ALL U.G. COURSES

ENVIRONMENTAL SCIENCE : THEORY INTO PRACTICE-I

ABILITY ENHANCEMENT COURSE (AEC)
SEMESTER - I/II COURSE CREDIT-2

AS PER THE UGCF-2022 AND NATIONAL EDUCATION POLICY 2020

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Syllabus

Environmental Science: Theory into Practice I

Syllabus	Mapping
Unit - I: Introduction to Environmental Studies Multidisciplinary nature of environmental studies; components of environment: atmosphere, hydrosphere, lithosphere, and biosphere. Scope and importance; Concept of sustainability and sustainable development; Brief history of environmentalism.	**Lesson 1:** Introduction to Environmental Studies **(Pages 1–21)**
Unit - II: Ecosystems Definition and concept of Ecosystem. Structure of ecosystem (biotic and abiotic components); Functions of Ecosystem: Physical (energy flow), Biological (food chains, food web, ecological succession), and Biogeochemical (nutrient cycling) processes. Concepts of productivity, ecological pyramids and homeostasis.	**Lesson 2:** Ecosystem: Concept, Structure, Pyramids and Succession **(Pages 22–40)** **Lesson 3:** Ecosystem: Biogeochemical Cycles, Functions, Energy Flow and Productivity **(Pages 41–60)** **Lesson 4:** Ecosystem: Types and Services **(Pages 61–75)**
Unit - III: Natural Resources Land resources: Minerals, soil, agricultural crops, natural forest products, medicinal plants, and forest-based industries and livelihoods; Land cover, land use change, land degradation, soil erosion, and desertification; Causes of deforestation; Impacts of mining and dam building on environment, forests, biodiversity, and tribal communities. Water resources: Natural and man-made sources; Uses of water; Over exploitation of surface and ground water resources; Floods, droughts, and international & interstate conflicts over water. Energy resources: Renewable and non-renewable energy sources; Use of alternate energy sources; Growing energy needs; Energy contents of coal, petroleum, natural gas and bio gas; Agro-residues as a biomass energy source. Case studies: Contemporary Indian issues related to mining, dams, forests, energy, etc (e.g., National Solar Mission, Cauvery river water conflict, Sardar Sarovar dam, Chipko movement, Appiko movement, Tarun Bharat Sangh, etc).	**Lesson 5:** Natural Resources: Land Resources **(Pages 76–93)** **Lesson 6:** Natural Resources: Water Resources **(Pages 94–109)** **Lesson 7:** Natural Resources: Energy Resources **(Pages 110–135)**

Unit - IV: Environmental Pollution

Environmental pollution (Air, water, soil, thermal, and noise): causes, effects, and controls; Primary and secondary air pollutants; Air and water quality standards.

Nuclear hazards and human health risks.

Solid waste management: Control measures for various types of urban, industrial waste, Hazardous waste, E-waste, etc; Waste segregation and disposal.

Pollution case studies: Ganga Action plan (GAP), Delhi air pollution and public health issues, Plastic waste management rules, Bhopal gas tragedy, etc.

Contents

LESSON

1

Introduction to Environmental Studies

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STRUCTURE

1.1 Learning Objectives

- Make the reader aware of the environment, its importance and its basic components.
- Develop an understanding of the concept, scope and importance of the discipline of Environmental Studies.
- Discuss the concept and necessity of a multidisciplinary approach to the subject.

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- Be aware of the historic milestones of environmentalism and environmental education.
- Make the readers know about the origin of the concept of 'Sustainability' and 'Sustainable Development'.

1.2 Introduction

The term Environment is derived from the French word *'Environ'* which literally means 'surrounding'. Anything and everything which surrounds us i.e. all living beings or biotic components (microbes, plants and animals) and non-living or abiotic components (air, water, sunlight etc.) present in nature, form the environment. The Environmental Protection Act, of 1986 defines the Environment as "environment includes water, air and land and the inter-relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organism and property". Interactions between the biotic and abiotic components lead to a functional ecosystem and sustainable life on the planet earth. We get all the basic goods and services (clean air and water, food, fodder, medicines, raw materials for industries, tourism etc.) from the environment. It is a well-known fact that anthropogenic activities and unsustainable consumption of natural resources by the human race have significantly damaged the environment and mother earth and the degradation is still going on at a fast pace. Therefore, it is our responsibility to protect the environment from getting degraded and polluted. Environmental education is indispensable to creating environmental awareness which ultimately will lead to environmental conservation.

