Bachelor of Computer Applications (BCA)

Environment Science

(OBCAVA204T24)

Self-Learning Material (SEM II)

Jaipur National University

Centre for Distance and Online Education

Established by Government of Rajasthan
Approved by UGC under Sec 2(f) of UGC ACT 1956
&
NAAC A+ Accredited

Jaipur National University

Course Code**:** OBCAVA204T24
Environment Science

TABLE OF CONTENT

Expert Committee

Prof. R.L. Raina
Former Vice Chancellor, JKLU
Professor of Communication, IIM Lucknow

Prof. Meena Godha
Dept. Of Life Science, JNU Jaipur

Course Coordinator

Ms. Saraswati Kumari
Assistant Professor
Department of Business & Management, JNU, Jaipur

Unit Preparation

Unit Writers

Dr. Juhi Sharma
Dept. Of Life Science, JNU Jaipur
(Unit 1-4)

Ms. Anupama Pareek
Dept. Of Life Science, JNU Jaipur
(Unit 5-9)

Assisting & Proofreading

Dr. Dildar Hussain
Dept. Of Life Science, JNU Jaipur

Editor

Prof. Indrani Jadhav
Dept. Of Life Science, JNU Jaipur

Secretarial Assistance

Mr. Mukesh

Course Introduction

"Environment Science" This course provides a comprehensive overview of the scientific principles, concepts, and methodologies necessary to understand the interrelationships of the natural world. It focuses on understanding how human activities impact the environment and explores strategies for mitigating these effects to promote sustainability.
This Course is assigned 2 credits and contains 9 units each unit is divided into sections and subsections. Each unit begins with a statement of objectives to indicate what we expect you to achieve through the unit. There are several assignments in each unit which you may attempt.

Course Outcomes

After studying this course, a student will be able to:

1. Understand the Core Concepts of environmental science, including ecology, biodiversity, and environmental chemistry.
2. Understand the structure and function of different environmental systems, such as the atmosphere, hydrosphere, lithosphere, and biosphere.
3. Analyze human activities which affect the environment, including pollution, deforestation, climate change, and resource depletion.
4. Evaluate conservation strategies and sustainable practices to protect and preserve natural resources.
5. Develop critical thinking and problem-solving skills through the analysis of environmental issues and case studies.

We hope you will enjoy the course.

Acknowledgement

The material we have used is purely for educational purposes. Every effort has been made to trace the copyright holders of materials reproduced in the book. Should any infringement have occurred, the editors apologise and will be pleased to make the necessary corrections in the future editions of this book.

Unit: 1

Ecosystem

Learning Objectives:

- Understand the Ecosystem
- Learn about its Structure & Functions
- Get known important terms
- Understand their meanings with examples

Structure:

1.1 Ecosystem: An Introduction

In ecology, an ecosystem is a basic and well-designed unit and a place for living organisms to interact with each other and their environment. Simply put, it's the network of interactions between species and their surroundings. This term "Ecosystem" was introduced and used by the English botanist A.G. Tansley in 1935.

Study of ecosystems examines how coexisting species interact with one another and how energy flows through the network of organisms within an ecosystem. It also examines how an organism interacts with others to live sustainably, harming or benefiting those involved. Nature shows that ecosystems can vary greatly in size, influenced by the number of non-living elements in the environment. In the harsh climates of the north and south poles, ecosystems have less plant and animal life compared to those in tropical climates, like forests. Thus, only those species that can survive in such a setting will be able to contribute to the ecosystem. A biosphere consists of various ecosystems working together.

A significant example of an ecosystem is a pond. Ecosystems can be found in ponds, lakes, deserts, grasslands, meadows, forests, etc.

1.1.1 Two Components of the Ecosystem

1. Biotic Components
2. Abiotic Components

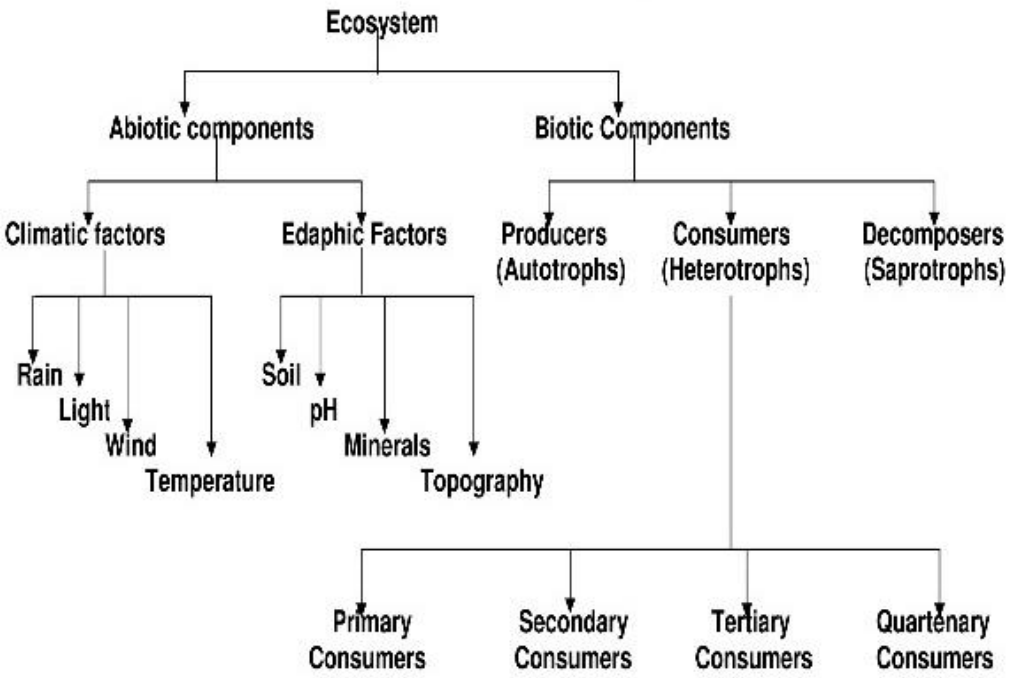

Figure 1.1: Components of the Ecosystem

Source: EDUINDEX NEWS

- **Abiotic factors** are nonliving elements of the environment that impact how living things interact. They consist of the following:
  Physical Environment: The ecosystem's surrounding conditions, including soil type, topographical characteristics, water availability, temperature, humidity, and sunlight.
- **Biotic elements** are the ecosystem's living creatures. They can be divided further into three major categories:

1. Producers: Through photosynthesis, plants, algae, and some microorganisms can create their food.
2. Consumers: Animals and other species that get energy from eating other organisms are considered consumers. These are further classified into the following categories:
   - Primary Consumers: They eat directly from the producers. They are known as herbivorous creatures like elephants, zebras, pandas, etc.
   - Secondary Consumers: They obtain their food from the primary consumers. Animals which are included in this category are omnivorous and carnivorous species, including lions, bears, pigs, crocodiles, etc.

- Tertiary Consumers: They eat from secondary consumers. This category includes carnivores which only eat meat and typically hunt their prey, such as a tigers, wolves, etc.
- Quaternary Consumers: The sources of their sustenance are tertiary consumers. For example, polar bear is the top predators in the Arctic region, primarily hunting seal that may eat small fishes that consumes zooplankton and algae.

3. Decomposers: Bacteria, fungi, and other creatures that disintegrate decaying organic materials and replenish the ecosystem with nutrients.

Figure 1.1 demonstrates the interconnectivity of these elements within an ecosystem. The energy from the sun is transformed or converted into food by producers, which consumers eat subsequently. Decomposers disintegrate the remains of deceased creatures, supplying the ecology with nutrients. All living things can access the materials and factors they need from their physical surroundings.

Understanding that different habitat types, such as forests, grasslands, oceans, or deserts, might have very different ecosystems is essential. Although each ecosystem has its specific mix of parts and interactions, the above flowchart captures the essential elements common to most ecosystems.

1.2 Structure & Functions of Ecosystem

The ecosystem provides the following services:

1. Ensuring stability, supporting life systems, and regulating essential ecological functions are key roles of this element.
2. Additionally, it oversees the transfer of nutrients from living and non-living components and vice versa.
3. It ensures harmony among the different trophic levels within the ecosystem.
4. Circulation of mineral throughout ecosystem is facilitated by this factor.
5. Abiotic components play a role in the synthesis of organic materials and the exchange of energy within the ecosystem.
6. Therefore, the functional elements or units within the ecosystem are as follows:
    - Productivity: Productivity refers to the speed at which biomass is generated.

- Energy flow: The systematic movement of energy from one trophic level to another within an ecosystem is energy flow. Solar energy is initially captured by producers, then transferred to consumers, and eventually returned to the environment through decomposers.
- Decomposition: Decomposition involves the breakdown of dead organic matter, primarily occurring in the topsoil.
- Nutrient cycling: In ecosystems, nutrients are utilized by organisms and then recycled through various processes for reuse by other organisms. These functions are further explained for a better understanding.

1. Productivity:

An ecosystem's gross primary productivity (GPP) measures how quickly organic matter is produced during photosynthesis. GPP has a crucial role in plant respiration. Net primary productivity (NPP) is determined by subtracting the respiration losses (R) from the gross primary productivity (GPP).

The biomass accessible for consumption by heterotrophs, such as herbivores and decomposers, equals GPP minus R, which equals NPP. Additionally, secondary productivity refers to the rate at which consumers generate fresh organic material.

2. Energy Flow

Energy flow and food chains are two features of ecosystems that make them dynamic as they link an ecosystem's biotic and abiotic elements. The Sun is the only energy source for all ecosystems on Earth, except the marine hydrothermal ecology, and less than 50% of the incident solar radiation is PAR (photosynthetically active radiation). Just 2-10% of PAR is absorbed by plants, but this little energy is enough to sustain all life on Earth.

All species depend on farmers for food, either directly or indirectly. Energy, therefore, travels singly from the sun through producers to consumers.

Ecosystems require a consistent energy source to synthesise the chemicals they need to fight the general trend towards growing disorderliness.

An ecosystem has a linear or one-way flow of energy.

The size of the boxes in Figure 1.2 demonstrates how less energy moves through the various trophic stages as time goes on. Each organism in a food chain or web uses the energy it receives at that point to support itself.

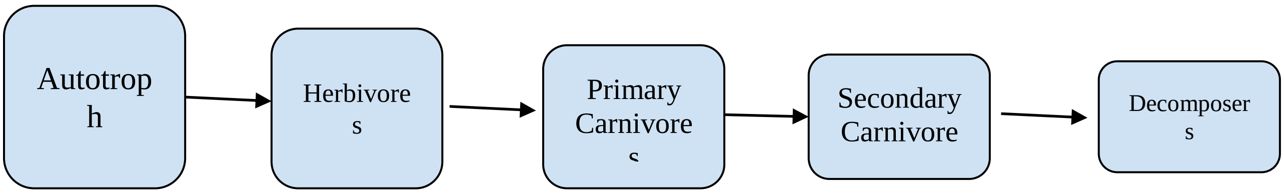

Figure 1.2: Energy Flow in an Ecosystem

1.3 Food Chain

The ongoing process of eating and being eaten by various species through a chain of producers (green plants) is called a food chain.

1.3.1 Types of food chains:

1. **Grazing Food Chain:** It begins with green plants that produce food for herbivores, providing food for predators. Only 10% of the energy is transferred from the lower trophic level to each trophic level in the grazing food chain, which is governed by a 10% law.
2. **Detritus Food Chain:** It begins with decaying biological materials. For protozoans, carnivores, and other species, detritivorous organisms produce food.

The energy source for the first-level customers is a significant point of difference between these two food chains.

In the grazing food chain, living plant biomass serves as the main energy source, while in the detritus food chain; the primary energy source is detritus, which refers to dead organic matter. The two chains work together to form a y-shaped food chain in an ecosystem.

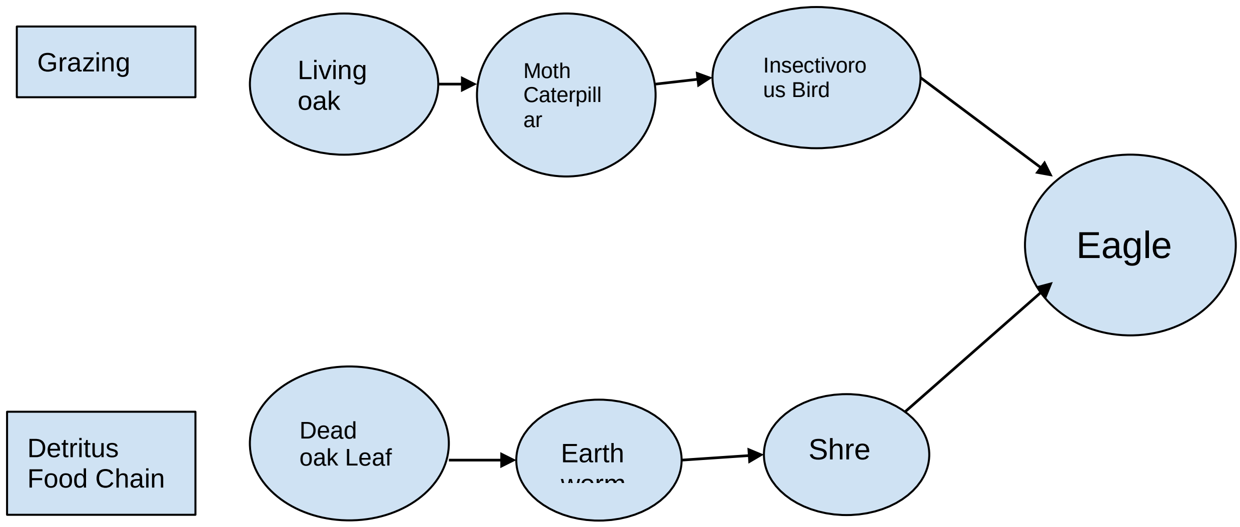

Figure 1.3: Y-shaped Food Chain

Another example of a food chain is mentioned below.

The grasshopper eats the plant, which is eaten by a mouse. The snake then eats a mouse, followed by an eagle. When the eagle dies, its body is broken down into nutrients by fungi. W of sun and water, these nutrients lead to grass growth.

1.4 Food Web

In 1927, Charles Elton introduced the concept of the food web, which he initially termed the "food cycle." According to Elton, a food web describes the interconnected feeding relationships in an ecosystem, where herbivores consume plants that derive energy from the sun and are in turn preyed upon by carnivorous animals. These carnivores can themselves become prey for other carnivores, forming a complex network of interactions within the ecosystem.

Groups of animals linked by their feeding habits, ultimately reliant on plants for sustenance, constitute a food chain. The entirety of interconnected food chains within a community is referred to as a food web. An organism in a food chain becomes a terminus when it no longer has predators, marking the end of that particular feeding cycle.

A food web represents relationships between species that make up an ecological community. A particular ecosystem's food chains are included in the food web. They serve as an example of numerous methods of feeding. The food web explains the energy transfer through species in a community.

The relationships between the food chains are interrelated in a natural environment or an ecosystem. The relationships within ecosystems are highly intricate, as one organism can participate in multiple food chains simultaneously. All these interconnected and overlapping food chains collectively form a food web within an ecosystem.

Every living thing is accountable and is a member of various food chains in the specific ecosystem. Food webs are an integral component of an ecosystem; they allow an organism to get food from multiple kinds of creatures of the lower trophic level.

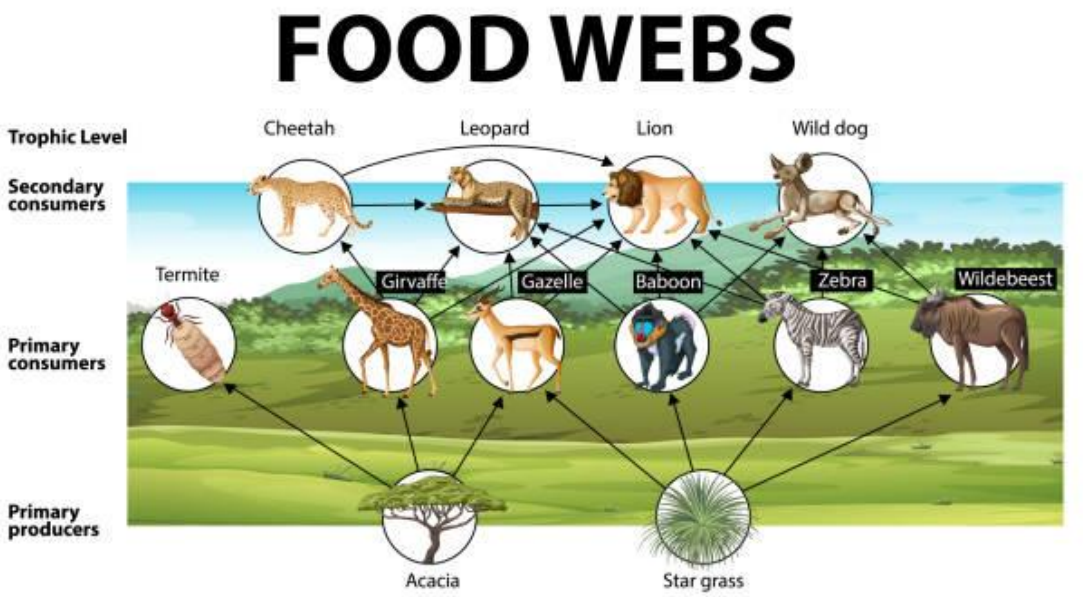

Figure 1.4: Food Web

Source: iStock

1.5 Ecological Pyramid

he ecological pyramid visually represents the different trophic levels of organisms based on their roles as producers and consumers. It illustrates the biomass or productivity present at each trophic level within an ecosystem.

The ecological pyramid consists of horizontal bars representing each trophic level, with the length of each bar indicating the total number of individuals, biomass, or energy at that level within an ecosystem. Food producers are typically located at the base and apex of the pyramid, while other consumer trophic levels occupy positions in between.

The amount of biomass and its distribution among the species at each trophic level is shown by biomass pyramids. Productivity pyramids illustrate biomass output or turnover within an ecosystem. Ecological pyramids typically start with producers, such as green plants, at the base and progress through various trophic levels. These levels include herbivores that consume plants, predators that prey on herbivores, carnivores that feed on those predators, and so forth.

At the top of the food chain lies the highest trophic level. Energy flows through the food chain in a predictable manner, beginning at the base where primary producers utilize photosynthesis to capture energy from the sun. This energy then ascends to higher trophic levels as it is transferred through consumption and predation.

The quantity of energy entering each trophic level should impact the abundance and biomass of organisms there. Pyramids of biomass and numbers will emerge when there is a direct association between energy, numbers, and biomass.

1.5.1 Types of Pyramids

1. Pyramid of Numbers

The overall number of people from various species present at each trophic level, also known as the population of the tropical group, is represented by a pyramid of numbers which can be either upright or fully inverted.

The pyramid of numbers only partially defines the trophic structure of an ecosystem because it is challenging to enumerate all the creatures present there. For example, the ecosystem of grassland is upright because the population decreases from a lower level to a higher level. However, the ecosystem of a tree is inverted because the population at each trophic level increases from lower to higher levels.

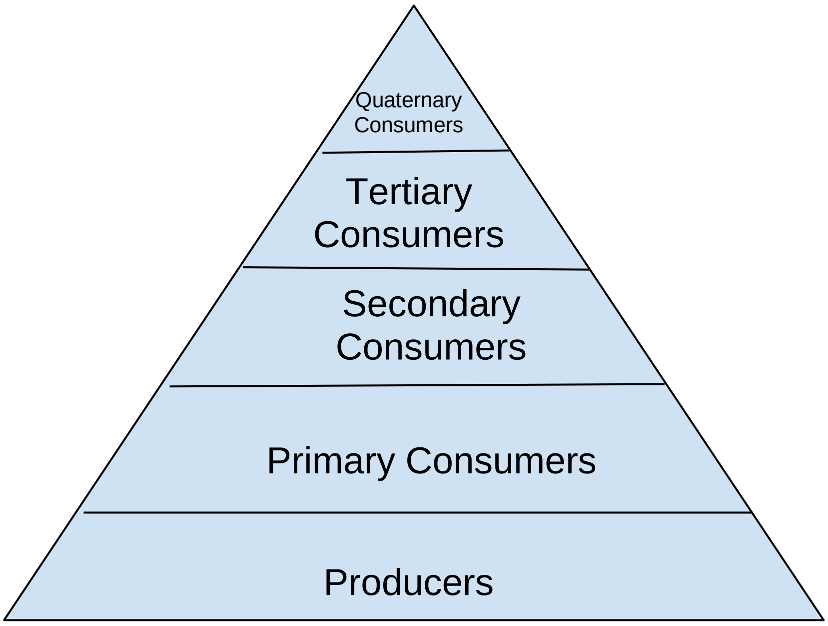

Figure 1.5: Pyramid of Numbers in Grassland Ecosystem

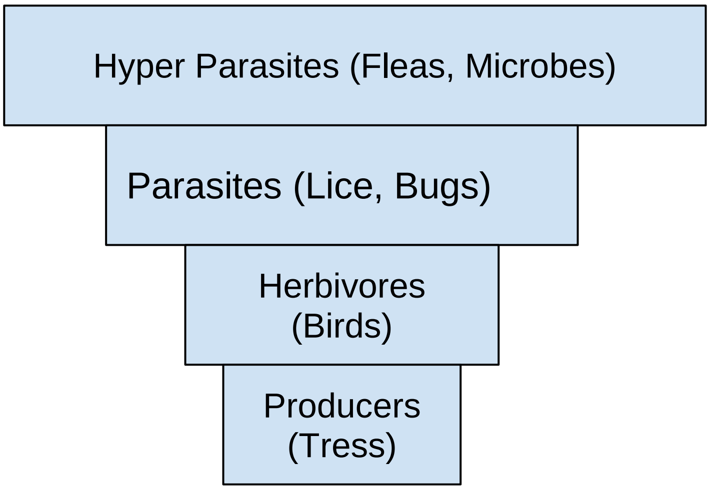

Figure 1.6: Pyramid of Numbers in Tree Ecosystem

2. Pyramid of Biomass

The biomass pyramid represents the dry weight of all creatures. Typically, it is calculated by gathering every organism in each trophic level separately and weighing their dry weight. The unit for measurement of biomass is g/m2. Because primary producers dominate the base of the biomass pyramid on land and a lower trophic level is present at the top, the biomass pyramid is always upright.

