biodegradable waste. These were recycled into the ground locally, with minimum environmental impact. Further, the products were made mostly out of wood or metal and these were generally reused or passed down to the generations.

With the industrialisation and the sustained urban growth of large population centres in England, the waste pile-up in the cities caused a rapid deterioration particularly in levels of sanitation and the general quality of urban life. The streets used to be choked with filth due to the lack of waste clearance regulations. This urged to call for establishing a mechanism of a municipal authority with waste removal powers during early 1750s, when Corbyn Morris in London announced, "... as the preservation of the health of the people is of great importance, it is proposed that the cleaning of this city, should be put under one uniform public management, and all the filth be...conveyed by the Thames to proper distance in the country".

However, the importance was recognized during the mid-19th century, when increasingly devastating cholera outbreaks occurred and the first legislation on the issue emerged. The social reformer, Sir Edwin Chadwick's report in 1842, *The Sanitary Condition of the Labouring Population* was probably, influential in for passing the first legislation aimed at waste clearance and disposal.

In the UK, the Nuisance Removal and Disease Prevention Act – 1846, installing the process of the provisions of regulated waste management in London. The Metropolitan Board of Works was the first citywide authority for centralized sanitation regulation for the rapidly expanding city. Further, the Public Health Act-1875 made it mandatory for every household to deposit the weekly waste in "moveable receptacles" for disposal — the first concept for a dust-bin.

The dramatic increase in waste demanded for faster disposal that led to the creation of the first incineration plants, which were then called, "destructors". In 1874, the first incinerator was built in Nottingham by Manlove, Alliott & Co. Ltd. to the design of Alfred Fryer. But, these were opposed strongly due to the large amounts of ash produced that spread over the neighbouring areas.

Similar municipal systems of waste disposal came up in the 20th century in other large cities of Europe and North America. In 1895, New York City was recorded as the first U.S. city with public-sector garbage management.

The early garbage removal was simply done by an open bodied dump trucks pulled by horses. They were motorized in the early 20th century and the first closed body trucks eliminated odours with a dumping lever mechanism in the

1920s in Britain. Soon they were also equipped with 'hopper mechanisms' where the scooper gets loaded at floor level and then hoists mechanically to deposit the waste in the truck. The Garwood Load Packer was the first truck in 1938, to incorporate a hydraulic compactor.

14.3 CHALLENGES OF WASTE MANAGEMENT

Of course, the waste transport within a country could be controlled by national regulations, but, the trans-boundary movement of waste posed the challenges.

14.3.1 International Waste Movement: The Basel Convention

The hazardous waste was the major concern of many countries in the world, particularly in Europe. The Basel Convention, ratified by 172 countries, deprecates movement of hazardous waste from developed to less developed countries. The provisions of the convention were integrated into the EU waste shipment regulation. Radioactive waste, though considered hazardous, was not taken under the jurisdiction of the Basel Convention.

14.3.2 Challenges in India and Other Developing Countries

Waste management practices are not uniform among countries (developed and developing nations); regions (urban and rural areas), and residential and industrial sectors can all take different approaches.

The most challenging part of waste management is lying with the countries of developing economies, such as India. These are often experiencing exhausted waste collection services, poor governance, inadequately managed and uncontrolled dumpsites, which are worsening the problem. It is an ongoing challenge in these countries and cities due to weak organisations, chronic under-resourcing and rapid urbanization. In addition to these challenges, the lack of understanding of different factors contributing to the hierarchy of waste management, affect the treatment of waste.

In developing countries, such as India, the waste management activities are usually carried by poor, for their survival. It has been estimated that 2% of population in Asia, Latin America and Africa are dependent on waste for their livelihood. The waste management practices are often involved by family organized, or individual manual scavengers with very little supportive network and facilities with increased risk of health effects. Further, their poverty is preventing their children from further education. In addition, the participation level of most citizens in waste management is too low and particularly, the residents in urban areas are not actively involved in the process of waste management.

Proper management of waste is important for building sustainable and liveable cities, but it is still remaining a challenge for many developing countries and cities. A report found that effective waste management is relatively expensive, usually comprising 20%–50% of municipal budgets. Operating this essential municipal service requires integrated systems that are efficient, sustainable, and socially supported. A large portion of waste management practices deal with municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity.

In a systematic review of global waste, its management and its impact on human health and life, it was concluded that about one fourth of all the municipal solid terrestrial waste is not collected and another one fourth is mismanaged after collection, often being burnt in open and uncontrolled fires. Altogether, this is about one billion tons per year.

It is also noticed that priority areas also lack a "high-quality research base", due to the absence of "substantial research funding", which is the need of motivated scientists often.

In some cases, waste can pose a challenging threat to human health. Health issues are associated throughout the process of waste management. Health issues can also arise indirectly or directly; directly, through the handling of said waste, and indirectly through the consumption of water, soil and food. Waste is produced by human activity, for example, the extraction and processing of raw materials. Waste management is intended to reduce adverse effects of waste on human health, the environment, planetary resources and aesthetics.

Yet another, the recent challenge is disposal of electronic waste (e-waste) that includes discarded computer monitors, motherboards, mobile phones and chargers, compact discs (CDs), headphones, television sets, air conditioners and refrigerators and so forth. According to the Global E-waste Monitor 2017, India generates approximately 2 million tonnes (MTe) of e-waste annually and ranks fifth among the e-waste producing countries, after the US, China, Japan and Germany.