1.3 Components of Environment

Planet earth is the only known planet in the universe with a diversity of life. As earlier mentioned, life could have been possible on the planet only because of the healthy interactions between biotic and abiotic components in such a manner where the flow of energy and biogeochemical cycle follows a well-defined path. The planet earth is categorized into different spheres which represent solid (rock/soil), liquid (water) and gaseous (air)

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phases. The overlapping zone of the three spheres, where life is available, is called the biosphere. A brief description of the spheres is given below:

1.3.1 *Lithosphere*

(Greek: *Lithos* means rock) Earth's structure can be stratified into outer crust, middle mantle and inner core regions (Figure 1.1). Lithosphere is the outermost layer of the crust which represents the land mass of the planet. It consists of rocks, soil, sediments and minerals. Various geological structures or landforms like high mountains, plateaus, deep valleys and sea beds make the surface of the lithosphere uneven. Mount Everest is the highest point in the lithosphere. Various geological processes like weathering & erosion, volcanic eruptions, and biogeochemical cycles take place in the lithosphere. Different terrestrial ecosystems like forests, grasslands, deserts etc. are found in the lithosphere.

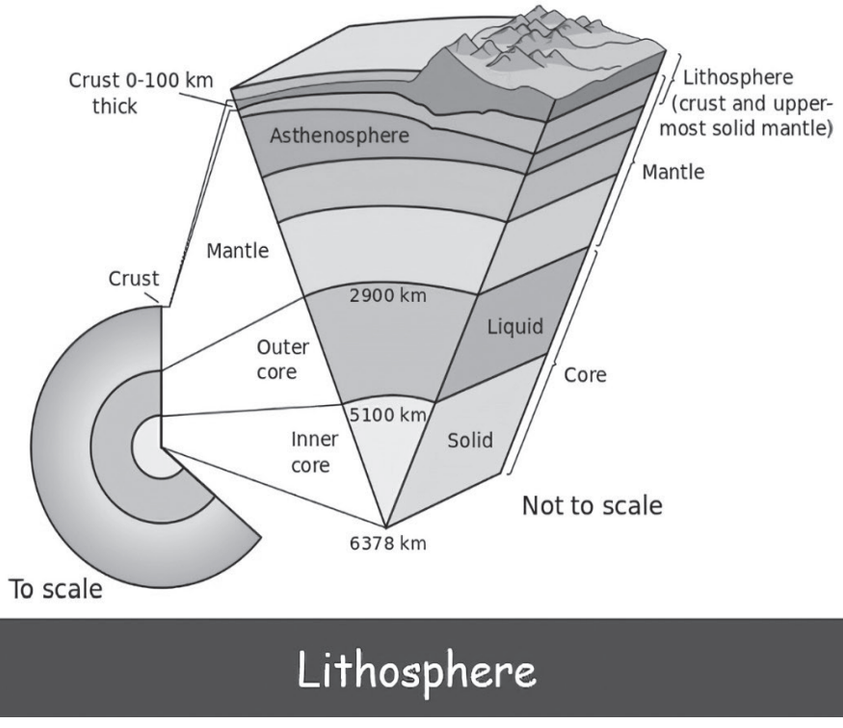

Figure 1.1: Cross section of Lithosphere

(Source: https://www.nationalgeographic.org/encyclopedia/lithosphere/)

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ACTIVITY

Take some time to think about the environmental damage you may have caused in the past day, week, or year as a result of your actions. You should then calculate how much destruction you will bring upon the planet during your lifetime if you keep doing what you're doing now.