The biomass pyramid is present in many aquatic ecosystems in an inverted form. This is because the producers are tiny phytoplankton that quickly develop and reproduce.

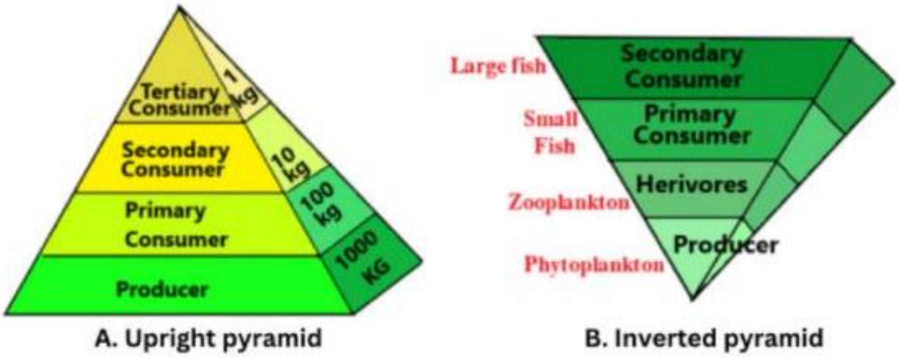

Figure 1.7: Pyramids of Biomass

Source: Science Query

3. Pyramid of Energy

The energy pyramid illustrates the flow of energy from lower trophic levels to higher trophic levels within an ecosystem. As energy is transferred from one organism to another, there is a significant loss of energy in the form of heat. This loss of energy is a fundamental aspect of energy transfer within ecological systems. The primary producers, such as autotrophs, have more energy easily accessible, whereas tertiary consumers have the least. As a result, shorter food chains have more energy availability even at the highest trophic levels.

An energy pyramid represents the amount of energy present at each trophic level within an ecosystem, as well as the loss of energy during the transfer to higher trophic levels.

As a result, the pyramid is always upward and has substantial energy at its base.

1.6 Biogeochemical Cycle

The words ``bio" and "geo" refer to the biosphere, "geochemical" refers to the elements that circulate through a cycle, and "chemical" refers to the geological components. The earth's energy from the sun is radiated back as heat while some substances remain in a closed system. These elements include Carbon, Nitrogen, Hydrogen, Oxygen, Phosphorus, and Sulphur. These, therefore, are recycled by the components of the ecosystem. These cycles exemplify the utilization of energy and transport essential components for life throughout the biosphere. They are critical because they recycle, store, and regulate vital materials through physical processes. Ecosystems can persist because these cycles demonstrate the interaction between living and non-living entities within ecosystems.

1.6.1 Types of Biogeochemical Cycles

1. Water Cycle

Water evaporates from various bodies of water, undergoes cooling and condensation in the atmosphere, and eventually returns to the ground as precipitation, completing the water cycle. Biogeochemical cycle is in charge of sustaining the weather. Water interacts with the environment and modifies the atmosphere's temperature and pressure in all its forms.

Evapotranspiration, which is the vapour emitted by leaves, is another mechanism that contributes to the water cycle. Water evaporates from leaves, soil, and water sources, enters the atmosphere, condenses, and eventually falls back to the ground as precipitation.

2. Carbon Cycle

The carbon cycle involves the exchange of carbon among the biosphere, geosphere, hydrosphere, atmosphere, and pedosphere. During photosynthesis, green plants combine carbon dioxide and sunlight to store carbon. When these plants die and decompose, carbon is released and can become buried in the soil, eventually forming fossil fuels. Burning these fossil fuels emits carbon dioxide into the atmosphere.

Furthermore, animals that consume plants acquire the carbon stored by those plants. When these animals die and decompose, the carbon is released back into the atmosphere. Additionally, carbon is released into the environment through animals' respiration. Substantial quantities of carbon dioxide are produced and stored as fossil fuels like coal and oil, which can be extracted for various purposes. When these fuels are burned, carbon is once again released into the atmosphere, particularly in industrial processes.

3. Nitrogen Cycle

The nitrogen cycle involves various transformations of nitrogen that circulates through the atmosphere and different ecosystems, including terrestrial and marine environments. Nitrogen gas is converted into ammonia, a valuable chemical, by bacteria present in plant roots. Fertilizers containing ammonia are also applied to plants. Ammonia is converted into nitrites and then into nitrates. Denitrifying bacteria transform nitrates back into nitrogen, which is then released into the atmosphere.

4. Oxygen Cycle

Lithosphere, biosphere, and atmosphere are all involved in this biogeochemical cycle. About 21% of the earth's atmosphere contains oxygen in its elemental form. During photosynthesis, plants release oxygen as a by-product. When humans and other animals inhale oxygen, they exhale carbon dioxide, which plants absorb. During photosynthesis, plants use this carbon dioxide to produce oxygen, thereby sustaining the cycle of oxygen generation and carbon dioxide absorption.

5. Phosphorus Cycle

Phosphorus travels through the hydrosphere, lithosphere, and biosphere throughout this biogeochemical cycle. The weathering of rocks releases phosphorus. Phosphorus is removed from the soil and water bodies by rain and erosion. To grow and thrive, animals and plants acquire this phosphorus from the soil and water. It is also necessary for the growth of microorganisms. When plants and animals die, they decompose and release stored phosphorus back into the soil and water. This phosphorus is then absorbed by new plants and animals, continuing the cycle.

6. Sulphur Cycle

This biogeochemical cycle passes through living things, water, and rocks. When rock weather, sulphur gets released into the atmosphere and changed into sulphates. The bacteria and plants absorb these sulphates and transform them into organic forms. Animals take in organic sulphur through their diet. The cycle is continued when an animal decomposes, returning sulphur to the soil where plants and bacteria once more consume it.

1.7 Summary

- ❖ A.G. Tansley, an English botanist, first coined and used the word "Ecosystem" in 1935.
- ❖ The study of ecosystems delves into how coexisting species interact and how energy flows through the interconnected network of organisms within an ecosystem.
- ❖ Abiotic factors are non-living components of the environment that impact how living things interact.
- ❖ Biotic elements are the ecosystem's living creatures.
- ❖ Rate at which biomass is produced is productivity.

- ❖ A method where energy moves systematically from one trophic level to another is called energy flow.
- ❖ The process by which dead organic matter is broken down is decomposition. The topsoil is where most degradation occurs.
- ❖ Within ecosystems, nutrients are absorbed by one organism and subsequently recycled through diverse processes to be utilized by other organisms.
- ❖ Living plant biomass is the primary energy source in the grazing food chain, whereas detritus, or dead organic matter, is the primary energy source in the detritus food chain.
- ❖ In 1927, Charles Elton introduced the idea of the food web, which he called the "food cycle."
- ❖ A food web visually represents the relationships between the species that comprise an ecological community.
- ❖ A food web is where all the food chains are interconnected and overlapping within an ecosystem,
- ❖ The ecological pyramid illustrates various creatures' trophic levels based on their roles as producers and consumers. An ecological pyramid depicts biomass or bio-productivity at each trophic level graphically.

1.8 Keywords

1. **Ecosystem**: It's a unit, both structurally and functionally, where living organisms interact with each other and their environment.
2. **Abiotic factors**: These are non-living components of the environment that impact how living things interact.
3. **Biotic elements:** These are the ecosystem's living creatures.
4. **Energy flow**: It's the systematic movement of energy from one trophic level to another.
5. **Nutrient cycling**: In ecosystems, nutrients are consumed by one organism and then recycled through diverse methods for use by other organisms. Food chain: The on-going process of eating and being eaten by various species through a chain of producers (green plants) is called a food chain.

1.9 Self-Assessment Questions

1. What does the study of ecosystems primarily focus on?

2. Define abiotic factors in the context of an ecosystem.
3. Describe the process of energy flow in an ecosystem, highlighting its importance.
4. Write a short note on the biogeochemical cycles.
5. Explain the concept of productivity in an ecosystem and its significance.
6. Discuss Charles Elton's contribution to the field of ecology, particularly concerning the concept of the food web.
7. Explain the interconnected nature of food chains within an ecosystem and how they collectively form a food web.
8. Elaborate on the ecological pyramid and how it represents the trophic levels and biomass of organisms in an ecosystem.
9. Compare and contrast the grazing and detritus food chain regarding their primary energy sources and the organisms involved.
10. Who is credited with coining and using the term "Ecosystem" for the first time?

1.10 Case Study

In a forest ecosystem, introducing an invasive species has disrupted the food chain. The dynamics of the food web can be changed by invasive species, which can significantly impact native species and cause ecological imbalances.

Questions:

Based on your understanding of this situation, answer the given questions.

1. What are the invasive species in the forest ecosystem, and what are their characteristics and ecological traits?
2. What are the direct and indirect impacts of the invasive species on different trophic levels in the forest food web?
3. How do human activities contribute to the spread of invasive species, and what are the implications for ecosystem management and conservation?

1.11 References

1. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
2. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit 2

Biodiversity

Learning Objectives:

- Know the concept of Biodiversity
- Understand the causes of its depletion
- Become aware
- Learn ways to conserve

Structure:

2.1 Biodiversity and its Values

Biodiversity encompasses the entirety of life on Earth, comprising every organism from minuscule bacteria dwelling on land to colossal whales. Additionally, biodiversity encompasses the intricate interconnections between these life forms and their respective habitats.

Values

"Biodiversity" often denotes the variety of separate species or populations of autonomously reproducing organisms. Earth hosts a multitude of such species, ranging from marine organisms to white-tailed deer, pine forests, blooming flowers, and imperceptible microbes invisible to the unaided eye.

The core principles underlying biodiversity can be categorized as follows:

1. Environmental Values: By examining the functioning of the ecosystem, it is possible to assess the environmental benefits of biodiversity. Intensive agricultural production ecosystems, for example, provide ecosystem services that support human needs and activities. These include creating and preserving healthy soil, conserving clean groundwater supplies through vegetation, and producing oxygen by plants and microalgae on or beneath the surface.
2. Economic values pertain to the significant financial influence exerted by biodiversity on various sectors such as food production, animal husbandry, healthcare, ethics, and societal norms. The biosphere serves as a valuable asset for numerous industries that play a pivotal role in shaping the global economy.
3. Consumption-related values: The naturally occurring goods utilised for food, including feed for cattle, wood products, fuelwood, and other things, are consumed daily. Humans, as per research, consume around 40,000 plant and animal species daily. Many people continue to rely on wildlife for their needs, including food, a temporary place to stay, and clothing.
4. Productive use values suggest that the goods are sourced and professionally advertised. The crops that we see today are an evolved form of wild varieties. Biotechnologists constantly work with wild plant species to develop new, more productive, disease-resistant plant varieties.

5. Aesthetic values: Biological diversity enriches life quality and plays a substantial role in shaping some of nature's most breathtaking attributes. Biodiversity notably enhances the scenic beauty of landscapes.

2.2 Types and Levels of Biodiversity

Biological diversity broadly describes the transition of life from genes to ecosystems. It includes their existence, genetic variations, environments, populations, and the ecosystems in which they are present, as well as other evolutionary advancements that keep the system functioning, changing, and adapting.

Depending on the degree of variations, biodiversity is divided into many components.

1. Genetic Diversity: It is the diversity of every species. No two members of the same species are alike. Humans, for instance, exhibit a great deal of biodiversity. There are significant distinctions between inhabitants of different places. Genetic diversity is necessary for a population to adjust to shifting environmental conditions.
2. Species Diversity: It denotes the variety and abundance of species. A region's species density fluctuates greatly depending on its environmental conditions. For instance, it is frequently seen that a human culture near water sources exhibits more species than elsewhere.
3. Ecological Diversity: It is the diversity present among an area's ecosystems. Numerous environmental ecosystems, including mangroves, deserts, and rainforests, exhibit a great diversity of living forms inhabiting there.

2.3 Depletion of Biodiversity

The term “Biodiversity loss” refers to the depletion of biodiversity and its elements due to various reasons and mainly human activities.

Year	Population	Land area converted for human use	Loss of species in ecosystems
1800	0.9 billion	7.6 %	-1.8 %
1900	1.7 billion	16.9 %	-4.9 %
2000	6.1 billion	39.3 %	-13.6 %
2100 *Green model*	8.7 billion	33.4 %	-11.6 %
2100 *Current model*	12 billion	49.1 %	-17 %

Figure 2.1: Loss of Biodiversity

Source: IBERDROLA

Five primary factors that contribute to the loss of biodiversity are habitat destruction, the introduction of invasive species, overexploitation of resources, pollution, and the effects of climate change induced by global warming. Human activities directly influence each of these circumstances.

- Habitat Loss: Habitat loss refers to the gradual depletion, fragmentation, or total eradication of the plant life, soil composition, hydrological systems, and nutrient resources within an ecosystem.
- Invasive Species: Any non-indigenous species that substantially modifies or disrupts the ecosystems it inhabits is classified as invasive. Due to their heightened competitiveness compared to native species, invasive species have the capacity to unsettle ecosystems. They can rapidly deplete food resources or seize habitats faster than native species can adapt to the altered conditions. Certain invasive species may also prey upon native species, potentially leading to the extinction of these native species if they lack natural defences against the invaders.
- Overexploitation: Overexploitation alternatively referred to as overhunting and overfishing, involves the excessive harvesting of aquatic or terrestrial animals, resulting in the depletion of certain species' populations and the extinction of others.

Furthermore, it signifies a rate of consumption that outpaces natural replenishment, impacting the flora and fauna of the planet.

- Pollution: Pollution is the introduction of undesirable or harmful substances into an environment. In polluted areas, the quality of food, water, and other habitat resources declines, sometimes to such an extent that certain species are compelled to migrate or face extinction if the environmental stress becomes too severe.
- Climate Change: Global warming denotes the gradual increase in Earth's average atmospheric temperature observed over the past century or two, primarily attributed to human activities. It specifically refers to the elevation in temperature resulting from heightened levels of greenhouse gases in the atmosphere, including carbon dioxide, methane, and others. This alteration in temperature and precipitation patterns disrupts the natural cycles of breeding and resource availability. Furthermore, the melting and disintegration of ice lead to the decline of ecosystems reliant on its presence.
- Population: The tropical regions, encompassing roughly a quarter of the Earth's surface, support nearly three-quarters of the global population. Tropical rainforests, harbouring half of all Earth's species, are particularly rich in biodiversity. Consequently, one of the factors driving biodiversity loss is the significant population pressure, leading to extensive resource exploitation and deforestation in these regions.
- Other factors: Earth's flora and animals suffer harm from natural disasters such as forest fires, droughts, floods, volcanic eruptions, earthquakes, etc. Pesticides and other contaminants, such as harmful heavy metals and hydrocarbons, wipe out the weak and delicate species.

Figure 2.2 states some more reasons that lead to the overall depletion of biodiversity.

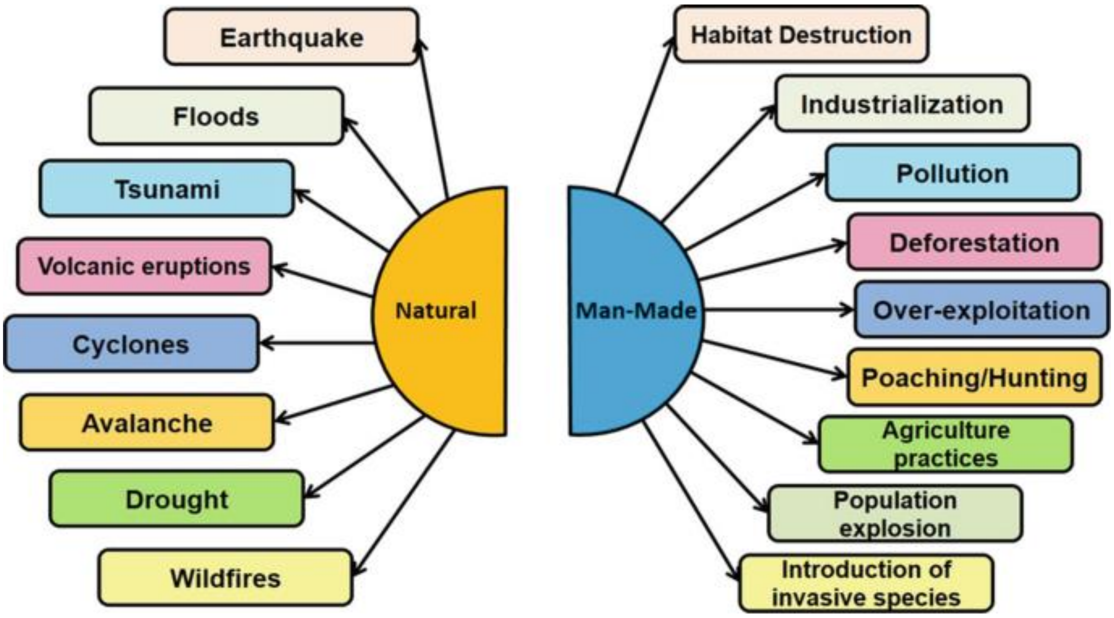

Figure 2.2: Causes of Depletion of Biodiversity

Source: Springer Link

The well-being of the human race will suffer due to biodiversity loss. It will increase the number of animals that spread disease among the local inhabitants.

2.4 Conservation

To facilitate sustainable development, it is imperative to safeguard and effectively manage biodiversity. Regions boasting higher species abundance tend to exhibit greater ecological stability compared to those with lower diversity. Given our direct reliance on a multitude of plant species to fulfil diverse needs, the conservation of biodiversity is paramount.

The primary objectives of biodiversity conservation include:

- Preserving species diversity.
- Promoting the sustainable utilization of ecosystems and species.
- Safeguarding essential ecological processes and systems that sustain life.

2.4.1 Methods of Biodiversity Conservation

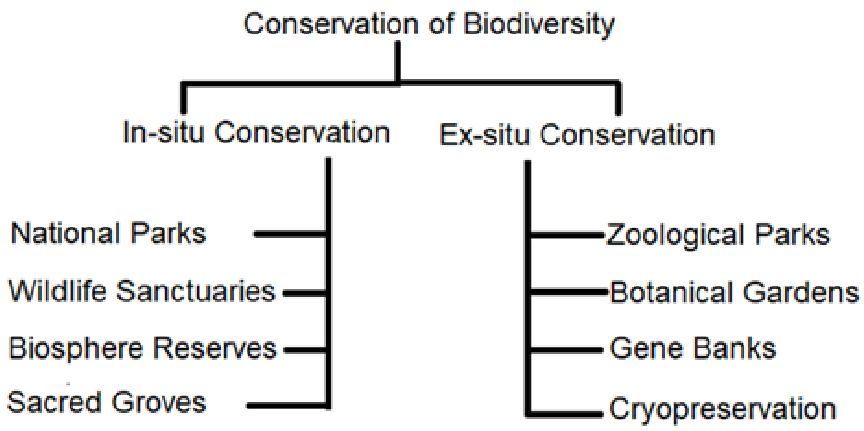

Figure 2.3: Conservation of Biodiversity: Methods

Source: EMBIBE

1. In-situ Conservation

In-situ biodiversity conservation involves the preservation of species within their natural habitats, thereby safeguarding the natural ecology. This approach entails the establishment and maintenance of protected areas such as national parks, wildlife sanctuaries, and biosphere reserves.

The advantages of in-situ conservation are numerous. Below are some key benefits of this approach:

- It provides a practical and cost-effective means of biodiversity preservation.
- Multiple species can be conserved simultaneously.
- Organisms can undergo more efficient evolution and adaptation to diverse environmental conditions within a natural ecosystem.

a. National parks

To safeguard species, the government administers the establishment and protection of National Parks, which are designated areas. Human activities are strictly prohibited within these parks. Examples include Kanha National Park and Bandipur National Park.

b. Wildlife Sanctuaries

These areas represent the sole habitats on the planet where wild animals thrive. Certain human activities, such as logging, farming, and gathering wood and other forest resources, are allowed within these zones as long as they do not impede conservation efforts. Moreover, tourists frequent these destinations for recreational purposes and to raise awareness about conservation.

c. Biosphere Reserves

Residents create and maintain biosphere reserves for the sustainable growth and protection of wildlife, flora, and the ecosystem. It comprises both terrestrial and aquatic ecologies. Activities like tourism and research are allowed within these reserves.

d. Sacred Groves

The entire forest's trees and creatures are revered and granted complete protection by a deity in sacred groves, a specific forest region. They aid in preserving the biodiversity of our nation. No one can harm any living thing in these holy groves since they are self-sustaining mini-ecosystems containing plants and animals. These can be found throughout India. The Khasi and Jaintia Hills in Meghalaya, the Aravalli Hills of Rajasthan, the Western Ghats regions of Karnataka and Maharashtra are some of the examples.

2. Ex-Situ Conservation

Ex-situ biodiversity conservation involves the breeding and upkeep of endangered species in controlled environments such as zoos, nurseries, botanical gardens, and gene banks. This method reduces competition among organisms for resources like food, water, and space.

The advantages of ex-situ conservation are as follows:

- The animals are given more time and opportunities for reproducing.
- It is possible to reintroduce the captive-bred species to the wild.
- It is possible to apply genetic approaches to protect threatened species.

a. Zoological Parks

Animals are relocated from their natural habitat to zoological parks for protection and reproduction. The general public is welcome to go there and witness these animals.

b. Botanical Gardens

A variety of living plant species are preserved here. It resembles a demonstration garden with a variety of plants. They aid in advocating, researching, and preserving threatened plant species.

c. Gene Banks

These institutions maintain collections of robust seeds (seed banks), living plants (orchards), tissue cultures, and frozen germplasm containing diverse genetic variations.