Measures of waste management need to consider integrated techno-economic mechanisms, effective disposal facilities, export and import control and optimal sustainable design of products.

Technologies

Traditionally, the waste management industry has been a late adopter of new technologies such as RFID (Radio Frequency Identification) tags, GPS and integrated software packages which enable better quality data to be collected without the use of estimation or manual data entry. This technology has been used widely by many organizations in some industrialized countries. Radio frequency identification is a tagging system for automatic identification of recyclable components of municipal solid waste stream.

14.4 TYPES OF WASTES

Based on the physical appearance, waste can be solid, liquid, or gaseous and each type has different methods of disposal and management. Some authors even include two more types as solidous (semi-solid or gel) and liquidous (vapour). However, depending on the characteristics of the waste inventory where and how it is produced, and the methods of its management, the wastes can be classified as

1. Industrial wastes
2. Biological wastes
3. Household wastes
4. Municipal wastes
5. Organic wastes
6. Biomedical wastes
7. Radioactive wastes

SAQ – 14.1

a) What is waste management?
b) Why is waste management important?
c) How the waste management is one of the major challenges of materials management?
d) Explain the challenges of waste management?

e) List out the different types of wastes.

ACTIVITY 14.1

Visit a manufacturing company which is nearby you. Observe the process of waste management in the company.

14.5 THE WASTE HEIRARCHY

The waste hierarchy refers to the following "3Rs"

- Reduce,
- Reuse and
- Recycle,

The above three basic principles classify the waste management strategies depending on their suitability in terms of waste elimination or minimisation. The waste hierarchy is the cornerstone of most waste minimization strategies. The objective of the waste hierarchy is to derive the maximum practical benefits from products and to generate the minimum amount of end waste (refer: resource recovery).

The waste hierarchy can be represented as a pyramid because the basic premise is that policies should promote measures to prevent the generation of waste. Thus the first step is to reduce or restrict the generation of waste.

The second step or the next preferred action is to seek alternative uses for the waste that has been generated i.e. by re-use.

The next step is to consider recycling which includes composting. Following this step is material recovery and waste-to-energy (often referred to as WtE or W2E).

The final action is disposal, in landfills or through incineration without energy recovery. This last step is the final resort for waste which could not be prevented, diverted or recovered.

The waste hierarchy represents the progression of a product or material through the sequential stages of the pyramid of waste management. The hierarchy represents the latter parts of the life-cycle for each product. This is diagrammatically shown in figure 14.1.