1.3.2 *Hydrosphere*

(Greek: *Hydro* means water) Hydrosphere represents water masses on the planet present in solid (ice cover, glaciers etc.), liquid (water bodies) and gaseous (water vapours) phases. Hydrosphere covers almost three-fourths of the total surface area of the earth. Oceans and seas represent marine ecosystem which contains 97 per cent of the total water content (having a very high concentration of salts) of the planet. The remaining 3 per cent of the water resources are freshwater present in the form of glaciers, rivers, lakes, ponds etc. (Figure 1.2). The hydrosphere is an integral part of the water cycle and plays a crucial role in maintaining normal climatic, meteorological, physical, chemical and biological functions on the planet. Oceans and seas are the largest sinks of carbon in the environment.

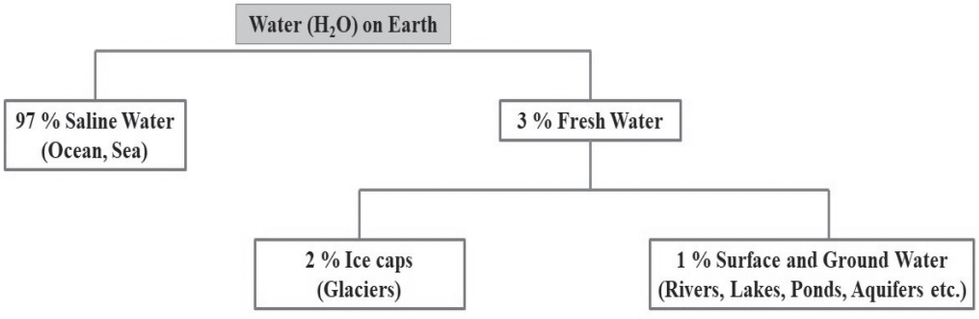

Figure 1.2: Distribution of Water Resources on the Earth

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1.3.3 *Atmosphere*

The (Greek: *Atmos* means vapour) thin sheet of gaseous mixture which envelops the planet earth is called the atmosphere. The content of water vapour, the density of the air mass and atmospheric pressure decrease rapidly with the increase in altitude. The composition of dry air is as follows:

Table 1.1: Composition of dry air

Component	Volume (%)
Nitrogen	78.084
Oxygen	20.946
Argon	0.934
Carbon Dioxide	0.040
Gases in traces	Remaining

The rate of change of temperature with the altitude is called the lapse rate. The atmosphere has been stratified into major four layers where temperature decreases (negative lapse rate) or increases (positive lapse rate). A brief description of atmospheric layers is as follows:

Troposphere: The altitude of this layer varies from 16 km at the equator to 8 km at the poles. The largest percentage of the air mass is found in this region. The upper layer is called the tropopause. Temperature decreases with an increase in altitude (–6.4°C per km) in this layer and varies from 15°C (ground Level) to – 56°C (tropopause).

Stratosphere: Temperature starts rising in this layer from tropopause (–56°C) to stratopause (–2°C) as ozone (O_3) layering the upper stratosphere absorbs solar radiation and temperature rises. The ozone layer in this region absorbs harmful UV radiation, particularly UV-B radiation (280 nm to 315 nm), because of which life is possible on the earth's surface. However, the ozone layer is depleting at a fast pace due to the presence of ozone-depleting substances (like chlorofluorocarbons - CFCs). Ozone holes are the places in the upper stratosphere where the concentration of ozone has depleted drastically.