2.4.2 Other Strategies of Conservation

- Livestock, agricultural animals, wood plants, and agricultural food products should all be preserved.
- Animals that have economic value ought to be protected.
- Animals should have access to other habitats.
- The overuse of natural resources needs to be avoided.
- Hunting and poaching of wild animals ought to be prohibited.
- It is necessary to create natural reserves and protected places.
- More trees should be planted, and deforestation should be stopped.
- Strict legislation should be put into place and adhered to.
- Alternative strategies for pollution control should be developed.
- It is essential to raise public awareness of the need to protect biodiversity.
- Preservation of threatened species in both their natural and artificial habitats should be done to prevent their extinction.

2.5 Summary

- ❖ The vast spectrum of life on Earth encompasses every individual organism, from the smallest land-dwelling bacteria to the immense whales in the oceans.
- ❖ "Biodiversity" commonly denotes the variety of distinct species or clusters of independently reproducing organisms.
- ❖ The economic significance of biodiversity extends to various aspects such as food production, animal feed, healthcare, ethics, and societal values. The biosphere serves as a valuable asset for numerous industries that play a crucial role in shaping the global economy.
- ❖ Biological diversity broadly describes the transition of life from genes to ecosystems. It includes their existence, genetic variations, environments, populations, and the

ecosystems in which they are present, as well as other evolutionary advancements that keep the system functioning, changing, and adapting.

- ❖ Genetic diversity is necessary for a population to adjust to shifting environmental conditions.
- ❖ A region's species density fluctuates greatly depending on its environmental conditions.
- ❖ We depend directly on a multitude of plant species to meet our diverse needs, just as we rely on different animal and microbial species for various purposes. Therefore, the conservation of biodiversity is essential to sustain these dependencies.
- ❖ The preservation of species in their natural habitat is considered in-situ biodiversity conservation.
- ❖ The practice of breeding and caring for endangered species in controlled environments such as zoos, nurseries, botanical gardens, and gene banks is referred to as ex-situ biodiversity conservation.

2.6 Keywords

1. Biodiversity: "Biodiversity" is often used to depict the assortment of unique species or populations of living organisms capable of reproducing independently.
2. Genetic Diversity: It is the diversity that every species member expresses genetically. No two members of the same species are exactly alike.
3. Species Diversity: It denotes the variety and abundance of species. A region's species density fluctuates greatly depending on its environmental conditions.
4. Ecological Diversity: It is the diversity present among an area's ecosystems. Numerous environmental ecosystems, including mangroves, deserts, and rainforests, exhibit a great diversity of living forms inhabiting there.
5. Habitat Loss: The thinning, fragmentation, or complete elimination of an ecosystem's plant, soil, hydrologic, and nutrient resources is known as habitat loss.

2.7 Self-Assessment Questions

1. What is the difference between in-situ and ex-situ conservation of biodiversity?
2. Why is genetic diversity necessary for populations?
3. Explain in detail two examples of in-situ conservation of Biodiversity.
4. As an aware student, what ways would you suggest to conserve the depleting biodiversity?

5. Mention five causes of Biodiversity Loss.
6. Why is it important to conserve biodiversity?
7. How do humans rely on different plant, animal, and microbial species, and why is it crucial to conserve biodiversity to meet our diverse needs?
8. Genetic diversity is necessary for a population to adjust to shifting environmental conditions. Comment.
9. Are Zoological and National parks the same? Explain their role in the conservation of biodiversity with some examples.
10. Mention some values that biodiversity contributes to.

2.8 Case Study

The fish population has been experiencing a significant decline in the coastal ecosystem. Within the coastal ecosystem, various piscine species exist, which carry out a vital function in perpetuating ecological equilibrium. The decreasing quantity of fish gives rise to apprehensions regarding the well-being and consistency of the environment, including potential consequences for nearby societies reliant on fishing as their means of subsistence.

Questions:

1. What factors contribute to the decline in fish population in the coastal ecosystem?
2. How might the decline in fish population affect the overall health and stability of the ecosystem?
3. What are the potential impacts of the declining fish population on the local communities that rely on fishing?

2.9 References

1. Corporativa, Iberdrola. "Biodiversity Loss, a Risk for the Environment and for Humanity."
2. "Conservation of Biodiversity- Definition & Methods." Embibe Exams, 25 Jan. 2023.
3. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
4. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
5. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit: 3

Water Pollution

Learning Objectives:

- Learn about water pollution
- Understand the pollutants
- Get known to its sources
- Learn ways to combat

Structure:

3.1 Sources of Water

3.2 Water Quality Standard

3.3 Pollutants

3.4 Effects of Water Pollution

3.5 Summary

3.6 Keywords

3.7 Self-Assessment Questions

3.8 Case Study

3.9 References

3.1 Sources of Water

Water is considered the most valuable resource and a necessary component of life. Water is essential to all life and would not exist otherwise. The term "source water" pertains to natural water sources such as rivers, streams, lakes, reservoirs, springs, and groundwater, which serve as the supply for both public and private drinking wells.

Surface water and groundwater are the two primary sources of water.

Surface water, groundwater, and rainwater collection are the main water sources used for drinking, washing, cooking, farming, and other commercial activities.

These water sources rely on rainfall and snowfall, both of which are a component of the hydrological cycle. Other sources could be recycled water.

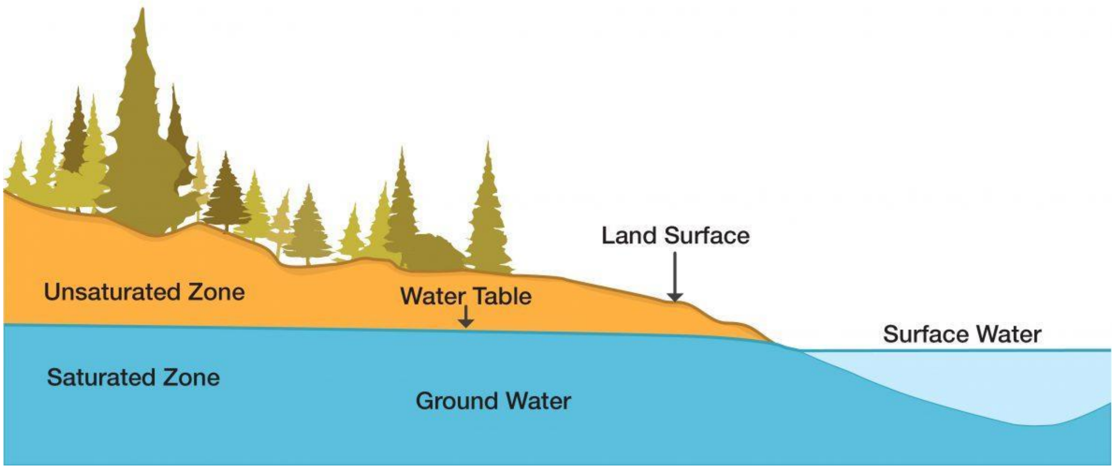

Figure 3.1: Sources of Water

Source: Centre For Disease Control and Prevention

As depicted in Figure 3.1, groundwater is situated beneath the Earth's surface, within the gaps amidst rocks and soil. Natural filtration processes, influenced by factors such as water depth and local geological conditions, can mitigate certain pollutants and bacteria within groundwater. Groundwater sourced from wells typically undergoes some form of treatment prior to reaching household taps due to its origin. Conversely, surface water accumulates on land or within various water bodies like streams, rivers, lakes, reservoirs, or oceans. These surface water sources continuously undergo processes of evaporation, seepage into groundwater reserves, and replenishment through precipitation in the form of rain and snowfall.

3.1.2 The Water Cycle

The continuous circulation of water among the oceans, atmosphere, and land is termed the hydrological or water cycle. Water present on land and in various water bodies such as oceans, lakes, and rivers undergoes evaporation, transitioning from a liquid to a vapor state, driven by sunlight and wind. Additionally, through a process called transpiration, plants absorb liquid water and release water vapor through pores in their leaves. This water vapor then ascends high above the Earth's surface through rising air currents in the atmosphere. Eventually, as the water vapor encounters cooler air, it condenses back into a liquid state, forming clouds. These clouds subsequently release precipitation, which falls back to Earth in the form of rain and snow.

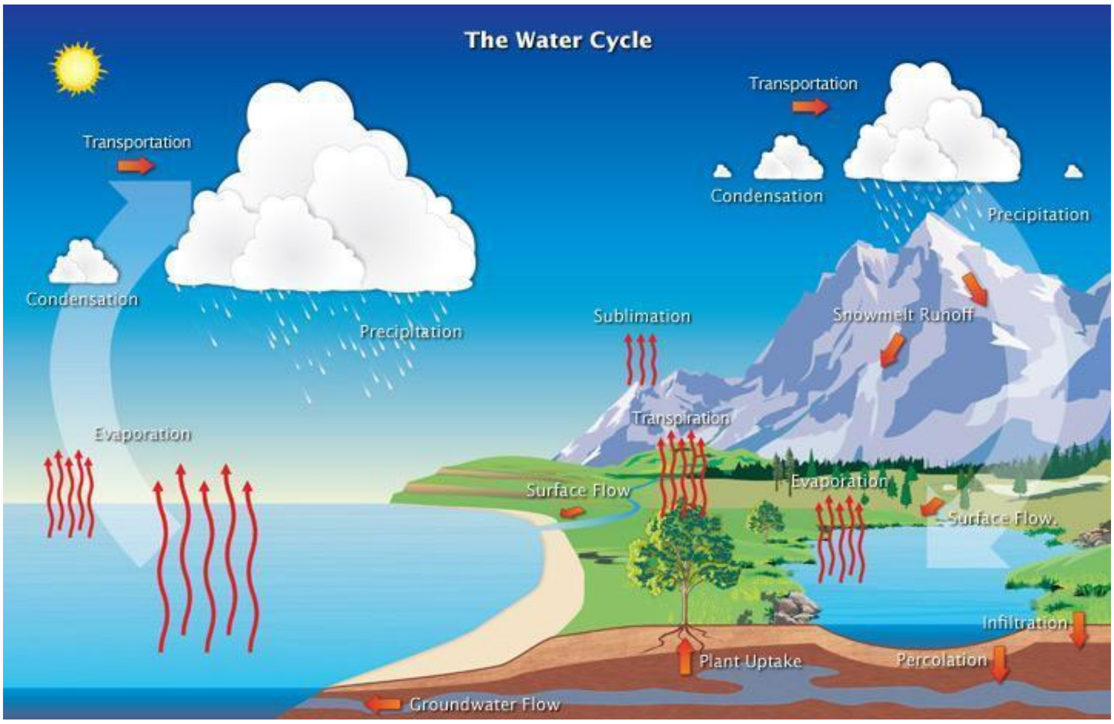

Figure 3.2: Hydrological/Water Cycle

Source: NASA

Rainfall on land has two main pathways: it can infiltrate into the soil and percolate downward to replenish groundwater reserves, or it can flow over the surface as runoff into rivers and streams.

Reservoirs serve as storage for water, facilitating its transfer between different locations through various operations. Evaporation, transpiration (the release of water vapour from plants), atmospheric movement of water vapour, precipitation, and the runoff of water across land back to the seas are all on-going processes involved in the continuous transfer of water.

3.2 Water Quality Standards

Access to clean drinking water is essential for preserving health and is acknowledged as a fundamental human right, forming a crucial aspect of robust health protection measures. Numerous international policy forums have emphasized the significance of water, sanitation, and hygiene in fostering both health and development.

The World Health Organisation (WHO) has created many normative "guidelines" in response to this, which provide an official assessment of the health risks related to exposure to harmful substances through water and the efficacy of methods for their control. The various recommendations from the World Health Organization (WHO) regarding safe recreational water environments, the safe utilization of wastewater and waste in agriculture and aquaculture, and drinking water quality standards have been developed autonomously.

Water quality standards consist of three fundamental components. These include regulations aimed at preventing degradation, the identification of intended uses for a body of water, and the establishment of criteria to protect those designated uses, all of which are essential for safeguarding both current uses and high-quality/high-value waters.

3.2.1 Water quality standard in India

1. Drinking water

Water intended for human consumption for drinking and cooking, regardless of its source, is categorized as drinking water. This designation encompasses all water supplied for human use, whether treated or untreated. In India, the Bureau of Indian Standards has set forth IS 10500:2012 as the minimum requirement for water quality.

2. Ground Water

The depth of the soils and subsurface geological formations that groundwater is in contact with affects the natural chemical composition of groundwater. The majority of the country's groundwater is typically suitable and suitable for drinking, agricultural, or industrial purposes. Groundwater found in shallow aquifers is primarily composed of mixed and calcium bicarbonate types, making it generally suitable for a variety of uses. But there are other kinds of water, too, such as water with sodium chloride. Deeper aquifers' quality varies from location to location and is typically considered acceptable for everyday uses. Coastal areas often encounter challenges related to high salinity levels, and there have been reports of notable concentrations of fluoride, arsenic, iron, and various other heavy metals in isolated pockets.

In the dry and semi-arid regions of Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh, Maharashtra, Karnataka, and Tamil Nadu, the prevalence of inland saline in groundwater is widespread.

The eastern coast is characterized by a short continental shelf and features deltaic and estuarine landscapes, whereas the western coast is distinguished by a vast continental shelf with backwaters and mud flats. In most of the coastal states of India, salinity issues have been reported in many locations. More than 1.1 lakh habitations have high concentrations of iron (>1.0 mg/l) in the groundwater.

Designated-Best-Use Class of water Criteria

The source of drinking water without traditional treatment, but following disinfection measures.

A

- Total Coliforms Organism MPN/100ml shall be 50 or less
- pH between 6.5 and 8.5
- Dissolved Oxygen 6mg/l or more
- Biochemical Oxygen Demand 5 days 20°C 2mg/l or less Outdoor bathing (Organised)

B

- Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more
- Biochemical Oxygen Demand 5 days 20°C 3mg/l or less

The source of drinking water following both conventional treatment and disinfection procedures.

C

- Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more
- Biochemical Oxygen Demand 5 days 20°C 3mg/l or less

Expansion of wildlife and fisheries.

D

- pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more
- Free Ammonia (as N) 1.2 mg/l or less Irrigation, industrial cooling, and regulated waste disposal.

E

- pH between 6.0 to 8.5
- Electrical Conductivity at 25°C micromhos/cm Max.2250
- Sodium absorption Ratio Max. 26
- Boron Max. 2mg/l

Below-E Not Meeting A, B, C, D & E Criteria

Table 3.1: Water Quality Criteria

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	**A**	• **Total Coliforms Organism MPN/100ml shall be 50 or less** • **pH between 6.5 and 8.5** • **Dissolved Oxygen 6mg/l or more** • **Biochemical Oxygen Demand 5 days 20°C 2mg/l or less**
Outdoor bathing (Organised)	**B**	• **Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more** • **Biochemical Oxygen Demand 5 days 20°C 3mg/l or less**
Drinking water source after conventional treatment and disinfection	**C**	• **Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more** • **Biochemical Oxygen Demand 5 days 20°C 3mg/l or less**

Propagation of Wildlife and Fisheries	**D**	• **pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more** • **Free Ammonia (as N) 1.2 mg/l or less**
Irrigation, Industrial Cooling, Controlled Waste disposal	**E**	• **pH between 6.0 to 8.5** • **Electrical Conductivity at 25°C micromhos/cm Max.2250** • **Sodium absorption Ratio Max. 26** • **Boron Max. 2mg/l**
	Below-E	**Not Meeting A, B, C, D & E Criteria**

Source: Central Pollution Control Board

3.3 Water Pollutants

Water pollutants can be categorised into four groups, which are as follows:

- Pathogens
- Organic materials
- Inorganic compounds
- Macroscopic pollutants

1. Pathogens: Pathogens include bacteria, viruses, protozoa, and other microorganisms. For example, bacteria are frequently found in water. However, as the number of bacteria rises, the water might become contaminated. Coliform and E Coli bacteria are the two most harmful bacteria.
2. Organic Materials: Carbon-containing molecules make up organic compounds. Methyl tert-butyl ether (MTBE) is a relatively typical volatile organic compound. MTBE was once employed as an air-cleaning gas additive. Although it was later outlawed, it will take some time for the water to be entirely free of it. Similar to how organic material-containing water can cause lethal illnesses like testicular tumours, leukaemia, kidney and thyroid cancer, lymphoma, and more.
3. Inorganic Materials: While inorganic elements might not be hazardous in modest absorptions, they can become dangerous water pollutants when they mix with other

substances in the water. For instance, inorganic materials include heavy metals like copper, arsenic, barium, mercury, zinc, and more.

Leaching from waste disposal, industrial mishaps, or even increased human activity levels can all contribute to its occurrence. This kind of water contamination also leads to severe health issues in humans and other organisms. Additionally, it can be highly lethal if it is present in larger doses.

4. Macroscopic pollutants: Due to their size and brightness, these kinds of contaminants are particularly noticeable in the water—the most prevalent example of garbage, mainly plastic waste, that finds its way into the sea. Plastic is unlawfully dumped in water because it does not disintegrate. They accumulate in oceans and other bodies of water because they cannot biodegrade.

The following are the leading causes and sources of water pollution:

- Wastewater is tainted with pathogens, a prevalent water contaminant, along with other hazardous microorganisms and chemicals that can cause serious illnesses.
- Farmers utilize chemical fertilizers and pesticides to safeguard their crops from pests and bacteria, contributing to agricultural pollution. However, when these substances interact with water, they form harmful toxins that can adversely affect plants and animals.
- When a substantial amount of oil spills into the ocean and fails to disperse, it presents a serious threat to marine life, adversely impacting fish, birds, sea otters, and other nearby marine animals.
- Industries generate substantial amounts of waste laden with harmful chemicals and pollutants, which not only contaminate the air but also pose risks to our environment and health.
- The combustion of fossil fuels such as coal and oil emits considerable ash into the atmosphere. When these particles, containing harmful chemicals, combine with water vapor, it leads to the formation of acid rain.
- Materials such as paper, plastic, food waste, metal, rubber, and glass, commonly found in household waste, are often disposed of in rivers and seas, leading to water pollution and posing risks to aquatic life.

Figure 3.3: Water Pollution

Source: Sibol Alaminos

3.4 Effects of Water Pollution

1. Diseases: Polluted water has several terrible impacts on human health, whether consumed through drinking or other means. Giardiasis, dysentery and other illnesses are brought on by it.
2. Ecosystem destruction: Ecosystems are highly sensitive to environmental changes, reacting even to small alterations in their surroundings. Failure to control water pollution could result in the collapse of entire ecosystems.
3. Eutrophication: Chemicals present in a body of water can facilitate the growth of algae. These algae accumulate on the surface of ponds or lakes, where they are consumed by bacteria. This consumption process reduces the oxygen levels in the water, adversely affecting the aquatic life inhabiting the area.

4. Affects the food chain: The absorption of toxins and pollutants in water by aquatic animals such as fish and shellfish, which are then consumed by humans, leads to disruptions in food chains.

3.5 Summary

- ❖ The term "source water" pertains to bodies of water, including rivers, streams, lakes, reservoirs, springs, and groundwater, which serve as the primary water supply for public and private drinking wells.
- ❖ Surface water, groundwater, and rainwater collection are the main water sources used for drinking, washing, cooking, farming, and other commercial activities.
- ❖ According to the water's depth and the location's local geology, natural groundwater filtration may eliminate some pollutants and bacteria.
- ❖ Surface water gets collected on the land or in a stream, river, lake, reservoir, or ocean.
- ❖ The perpetual circulation of water among the oceans, the atmosphere, and the land is referred to as the hydrological cycle or water cycle.
- ❖ The Bureau of Indian Standards established IS 10500: 2012 as India's minimum water quality requirement.
- ❖ Carbon-containing molecules make up organic compounds.
- ❖ Organic material-containing water can cause lethal illnesses like testicular tumours, leukaemia, kidney and thyroid cancer, lymphoma, and more.
- ❖ When a substantial amount of oil spills into the ocean and fails to disperse, it poses a severe threat to marine life, negatively impacting fish, birds, sea otters, and other nearby marine animals.
- ❖ If pollution of water is not controlled, an entire ecosystem could collapse.

3.6 Keywords

1. Source water: It denotes bodies of water, including rivers, streams, lakes, reservoirs, springs, and groundwater, which serve as the water source for both public and private wells used for drinking purposes.
2. Hydrological cycle: The on-going transfer of water between the seas, the atmosphere, and the land is termed the hydrological cycle or water cycle.
3. Pathogens: Pathogens include bacteria, viruses, protozoa, and other microorganisms.

4. Eutrophication: It is a process in which chemicals aid algal development in a body of water and negatively impact aquatic life.

3.7 Self-Assessment Questions

1. Name three primary sources of water that are used for various purposes.
2. How does natural filtration of groundwater help eliminate pollutants and bacteria?
3. What are the environmental impacts of oil spills in the ocean?
4. What are the consequences of uncontrolled water pollution on ecosystems?
5. 5. Mention any three sources of water pollution.
6. 6. Categorise water pollutants of them in brief.
7. Explain the concept of eutrophication and its role in water pollution.
8. Evaluate the effectiveness of various water pollution prevention and control measures, such as wastewater treatment plants, watershed management, and regulatory policies. Discuss the challenges and limitations associated with implementing these measures.
9. Analyse how economic activities, industrialisation, urbanisation, and agricultural practices contribute to water pollution and propose strategies for sustainable water management that consider social and economic dimensions.
10. Examine the role of emerging contaminants in water pollution and their potential long-term implications.

3.8 Case Study

India faces a severe problem with water pollution, which the Yamuna River best demonstrates. This precious water has become contaminated due to rapid industry and urbanisation. Industrial effluents, untreated sewage, and solid waste dumping have produced high amounts of harmful pollutants, harming human health and the river's ecosystem. Aquatic biodiversity has decreased, and waterborne illnesses have grown widespread. Effective solutions necessitate sustainable industrial practices, improved wastewater treatment, and community involvement, notwithstanding government initiatives like the Yamuna Action Plan. India must take extensive action to combat water pollution to protect this precious resource.