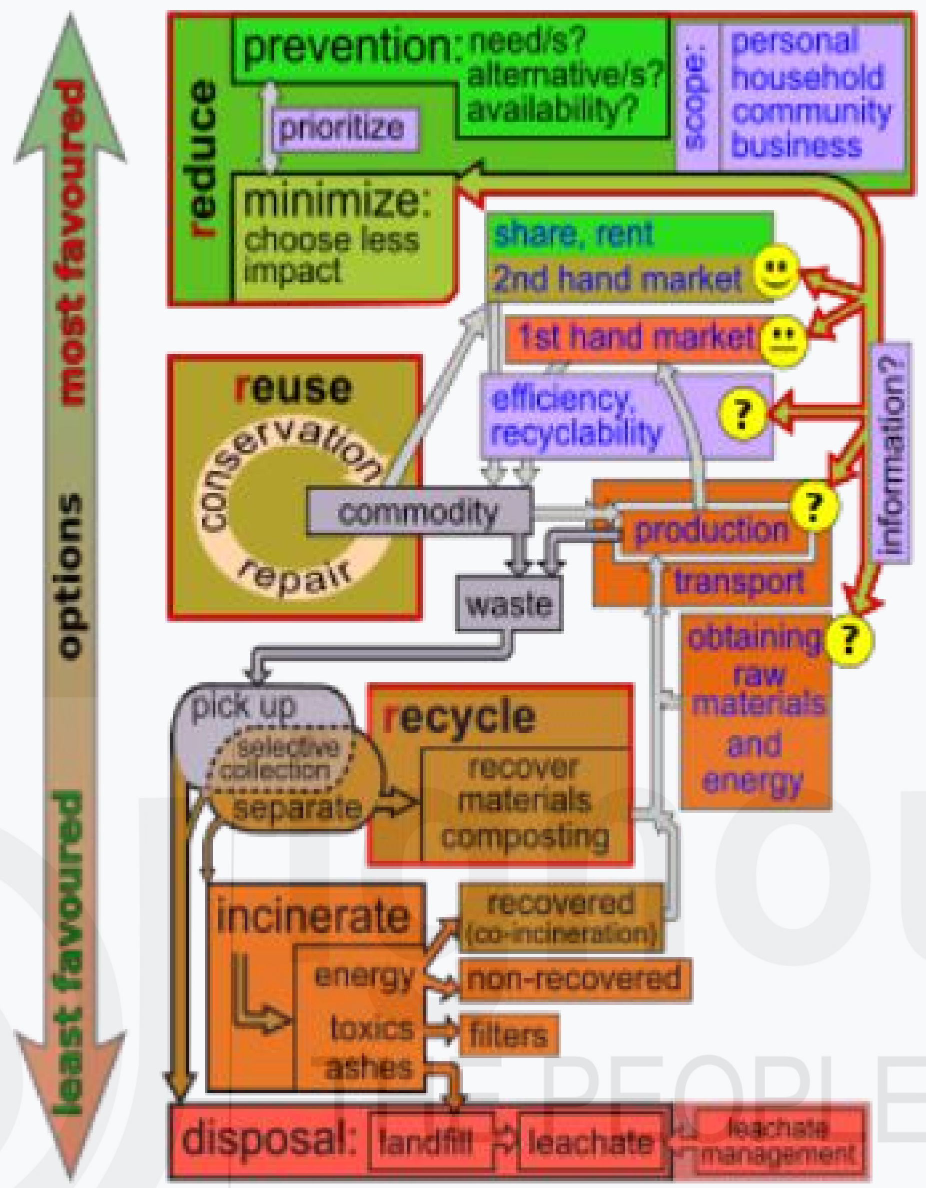

Fig 14.1: The Waste Hierarchy

Life-Cycle of a Product Vs Waste Hierarchy

The life-cycle begins with design, and proceeds through manufacture, distribution, and primary use and then follows through the waste hierarchy's stages of reduce, reuse and recycle. Each stage in the life-cycle offers opportunities for policy intervention, to rethink the need for the product, to redesign to minimize waste potential, to extend its use. Product life-cycle analysis is a way to optimize the use of the world's limited resources by avoiding the unnecessary generation of waste.

Resource Efficiency

Resource efficiency reflects the understanding that global economic growth and development cannot be sustained at current production and consumption patterns. Globally, humanity extracts more resources to produce goods than the planet can replenish. Resource efficiency is the reduction of the environmental impact from the production and consumption of these goods, from final raw material extraction to the last use and disposal.

Polluter-Pays Principle

The polluter-pays principle mandates that the polluting party pays for the impact on the environment. With respect to waste management, this generally refers to the requirement for a waste generator to pay for appropriate disposal of the unrecoverable material.

14.6 LOGISTICS OF WASTE: HANDLING AND TRANSPORT

Moulded Wheeled Plastic Waste-Bin

Waste collection systems vary widely among different countries and regions. One of the most common waste collection systems uses the Moulded Wheeled Plastic Waste Bin (see fig.14.2*) Domestic waste collection services are often provided by local government authorities, or by private companies for industrial and commercial waste. Some areas, particularly those in under developed countries, do not have formal waste-collection systems.

Fig 14.2: Waste Bin

14.6.1 Waste Handling Practices: Global Scenario

Curb-side collection is the most common method of disposal in most European countries, Canada, New Zealand, United States, and many other parts of the developed world where waste is collected at regular intervals by specialised trucks. This is often associated with curb-side waste segregation.

In some countries such as Europe and North America, vacuum collection is used in which waste is transported from the home or commercial premises by vacuum along small bore tubes.

In rural areas, waste is collected and taken to a transfer station with an appropriate disposal facility.

In some areas unsegregated waste is collected at the curb-side or from waste transfer stations and then sorted into recyclables and unusable waste. Such systems are capable of sorting large volumes of solid waste, salvaging recyclables, and turning the rest into bio-gas and soil conditioner.

The local government of San Francisco, in support of its goal of "ZERO WASTE BY 2020", imposed its *Mandatory Recycling and Composting Ordinance* , mandating everyone in the city to maintain "Fantastic 3" bin system (Blue for recyclables, Green for compostables, and Black for landfill-bound materials) provided to residents and businesses and serviced by San Francisco's sole refuse hauler, Recology. The three streams are collected with the curb-side. The city's "Pay-As-You-Throw" system charges customers by the volume of landfill-bound materials, which provides a financial incentive to separate recyclables and compostables from other discards. The ‘Zero Waste by 2020’ Program by the Department of the Environment in the city achieved 80% diversion, the highest diversion rate in North America.

In India, the 2-bin system (Green for Wet and Blue for Dry Waste) and the collection of wet waste and dry waste through motored trucks is implemented.

14.6.2 Waste Segregation

This is the activity of separating of wet waste and dry waste. The idea is to recycle dry waste easily and to utilize wet waste as compost. When segregating waste, the amount of waste that gets land-filled reduces considerably, thereby reducing the pollution of air and water. Most important here is that the waste segregation should be done based on the type of waste and the most appropriate treatment and disposal. This also eases application of different processes to the waste, like composting, recycling and incineration. One way to practice waste management is to ensure there is awareness. The process of waste segregation should be explained to the community.

Institutions/Government should make it as easy as possible for their staff to correctly segregate their waste. This can be sought by proper labelling, ensuring sufficient accessible bins and clearly indicating why segregation is so important. Labelling is more important particularly, when dealing with nuclear waste due to its harmful effects to human health. Recommended colour coding of containers

- Yellow - for infectious waste
- Brown - for chemical and pharmaceutical waste
- Black - for general waste

Segregated waste can provide the advantages in the following dimensions.

- cheaper and easy way to dispose of
- reduced manual sorting as compared to that of mixed waste
- less legal obligations,
- cost savings
- protection of human health and
- the environment safety

14.6.3 Financial Supports

In many countries, domestic waste disposal is funded from a national or local tax which may be obtained from income tax or property tax. Commercial and industrial waste disposal is typically charged for as a commercial service, often as an integrated charge which includes disposal costs. This practice may encourage disposal contractors to opt for the cheapest disposal option such as landfill rather than the environmentally best solution such as re-use and recycling.