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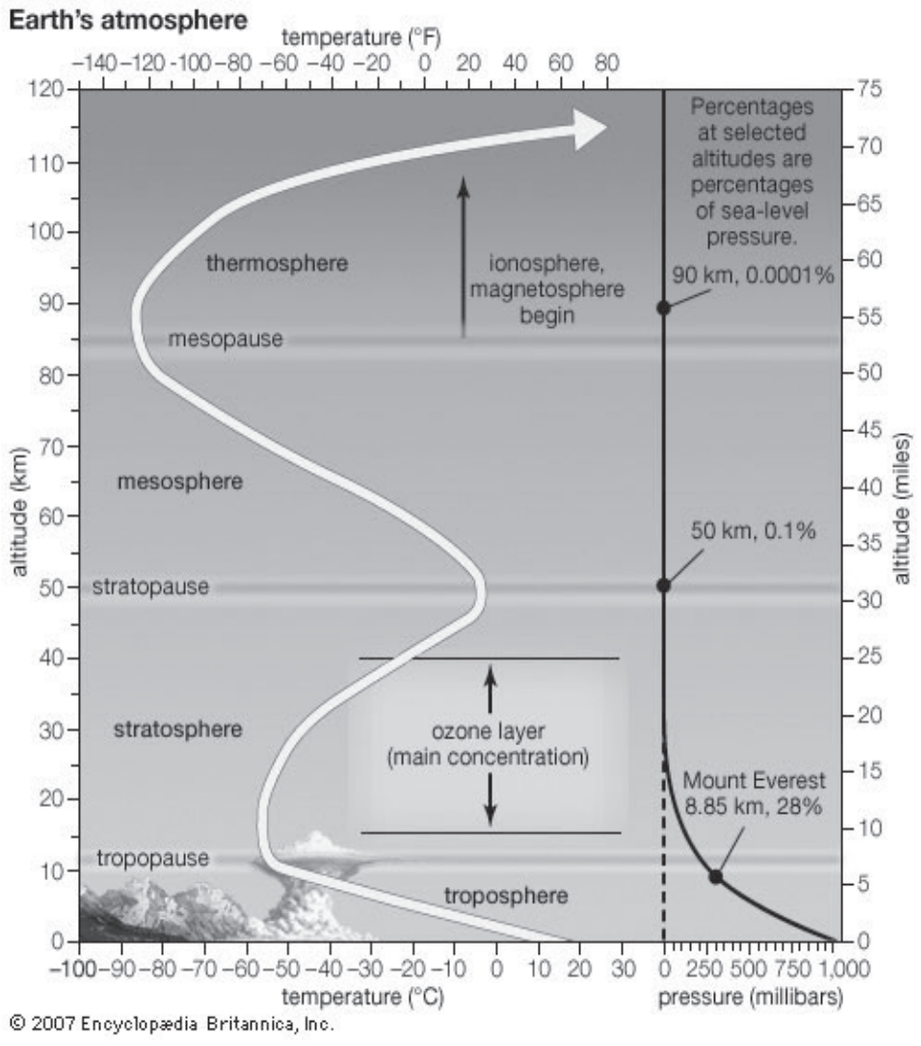

Figure 1.3: Layers of atmosphere and temperature change with latitude

(Source: Britannica Encyclopedia; https://www.britannica.com/science/ozone-layer)

Mesosphere: Temperature starts decreasing again and reaches –96°C at the upper boundary of the layer i.e. mesopause. The density of air is very low and important chemical species found in this region are O_2^+ and NO^+ which do not absorb much solar radiation. This causes the decline in ambient temperature in this region.

Thermosphere: Ionic oxygen atoms and other ions in this layer absorb short-wave solar radiation which increases the temperature in this layer rapidly from –96°C (lower boundary) to 1200°C (upper layer).

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Table 1.2: Layers of atmosphere and their composition

Layer	Altitude (km)	Temperature Variation (°C)	Prominent Chemical Species	Characteristics
Troposphere	0–11	15 to (–56)	N_2, O_2, Ar, CO_2, H_2O	Weather occurs
Stratosphere	11–50	(–56) to (–2)	O_3	Ozone Layer presence
Mesosphere	50–85	(–2) to (–96)	O_2^+, NO^+	Meteors burn in this layer
Thermosphere	85–500	(–96) to 1200	O_2^+, O^+, NO^+	Auroras occur here

(Source: Environmental Chemistry by A K Dey)