Questions:

1. How have rapid urbanisation and industrialisation contributed to the contamination of the Yamuna River in India? Discuss the sources of pollutants and their impact on human health and the river's ecosystem.
2. What are the consequences of water pollution in the Yamuna River for surrounding communities?
3. Explain the prevalence of waterborne diseases and their effects on the local population.

3.9 References

1. "Study Session 4 the Water Cycle and Sources of Water." Study Session 4 The Water Cycle and Sources of Water. Open.edu
2. "Water Sources." Centers for Disease Control and Prevention
3. "Vikaspedia Domains." Vikaspedia
4. "Water Quality : Guidelines, Standards and Health." World Health Organization, www.who.int
5. Water Pollutants - Lists, Effects, Examples, Solved Questions - TOPPR, www.toppr.com
6. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
7. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
8. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit: 4

Air Pollution

Learning Objectives:

- Learn about Air Pollution
- Understand its sources
- Understand its effects
- Know about the air quality standard

Structure:

4.1 Composition of Atmosphere

A planet's atmosphere comprises one or more layers of gases held in place by the planet's gravity. The earth retains its atmosphere when the gravity is strong and the atmosphere's temperature is low.

Oxygen constitutes 21% of the Earth's atmosphere, alongside nitrogen (78%), argon (0.9%), carbon dioxide (0.04%), and other gases. The quantity of water vapor in the atmosphere fluctuates with altitude and is approximately 1% at sea level. Carbon dioxide primarily contributes to the greenhouse effect. It is opaque to outgoing terrestrial radiation but transparent to incoming solar energy. Carbon dioxide absorbs some of the radiation emitted by the Earth and reflects some back toward the surface.

Dust particles are also present in the atmosphere, originating from diverse sources such as fine dirt, smoke, soot, pollen, dust, and meteorite fragments. Water vapor condenses around dust and salt particles to form clouds, which act as hygroscopic nuclei.

4.1.1 Gases in the Atmosphere

1. Carbon Dioxide

In meteorology, carbon dioxide plays a critical role. It is opaque to outgoing terrestrial radiation but transparent to incoming solar radiation (insolation). Carbon dioxide filters outgoing terrestrial radiation and reflects some of it back towards the planet's surface. The primary driver of the greenhouse effect is carbon dioxide. Even if the amount of other gases in the atmosphere has stayed constant over the past few decades, the volume of carbon dioxide has been rising principally due to the burning of fossil fuels. This increasing carbon dioxide concentration is the main contributor to global warming.

2. Nitrogen

Nitrogen makes up about 78% of the atmosphere, but using nitrogen straight from the air is impossible.

Proteins are also made by biotic organisms using nitrogen. The nitrogen needed by living organisms is provided through the nitrogen cycle.

3. Oxygen

21% of the air is made up of oxygen. All living things need it, as breathing depends on it. It is also essential for burning.

4. Argon

0.9% of the atmosphere is made up of argon. Their primary application is in light bulbs.

5. Ozone Gas

Ozone is another important component of the atmosphere, predominantly located between 10 and 50 kilometres above the Earth's surface. It acts as a shield by absorbing the sun's ultraviolet radiation and preventing it from reaching the Earth's surface. The ozone layer in the stratosphere is the only part of the atmosphere that contains a significant concentration of ozone gas.

4.2 Air Quality Standards

An air quality standard specifies what constitutes clean air by determining the level of a pollutant in outdoor air that does not pose a threat to public health over a specified period. The National Ambient Air Quality Standards (NAAQS) are guidelines for air quality set by the Central Pollution Control Board (CPCB) and applied nationwide.

Efficient management of ambient air quality relies on these criteria. The initial ambient air quality standards were established in 1982 following the Air Act. Subsequently, revisions were made to these standards in 1994, and the NAAQS underwent its most recent update in 2009.

The 2009 standards standardized national regulations and lowered the maximum permissible levels for pollutants. Previously, industrial zones were subjected to fewer regulations compared to residential areas. The National Air Quality Monitoring Programme (NAMP) monitors compliance with the NAAQS, which is implemented by the CPCB.

4.3 Sources and Effects of Air Pollution

4.3.1 Sources

There are four main categories of air pollution sources:

- Mobile sources: These include vehicles such as buses, trucks, planes, and trains.
- Stationary sources: These encompass factories, industrial complexes, and power plants.
- Local sources: These consist of cities, towns, and wood-burning stoves.
- Natural causes: These involve phenomena like volcanoes, wildfires, and wind-borne dust.

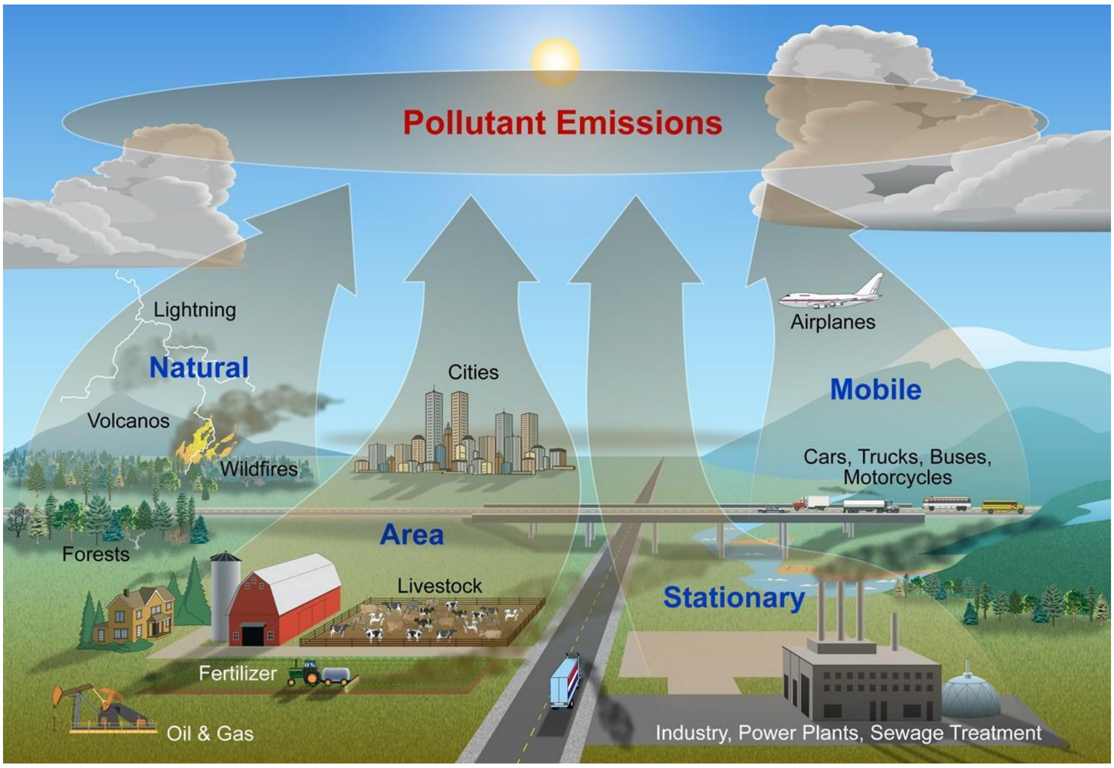

Figure 4.1: Air Pollutants

Source: National Park Service

2 categories of air contaminant

1. Primary pollutants

Primary pollutants are substances that directly contribute to air pollution. One notable contaminant is sulphur dioxide, which is emitted by manufacturers.

2. Secondary Pollutants

Secondary pollutants result from the interaction and mixture of primary pollutants. For example, when smoke and fog combine, they produce smog as a secondary pollutant.

Causes of Air Pollution

1. Fossil Fuels

Sulphur dioxide is extensively emitted into the atmosphere during the combustion of fossil fuels. Additionally, carbon monoxide, generated from the inefficient burning of fossil fuels, also contributes to air pollution.

2. Automobiles

Vehicle emissions, originating from trucks, cars, buses, and jeeps, pose a significant threat to the environment. They are the primary contributors to human health issues and greenhouse gas emissions.

3. Farmers' Activities

Ammonia ranks among the most hazardous substances emitted during agricultural activities. Additionally, harmful compounds released by insecticides, pesticides, and fertilizers pose threats to the atmosphere.

4. Industries and Factories

Industry and manufacturing are leading suppliers of carbon monoxide, organic compounds, hydrocarbons, and chemicals. These degrade the quality of the atmosphere by dispersing into it.

5. Mining Operations

In mining operations, large machinery is employed to extract minerals from beneath the soil. However, the dust and chemicals released during this process pose health risks to both workers and nearby communities, while also contributing to air pollution.

6. Homegrown Sources

Paints and household cleaning products emit toxic chemicals into the air. When walls are freshly painted, they release the odour of the chemicals used in their production, which can affect breathing and contribute to air contamination.

4.3.2 Effects of Air Pollution

The environment is adversely affected by air pollution in the following ways:

1. Diseases

Air pollution has led to the development of numerous respiratory and cardiovascular illnesses among people. Incidences of lung cancer have risen in the past few decades. Children living near polluted areas are more prone to asthma and pneumonia. Every year, air pollution directly or indirectly contributes to numerous deaths.

2. Global Warming

The emission of greenhouse gases has disrupted the balance of gases in the atmosphere, leading to a rise in the Earth's temperature. This phenomenon, known as global warming, has resulted in rising sea levels and melting glaciers, leading to the submersion of various locations. Several factors contribute to the increase in global warming, including:

- Deforestation

Plants serve as the primary source of oxygen, contributing to environmental equilibrium by absorbing carbon dioxide and releasing oxygen. However, an imbalance in the environment, such as increased levels of greenhouse gases, has led to global warming.

- Employing Vehicles

Even over very short distances, the operation of a car emits various gaseous pollutants. Burning fossil fuels in vehicles releases significant amounts of carbon dioxide and other toxins into the atmosphere, contributing to elevated temperatures.

- Chlorofluorocarbon

Humans have been introducing chlorofluorocarbons (CFCs) into the environment through the widespread use of air conditioners and freezers, affecting the ozone layer in the atmosphere. The ozone layer acts as a shield, protecting the Earth's surface from the sun's harmful ultraviolet rays. However, CFCs have led to the thinning of the ozone layer, allowing more ultraviolet light to penetrate, thereby contributing to the increase in the Earth's temperature.

- Industrial Progress

The advent of industrialization has led to a significant increase in the Earth's temperature, primarily driven by emissions from industries. According to a 2013 report by the Intergovernmental Panel on Climate Change, global temperatures rose by 0.9 degrees Celsius between 1880 and 2012. This increase represents a rise of 1.1 degrees Celsius compared to the pre-industrial average temperature.

- Agriculture

Various agricultural practices contribute to the production of methane and carbon dioxide, thereby elevating the Earth's temperature by increasing the concentration of greenhouse gases in the atmosphere.

- Overpopulation

With a larger population, there are more people breathing, leading to an increase in the amount of carbon dioxide, the primary gas contributing to global warming, in the atmosphere.

- Volcanoes

Volcanic eruptions are one of the prominent natural causes of global warming. They release smoke and ash into the atmosphere, which can affect the climate.

- Water Vapour

Water vapour is indeed a greenhouse gas. As the Earth's temperature increases, more water evaporates from water bodies and remains in the atmosphere, further contributing to global warming.

3. Acid Rain

When fossil fuels are burned, dangerous compounds such as sulfur and nitrogen oxides are emitted into the atmosphere. These chemicals react with water droplets, resulting in the formation of acidic rain, which can be harmful to people, animals, and plants. Acid rain is primarily driven by sulphur and nitrogen particles that mix with the wet ingredients of rain. The sulphate and nitrogen ions that combine with water can be caused by industrial emissions or lightning strikes, which release sulphate and nitrogen ions into the atmosphere. Thus, it can have some hazardous effects, such as.

- All nutrients necessary for plant development and survival are washed away.
- It affects the respiratory system of both humans and animals.
- In addition to corroding water pipes, acid rain contributes to the leaching of heavy metals such as iron, lead, and copper into drinking water.
- It damages structures and historical landmarks built with metal and stone materials.

4. Ozone Layer Depletion

The lowest layer of the Earth's atmosphere primarily contains the ozone layer. This layer can block between 97 and 99 percent of the sun's harmful ultraviolet (UV) rays, which are essential for supporting life on Earth. Without the ozone layer, millions of people would be at risk of developing skin diseases, and their immune systems would be weakened.

The primary cause of thinning in the ozone layer is the release of hydrochlorofluorocarbons, halons, and chlorofluorocarbons into the atmosphere. Despite the depletion of the ozone layer, the sun's harmful ultraviolet radiation continues to cause skin conditions and eye problems in people.

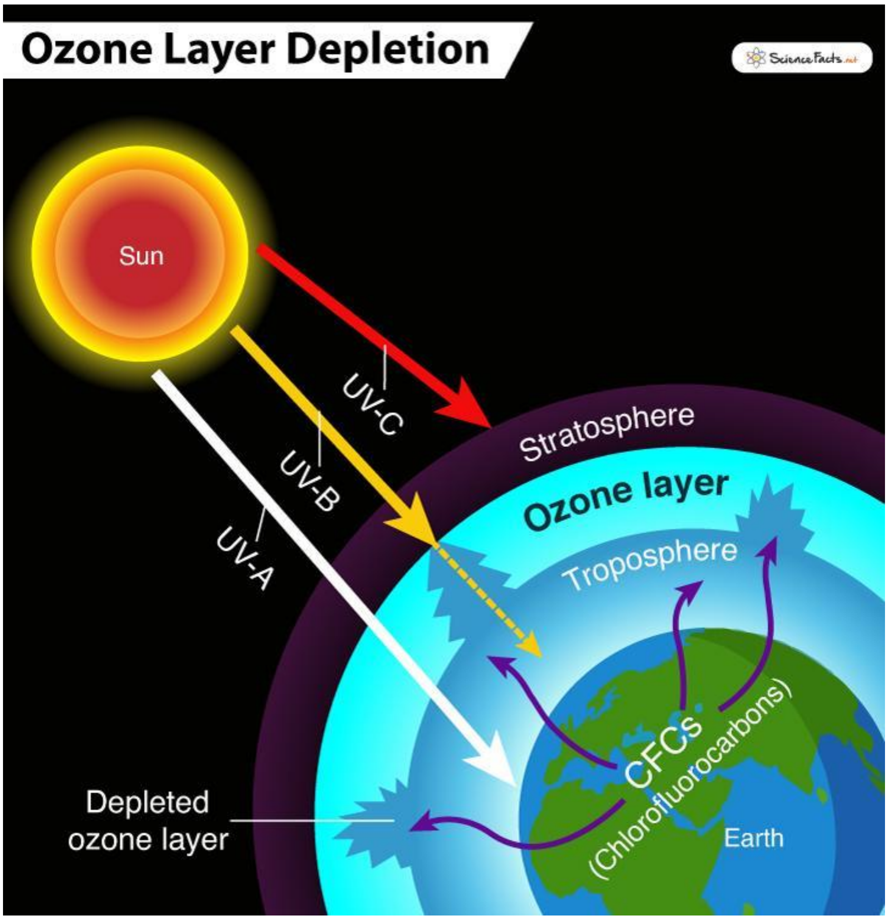

Figure 4.2: Ozone Layer Depletion

Source: Science Facts

The depletion of the ozone layer has a detrimental impact on the environment.

- Effects on Human Health

As the ozone layer deteriorates, people will be directly exposed to the sun's harmful UV radiation. Humans are susceptible to serious health issues like cancer, skin disorders, cataracts, sunburns, accelerated ageing, and weaker immune systems.

- Animals

Direct UV radiation exposure causes skin and eye cancer in animals.

- Environmental Impacts

Intense UV radiation can hinder plant growth, flowering, and photosynthesis. Woodlands also suffer from the adverse effects of UV light.

- Marine Life

The detrimental effects of UV light exposure on plankton are significant, considering their position higher in the aquatic food chain. The decline in plankton populations also affects other species in the food chain.

One significant factor contributing to air pollution from various sources is the greenhouse effect. Greenhouse gases, which include gases capable of absorbing infrared radiation (heat energy) from the Earth's surface and reradiating it back to the surface, contribute to this effect. Carbon dioxide, methane, and water vapour are among the most significant greenhouse gases.

The greenhouse effect operates similarly on Earth as it does in a greenhouse. Gases in the atmosphere, such as carbon dioxide, act like the glass roof of a greenhouse, trapping heat and warming the planet.

During the day, the Sun radiates energy through the atmosphere, warming the Earth's surface. At night, the Earth's surface cools, releasing heat back into the atmosphere. However, greenhouse gases in the atmosphere trap some of this heat, helping to maintain the planet's average temperature at around 58 degrees Fahrenheit (14 degrees Celsius).

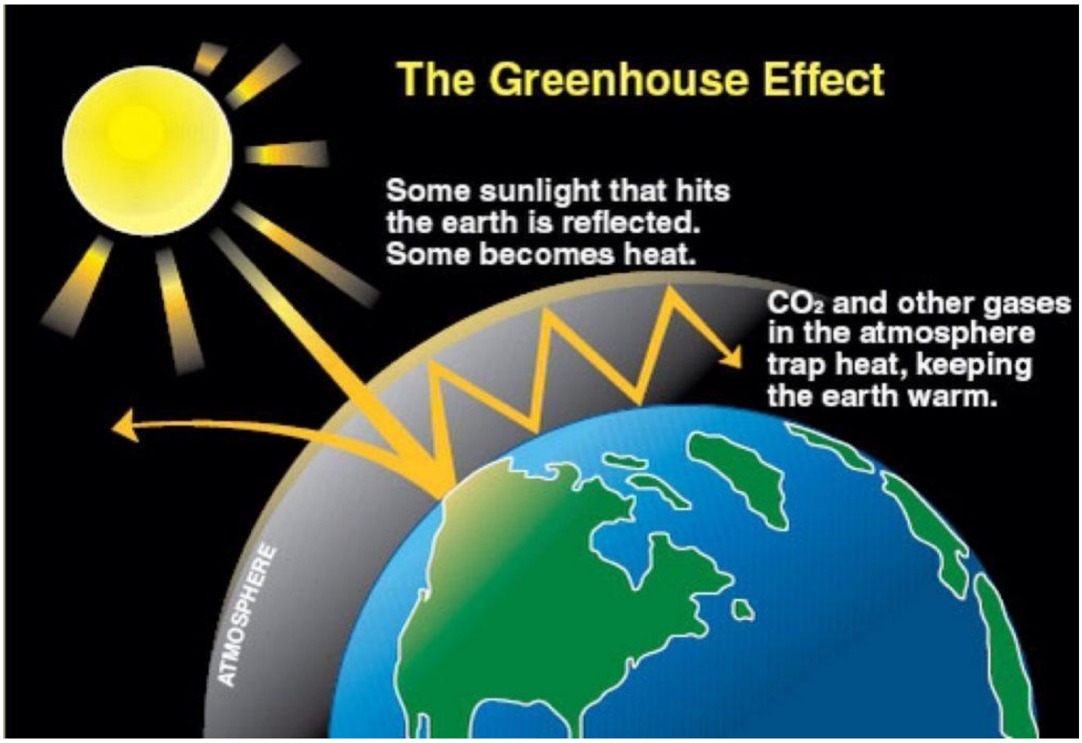

Figure 4.3: Greenhouse Effect

Source: Medium

There are two types of causes of the greenhouse effect.

1. Natural: The sun makes the earth habitable. 70% of the solar energy that reaches our planet passes through the atmosphere, with just 30% of it being reflected in space.

The earth's surface, oceans, and atmosphere reflect and heat the gas. The heat is then returned by reflection.

2. Human-Induced: A portion of rays reflected during the natural greenhouse effect is reflected into space. Nearly 90% of it is taken up by greenhouse gases. This causes the gases to reflect more heat towards the earth, increasing its warmth.

4.4 Summary

- ❖ The atmosphere consists of layers of gases surrounding a planet, held in place by the planet's gravity. Strong gravity results in the formation of one or more layers of gases enveloping the planetary body.
- ❖ In meteorology, carbon dioxide plays a crucial role. It is opaque to outgoing terrestrial radiation but transparent to incoming solar radiation (insolation).
- ❖ An air quality standard establishes clean air as the level of a contaminant present in outdoor air that does not pose a risk to public health over a specified period of time.
- ❖ Sulfur dioxide is extensively emitted into the atmosphere during the combustion of fossil fuels. Additionally, carbon monoxide, produced from inefficient burning of fossil fuels, also contributes to air pollution.
- ❖ Industry and manufacturing are the primary sources of carbon monoxide, organic compounds, hydrocarbons, and chemicals.
- ❖ The release of hydrochlorofluorocarbons, halons, and chlorofluorocarbons into the atmosphere is the primary cause of the thinning of the ozone layer.

4.5 Keywords

1. Atmosphere: The atmosphere consists of layers of gases that envelop a planet and are held in place by the planet's gravity.
2. The air quality standard defines clean air as the amount of a contaminant present in outdoor air without endangering public health averaged over time.
3. National Ambient Air Quality Standards: The Central Pollution Control Board (CPCB) established and used these air quality guidelines nationwide.
4. Greenhouse Gas: Any gas capable of absorbing infrared radiation (net heat energy) emitted from the Earth's surface and re-radiating it back to the surface is considered a greenhouse gas, contributing to the greenhouse effect.