The governments usually encourage projects on solid waste management and often come forward for financing, because it is seen as an important service rendered to the citizens. Several Government organizations (such as UGC, DST in India), donors and grants are a funding mechanism depending on the interest of the donor organization as much as it is a good way to develop a city's waste management infrastructure, attracting and utilizing grants is solely reliant on what the donor considers as important.

In some areas like Taipei, the city government charges its households and industries for the volume of rubbish they produce. Waste is collected by the city council only if it is put in government issued rubbish bags. This policy has been quite fruitful in reducing the volume of waste the city produces and increased the recycling rate and generate funds also.

The World Bank finances and advises on solid waste management projects using a diverse suite of products and services, including traditional loans, results-based financing, development policy financing, and technical advisory. World Bank-financed waste management projects usually address the entire lifecycle of waste right from the point of generation to collection and transportation, and finally treatment and disposal.

SAQ – 14.2

a) Discuss the waste hierarchy in detail.
b) Explain handling and transportation methods of waste.
c) Briefly explain different strategies used to collect and transport the waste.
d) Why is Waste Segregation done? What are its advantages?
e) How should the Institutions/Government make their staff to segregate their waste correctly?
f) Why is the financial support given to domestic waste disposal?

ACTIVITY 14.2

Observe municipal waste collection vehicle. Enquiry them why they collect the wet waste and dry waste separately.

Visit a hospital and observe the waste collecting containers or bags. Ask the staff the reason behind using the different colours. Enquiry them what happens if they don't use recommended colour coding of containers in the hospital. Write your understanding here.

14.7 WASTE TO WEALTH (W2W)

There is no item useless on this world. Every matter or material has some use and its own identity and utility if it exists. Its existence itself is evidence of this fact. The intelligence of the manager lies in finding the right utility of the material may it be fresh new product or used product or the so called waste. Thus, waste can be converted to wealth.

To see the wealth in waste, the waste management can use the following strategies

1. Reduce
2. Reuse or Recycle

3. Recover

The first strategy is to produce zero waste. When this is impossible, we try to minimize the waste. If this is also not possible, then we think of reusing it or recycle it. Further, if it is not reusable or not recyclable and we may next think to recover some utility or energy. We hall discuss these strategies in detail now.

14.8 REDUCE

Reducing refers to lowering or minimizing the waste generation if not totally eliminated.

14.8.1 Waste Minimization, Avoidance/ Reduction Methods

First and foremost strategy of waste management for anybody is the prevention of waste material being created, also known as waste reduction. Waste Minimization focuses on reducing the quantity of harmful and/or hazardous wastes through a thorough application of innovative or alternative procedures.

Some methods of avoidance or reducing the waste could be

- reuse of second-hand products,
- repairing broken items instead of buying new ones,
- designing products to be refillable or
- reusable (such as cotton instead of plastic shopping bags),
- encouraging consumers to avoid using disposable products (such as disposable cutlery),
- removing any food/liquid remains from cans and packaging, and
- designing products that use less material to achieve the same purpose (for example, light-weighting of beverage cans)

14.8.2 Disposal methods: Landfill

Landfill has been easy and the most common method of organized waste disposal and is remaining so in many places around the globe.

The landfill is a site for the disposal of waste materials by burial. Of course, landfill is the oldest conceptual method of waste treatment by dumping in pits at a outhouse or a place away from regular movements. Historically, refuse was simply left in piles or thrown into pits. May be, the burial of the waste is modern. Landfills must be open and available to users every day. While the majority of its customers are municipalities, commercial and construction companies, residents are also allowed to use the landfill in most cases.

14.8.3 Incineration

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. Incineration can be carried out in various ranges, on a small range by individuals and on a large range by industry.

In many traditions there is a day in a year, particularly dedicated to incineration of waste and useless materials. For example, in Hindu traditions, a night before Holi, the festival of colours, a HOLY fire is performed in which all the wastes, unused and old materials (usually made up of wood in olden days) are burnt. In some parts of of India, the holy fires are performed even on festivals like Bhogi, Dhuni, Dussera, Lohri etc. where the old useless waste materials are incinerated.

This method is very useful for disposal of both municipal solid waste and solid residue from waste water treatment. About 80 to 95% by volumes of solid waste can be reduced by this process.

Incinerations are often described as "thermal treatment" since these are high temperature waste treatment systems, which convert waste materials into heat, gas, steam, and ash.

It is used to dispose of solid, liquid and gaseous waste. It is identified and believed as the best and practically feasible method of disposing of certain hazardous waste materials (particularly biological medical waste).

In the countries where land is scarce (e.g.Japan), the incineration is the only option, since the facilities generally do not require as much area as landfills.

Waste-to-Energy (WtE) or Energy-from-Waste (EfW) or Waste to Wealth (W2W) are broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam or electricity. However, there is a controversy on this method of waste disposal, due to issues and problems associated with emission of gaseous pollutants including substantial quantities of oxides of carbon, nitrogen and sulphur (COx, NOx and SOx).

Further, the combustion process in an incinerator is not always perfect and thence, it raises the worries regarding pollutants in gaseous emissions produced from incinerator stacks. More particularly, focus is on very persistent organic compounds produced such as dioxins, furans, and PAHs, which have serious impact on environment. Further, some heavy metals such as mercury and lead may get volatilised in the combustion process.