Earth's environmental spheres

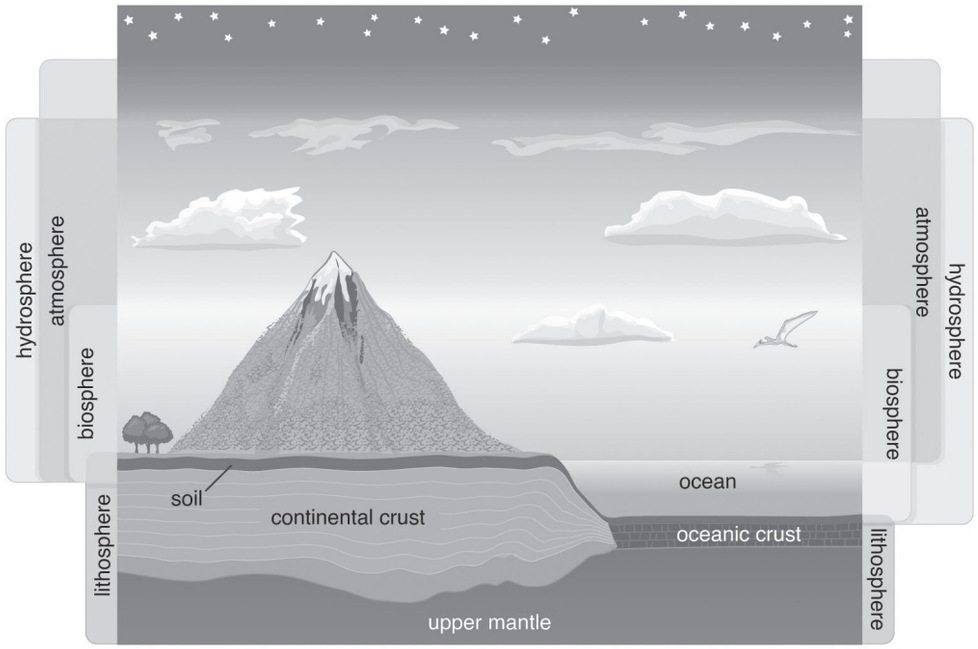

Figure 1.4: Biosphere

(Source: Britannica Encyclopedia https://www.britannica.com/science/biosphere)

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1.3.4 *Biosphere*

(Greek: *Bios* means life) this is the self-regulating overlapping region of the atmosphere, lithosphere and hydrosphere in the environment where life sustainably exists and is nourished and flourishes by the healthy interaction between biotic (autotrophs and heterotrophs) and abiotic components (air, water, sunlight, soil, rock etc.) of the nature.

IN-TEXT QUESTIONS

1. The lowest layer of the atmosphere is _____.
2. The hydrosphere is the layer of gases surrounding to earth. (True/False)
3. Combination of Lithosphere, Hydrosphere and Atmosphere forms:
   (a) Biosphere
   (b) Troposphere
   (c) Exosphere
   (d) Core
4. The core of Earth is the part of Biosphere. (True/False)
5. The rate of change of temperature with the altitude is called _____.

1.4 Environmental Education

In the second half of the twentieth century, global concerns were raised to make people environmentally aware. This was the time when it was recommended to design separate courses for environmental education and establish an independent and multidisciplinary discipline, commonly called Environmental Science or Studies. According to UNESCO (1971), the objectives of environmental studies are:

- Creating awareness about environmental problems among people.
- Imparting basic knowledge about the environment and its allied problems.
- Developing an attitude of concern for the environment.

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- Motivating the public to participate in environmental protection and environmental improvement.
- Acquiring skills to help the concerned individuals in identifying and solving environmental problems.
- Striving to attain harmony with Nature.

UNESCO and UNEP jointly organized the first intergovernmental conference on environmental education in 1977 in Tbilisi, Georgia. The goals of the conference were:

- To foster clear awareness of and concern about, economic, social, political, and ecological interdependence in urban and rural areas;
- To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment;
- To create new patterns of behaviour of individuals, groups, and society as a whole towards the environment.

The categories of environmental education objectives are:

- **Awareness:** To help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.
- **Knowledge:** To help social groups and individuals gain a variety of experiences, and acquire a basic understanding of, the environment and its associated problems.
- **Attitudes:** To help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
- **Skills:** To help social groups and individuals acquire the skills for identifying and solving environmental problems.
- **Participation:** To provide social groups and individuals with an opportunity to be actively involved at all levels in working toward the resolution of environmental problems.

Environmental Education in India: India also started taking significant steps to propagate environmental education. At the post-graduation level, environmental education was started by many central and state universities

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in India during 1985-2000. In 1991, Hon. Supreme Court of India gave a historical ruling to implement environmental education at all levels and gave directions to make Environmental Studies a compulsory paper for all the streams at undergraduate levels in Indian universities. At present, various short-term and regular courses on the environment and its various dimensions are being run in various universities in India.