4.6 Self-Assessment Questions

1. What are the two most abundant gases in the Earth's atmosphere, and what are their respective percentages?
2. Explain the relationship between fossil fuel combustion and the release of sulphur dioxide and carbon monoxide release into the atmosphere. How do these pollutants contribute to air pollution?
3. Discuss the role of hydro chlorofluorocarbons, halons, and chlorofluorocarbons in the depletion of the ozone layer. How do these emissions impact the atmospheric environment, and what are the potential consequences of ozone layer depletion?
4. Explain the phenomenon of acid rain and its connection to air pollution. What are the primary pollutants responsible for acid rain, and what are this phenomenon's environmental and ecological impacts?
5. Describe the impact of air pollution on climate change. How do greenhouse gases and air pollutants interact to influence the Earth's climate, and what are the consequences of this interaction?
6. What are the primary sources of air pollution, and how do they contribute to the deterioration of air quality?
7. Explain the role of industrial activities in air pollution.
8. Discuss the primary pollutants emitted during combustion and their environmental and health impacts.
9. What are the primary greenhouse gases responsible for the enhanced greenhouse effect, and how do they contribute to global warming? Discuss their sources.
10. What are the primary substances responsible for ozone depletion, and how do they affect the ozone layer?

4.7 Case Study

The 1980s saw a significant acid rain outbreak in the Scandinavian region, which hurt the ecology. Wind currents brought industrial emissions from nearby nations, especially sulphur dioxide and nitrogen oxides, precipitating acid rain in Norway, Sweden, and Finland. Acid rain caused lakes and rivers to become more acidic, which killed aquatic life and reduced biodiversity. In addition, woods were harmed by acid rain, which inhibited tree development and caused a loss of foliage. The forestry and fishery industries experienced losses, having a considerable negative economic impact. The afflicted nations established stricter emission limits and international partnerships to reduce pollution emissions to fight this problem.

Questions:

1. Describe the environmental impacts of acid rain on aquatic ecosystems in the Scandinavian region during the 1980s. How did the acidification of lakes and rivers affect marine life and biodiversity in the affected areas?
2. Explain the consequences of acid rain on forest ecosystems in Norway, Sweden, and Finland. Discuss the specific damages caused to forests, including the effects on foliage and tree growth and the subsequent economic implications for the forestry industry.
3. Discuss some measures to prevent or reduce acid rain possibilities.

4.8 References

1. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
2. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
3. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit: 5

Noise Pollution

Learning Objectives:

- Know about Noise Pollution in detail
- Understand its sources
- Learn about its effects
- Learn ways to control noise pollution

Structure:

5.1 Noise Pollution: Introduction

Noise pollution refers to any disruptive sound that negatively impacts the health and well-being of people and other species. It is defined by the World Health Organization (WHO) as noise levels exceeding 65 decibels (dB). However, discomfort typically begins at 75 dB, and noise becomes hazardous at 120 dB. It is recommended to keep noise levels below 65 dB during the day. Research indicates that noise levels above 30 dB at night can disrupt sleep quality.

5.1.1 Noise Pollution - Types

The three categories of pollution are as follows:

- Vehicle Noise
- Residential Noise
- Industrial Noise

1. Vehicle Noise

It primarily consists of traffic noise, which has been louder in recent years as more cars have been on the road. The increase in noise pollution causes age-related hearing loss, headaches, hypertension, and other problems.

2. Residential Noise

It includes noise made by appliances, household tools, etc. The primary sources are things like speakers, transistors, and musical instruments.

3. Industrial Noise

The loud noise is a result of the heavy industrial machinery. Numerous studies have found that industrial noise pollution reduces hearing capacity by 20%.

5.2 Levels of Noise

The duration for hearing loss to develop decreases as sound volume increases. The risk of hearing loss also rises with longer exposure times, especially when proper hearing protection is not worn or sufficient rest periods are not provided for the ears between exposures.

When in operation, a motorcycle engine is roughly 95 dB louder than ordinary conversation and approximately 60 dB louder than a whisper. Prolonged exposure to noise levels exceeding 70 dB may begin to harm your hearing. Instant damage to your ears can occur from exposure to loud noises above 120 dB.

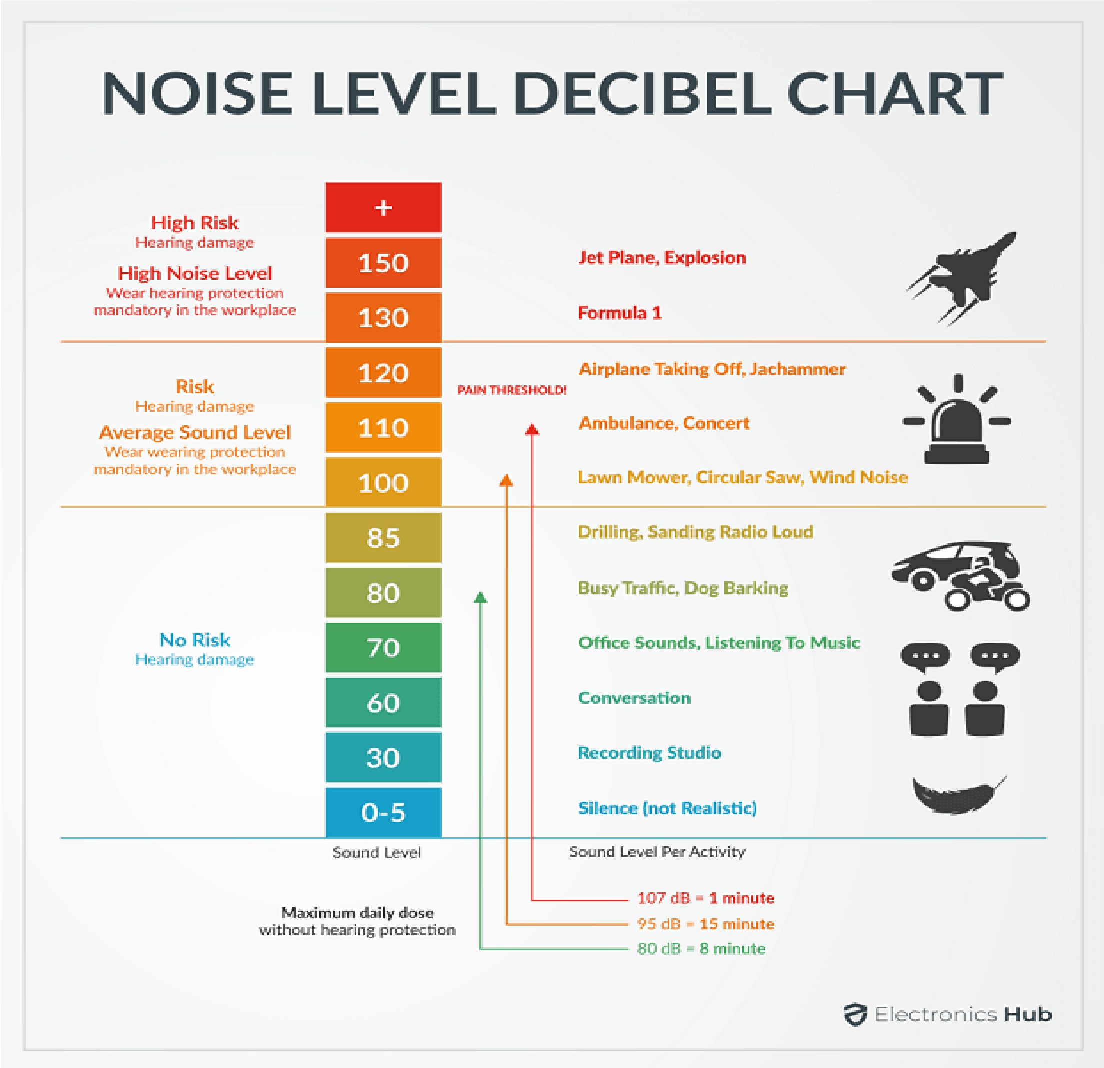

Figure 5.1: Noise Level Decibel Chart

Source: Electronics Hub

Figure 5.1 demonstrates the noise level produced by different human activities and instruments.

5.2.1 Noise Exposure Limits

Occupational hazards such as noise are well known and must be managed.

Occupational exposure limits for noise in the workplace are put into place to achieve this. As each nation has noise exposure limitations, professionals must check the local legislation to determine the standards established for the country where their firm conducts business.

Country	8-hr average dB(A) exposure	The Upper limit for peak sound pressure level
China	70-90	115
India	90	140
Netherlands	85	140
Poland	85	135
United Kingdom	85	140
USA	90	140

Table 5.1: Noise Limitations By Different Countries, (Source: IOSH)

While regulations vary from country to country, a time-weighted average (TWA) of 85 dB(A) is widely recognized as the standard benchmark. TWA calculates a worker's daily exposure to hazards such as noise. It represents the average level of exposure to a detrimental condition, such as noise, over a specified period, such as an 8-hour workday or a 40-hour workweek, without causing adverse or severe effects.

5.3 Sources and Effects of Noise Pollution

5.3.1 Sources/Causes

1. Industrialisation

Many industries utilize large machinery that generates considerable noise. Additionally, various equipment such as grinding mills, exhaust fans, compressors, and generators also contribute to the production of significant noise.

2. Lack of Urban Planning

In many developing countries, poor urban planning is a major contributor to noise pollution. Overcrowded living conditions in large families, conflicts over parking, and frequent disputes over basic amenities all contribute to this problem. Additionally, when residential areas are located close to industrial sites, noise pollution can further impact urban environments. In such cases, the noise generated by nearby industrial facilities can disrupt residents' ability to maintain their overall well-being.

3. Social Occasions

Many social events are characterized by high levels of noise, whether it be weddings, parties, pubs, discos, or places of worship. Often, people disregard local government regulations and cause disturbances in the neighbourhood.

4. Transportation

The constant noise generated by numerous cars on the roads, planes flying over residential areas, and underground trains can be overwhelming for people, making it difficult for them to adjust to the constant racket.

5. Building Activities

Construction projects, such as mining, bridge, dam, building, station, road, and flyover construction, are prevalent worldwide. These projects involve construction workers actively participating in these activities, while others experience the associated noises from their homes or during travel.

Long-term exposure to construction noise impairs the hearing capacities of those subjected.

A portion comprises people who hear these noises from their homes or while travelling, while another contains construction workers who participate in these activities.

6. Household tasks

Modern society heavily depends on various devices in daily routines, surrounded by them at all times. Devices like TVs, cell phones, mixer grinders, pressure cookers, vacuum cleaners, washing machines and dryers, coolers, and air conditioners contribute slightly to noise levels. While individually these may not significantly impact individuals, collectively they diminish the quality of life in neighborhoods. Despite seeming minor, this type of pollution carries significant repercussions, adversely affecting environmental health, impacting humans and local wildlife, and leading to various negative consequences.

7. Audible Air Traffic Noise

While it may be surprising to some, air travel is a significant contributor to noise pollution. A single aircraft can generate up to 130 dB of noise.

5.3.2 Noise Pollution: Effects

1. Hearing Issues

Any unwanted sound that our ears are not naturally designed to filter can lead to health issues. Our ears can tolerate a certain volume of noise without causing harm. However, prolonged exposure to loud noise can easily result in hearing loss and damage to the eardrums, leading to conditions such as tinnitus or deafness. Additionally, constant exposure to loud noise can diminish our sensitivity to sounds that our ears typically use to regulate bodily functions, such as controlling our heartbeat.

2. Psychological Problems

Excessive noise pollution can negatively impact psychological health in various workplaces, including offices, construction sites, pubs, and even our homes. Studies indicate that high levels of noise can contribute to aggressive behaviour, sleep disturbances, chronic stress, and fatigue, feelings of sadness, anxiety, irritability, hysteria, and hypertension in both humans and animals. Increased noise levels can make individuals more irritable and diminish their patience. Over time, these effects can lead to more severe and persistent health problems later in adulthood.

3. Physical Problems

When exposed to loud, continuous noise, gastritis, colitis, and even heart attacks may develop. Noise pollution can cause headaches, elevated blood pressure, respiratory irritation, and a racing pulse.

4. Cognitive Problems & Behavioural Modifications

Noise can disrupt brain activity and concentration levels, leading to subpar performance over time. Similar to other sound waves, excessive noise can dull cognitive function and slow down response times once it reaches the brain.

Furthermore, noise pollution can impede memory function, making studying challenging. Research indicates that learning difficulties affect schoolchildren residing near airports or train stations. Individuals living close to airports or busy roads often experience headaches, rely on sedatives and sleeping pills more frequently, are at higher risk of minor accidents, and are more likely to seek mental health care.

5. Insomnia disorders

Even though it may not appear significant initially, excessively high noise levels can disrupt your sleep, leading to annoyance and discomfort. Lack of sufficient sleep can result in various fatigue-related issues, impacting your performance at work and home.

6. Cardiovascular issues

Cardiovascular issues, high blood pressure, and cardiac problems resulting from stress are increasingly prevalent. Studies indicate that loud noise disrupts normal blood flow, leading to elevated blood pressure and heart rate.

7. Impact on Wildlife Life

Noise pollution affects animals much more than humans. According to a recent study by Biology Letters, various animals are impacted by human noise.

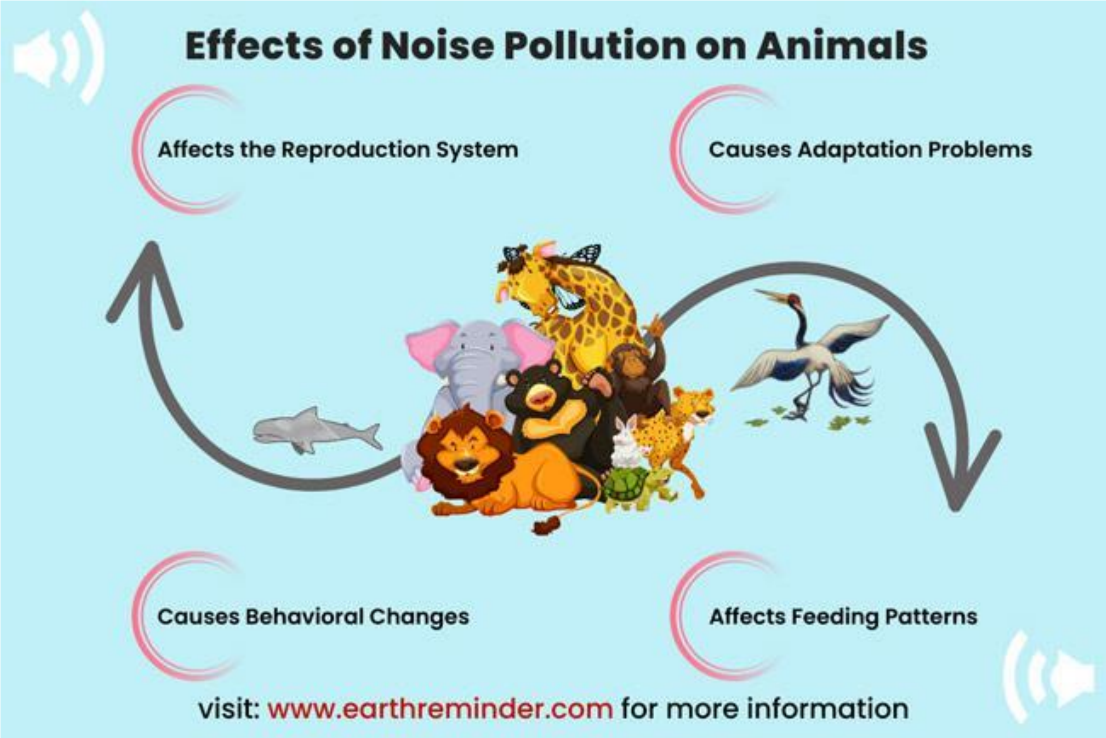

Figure 5.2: Effects of Noise Pollution on Animals

Source: Earth Reminder

Animals exposed to excessive noise pollution are more susceptible to losing their orientation and may exhibit various behavioural issues. Wildlife can suffer from hearing loss, making them vulnerable to predation and contributing to population declines. Additionally, some animals may lose their hunting abilities, disrupting the ecological balance.

5.4 Prevention of Noise Pollution

WHO acknowledges that addressing this unseen threat requires awareness. While options for reducing noise pollution are limited at present, governments can assist in the following ways:

- Implementing regulations that encompass both preventative and remedial measures.
- Governments can safeguard certain areas, such as rural regions, areas of natural significance, city parks, etc., to ensure noise management and prevent noise pollution.
- Monitoring and maintaining the distance between residential areas and noise sources, such as airports, to minimize exposure to excessive noise.
- Creating pedestrian zones where vehicles are only allowed for occasional item deliveries.
- Implementing penalties for exceeding noise restrictions.
- Enforcing controls on noise levels in pubs, clubs, events, and discos to address noise pollution.
- Eliminating all public loudspeakers can be considered as another option to reduce pollution.
- Enhanced urban design practices can facilitate the establishment of "No-Noise" zones where vehicular and industrial noise is strictly prohibited.
- Implementing more effective alternatives to conventional asphalt can result in a 3 dB reduction in traffic noise.

Some other practices that can be applied by an individual in their effort to reduce noise pollution are as follows:

- Keep an eye on the area's noise level and reduce your noise production.
- Emphasize the development of areas with abundant trees, known to reduce noise levels by 5 to 10 dB.
- Lowering the volume of televisions, music systems, and radios can contribute to quieter homes.
- Refraining from participating in loud recreational activities and avoiding noisy environments.
- Employing suitable noise absorbents when operating noisy machinery.
- Utilize headphones when listening to music to minimize noise.

- Wear earplugs in noisy environments to reduce overall noise exposure.
- Consider alternative modes of transportation such as electric vehicles or bicycles instead of driving.
- Regularly maintain and lubricate your car to prevent excessive noise.
- Use noise-absorbing materials to insulate your home during new construction.

5.5 Summary

- ❖ Any upsetting sound that interferes with people and other species' health and well-being is called noise pollution.
- ❖ The World Health Organization (WHO) defines noise pollution as noise levels exceeding 65 dB.
- ❖ The risk of hearing loss increases with exposure length, particularly when hearing protection is not worn or adequate rest periods are not provided for the ears between exposures.
- ❖ Although the restrictions differ from nation to nation, a time-weighted average (TWA) of 85 dB (A) is the generally acknowledged benchmark.
- ❖ TWA (Time-Weighted Average) estimates a worker's daily exposure to hazards such as noise. It represents the average frequency at which a worker is exposed to an unfavorable condition like noise over a set period.
- ❖ In urban areas, when residential properties are near industrial structures, it can lead to noise pollution. In such scenarios, the noise emanating from industrial sites could affect residents' overall well-being negatively.
- ❖ Excessive noise can disrupt brain activity and concentration levels, leading to diminished performance over time. Similar to other sound waves, excessive noise can dull cognitive function and slow down response times once it reaches the brain.

5.6 Keywords

1. Noise Pollution: Any upsetting sound that interferes with people's and other species' health and well-being is called noise pollution.
2. Time-weighted average: It is a method for gauging a worker's daily exposure to hazards such as noise. Time-Weighted Average (TWA) denotes the average

frequency at which a worker encounters adverse conditions like noise over a predefined period.

3. Psychological problems: These include aggressive behaviour, sleep disruption, ongoing stress, weariness, sadness, anxiety, hysteria, hypertension, etc.
4. Ecological Equilibrium: It is a dynamic equilibrium within an organismal community when genetic, species and ecosystem diversity stay largely stable and are only gradually changing due to natural succession.

5.7 Self-Assessment Questions

1. Write the familiar sources of noise pollution in urban environments.
2. What are the effects of noise pollution on human health and well-being?
3. What simple measures can individuals take to reduce noise pollution in their daily lives?
4. How does prolonged exposure to noise pollution contribute to chronic health conditions?
5. How can urban planning and architectural design contribute to minimising the impacts of noise pollution on human health and well-being?
6. What is the concept of time-weighted average (TWA), and how is it used to assess noise exposure?
7. What are the cognitive effects of noise pollution on brain activity and concentration levels?
8. What is the generally accepted benchmark for noise exposure in occupational settings?
9. How does the World Health Organisation define noise pollution?
10. What is the recommended noise level threshold set by the WHO?

5.8 Case Study

A study examined how noise pollution affects avian behaviour and communication among urban bird species. Field research showcased that loud anthropogenic noise interferes with bird vocalisations, which impacts mate attractiveness, territorial defence, and breeding success. Additionally, stress reactions brought on by noise affect foraging habits and lower foraging effectiveness. The study emphasised the necessity for noise reduction measures to save urban bird populations and their ecological integrity.

Questions:

1. How does noise pollution affect the communication and behaviour of wildlife species in urban environments?
2. What are the observed effects of noise pollution on the reproductive success and breeding behaviours of animals in urban areas?
3. In what ways does noise pollution influence the foraging patterns and ecological interactions of wildlife species within urban ecosystems?

5.9 References

1. "Noise: Sound Levels and Their Relevance." IOSH
2. "Causes and Effects of Noise Pollution on Humans and Animals." Conserve Energy Future.
3. Alimohammadi, Iraj, et al. "Effect of Chronic Noise Exposure on Aggressive Behaviour of Automotive Industry Workers." The International Journal of Occupational and Environmental Medicine, U.S. National Library of Medicine, Oct. 2018.

Unit: 6

Solid Waste Management

Learning Objectives:

- Learn about Solid Waste Management
- Learn to classify waste
- Understand its composition
- Know its characteristics

Structure:

6.1 Municipal Waste- Introduction

Any undesired material in our environment or from everyday products that is neither liquid nor gas is considered solid waste. These wastes need to be disposed of carefully by following recognised protocols. Solid waste management has been an issue due to improper disposal for as long as people have lived in towns and neighbourhoods.

The complete process of collecting, treating, and disposing of solid waste is called "solid waste management". This waste management process involves gathering and disposing of wastes from diverse sources.

Figure 6.1: Solid Waste Management

Source: Netsol Water

Municipal Solid Waste

Municipal solid waste (MSW) comprises everyday items discarded by the general public. The composition of MSW varies significantly across different municipalities and undergoes substantial changes over time.

Persistent wastes like plastic film and non-recyclable packaging make up most trash streams in cities with well-developed waste recycling systems. Municipal solid waste categories eliminate industrial, agricultural, medical, and radioactive waste and sewage sludge. The municipality is in charge of collecting trash within a given area.