14.9 REUSE / RECYCLING

Recycling, as the name suggests is a resource recovery process that refers to the collection and reuse of waste materials e.g. bottles, empty beverage containers. This process is carried out in the following four stages,

14.9.1 Stages of Recycling/Reuse

Stage 1: Collection of waste material
Stage 2: Segregation or categorization
Stage 3: Breaking down or mutilating
Stage 4: Regenerating or Remaking
Stage 5: Reusing or Realizing

14.9.2 Waste Material Collection: Kerbside or Single-Stream Recycling

Materials to be recycled may be collected separately from general waste using dedicated bins and collection vehicles. This procedure is called ***kerbside collection***. In some communities, the producer of the waste is asked to separate the materials into different bins (e.g. for paper, plastics, glass and metals) prior to its collection. In other communities, all recyclable materials are placed in a single bin for collection, and the sorting is handled later at a central facility. The latter method is known as "***single-stream recycling***."

14.9.3 Acceptance of Waste Material

The type of material accepted for recycling varies from city to city and country to country owing to different recycling programs and practices. However, the variation in acceptance can be understood from the resale value of the material after reprocessing. The acceptance of these materials can even affect the global economies also. One good example is; in July 2017, the China announced an import ban of 24 categories of recyclables and solid waste, including plastic, textiles and mixed paper. This caused tremendous impact globally, on developed countries who exported directly or indirectly to China.

14.9.4 Segregation of Materials: Types of Solid Waste Materials

The following are the most common consumer products asked in kerbside collection which can be recycled or reused (the list under each category is not exhaustive). Such collected material are often segregated into the various categories are listed below.

Metallic type

- aluminium such as beverage cans,
- copper such as wire, copper winding
- iron material such as old furniture/equipment,
- steel from food/aerosol cans, utensils

Plastic type

- rubber tyres, mats
- leather material
- polyethylene and PET bottles,
- PVC, LDPE, PP, and PS (see resin identification code)

Paper type

- paper board cartons,
- newspapers, magazines, notebooks and light paper,
- packing papers, used decoration paper
- corrugated fibre board boxes

Glass/Ceramic type

- glass bottles and jars, broken glass tumblers
- Beverage (beer/whisky etc), Cool drink/soft drink bottles,
- Burnt electric bulbs/tubes, mirrors, table glass etc.
- Broken cups/saucers/jars, ceramic metrials

Textile type

- Jute/fibre bags, cement bags
- Used bed sheets, curtains,
- Used/torn out cloths, dresses
- Used school bags, uniforms etc.

Complex materials

- Electronic gadgets, part and components
- Computer peripherals, components
- Products of combinations of the above

Most of the items may be composed of a single type of material, making them relatively easy to recycle into new products. But, the recycling of complex products (such as computers and electronic equipment) is more difficult, due to the additional dismantling and separation required. Sometimes they are impossible or infeasible or uneconomic to recycle.

There are several benefits of recycling. Moreover, with the advent of new technological advancements, even more materials are recyclable and more kinds of materials are taking birth, perhaps, rising a hope to clean up the Earth.

Recycling is beneficiary in for not only the environmental sustenance but also enhances the economy. The materials from which the items are made can be produced into new products.

14.9.5 Biological reprocessing

Materials that are organic in nature are recoverable. Such materials include plant material, food scraps, and paper/wood products etc. These can be recovered through composting and digestion processes by decomposing the organic matter.

Results of Recycling

The resulting organic material is then recycled as

- mulch or compost for agricultural or landscaping purposes.
- gas from the process (such as methane)
- for generating electricity
- generating heat (CHP/ cogeneration)
- as fuel

There are different types of composting and digestion methods and technologies. They vary in complexity from simple home compost heaps to large scale industrial digestion of mixed domestic waste.

Methods of Biological Reprocessing

The different methods of biological decomposition are classified as

- aerobic methods or
- anaerobic methods
- hybrid methods

The anaerobic digestion of the organic fraction of solid waste is more environmentally effective as compared to landfill, or incineration. The objective of biological processing in waste management is to control and accelerate the natural process of decomposition of organic matter.

SAQ – 14.3

a) List out the strategies to see wealth in waste.
b) What does the word 'REDUCE' indicate?
c) Explain the strategies involved in 'REDUCE'.
d) Write the Waste Minimization, Avoidance/ Reduction Methods.
e) Briefly discuss Disposal methods.
f) What is Incineration? Explain.
g) Describe the different stages of Recycling/Reuse.
h) What is kerbside collection?
i) How does the Acceptance of Waste Material become a global issue?
j) Explain Segregation of Materials in detail.
k) What is Biological reprocessing?
l) State the Results of Recycling.
m) Write the Methods of Biological Reprocessing.

ACTIVITY 14.3

How is Waste to Wealth (W2W) possible in your vicinity? Explain it with an example by considering the above discussed strategies.

14.10 RECOVER: WASTE TO ENERGY (W2E)

Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes as listed below

- combustion,
- gasification,
- pyrolysis or pyrolyzation
- anaerobic digestion, and
- landfill gas recovery.

This process is often referred to as waste-to-energy or W2E, which accounts for 16% of global waste management.

14.10.1 Combustion

Waste to Energy (W2E) recovery is in fact a part of the non-hazardous waste management hierarchy. Conversion of non-recyclable waste materials into electricity and heat, means generation of renewable energy source and can lower the carbon emissions by offsetting the need for energy from fossil sources as well as reduce methane generation from landfills.

The energy content of waste products can be extracted directly by combustion as direct fuel, or indirectly by processing them into another type of fuel. Thermal treatment ranges from using waste as a simple fuel source (for cooking/heating/gas fuel) to fuel to generate steam for boilers and electricity in a turbine.