1.5 Difference between Environmental Science and Environmental Studies

Environmental Studies: Environmental study is a multidisciplinary subject which studies various dimensions (scientific, social, cultural, economic, political etc.) of the environment, its issues and challenges and tangible solutions in a holistic way. It studies the human-environment interaction and its results at the micro and macro level.

Environmental Science: It strictly deals with the scientific aspects of the environment, its complex problems and the tangible solutions whereas Environmental Studies, in addition to the scientific aspects, also deals with the socio-economic, cultural, traditional, legislative and historical dimensions of the environmental issues. For example, suppose a river is getting polluted due to the discharge of untreated wastewater into the river. The student of Environmental Science will observe the causes, Physicochemical and biological changes within the river water, its effect on the aquatic and adjoining ecosystem and scientific mitigation measures for the river pollution. In addition to the above dimensions, Environmental Studies will also observe the impact of the pollution on the nearby population, their livelihood and culture etc.

1.6 Multi-Disciplinary Nature of Environmental Studies

Multidisciplinary means interaction of various subjects or disciplines. Environmental studies deal with all the aspects of biotic and abiotic components of the environment. Also, the Environment and environmental issues are complex in nature. Therefore, experts from different subjects or disciplines are required to understand different aspects of the environment. We may require expertise from different disciplines to resolve various environmental issues.

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The Multidisciplinary Nature of Environmental Studies may be understood by a small case study. Suppose a developmental activity (Dam, Mining, Highway etc.) is proposed within a given region. Before starting such projects, an Environmental Impact Assessment (EIA) is conducted to assess and mitigate the possible degradation of the environment and population living within the region. To effectively conduct the EIA, expertise from the following disciplines will be required:

- **Life Sciences (Zoology and Botany):** To assess the biodiversity richness and endemism of the given region and possible reversible or irreversible changes in the biological diversity of the region by anthropogenic activities. An expert from life sciences will also assess the ecosystem goods and services being provided by the nature in the specific region.
- **Earth Sciences (Geology, Geography, Geochemistry etc.):** Earth Sciences will study the details of geological and geographical terrain, soil/rock profile, tectonic and seismic activity in the region etc.
- **Chemical Sciences:** It will be helpful in understanding various chemical processes and reactions taking place in different matrices of the environment. It is also important to understand the fate and effect of pollutants on air, water, and soil.
- **Anthropology, History and Archaeology:** To assess the historical or archaeological importance of the monuments, tribal population, traditions or practices in a region or at the site of the construction.
- **Social Sciences, Sociology and Economics:** To assess the socio-economic stature of the population and possible changes the same with ongoing developmental projects.
- **Law and Legal Aspects:** Expertise from a legal background is also required to satisfy different legal aspects during a developmental project activity (like land acquisition, relocation and rehabilitation etc.).
- **Mathematics, Computer Modelling and Statistics:** We need different statistical tools and models to statistically validate the obtained data from the study. Also, we are using numerous mathematical and computational models in day-to-day activities like meteorological predictions.

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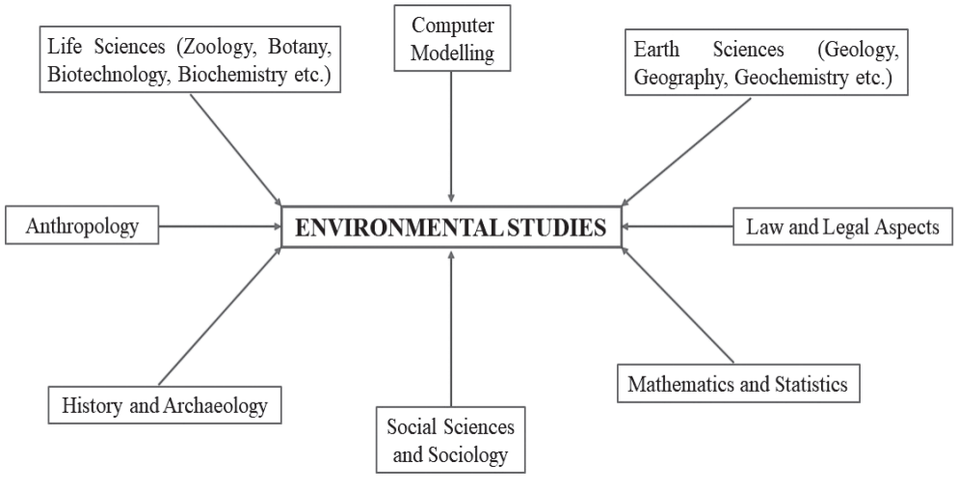