The term "residual waste" describes garbage from residential sources that have not been moved or separated for processing.

6.2 Classification of Solid Waste

There are two main categories in which solid waste can be categorised- Biodegradable and Non-Biodegradable. At the same time, Municipal Solid waste consists of both, some other types of substantial waste fall under the two. Some of them are mentioned below.

Figure 6.2: Classification of Solid Waste

Source: INTOSAI

1. Dangerous waste

"Hazardous waste" describes a specific category of dangerous material. Industrial and medical waste are regarded as hazardous because they contain harmful substances.

Toxic, incredibly flammable, or explosive, hazardous wastes can damage people, pets, and plants.

Hazardous household waste includes old batteries, shoe polish, paint cans, pharmaceutical containers, and medicine bottles.

In the industrial sector, hazardous waste primarily originates from industries dealing with metals, chemicals, paper, pesticides, dyes, refining, and rubber goods. Direct contact with toxic waste materials such as mercury and cyanide can be lethal.

2. Hospital Waste

Hospital waste is generated during various procedures such as diagnosis, therapy, or immunization of individuals or animals, as well as in the research, development, and testing of biological products. This category encompasses contaminated trash, disposables, anatomical waste, cultures, expired medications, chemical wastes, disposable syringes, swabs, bandages, bodily fluids, and human excreta.These materials are highly contagious and can present a significant risk to human health if not handled carefully and with scientific rigor.

Infectious hospital waste comprises discarded blood, sharps, surplus microbiological cultures and stocks, identifiable body parts (such as amputation-related tissue), additional human or animal tissue, used bandages and dressings, discarded gloves, and other medical supplies that may have been in contact with blood or other bodily fluids.

3. Wastes from Construction and Demolition

Construction and demolition waste refers to materials remaining after the construction, renovation, repair, or demolition of buildings, homes, and other structures. It mainly includes soil, stones, concrete, bricks, wood, roofing, plumbing, heating, electrical materials, and miscellaneous items from the general waste stream. However, when generated in significant volumes at construction sites, this waste is typically managed by vendors for filling low-lying areas or by municipal authorities for disposal in landfills.

4. Industrial Wastes

This category encompasses solid waste residues remaining after manufacturing and various industrial processes, which consist of a diverse array of compounds. They undergo distinct treatment procedures compared to municipal waste due to their composition. Nevertheless, municipal landfills often receive and manage solid wastes from small-scale industrial operations, as well as ash from power plants.

5. Sewage Wastes

Sewage wastes refer to the residual solids from sewage treatment, primarily organic in nature. They result from the processing of sewage, including both untreated and treated sewage containing organic sludge. Grit, an inorganic component of raw sewage that is isolated during the first stage of treatment, must be buried or disposed of right away because it entraps putrescible organic materials that could contain infections. Most treated, dewatered sludge can be used to improve soil, but doing so is only sometimes cost-effective. Therefore, unless specific planning is done for disposal, the solid sludge enters the municipal trash stream.

6.3 Composition of Solid Waste

One crucial factor influencing emissions from solid waste treatment is the composition of the waste, as different types of waste contain varying proportions of degradable organic carbon and fossil carbon. Waste compositions and the methodologies used to collect data on waste composition in Municipal Solid Waste can vary significantly across different countries and regions.

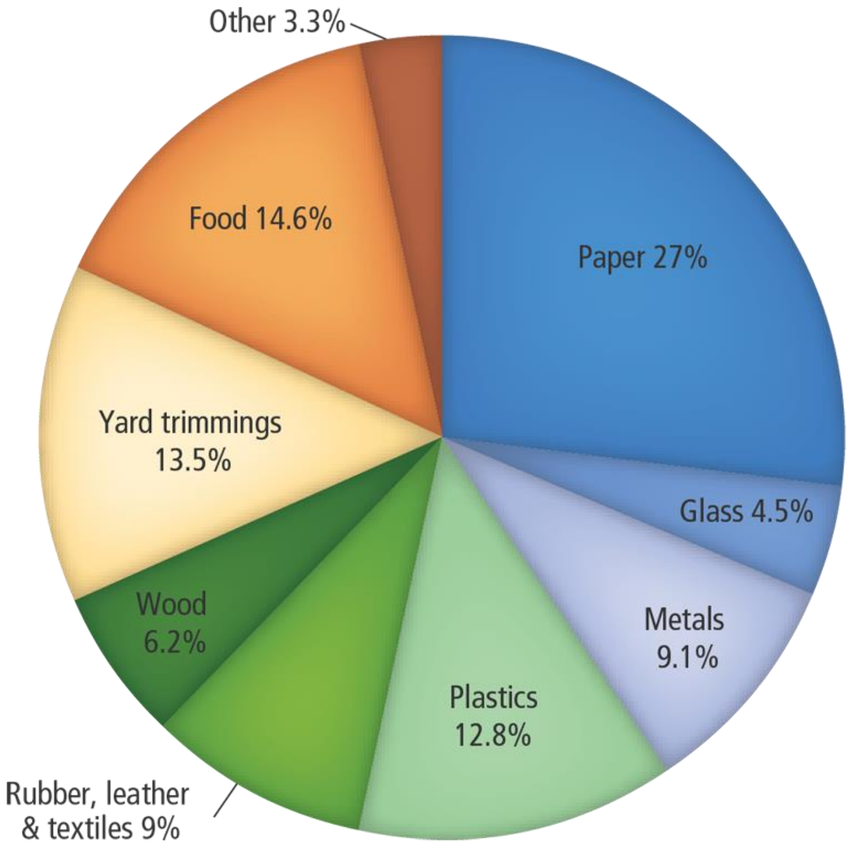

Figure 6.3: Composition of Municipal Solid Waste

Source: EPA

Wastes such as food, textiles, paper, and yard waste are all degradable. Non-fossil carbon is also present in small amounts in ash, dust, rubber, and leather but is hardly biodegradable. The majority of the fossil carbon in MSW is found in some textiles and plastics (particularly plastics found in disposable diapers). Small amounts of fossil carbon can also be found in paper and synthetic leather.

Plastic waste, also known as “plastic pollution”, refers to “the build-up of plastic objects such as bottles and other items in the Earth's environment, which adversely impacts animals, wildlife habitats, and humans”.

Chemical Composition of Solid Waste

- Heat content, called calorific value, is the quantity of heat energy created when the trash is burned.
- Moisture content is the amount of water in the waste
- Ash content is the amount of material left over after burning the waste

6.4 Characteristics of Solid Waste

The characteristics of Solid Waste are divided into two categories: Physical Characteristics and Chemical Characteristics.

1. Physical Characteristics

The physical characteristics of waste are

- Density

When developing a solid waste management system, including the design of sanitary landfills, storage facilities, collection methods, and transport vehicles, one crucial consideration is the density of the garbage, which refers to its mass per unit volume (kg/m3). When choosing typical values, extreme caution should be taken because the densities of solid wastes vary significantly depending on geographic location, year's season, and amount of time in storage. Delivered municipal solid wastes

It has been discovered that the typical value for compaction vehicles is around 300 kg/m3.

- Moisture Content

Moisture content, calculated by dividing the weight of water (wet weight minus dry weight) by the total wet weight of the trash, indicates the proportion of water present in solid waste. Higher moisture levels increase the weight of solid wastes, thereby raising the costs associated with collection and transportation. Additionally, moisture content is crucial in assessing the economic viability of waste treatment via incineration. Wet waste requires energy for water evaporation and heating the resulting water vapor, impacting the overall efficiency and cost-effectiveness of the incineration process.

The typical moisture content range falls between 20% to 40%, representing the extremes observed in waste composition, such as in a desert climate or during the wet season in regions with significant precipitation. However, values exceeding 40% are not uncommon.

- **Size**

When recovering materials, especially mechanical methods like trommel screens and magnetic separators, it's crucial to consider the size and size distribution of the component elements in solid wastes.

Because it affects the design of mechanical separators and shredders, it is crucial to measure the size distribution of waste stream particles.

2. Chemical Characteristics

The chemical characteristics of waste are

1. Lipids

This group of substances comprises fats, oils, and grease. Fats, cooking oils, and waste are the primary sources of lipids. Lipids contribute to the liquid content during waste decomposition because they become liquid at temperatures just slightly higher than ambient.

Despite being biodegradable, lipids degrade very slowly because they are poorly soluble in water.

2. Carbohydrates

Carbohydrates, comprising sugars and sugar polymers like starch and cellulose, with the general formula (CH2O)x, are predominantly present in food and yard waste. They readily undergo biodegradation, breaking down into methane, carbon dioxide, and water. However, the decomposition of carbohydrates attracts flies and rats, hence it's advisable not to leave them exposed for extended periods.

3. Proteins

Proteins comprise an organic acid with an amine group (NH2) that has been replaced. Proteins are substances having the elements carbon, hydrogen, oxygen, and nitrogen.

They are primarily discovered in gardens and food waste. These compounds' partial breakdown may lead to the generation of amines with foul scents.

4. Natural Fibres

Natural fibres, such as the biodegradable components cellulose and lignin, are commonly found in food waste, paper products, and yard debris. Due to their highly flammable nature and high concentration of paper and wood materials, they are suitable for incineration.

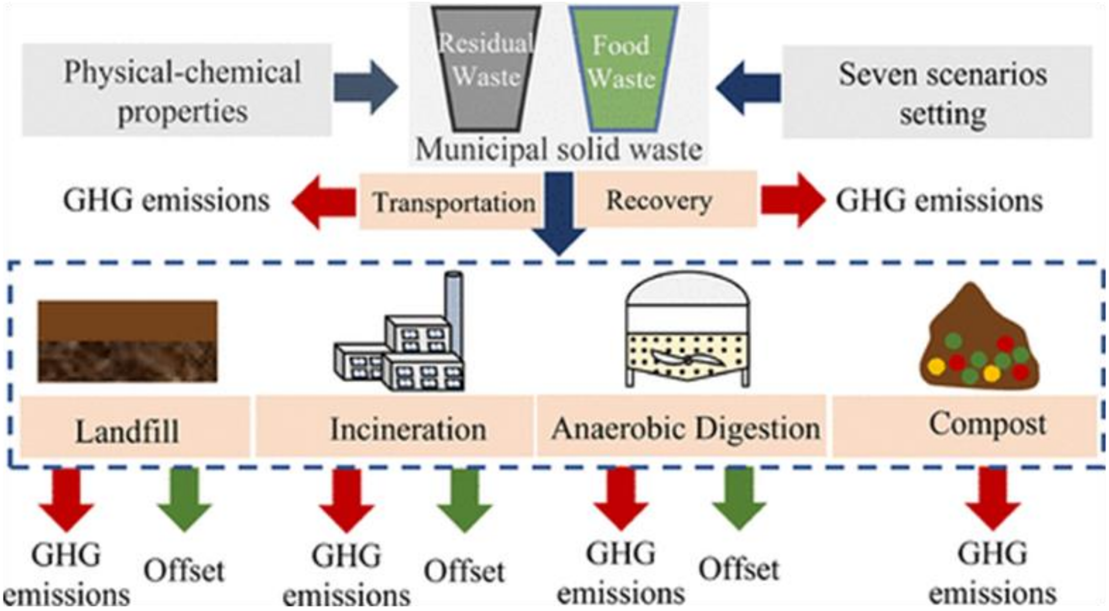

Figure 6.4: Characteristics of Solid Waste

Source: ACS Publications

6.5 Summary

- Any undesired material in our environment or from everyday products that is neither liquid nor gas is considered solid waste.
- Municipal solid waste (MSW) is a kind of waste that includes common goods discarded by the general public.
- Municipal solid waste categories eliminate industrial, agricultural, medical, and radioactive waste and sewage sludge. The municipality is in charge of collecting trash within a given area.
- There are two main categories in which solid waste can be categorised- Biodegradable and Non-Biodegradable.
- In the industrial sector, hazardous waste primarily originates from industries involved in metals, chemicals, paper production, pesticides, dyes, refining, and rubber goods. Direct contact with toxic waste substances such as mercury and cyanide can have fatal consequences.

- ❖ Hospital waste is generated during the diagnosis, treatment, or immunization of individuals or animals, as well as during the study, development, and testing of biological products.
- ❖ Plastic waste, also referred to as “plastic pollution”, denotes “the accumulation of plastic items like bottles and various objects in the Earth's environment”. This accumulation poses harmful effects on animals, wildlife habitats, and human health.
- ❖ The moisture content plays a vital role in assessing the economic feasibility of waste treatment through incineration. Wet waste necessitates energy for both water evaporation and elevating the temperature of water vapour, influencing the overall cost-effectiveness of the incineration process.

6.6 Keywords

1. Solid Waste: Any undesired material in our environment or from everyday products that is neither liquid nor gas is considered solid waste.
2. Solid Waste Management: Solid Waste Management encompasses the comprehensive process of gathering, treating, and disposing of solid waste materials.
3. Residual Waste: It describes garbage from residential sources that have yet to be moved or separated for processing.
4. Calorific value: The quantity of heat energy created when the trash is burned.

6.7 Self-Assessment Questions

1. What is solid waste, and how is it different from liquid or gas waste?
2. What does municipal solid waste (MSW) include, and who is responsible for its collection?
3. How can solid waste be categorised into biodegradable and non-biodegradable?
4. What are some examples of industries that produce hazardous waste, and what are the potential dangers associated with exposure to such waste?
5. What is hospital waste, and what are its sources and characteristics?
6. How does the moisture content of waste affect the feasibility of waste treatment by incineration?
7. Write a note on the physical characteristics of solid waste.
8. Write a note on the chemical characteristics of solid waste.
9. Write a short note on Municipal Solid Waste.

10. Write a short note on Municipal Solid Waste and Industrial waste composition.

6.8 Case Study

The Brazilian city of Curitiba is an excellent case study in solid waste management. Curitiba adopted an innovative waste management system that prioritised recycling, waste reduction, and community involvement in the 1970s in response to rising garbage creation and a shortage of landfill space. Citizens were urged to sort their rubbish into various categories as part of the city's extensive recycling programme. Curitiba also established a network of parks and green spaces that acted as trash collection sites, fostering neighbourhood involvement and instruction. The city also invested in waste-to-energy facilities to turn non-recyclable waste into electricity. Due to these activities, Curitiba saw reduced landfill usage, a 70% recycling rate, and much better environmental conditions.

Questions:

1. How did Curitiba, Brazil, successfully implement a comprehensive recycling program as part of its solid waste management system, and what factors contributed to its high recycling rate of approximately 70%?
2. What were the innovative strategies and community engagement approaches employed by Curitiba to encourage waste reduction and segregation, including establishing green spaces and parks as waste collection points?
3. What were the environmental and social benefits observed in Curitiba due to its waste-to-energy plants, which converted non-recyclable waste into electricity, and how did this approach contribute to reducing landfill use and improving overall environmental conditions in the city?

6.9 References

1. “Classification of Solid Wastes.” Environmental Information System, www.envis.org
2. “Solid Waste: Sources, Composition and on-Site Storage.”
3. “Environmental Engg.” EE: Characteristics of Solid Waste,

Unit: 7

Collection and Conveyance

Learning Objectives:

- Learn the process of solid waste management
- Know about sanitary landfills
- Understand solid waste disposal
- Learn about Composting

Structure:

7.1 Collection and Conveyance

Waste management encompasses various processes, including waste collection, which entails the transportation of solid waste from its origin and disposal site to a facility for treatment or final disposal, such as a landfill. As municipalities strive to reduce landfill usage through diversion programs, garbage collection now often incorporates curbside pickup of recyclables, which are distinct from general refuse.

Efficient solid-waste collection is essential for safeguarding environmental quality, ensuring public safety, and promoting public health. This aspect of waste management is labor-intensive, constituting approximately three-quarters of the total cost associated with solid-waste management.

A driver and two loaders are needed for each collecting vehicle and, typically, enclosed compacting trucks with a maximum volume of 30 cubic metres (40 cubic yards). The vehicle's waste volume is less than half of its loose volume after compaction.

Identifying the optimal collection route poses a significant challenge, especially in large and densely populated urban areas. Determining the most suitable course entails intricate computer calculations that take into account numerous design elements within a vast and complex network. By selecting an optimal route, municipalities can maximize the efficiency of their workforce and equipment utilization.

Solid waste collection is divided into two categories:

Primary Collection: "It involves collecting solid trash from its source and transporting it to its final disposal location, but it most frequently entails going to public collection bins or points, processing, or transfer stations".

Secondary Collection: "It is the process of gathering waste from communal trash cans, holding facilities, or transfer stations and transporting it to the final disposal location".

7.1.1 Basic Collection Scheme

Based on the availability of service

- "Communal system"
- "Block Collection"
- "Kerbside/alley"

- “Door-to-door collection”

1. Communal System

Since this system depends primarily on public cooperation, improving a communal system's design, operation, and maintenance practices is essential. A primary limitation of this system is that containers or collection points are situated in public spaces, often lacking a sense of ownership from the public. Consequently, this setup frequently leads to the indiscriminate disposal of waste outside the designated containers.

2. Block Collection

Garbage must be transported to collection vehicles by garbage generators. This technique minimises the distribution of waste on roadways while having low to medium labour and vehicle productivity.

3. Kerbside

Most industrialised nations and the affluent regions of some developing countries use this form of collection. On a set day (or days), waste producers leave their trash cans or bags (sacks) on the curb or in the alley for collection by outside parties. Regular and well-planned pickup services are necessary so that generators know when to place their garbage outside.

4. Door-to-door Collection

This is more usual in industrialised nations, although in many developing countries, more and more wealthy groups are founding micro-enterprises and community-based organisations to carry out this function. Although this technology is still relatively unknown to the general public, it maximises crew efficiency by eliminating the need to retrieve containers, just like when waste is bagged.

7.1.1.1 Methods Based on Mode of Operation

- Hauled Container System

To replace the full garbage container being transported to the processing point, transfer station, or disposal site, an empty storage container (sometimes called a drop-off box) is transported to the storage location.

- **Stationary Container System**

In this method, containers used to store waste stay at the collection point. Typically, collection workers carry waste from storage containers into collection vehicles when they arrive beside the storage containers. They take the material to the processing, transfer, or disposal facility.

7.1.2 Conveyance

About 60 to 80 per cent of all costs paid in solid waste management go towards transporting the garbage gathered in the numerous community bins. Every day, the vehicles travel many routes to the disposal site.

Types of Transport vehicles used:

- Container carrier system
- Electric vehicles
- Animal carts
- Tractor-trailer
- Three-wheeler auto-rickshaws
- Dumper Placer
- Special municipal vehicle
- Trucks
- Compaction vehicles
- Rail Transport
- Short-range diesel vehicles

Planning a route for a vehicle can be facilitated by the following methods:

1. Heuristic
2. Deterministic
3. Deterministic-Heuristic

- **Heuristic Approach**

The development of a few straightforward principles systematised the outdated practice of allocating routes based on prior knowledge and intuition. However, how effective they are depends on the user's background. Route balancing and micro routing should be completed after macro routing.

- **Determined Approach**

These procedures employ cutting-edge mathematical methodologies. Much of the data about the locations of collection bins, processing and disposal facilities, and the amounts of waste collected at individual collection bins would be accessible under the current system. This information must be estimated while designing a new system, which calls for using simulation techniques.

Macro-scale studies and plans have been developed to assess potential solutions for addressing the comprehensive solid waste issue, encompassing the entire system from waste generation to collection, treatment, and economic planning.

- **Heuristic-Deterministic Approach**

In the heuristic-deterministic technique, a computer program assesses many potential solutions before selecting the best one.

7.2 Disposal of Solid Waste

Solid waste disposal management refers to the process of collecting and managing solid wastes. It encompasses methods for recycling materials that are not considered trash or rubbish. Solid waste management involves the transformation of waste into a valuable resource.

Improper disposal of municipal solid waste can result in unsanitary conditions that contribute to environmental pollution. Rodents and insects attracted to improperly managed waste can transmit diseases. Managing solid waste poses significant technical challenges, in addition to various administrative, social, and economic issues.

7.2.1 Methods of Disposal

Some methods that are incorporated for the disposal of solid waste are mentioned below:

1. Landfill

During this process, non-recyclable or non-reusable debris is separated and distributed as a thin layer in low-lying areas throughout a city. Each layer of trash is covered with a layer of soil. However, once this process is completed, the area becomes unsuitable for building construction for the next two decades. Instead, it can only be utilized as a park or playground.

- **Sanitary landfill**

In a sanitary landfill, garbage is often buried in layers and crushed into a solid mass in a pit with a covered bottom. In 1935, Fresno, California, became the first city to use this way of discarding rubbish.

Sanitary landfills' primary objective is to keep trash safe by reducing the damage brought on by amassing waste and enabling safe decomposition. To hasten decomposition, waste is alternatively covered with dirt. Methane, a dangerous gas produced by decaying, is collected at the landfill and used to make power rather than released into the sky. At the sanitary landfill, a clay lining keeps the environment and rubbish separate.