14.10.2 Pyrolysis

Pyrolysis and gasification are two more forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen supply. The process is normally carried out in a sealed vessel under high pressure.

Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery).The solid residue (char) can be further refined into products such as activated carbon.

14.10.3 Gasification

Gasification and advanced Plasma arc gasification are the processes of converting organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen, which in turn can then be burnt to produce electricity and/or steam.

14.10.4 Process of Pyrolysis

Pyrolysis is often used for conversion of many kinds of domestic and industrial residues into a recovered fuel. Different types of waste input (such as plant waste, food waste, tyres) placed in the pyrolysis process potentially yield an alternative to fossil fuels. It is a process of thermo-chemical decomposition of organic materials by heat in the absence of stoichiometric quantities of oxygen; the decomposition produces various hydrocarbon gases. During pyrolysis, the molecules of object vibrate at high frequencies to an extent that molecules start breaking down. The rate of pyrolysis increases with temperature. In industrial applications, temperatures are above 430°C (800°F). Slow pyrolysis produces gases and solid charcoal. Pyrolysis of waste wood and plastics can potentially produce fuel. The solids left from pyrolysis contain metals, glass, sand and pyrolysis coke which does not convert to gas.

Compared to the process of incineration, certain types of pyrolysis processes release less harmful by-products that contain alkali metals, sulphur, and chlorine. However, pyrolysis of some waste produces gases which can impact the environment such as HCl and SO_2.

14.10.5 Resource Recovery

Resource recovery is the systematic diversion of waste, which was intended for disposal, for a specific next use. It is the processing of recyclables to extract or recover materials and resources, or convert to energy. These activities are performed at a resource recovery facility.

Examples:

1. Wood chippings in pallets and other packaging materials can be recycled to useful products for horticulture.
2. The recycled chips can cover paths, walkways, or arena surfaces.
3. Many items thrown away, consists of metallic components, are recycled to create a profit, such as the components in circuit boards.
4. The composite materials can be produced out of wastes

Resource recovery, in contrast to waste management uses life cycle analysis (LCA) to offer alternatives to waste management. For mixed Municipal Solid Waste (MSW) the process goes in the sequential path as administration, sourcing, collection, categorization & separation, followed by reuse and recycling of the non-organic fraction and energy and compost/fertilizer production of the organic material through anaerobic digestion.

Advantages of Resource Recovery

The chief advantages of resource recovery can be as listed as follows

- The resource recovery not only protects but also improves environment and focuses on the environmental sustenance too.
- The resource recovery practices are cost-effective
- It lowers down the amount of waste for disposal,
- It saves space in landfills,
- The recovery practices conserve natural resources.

14.11 OUTCOMES OF WASTE MANAGEMENT

Application of rational and consistent waste management practices can yield a range of development economically, environmentally, socially. Its output can also out-speak inter-generational equity, and the beauty of W2E is that it uses technology, tools and techniques of cross-functional areas of engineering, medicine, agriculture, pharmacy, economics and so forth.

We shall now discuss about the major outcomes of Waste Management through the following paragraphs,

14.11.1 **Economic Outcomes**

Improving economic efficiency through the means of resource use, treatment and disposal and creating markets for recycles can lead to efficient practices in the production and consumption of products and materials resulting in valuable materials being recovered for reuse and the potential for new jobs and new business opportunities.

14.11.2 **Social Outcomes**

By reducing adverse impacts on health by proper waste management practises, the resulting consequences are more appealing civic communities. Better social advantages can lead to new sources of employment and potentially lifting communities out of poverty especially in some of the developing poorer countries and cities.

14.11.3 **Environmental Outcomes**

Reducing or eliminating adverse impacts on the environment through reducing, reusing and recycling, and minimizing resource extraction can result in improved air and water quality and help in the reduction of greenhouse gas emissions.

14.11.4 **Inter-generational Equity Outcomes**

Following effective waste management practises can provide subsequent generations a more robust economy, a fairer and more inclusive society and a cleaner environment.

14.12 WASTE VALORISATION

Waste valorisation also called beneficial reuse, value recovery or waste reclamation is the process of valorising (given economic value) to waste products or residues, by reuse or recycling in order to create economically useful materials. The term comes from practices in sustainable manufacturing, economics, industrial ecology and waste management. This term is often used in industrial processes where residue from creating or processing one wasted product or material to be used as a raw material or energy feedstock for another industrial process. Industrial wastes in particular are good candidates for valorising because they tend to more consistent and predictable than other waste, such as household waste.

Historically, most industrial processes treated waste products as something to be disposed of, causing industrial pollution if not handled properly. However, increased regulation of residual materials and socioeconomic changes, such as the introduction of ideas about sustainable development and circular economy in the 1990s and 2000s increased focus on industrial practices to recover these resources as value add materials. Academics focus on finding economic value to reduce environmental impact of other industries as well, for example the development of non-timber forest products to encourage conservation. The new innovative products in construction field onother good example in this case.

14.13 LIQUID WASTE-MANAGEMENT

Liquid waste is considered very important category of waste management as it is difficult to deal with. The major challenge is that, unlike solid wastes, liquid wastes cannot be easily picked up and removed from an environment. Liquid wastes spread out, and easily pollute other sources of liquid if brought into contact. Further, this kind of waste also soaks into objects to pollute soil and groundwater. This in turn carries over to pollute the plants, the animals in the ecosystem, as well as the humans within the area of the pollution.