Figure 1.5: Multidisciplinary Nature of Environmental Studies

1.7 Scope and Importance of Environmental Studies

The multidisciplinary approach to the subject can be implemented in a wide range of applications and fields related to environmental awareness, education and conservation. Hence, the subject has a vast scope and the expert on the subject can serve in numerous ways in different spheres of society. Students may opt for the subject and make a professional career in Environmental Studies or Environmental Science. The experts and professionals of the subject are required and recruited in various sectors like:

- **Academics:** As discussed above, the subject has been introduced in numerous schools, colleges and universities in India and abroad, at school, under-graduation and post-graduation levels. The student may pursue the subject. Worldwide, a large number of dedicated departments, centres, universities and institutions have been established for the subject. An interested professional may join the teaching and academics and make the next generation aware of environmental issues and their tangible solutions. Many dedicated institutes, like WII Dehradun, FRI Dehradun, IIFM Bhopal etc., have been established to propagate education in specialized fields of the environment.
- **Research & Development:** Research and post-doctoral works have been going on worldwide to understand the ecological mechanisms

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and to get cost-effective cutting-edge technologies to mitigate environmental issues and challenges.

- **Industries:** In order to effectively implement the environmental guidelines and technologies and to mitigate the environmental degradation directly or indirectly caused by the industries, a large number of industries have been recruiting environmental engineers/ scientists/experts.
- **Ministries and Agencies:** Ministry of environment and various environmental agencies & conventions of national and international repute frequently create vacancies for environmental experts. A few examples of such agencies are UNEP, IPCC, CITES, RAMSAR, USEPA etc.
- **Non-governmental Organizations (NGOs) and Consultancy:** A large number of national and international NGOs and consultancies are working as an extended hand to conserve the environment and its various components. Most of the NGOs and consultancies are old and have an experienced workforce. Some of the examples are the Bombay Natural History Society, IUCN, Conservation International, World Wide Fund for Nature, Wildlife Trust of India, Centre for Environmental Education, Centre for Science and Environment, Kalpavriksha, Madras Crocodile Bank Trust etc.
- **Green Journalism:** Environmental awareness is indispensable for environmental conservation and media (print, electronic and social media) is the strongest medium to propagate the awareness. Green journalism is the term given when the media raises environmental issues and practical solutions suggested by experts on the subject.
- **Environmental legislation and Green Advocacy:** For effective environmental conservation, it is indispensable to have stringent legislative provisions and effective implementation of the same. Legal experts specialized in environmental law may act significantly in environmental conservation.

In the last five decades, Environmental Studies or Environmental Science has emerged as an important multidisciplinary subject dealing with all the aspects of issues and challenges of the environment and it also suggests practical solutions to environmental problems. The subject is

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still evolving as environmental problems are also growing in intensity and magnitude at a fast pace. Anthropogenic activities have created the issues like pollution caused by conventional and emerging pollutants, biodiversity loss, global warming-climate change, growing global energy demands, utmost pressure on natural resources etc., which are causing serious threats to life on the planet. Environmental Studies have given tangible solutions to the environmental problems. Some of the prominent fields, that the subject addresses may be summarized as Environmental Education and Ethics, Ecosystem and ecology, Natural Resources Management, Energy Efficiency and Audit, Renewable sources of energy, Global warming-climate change, Biodiversity Conservation, Pollution monitoring and mitigation, Population and Environment, Waste management etc. Hence, it is necessary to make the newer generations aware of the basics and details of the subject.