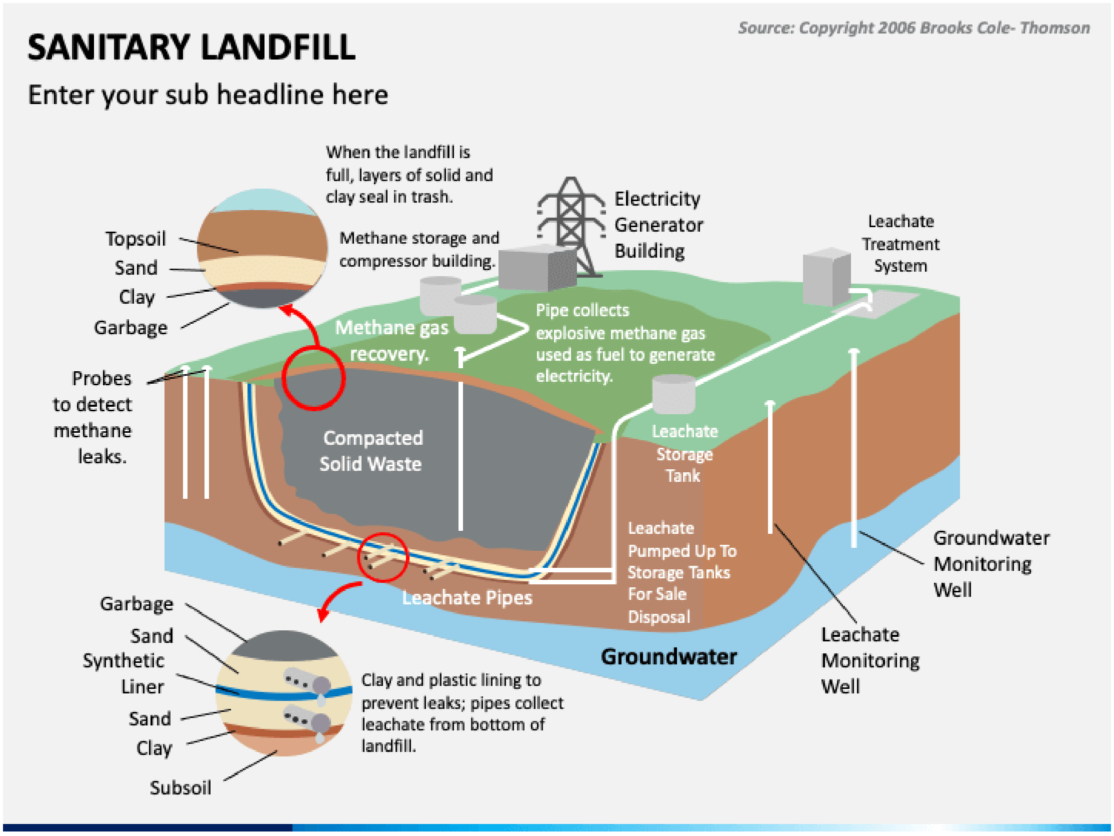

Figure 7.1: Sanitary Landfill System (Source: Brooks Cole-Thomson)

Because when garbage begins to break down, sanitary landfills produce carbon dioxide and methane, which make them good energy sources.

These gases have the potential to be harvested, cleaned, and used to produce energy. The nation's landfills create about 95.6 million tonnes of carbon dioxide annually. The sanitary landfills were designed with engineering technology in mind; a leachate control system and good soil liner ensure minor seepage or damage. However, the fundamental problem with a sanitary landfill is that it potentially harms the environment and requires a lot of area and resources to store the rubbish. Also, Leachate, a foul-smelling liquid waste produced by rainwater soaking into the landfill, can leach chemicals from the garbage into the groundwater. This is why it's essential to line the landfill correctly and keep it away from a river, stream or lake.

2. Open Dumps

Open dumping site is “one where solid waste is dumped in a fashion that does not protect the environment, is subject to open burning, and is out in the open where pests, scavengers, and the elements can access it”. Although some open dumps are removed shortly after they are created, most will stay there permanently if the place is in a wilderness or public area with minimal public amenities.

Potential concerns of open dumping include releasing harmful chemicals and heavy metals into the air and water, the growth of disease-carrying rodents and insects, and bodily threats from hypodermic needles, unpleasant odours, and piercing devices. Additionally, the sector that produces energy uses open dumps.

3. Incineration Plants

Incineration involves burning garbage at high temperatures in large furnaces. There are 2,500 incineration facilities worldwide. They can dispose of over 420 million tonnes of waste annually. Organic materials are transformed into bottom ash, flue gases, particles, and heat.

It is a landfill reduction strategy that cuts the amount of rubbish by 95–96%. Incinerating or thermally treating trash is highly frequent in places like Japan, where there is a lack of available land. Some countries did not always have a system for separating things before burning poisonous, bulky, or recyclable objects when incinerators were erected just a few decades ago. However, burning trash is terrible since it pollutes the air and water, produces tons of hazardous ash, and releases ashes. Incineration is now mainly used to control infectious waste as a last resort.

4. Composting

The biological process of composting enables the organic component of garbage to decompose under tightly regulated conditions. Microbes break down the organic waste, which can result in a volume reduction of up to 50%.

The term for this stabilised product is compost or humus. It can be used as a mulch or soil conditioner and has the texture and smell of potting soil. Waste and sewage sludge can be digested and recycled simultaneously by composting.

Composting is expected to gain popularity as landfill, and solid-waste incineration choices are constrained by more stringent environmental rules and site limitations. The process involves several steps including size reduction, waste digestion, and sorting and classifying the waste. Compostable items include fruits, vegetables, dairy products, cereals, bread, unbleached paper napkins, coffee filters, eggshells, meats, and newspapers. However, composting is not suitable for plastic utensils, condiment containers, plastic wraps, plastic bags, foil, silverware, drinking straws, bottles, polystyrene, plastic-based chemicals, grease, glass, and metal.

Vermicomposting

Vermiculture is the intentional cultivation of a particular type of earthworm that actively breaks down organic waste into nutrient-rich compounds (manure). These earthworms can collect degrading organic stuff and expel it as nutrient-rich worm dung. Producing vermicompost is the primary goal of vermiculture. Technically referred to as worm excrement, worm castings are a fine, nutrient-rich organic soil additive. Castings, leftover bedding, and other organic materials make up vermicompost.

Although the titles are frequently used interchangeably, both are worm dung and suitable for soil health. The use of earthworms for composting, soil bioremediation, and other purposes is called vermitech.

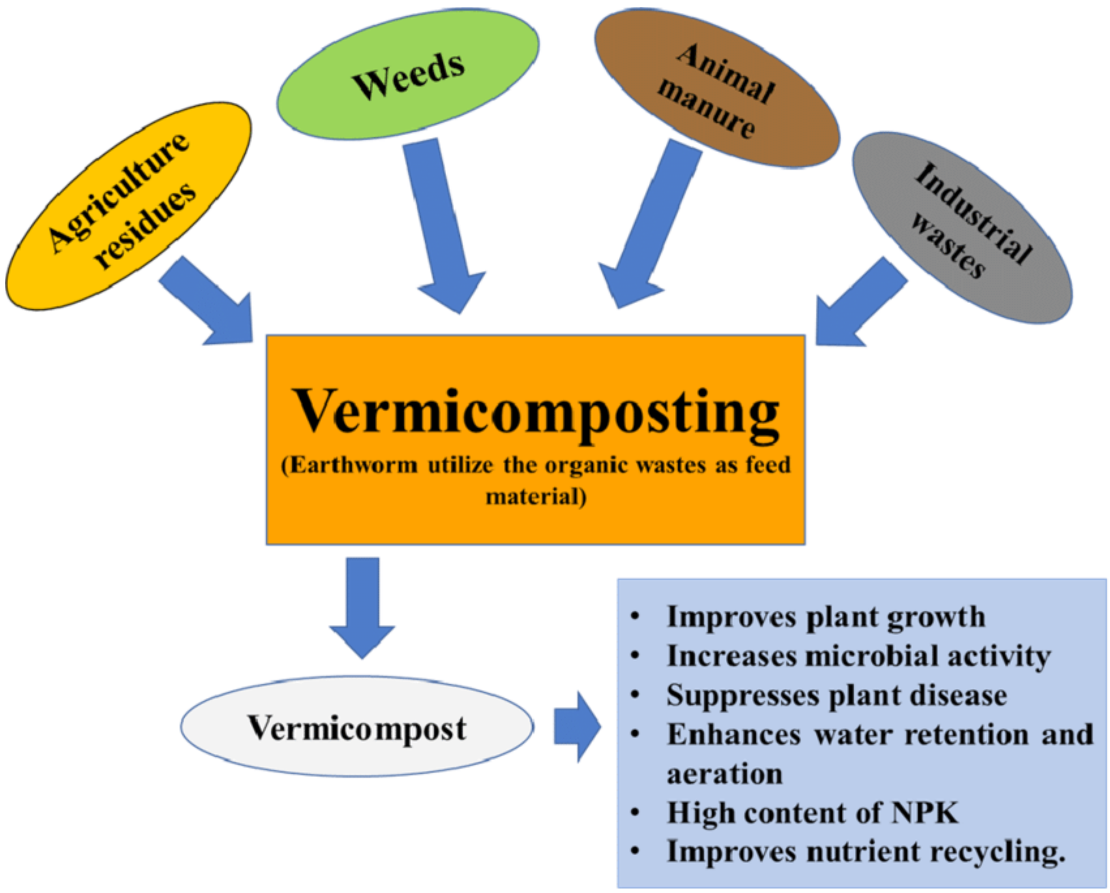

Figure 7.2: Vermicomposting, (Source: Research Gate)

7.3 Resource Recovery

The process of extracting materials or energy for reuse from solid waste is termed resource recovery. The objective is to maximize the economic, environmental, and social benefits before resorting to indefinite disposal in a landfill. To guide resource recovery efforts, the Environmental Protection Agency (EPA) and environmentalists have established a hierarchy: prioritize reduction, followed by reuse, recycling, incineration with energy recovery, and finally, landfilling. Utilising the hierarchy will decrease production-related resource consumption and solid waste.

7.3.1 Sources of Resource Recovery

1. Solid Waste

Recycling is a method aimed at recovering resources by collecting and reusing waste products, such as empty beverage containers. The raw resources used to create the things can be used to develop new goods. Recycling materials can be collected directly from mixed trash streams or ordinary rubbish using designated bins and collection vehicles.

The most frequently recycled consumer goods are newspapers, magazines, glass jars and bottles, paperboard cartons, and light paper, as well as corrugated fiberboard boxes, steel food and aerosol cans, old steel furniture or equipment, polyethene and PET bottles, aluminium beverage cans, copper wire, and steel food and aerosol cans.

2. Wastewater and other excreta

Sewage sludge, faecal sludge, wastewater, and human excrement all contain valuable resources that can be recovered. These include organic matter, water, energy, the fertilising nutrients potassium, phosphorus, nitrogen, and micronutrients like sulphur and nitrogen. Other raw materials, such as bioplastics and metals like silver, can be recovered from wastewater with growing interest.

3. Organic Matter

Organic waste that is disposed off can be recycled by utilising biological composting and digestion processes. Such waste includes plant debris, food scraps, and paper products. The resulting organic material is then recycled in landscaping or agriculture as mulch or compost. Waste gases, including methane, can also be recovered to increase combined heat and power (CHP)/cogeneration efficiency. Biological processing aims to speed up and regulate the organic matter's natural degradation process.\

4. Industrial Waste

Recovering wastes from industries in terms of defective or damaged machine parts can be recycled and reused instead of entirely new raw material in its place. Similarly, some waste products can be upcycled to create a new product.

7.4 Summary

- ❖ Waste management comprises the process of waste collection, entailing the transportation of solid waste from its production site to a facility for treatment or disposal in a landfill.
- ❖ The main drawback of the communal system is that containers/collection points are located in public spaces (lack ownership by the public), which often results in indiscriminate disposal outside the container.

- ❖ To replace the full garbage container being transported to the processing point, transfer station, or disposal site, an empty storage container (sometimes called a drop-off box) is transported to the storage location.
- ❖ Macro-scale studies and plans were produced to evaluate potential solutions to the complete solid waste problem, which involves the entire system's generation, collection, treatment, and economic planning.
- ❖ Solid waste disposal management is typically “used to describe the procedure for gathering and handling solid wastes”.
- ❖ In 1935, Fresno, California, became the first city to use sanitary landfills to discard rubbish.
- ❖ Incineration involves burning garbage at high temperatures in large furnaces.
- ❖ Vermiculture is the intentional cultivation of a particular type of earthworm that actively breaks down organic waste into nutrient-rich compounds (manure).
- ❖ A hierarchy for resource recovery has been established by the “Environmental Protection Agency” (EPA) and environmentalists: “reduce first, then reuse, recycle, incinerate with energy recovery, and landfill last”.

7.5 Keywords

1. Primary Collection: It involves collecting solid trash from its source and transporting it to its final disposal location, but it most frequently entails going to public collection bins or points, processing, or transfer stations.
2. Secondary Collection: It is the process of gathering waste from communal trash cans, holding facilities, or transfer stations and transporting it to the final disposal location.
3. Heuristic-Deterministic Approach: It is a technique where a computer program assesses many potential solutions before selecting the best one.
4. Solid waste management: It is the process of transforming waste into a valuable resource.
5. Open dumping site: It is one where solid waste is dumped in a fashion that does not protect the environment, is subject to open burning, and is out in the open where pests, scavengers, and the elements can access it.

7.6 Self-Assessment Questions

1. What is the primary purpose of waste management?
2. What is the process involved in waste collection?
3. What is the drawback of the communal waste management system?
4. Evaluate the pros and cons of incineration as a method of solid waste disposal.
5. Discuss the process of vermicomposting and its significance in solid waste management.
6. Analyse the practice of incineration as a method of solid waste disposal. Describe the technology and equipment used in incineration plants and the environmental and health considerations associated with this method. Discuss the potential for energy recovery through incineration.
7. Compare and contrast the environmental impacts and resource recovery potential of sanitary landfilling, vermicomposting, and incineration.
8. What do you understand by Resource Recovery?
9. Describe the process of collection and conveyance of solid waste from its production site to a disposal facility.
10. Differentiate between Sanitary landfills and Open Dumps.

7.7 Case Study

Adopting resource recovery practices transformed the solid waste management system in a small municipality suffering from constrained landfill space and rising trash generation. The community saw impressive results by taking a comprehensive approach to prioritise recovering priceless resources, including metals, polymers, and biological debris. Modern sorting technologies were installed at an established recycling facility, effectively separating recyclable materials. An anaerobic digestion facility was built concurrently to transform organic waste into nutrient-rich compost for use in agriculture and biogas for electricity production. In addition to reducing the amount of garbage dumped in landfills, these resource recovery programmes also produced economic opportunities and environmental advantages. The success of the municipality is a testament to how resource recovery can be used to create waste management systems that are resilient and sustainable.

Questions:

1. What were the main goals of the resource recovery initiatives implemented in the small town's waste management system?
2. How did the recycling facility contribute to separating recyclable materials in the town's solid waste management system?
3. What were the benefits of converting organic waste into biogas and nutrient-rich compost through the anaerobic digestion plant?

7.8 References

1. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
2. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
3. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit: 8

Biomedical Waste

Learning Objectives:

- Know about Biomedical Waste
- Learn about its generation
- Learn the process of collection
- Become aware of its disposal

Structure:

8.1 Biomedical Waste

Biomedical waste refers to any refuse containing infectious or potentially infectious components, typically generated during the diagnosis, treatment, and immunization of humans and animals. India produces an estimated three million tonnes of medical waste annually, with projections indicating an annual increase of 8%.

There are both solid and liquid kinds of biomedical waste. Biomedical waste's infectivity and other toxicity are the first of its main hazards.

Biomedical waste includes

- Waste from human anatomy, encompassing tissues, organs, and body parts
- Animal waste generated by veterinary hospitals during research

- Biotechnology and microbiology waste
- Waste sharps, such as scalpels, syringes, hypodermic needles, and broken glass
- Cytotoxic substances and discarded medications
- Contaminated waste, comprising dressings, bandages, plaster casts, bloody materials, tubes, and catheters
- Liquid waste generated in any diseased regions
- Chemical wastes and incinerator ash

These items which are mentioned above are classified into various categories by WHO.

8.1.1 Biomedical Waste Types

The World Health Organisation (WHO) divides biomedical waste into eight categories.

Figure 8.1: Categories of Medical Waste

Source: SEPCO Environment

1. Infectious waste: Any biological waste that is infected.
2. Sharps - Items with a pointy edge, such as razors, scalpels, and shattered glass.

3. Pathological Waste: Human or animal body components, including tissues, bodily fluids, and blood.
4. Pharmaceutical waste: It comprises unused medications, lotions, and pharmaceuticals.
5. Hazardous toxic waste and genotoxic waste: These include poisonous substances.
6. Radioactive Waste: Refers to waste potentially containing radioactive materials.
7. Chemical Waste: Liquid waste originating from batteries, machinery, and disinfectants.
8. Other non-hazardous garbage.

8.2 Generation of Biomedical Waste

Biomedical waste, a by-product of biological and medical procedures such as illness diagnosis, treatment, or prevention, is primarily generated by hospitals, health clinics, nursing homes, emergency medical services, medical research laboratories, doctors', dentists', and veterinarians' offices, as well as home health care facilities, mortuaries, or funeral homes. This type of waste, characterized by its infectious or potentially contagious nature, is also known as medical refuse or clinical waste within healthcare settings.

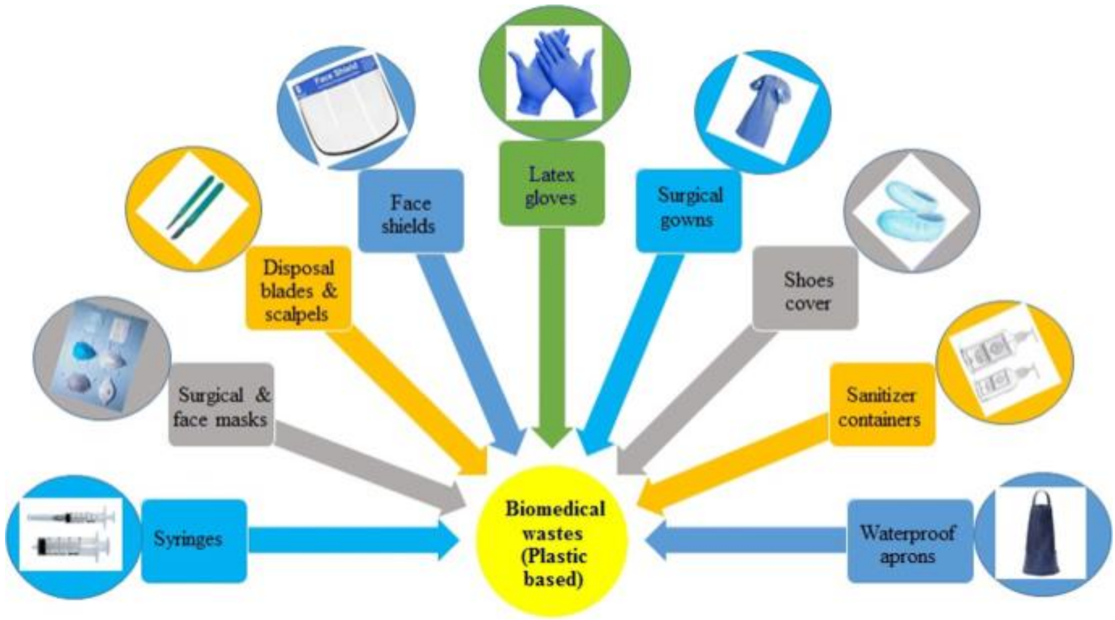

Figure 8.2: Examples of Biomedical Wastes

Source: Springer Link

8.3 Collection of Biomedical Waste

Part of the process involves using different types of containers to gather biological waste from areas such as operating rooms, laboratories, wards, kitchens, and hallways. Proper arrangement of bins and containers is essential to ensure 100% collection. Sharps should always be placed in puncture-proof containers to safeguard workers handling them from injuries and infections.

After collection, biomedical waste is stored properly. Waste from different categories must be collected separately in identifiable containers. Storage times should be 8 to 10 hours in large hospitals (those with more than 250 beds) and 24 hours in nursing homes. Each container can be labelled with the ward or room it is kept in.

Segregation of biomedical waste during collection is vital in proper treatment and disposal. For instance,

The Central Pollution Control Board (CPBC) has established distinct, colour-coded bins for disposing of different types of biomedical waste.

- Yellow Bin: For laboratory waste, anatomical waste, chemical waste, filthy waste, waste from chemotherapy, and waste from abandoned clothes and medications.
- Red Bin: Contaminated plastic waste.
- Blue Bin: Glass garbage and metallic implants.
- Black Bin: Hazardous and other waste.
- Green Bin: General wastes.

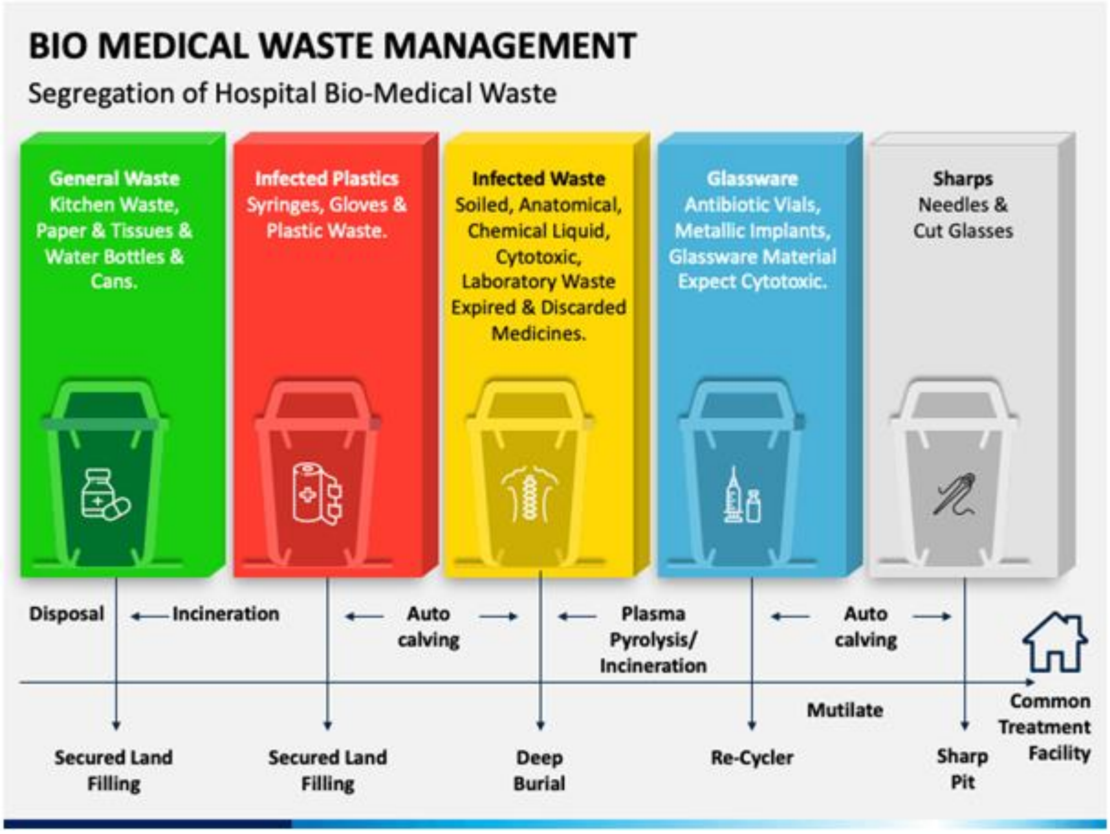

Figure 8.3: Segregation of BioMedical Waste

Source: Clutch Health

8.4 Disposal

Not all biological waste is disposed of in the same way; various disposal businesses employ multiple techniques. These methods are mentioned below.