Sewage sludge

Sewage sludge is produced by waste water treatment processes. Due to rapid urbanization, there has been an increase in municipal waste water that results 0.1–30.8 kg of sewage per population equivalent per year (kg/p.e/year). Common disposal practices of sewage sludge are incineration, composting, and landfill.

SAQ – 14.4

a) List the processes used for Energy recovery from waste.

b) Briefly explain the following processes.

    i. combustion,

    ii. gasification,

    iii. pyrolysis or pyrolyzation

c) Explain the Process of Pyrolysis.

d) What is Resource recovery? Give some examples.

e) Write the Advantages of Resource Recovery.

f) How Energy recovery from waste is possible? Explain in detail.

g) What are the outcomes of waste management? Briefly explain them.

h) What is Waste valorisation?

i) Discuss Liquid Waste-Management.

ACTIVITY 14.4

We often listen that our daily domestic waste is useful. How does our daily domestic waste become wealth? Suggest your opinion on implementation of using waste.

14.14 MUDA – THE SEVEN WASTES

Waste reduction is undoubtedly the best and the most effective way to enhance profitability. Taiichi Ohno, the chief engineer of Toyota Production System (TPS), was the first to identify this as a key concept under the head MUDA.

"MUDA" is a traditional Japanese term which means, '*be careful*' about:

None and *not useful* or *wasteful* or *unproductive* or *does not add value*.

In fact, Toyota has identified three types of wastes, these are

1. MUDA – The Waste,
2. MURA – The Unevenness and
3. MURI – The Overburden

TPS chose the above three words starting with the prefix mu; these are largely recognized in Japan for product improvement campaigns. However, MUDA has drawn more attention than the other two since many lean practitioners failed to see in the same prominence in the other two wastes, mura (unevenness) and muri (overburden).

A process adds value by producing goods or providing services for which a customer pays. Obviously, processes consume resources and waste occurs if more than required resource is consumed. If these wastes are identified and forestalled, this not only adds to profitability but saves the resources too.

The Seven Wastes in Industry

The key of lean manufacturing is the detection of the activity of the process that adds value and that does not. Once all the activities are classified into the two categories, it is possible to start actions for improving the former and eliminating the latter. After value-adding work has been separated from the waste, it (waste) can be subdivided into pure waste and "needed but non-value adding" waste. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. Thus to eliminate waste, it is important to understand exactly what a waste is and where it exists.

"The seven wastes" is a tool to further categorize MUDA. (Remember the seven wastes with an acronym 'DO-IT-OWM' framed by the first letters of the seven wastes as shown below)

D	for	Defect
O	for	Over-production
I	for	Inventory
T	for	Transportation
O	for	Over-processing
W	for	Wait
M	for	Motion

These are briefly discussed here below.

14.14.1 Defects

Occurrence of a defect attracts additional cost incursion due to reworking the part, rescheduling production, etc. Having a direct impact down the line, defects result in in rework or scrap and hence heavily cost organizations in several forms such as costs of

- reworking,
- rejection,
- re-inspecting,
- quarantining inventory,
- rescheduling,
- capacity loss,
- overuse of machine,
- material loss,
- manpower loss and
- overheads

In the recent days revolutionary changes have made organizations to become world-class or lean enterprises. The first step to achieve this goal is to identify and attack the seven wastes. Like Toyota and other world-class organizations, it is high time for any organization to realize that

"***Customers will pay for value, but never for waste***."

14.14.2 Overproduction

Overproduction refers to procuring or producing an item before it is actually required or manufacturing or purchasing more than what is needed. Generally, it often occurs during the production of large batches, supplying more than what the consumer needs.

Overproduction is as dangerous as cancer or a virus and is considered the worst MUDA since it hides and/or generates all the others. It results in excess inventory, excess motions, and more transportation which then incur the expenditure of resources on storage space and preservation and so on. These activities do not benefit the customer. On realizing this fact, the TPS observes JIT manufacturing, i.e., every item is made just as it is needed. The concept is to schedule and produce only what can be immediately sold/ shipped and improve machine changeover/setup capability.

A simple solution to overproduction is

"Turn off the tap when pot is filled"

However, this requires a lot of courage as the problems that overproduction is hidden will blow up.

14.14.3 Inventory

Inventory, may it be in the form of raw materials (R/M), in-progress (I/P), or finished goods (F/G), is a capital expenditure that has not yet produced any income either by the producer or by the consumer.

Further, the excess inventory hides problems on the shop floor. This should be recognized and resolved to improve operating performance. Further, excess inventory

- delays the identification of problems,
- increases lead times,
- consumes productive floor space,
- delays the identification of materials,
- inhibits communication, and so forth

The concept of JIT inventory system thence took birth and is the best solution to arrest this waste. By achieving a seamless flow between work centres, many companies have cut down inventories and their associated costs to better their customer service. Modern materials managers realized the fact that the inventory not only eats away the capital but also kills profits. So, the materials managers often call

'Inventory store is Industry's Graveyard'.

14.14.4 Transportation

Whenever a product is transported, it has the risk of damage, loss, delay, etc. Transportation does not make any transformation to the product that the consumer pays for. A good exercise is needed to find the optimal way to reduce the transportation cost. Operation research techniques (transportation, trans-shipment, assignment, travelling salesman problem, sequencing, etc.), mappings, string diagram, REL chart, trip frequency chart, flowcharts, etc., along with the latest computerized techniques, are available to use in these cases.