1. Autoclaving

The autoclaving process utilizes steam sterilization instead of costly incineration. It involves exposing the waste to hot steam for a specific duration, effectively eliminating all germs. This method is highly efficient, cost-effective, and poses no health risks. While autoclaving may not be suitable for all biomedical waste, it sanitizes over 90% of it before disposal in landfills.

2. Incineration

It is rapid, simple, and straightforward. It eliminates bacteria while removing trash. Emissions can be harmful when burning toxic materials. Before opting for incineration as the primary method of disposal, materials should undergo thorough examination to ensure they are safe to burn.

3. Chemicals

Chemical disinfection is a common method used in biomedical waste management, particularly for liquid waste. Chlorine is often utilized to eradicate pathogens and microorganisms by incorporating it into the liquid waste. Solid waste can also be chemically treated for disposal, although it is recommended to grind it beforehand for effective disinfection. Once decontaminated, liquid waste is typically discharged into the sewer system.

4. Microwaving

The waste is shredded into small pieces, mixed with water, and then heated internally to eliminate bacteria and other potentially hazardous substances. The shredding aspect of this process reduces the volume of biomedical waste and is considered to be more energy-efficient compared to incineration. This represents one of its primary advantages. Similar to autoclaving, this method can be applied to approximately 90% of biomedical wastes, although not all types.

Figure 8.4 demonstrates a complete process of managing biomedical waste.

Figure 8.4: Treatment and Disposal of Biomedical Waste

Source: IWMI

8.5 Summary

- Any garbage that contains infectious or possibly contagious elements is considered biomedical waste.
- The amount of medical waste produced in India each year is approximately three million tonnes, which is anticipated to increase by 8% yearly.
- Biomedical waste's infectivity and other toxicity are the first of its main hazards.
- Segregation of biomedical waste during collection is vital in proper treatment and disposal.
- In the autoclaving procedure, steam sterilisation is used. Autoclaving merely introduces scalding steam for a set time as opposed to expensive incineration.

- ❖ Chemical disinfection is a typical biomedical waste management technique for liquid waste.

8.6 Keywords

1. Biomedical waste: Any garbage that contains infectious or possibly contagious elements.
2. Pathological Waste: Human or animal body components, including tissues, bodily fluids, and blood.
3. Genotoxic waste: This includes poisonous substances.
4. Incineration: It is a process that safely eliminates bacteria while completely removing the trash.

8.7 Self-Assessment Questions

1. How would you define biomedical waste?
2. What are the critical hazards associated with biomedical waste?
3. Why is proper collection and disposal of biomedical waste important?
4. What examples of infectious or contagious elements may be present in biomedical waste?
5. What are the different types of biomedical waste commonly found in healthcare facilities?
6. Compare and contrast biomedical waste's infectivity and toxicity hazards.
7. Explain the process of autoclaving in the context of biomedical waste management, and discuss its advantages and limitations compared to incineration.
8. Describe the chemical disinfection process as a technique for managing liquid biomedical waste.
9. Discuss the potential environmental implications of improper biomedical waste management and the importance of adopting appropriate disposal practices.
10. What are the key benefits of using autoclaving instead of incineration for biomedical waste treatment?

8.8 Case Study

Introducing an effective biomedical waste management system in a nearby healthcare facility changed how medical waste was managed. The facility successfully separated waste categories, such as sharps, infectious materials, and medications, by introducing colour-coded bins, holding routine employee training, establishing designated storage spaces, and outfitting them with suitable containers to ensure safe containment and avoid leaks.

A licenced waste management business was recruited to handle the transportation and treatment of the garbage and guarantee adherence to environmental requirements. The institution lowered its environmental impact, decreased the risk of infection, and promoted a safer and healthier environment for patients, staff, and the community through this improved waste management system.

Questions:

1. Based on your reading, point out how colour-coded dustbins segregate waste.
2. Explain the methods used in the disposal of biomedical waste.
3. Mention the types of biomedical waste.

8.9 References

1. "Types of Biomedical Waste Disposal: BWS." BWS - Biomedical Waste Services
2. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
3. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
4. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.

Unit: 9

Non-Conventional Energy Sources

Learning Objectives:

- Learn about renewable sources of energy
- Understand their Potential
- Become aware of their use
- Get known to the possibilities

Structure:

9.1 Introduction

The term "conventional sources of energy" refers to sources naturally found on or beneath the Earth that take a long time to develop or replenish. These energy sources are typically non-renewable as well. Commercial and non-commercial energy sources comprise the second division of traditional energy sources.

Non-conventional sources of energy, also referred to as renewable sources of energy, are natural resources that may constantly provide helpful power for a long time and are still usable after they have been used up. Sunlight, wind, river flow, and the ocean are examples of non-conventional energy sources.

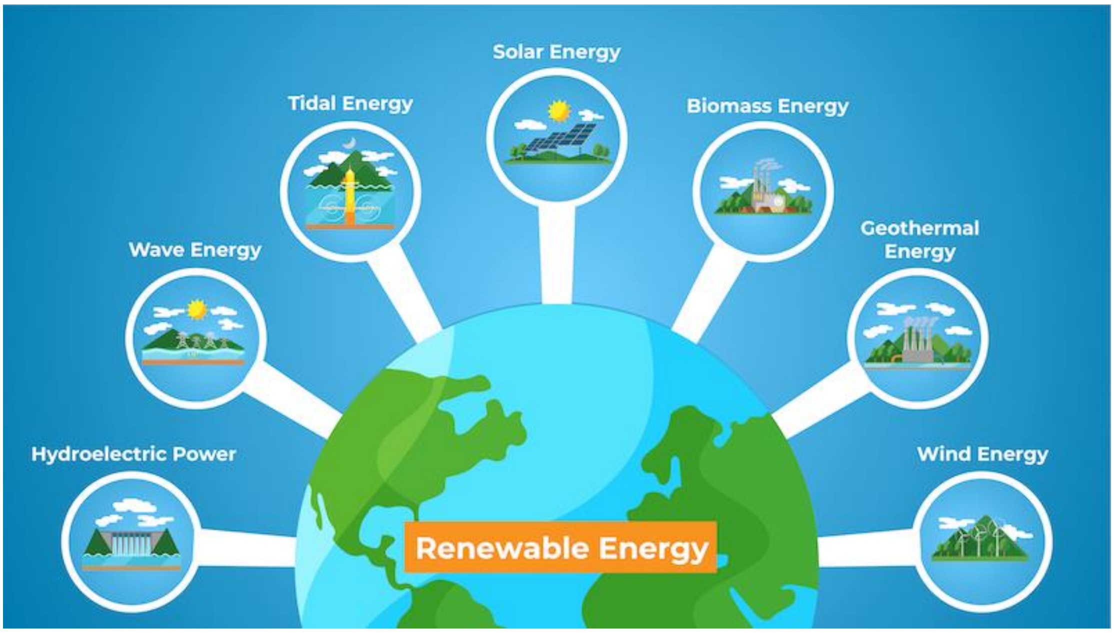

Figure 9.1: Renewable Energy Examples,(Source: Greenesa)

As energy demand rises, the population becomes increasingly dependent on fossil fuels like coal, oil, and gas. The necessity to ensure the energy supply for the future arises from the fact that the cost of petrol and oil is increasing with each passing day. The government of India has established a distinct department called the "Department of Non-Conventional Sources of Energy" for the efficient use of non-conventional sources.

9.1.1 Difference between Conventional and Non-conventional Sources of Energy

Conventional sources of energy	**Non-conventional sources of energy**
Fossil fuel, CNG, coal, oil, and natural gas are conventional energy sources.	Solar Energy, Wind Energy, Bio Energy, Hydro Energy, Tidal Energy, and Ocean Energy are examples of non-conventional energy resources.
Conventional sources of energy are non-renewable by any natural process.	Non-conventional energy resources are renewable.
These resources are available in a limited quantity.	Non-conventional energy sources are eco-friendly.
Conventional resources can also be classified as commercial and non-commercial energy resources.	Non-conventional energy sources do not increase pollution.

9.1.2 Renewable Sources of Energy: Types

1. Solar Energy

It is the energy generated by the Sun. It is created inside the Sun due to nuclear fusion and fission. Electromagnetic waves are radiation that this energy takes to travel. Some photovoltaic cell panels that gather this energy use it to generate power for household appliances by absorbing solar energy. The water in the solar heater is heated using solar heating panels.

2. Wind Energy

The mechanism by which wind is used to produce power is known as wind energy. Power output rises with increasing wind up to the maximum output of the specific turbine. Wind farms favour locations with more robust, more consistent winds. These are typically found at elevations above sea level. Wind turbines use the wind to produce power. Since no fossil fuels are burned to produce energy, there is no pollution.

3. Tidal Energy

Tidal power is a type of hydropower that produces electricity by utilising the energy of tides. Tidal power produces electricity in regions where the sea has waves and tides. India may implement "ocean thermal level conversion," enabling it to create 50,000mW of electricity to meet the demand.

4. Geothermal Energy

“The heat energy from hot rocks in the planet's crust is known as geothermal energy”. Therefore, greenhouse gases held in the earth are released by geothermal wells, but these emissions are far lower per energy unit than those from fossil fuels. Since this energy saves 80% on fossil fuels, it often has cheap operating expenses. The utilisation of geothermal energy has increased as a result. It does not produce pollutants and aids in mitigating global warming.

5. Biomass Energy

Organic material that comes from plants, animals, timber, and sewage is known as biomass. These materials burn to create heat energy, which is then converted into electrical energy. Additionally, cooking, lighting, and the creation of electricity are all possible with biomass energy. A valuable source of manure is the residue that remains after removing the biogas. More than 14% of the world's energy is produced by biomass, making it a significant energy source.

6. Hydro Energy

Rivers in motion typically have access to this energy. To hold river water in a convenient area, a dam is constructed. By providing a restricted path for the flow, the potential energy contained in this stored water can be transformed into kinetic energy. As a result, a fast-moving water stream is created, which powers massive turbines to generate electricity.

9.2 Potential of India in Renewable Energy

One of the most critical factors in determining a country's economic development and welfare is power, that is, energy. For the Indian economy to thrive sustainably, a sufficient electricity sector must exist and be developed.

India is the world's third-largest renewable energy generator, with 136 GW of the 373 GW of total installed electricity capacity from renewable sources in 2021. In terms of installed hydroelectric power capacity, India is placed fifth. India had installed a utility-scale hydroelectric capacity of 45,699 MW as of the end of March 2020, or 12.35% of its total utility power production capacity.

9.2.1 Need for Renewable Energy in India

Due to the historical and ongoing continuous use of fossil fuels for most electricity generation globally, including in India, there is an increasing climate issue. Renewable energy can lessen the effects of climate change and improve energy security. The 21st century's peace strategy is renewable energy.

There are unstable non-renewable energy supplies due to regional conflicts and restrictions on the supplying countries. For instance, the two largest energy producers in the world, Iran and Russia, are subject to several international sanctions, which lowers the supply of energy products in global markets.

To encourage a green economy and sustainable development by lowering pollution's negative externalities.

India has pledged to increase its share of renewable energy capacity to 450 GW by 2030 as a signatory to the Paris Climate Agreement. Therefore, switching to renewable energy is required to uphold our obligations to the global community.

The Indian government has established ambitious objectives, including achieving net-zero carbon emissions by 2070, reducing the nation's projected carbon emissions by 1 billion tonnes by 2030, decreasing the carbon intensity of the economy by less than 45% by the decade's end, and increasing the installed capacity of renewable energy in India to 500 GW by 2030.

Using renewable energy sources to generate electricity:

The Indian government has established ambitious objectives, including achieving net-zero carbon emissions by 2070, reducing the nation's projected carbon emissions by 1 billion tonnes by 2030, decreasing the carbon intensity of the economy by less than 45% by the decade's end, and increasing the installed capacity of renewable energy in India to 500 GW by 2030.

1. Solar thermal power and PV power:

The electrical energy needed for localised usage in the outlying areas of India is predicted to be over 11,000 MW; a significant portion of this is anticipated to come from PV systems that are not connected to the grid. Solar thermal power and PV electricity. These devices may be placed as far up on rooftops to use no land space. Grid-connected PV power systems in India have a combined installed capacity of over 4101.68 MW despite their modest capabilities.

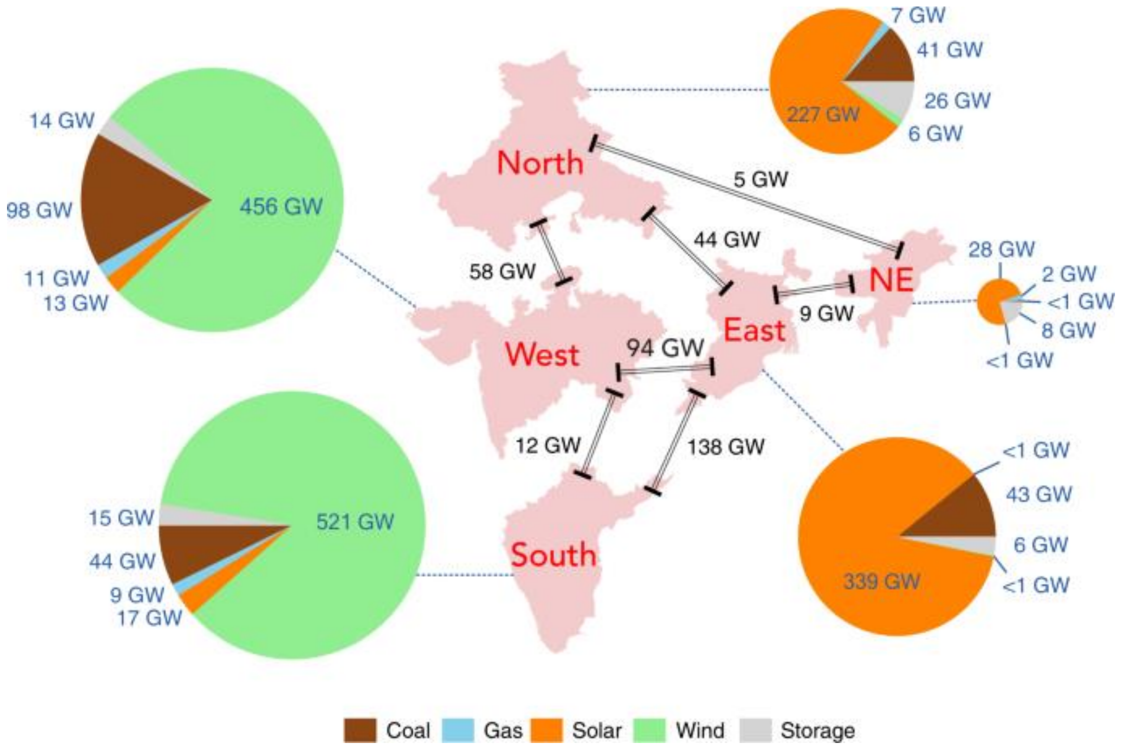

Figure 9.2: India's Potential in Solar and Wind Energy

Source: Nature

2. Water-based electricity

India has a lot of potential for producing hydroelectric electricity; it is now the sixth-largest hydroelectric power generator in the world. The majority of our nation's renewable energy comes from hydroelectric power projects. They also offer water for drinking, agriculture, flood control, and electricity production. India has enormous hydro potential, which may be economically utilised, amounting to around 84,000 MW at a 60% load factor. In India, about 49 sizable hydropower projects with a combined installed capacity of 15,006 MW are currently being built. Additionally, pumped storage projects with a combined installed capacity of 94,000 MW and small, mini, and micro hydel schemes with a potential installed capacity of 6,740 MW have been discovered.

3. Wind Energy

Wind energy has much potential in India as a viable alternative energy source. Wind turbines can transform the wind's kinetic energy into mechanical energy, which can then be used to create electricity. Using the wind's energy to rotate rotors with blades like propellers, a generator can be spun to generate electricity when the generator is connected to the main shaft. Because the wind speeds offshore are typically more significant and more consistent, preliminary evaluations throughout the 7,600 km long Indian coastline have revealed promise for the development of offshore wind power.

4. Biomass Energy

Over 70% of the nation's population relies on biomass, making it a significant alternative energy source. The most effective way to use biomass fuels is to employ a combined heat and power (or cogeneration) system to produce heat and electricity. For supplying power to the grid, 288 biomass power and cogeneration projects of 2,665 MW capacity have been built in the nation.

5. Wave Energy

Because of how the wind interacts with the water's surface, wave energy available at the ocean's surface is indirectly derived from solar energy. Wave energy converters can harness wave energy for electricity production and practical tasks like water desalination or water pumping. India's 7,500 km coastline has a 40,000 MW wave energy potential.

6. Tidal Energy

The leading cause of short-term sea-level changes are tides, brought on by the interaction of the earth's rotation, the gravitational pull of the sun, and the moon. By building a reservoir behind a barrage and allowing tidal water to travel through turbines in the barrage, electrical energy can be collected from tides in many ways.

According to estimations, India has a potential for 8,000 MW of tidal energy.

7. Geothermal Energy

The thermal energy kept in the earth's interior is known as geothermal energy. In some locations, the ground naturally produces steam and hot water at high pressure and

temperatures, which can be used for energy generation, heating homes and businesses, greenhouses, and other local uses.
Estimates indicate that India possesses 10,600 MW of untapped geothermal energy potential, which must be realised.

By 2030, India's electricity demand is expected to reach 950,000 MW. Renewable energy sources, including solar, wind, and hydropower, could partly meet India's energy needs. If India abandons coal, oil, and natural gas, it is likely that by 2030, 70% of the country's electricity will come from renewable sources.

9.3 Summary

- ❖ The term "conventional sources of energy" refers to sources naturally found on or beneath the Earth that take a long time to develop or replenish.
- ❖ Non-conventional sources of energy, also referred to as renewable sources of energy, are natural resources that may constantly provide helpful power for a long time and are still usable after they have been used up.
- ❖ As energy demand rises, the population becomes increasingly dependent on fossil fuels like coal, oil, and gas.
- ❖ The mechanism by which wind is used to produce power is known as wind energy.
- ❖ More than 14% of the world's energy is produced by biomass, making it a significant energy source.
- ❖ India is the world's third-largest renewable energy generator, with 136 GW of the 373 GW of total installed electricity capacity from renewable sources in 2021.

9.4 Keywords

1. Geothermal Energy: The heat energy from hot rocks in the planet's crust is known as geothermal energy.
2. Biomass: Organic material from plants, animals, timber, and sewage is known as biomass.
3. Wind Energy: The mechanism by which wind is used to produce power is known as wind energy.
4. Conventional energy sources refer to sources naturally found on or beneath the Earth that take a long time to develop or replenish.

5. Non-conventional energy sources: These refer to renewable energy sources, natural resources that may constantly provide helpful power for a long time.

9.5 Self-Assessment Questions

1. Name two renewable sources of energy commonly used today and briefly describe their sustainability.
2. Compare and contrast solar and wind power's economic viability and scalability as renewable energy sources.
3. What are some of the renewable energy resources available in India, and why is the country well-suited for their utilisation?
4. Discuss the government's initiatives and policies to harness the potential of renewable energy resources in India.
5. Explain India’s potential in Geothermal Energy in brief.
6. Compare and contrast the advantages and limitations of biomass and geothermal energy as renewable energy sources.
7. Evaluate the potential of tidal energy as a reliable and scalable renewable energy source, considering its advantages and technological challenges.
8. Assess the potential of offshore wind energy in India, considering factors such as resource availability, technological feasibility, and policy support required for its development.
9. What is India’s current status in renewable energy sources?
10. What is biomass energy?

9.6 Case Study

India relishes enough sunlight all year, making solar energy a perfect renewable resource. The Jawaharlal Nehru National Solar Mission is just one of the programmes and policies the Indian government has put in place to encourage the use of solar energy. Due to this, India's solar power capacity has significantly increased, with large-scale solar parks and rooftop solar systems becoming more prevalent. In addition to lowering the nation's reliance on fossil fuels, this renewable energy source aids in reducing global warming and advancing sustainable development.

Questions:

1. What is one significant advantage of solar power as a renewable energy source in India?
2. How has the government of India contributed to the growth of solar power generation in the country?
3. What are some of the visible impacts of the increased adoption of solar power in India?

9.7 References

1. Lekha Chandran, The Potential Of Renewable Energy Sources In The Energy Sector In India, 2015.
2. “Renewable Energy in India.” Civilsdaily, 27 Aug. 2022
3. Agarwal Shikha, Suesh Sahu, Environmental Engineering and Disaster Management, Dhanpat Rai & Co., 2010
4. Brunner R.C., Hazardous Waste Incineration, McGraw Hill Inc. 1989.
5. Cunningham, W.P, Cooper, T.H. Gorhani, E & Hepworth, M.T., Environmental Encyclopedia, Jaico Publishing House, Mumbai, 2001.