Transportation is considered as the waste for a simple reason and the known fact that,

Transportation adds a cost but never the value.

14.14.5 Over-processing

Over-processing means more work is done on a piece than what is needed by the customer. many organizations use expensive high precision equipment where simpler tools would be sufficient. This also includes using tools that are more precise, complex, or expensive than absolutely required. This often results in poor plant layout and attracts high asset overutilization in order to recover the high cost of the equipment. Toyota is famous for its use of low-cost automation, combined with immaculately maintained, often older machines. A simple example everybody knows is that over-processed food loses all the nutrients. Another good example is with an over cautious hyper-diabetic patient who if over-controls his/her diet may fall short of glucose levels in the body.

"***Over Processing is like using a sledgehammer to crack a nut***".

14.14.6 Waiting

If goods are not in transport nor are being processed, then they must be waiting. Typically, more than 99% of a product's life in traditional batch and queue manufacture will be spent waiting to be processed or in shelf in stores waiting for issuing. Most of a product's lead time is eaten away in waiting for the next operation. The waiting often occurs due to

- poor material flow,
- too long production runs,
- logistic problems,
- non-availability of tools or materials in time,
- long distances between work centres, etc.

Keeping to the above reasons in mind, the process has to be intelligently linked up in such a way that one feeds directly the next, which can drastically reduce waiting. An hour lost in a bottleneck process is an hour lost to the entire factory's output, which can never be recovered, because…

"Time and tide waits for none"

14.14.7 Motion

Motion refers to the movements of producer, worker, or equipment. This waste is more concerned with ergonomics and is seen in all instances of bending, stretching, walking, lifting, reaching, etc. The issues under this waste are related to health, safety and security of humans, machinery, and assets. Hence, jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel, because every movement has energy and so,..

"A wasted movement means wasted energy".

After understanding all the seven wastes, we can notice that for each waste, there is a strategy or a method and a reason to reduce or eliminate its effect on a company, thereby improving the overall performance and quality (Table 14.**).

Table 14.** Methods to Prevent/Avoid Waste	
The Waste	**Prevention/Avoidance Method**
Defect	Perform each Operation without error, Establish quality in every process
Over Production	Produce only the amount of goods necessary, not faster/sooner/more
Inventory	Provide material exact quantity needed by the customer at right time
Transport	Minimize distance between processes and avoid temporary material locations.
Over Processing	Put required amount of effort and time only for processing each operation.
Waiting	Assure Machine availability; Perform preventative maintenance. Use man machine chart to ensure optimization of operators' time.
Motion	Simplify & standardize work sequence to eliminate unnecessary movements.

Do You Know

The Eighth Waste

The Eighth Waste In the latest ion of the lean manufacturing classic Lean Thinking, underutilization of employees has been added as an eighth waste to Ohno's original seven wastes. Organizations employ their staff for their nimble fingers and strong muscles but forget to ensure that the employees come to work every day with a free brain. It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance.

SAQ 14.5

a) Discuss the contributions of Taiichi Ohno toward MUDA and its application in Toyota.

b) What is MUDA? Briefly explain the concept of MUDA. What are the advantages of MUDA.

c) Explain the nature and scope of MUDA in Indian industrial backdrop.

d) What are the seven wastes in MUDA? Brief out each.

e) With suitable examples discuss how wastes occur in the following aspects in an industry:

   i. Inventory

   ii. Transportation

   iii. Overproduction

   iv. Waiting

f) What are the seven wastes described under MUDA? How do you forestall or avoid them?

g) Distinguish between over-processing and under-processing with examples. Are both considered as wastes? Why?

h) What do you understand by the concept of “turning of the tap” in production in an industry? Explain.

ACTIVITY 14.5

Just observe the seven wastes discussed here in day-to-day activities at your home. (For example, waste occurs in kitchen commodities.) Try to reduce or stop these wastes for about one week and find the difference.

Do you think the application of MUDA is a successful formula for Indian industry? Discuss.

14.15 SUMMARY

Waste management is one of the major challenges of materials management. Based on the physical appearance, waste can be solid, liquid, or gaseous and each type has different methods of disposal and management. The waste hierarchy refers to "3Rs" Reduce, Reuse and Recycle. The first step is to reduce or restrict the generation of waste. The second step is to seek alternative uses for the waste that has been generated i.e. by re-use. The next step is to recycle which includes composting. Next step is material recovery and waste-to-energy. The final action is disposal, in landfills or through incineration without energy recovery. “MUDA” is a traditional Japanese term which means, ‘*be careful*’ about *none* and *not useful* or *wasteful* or *unproductive* or *does not add value*.

14.16 KEYWORDS

Reduce: It refers to lowering or minimizing the waste generation if not totally eliminated.

Recycle or Reuse: It is a resource recovery process that refers to the collection and reuse of waste materials e.g. bottles, empty beverage containers.

Recovery: Conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes.

Combustion: Conversion of non-recyclable waste materials into electricity and heat.

Pyrolysis: Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon.

Gasification: Gasification and advanced Plasma arc gasification are the processes of converting organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen, which in turn can then be burnt to produce electricity and/or steam.

LCA: Life Cycle Analysis to offer alternatives to waste management.

Waste valorisation: It is beneficial reuse, value recovery.

MUDA: The Waste

MURA: The Unevenness

MURI: The Overburden

14.17 FURTHER READINGS

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