Resource Conservation advocated by Mahatma Gandhi

The importance of resource conservation was an issue that Mahatma Gandhi thought deeply about. He pioneered the idea that "*Earth provides enough to satisfy every man's needs, but not every man's greed*." at a time when few people understood how quickly the world's resources would be depleted. Most people at the time believed that the Earth's natural resources were infinite. Consequently, this was a novel idea that called for a radically different way of life. Gandhiji advocated for a minimalist lifestyle as a way to preserve the planet's limited resources.

1.8 Important Landmarks In Environmentalism

In the western world, the first-ever concern about environmental degradation was raised after the publication of the book '*Silent Spring*' by Rachael Carson in 1962. This book raised the issue of excessive use of chemical fertilizers and pesticides in the U.S. and its impact on different biotic and abiotic components of the environment. In 1970, the book '*Limit to Growth*' by the Club of Rome attracted global attention. Ramsar Convention came into existence on 02nd February 1971 with the aim to conserve wetlands globally. Hence, **World Wetlands Day** is observed every year on **02nd February**. In 1972, United Nations Conference on

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Human Environment was organized in Stockholm between 5th June – 16th June where India also presented its view on environmental degradation. In remembrance of this conference, **World Environment Day** is celebrated every year on **05th June**. India started Project Tiger in 1973 to save its national animal of India. In between, India and the world witnessed the worst industrial disasters, **Bhopal Gas Tragedy (02nd and 03rd December 1984) and Chernobyl Nuclear Disaster (26th April 1986)**, which taught many lessons to the globe. Vienna Convention (1985) and Montreal Protocol (16th September 1987) were signed to protect the Ozone layer from getting depleted by Ozone-Depleting Substances (ODS). The concept of **Sustainable Development** was introduced to the world by **Brundtland Commission Report (*Our Common Future*)** in 1987. Intergovernmental Panel on Climate Change (IPCC) came into the existence in 1989 to formulate the framework to combat global warming-climate change. Agenda 21 was adopted at the Earth Summit in Rio de Janeiro in 1992. UN trio sister conventions (UNFCCC, UNCBD and UNCCD) were also signed in 1992. In 1997, Kyoto Protocol was signed to curb the emission of greenhouse gases responsible for global warming. The World Summit on Sustainable Development (Rio $^{+10}$) was conducted in 2002 in Johannesburg.

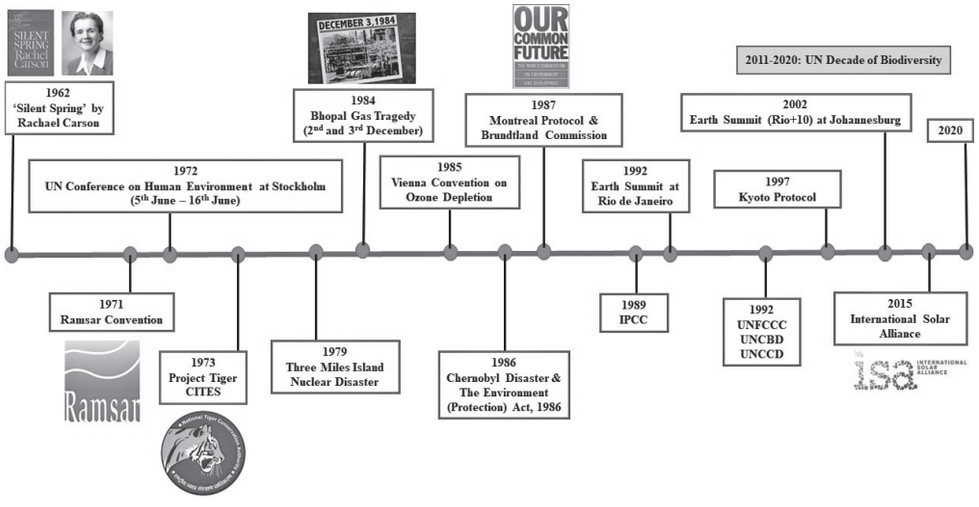

Figure 1.6: Important Milestones in the history of Environmentalism

The Govt. of India took the initiative to form the International Solar Alliance (30 November 2015; headquartered at Gurugram, India) during

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the famous Paris convention of UNFCC, in order to motivate the tropical and sub-tropical countries to maximize the use of solar energy instead of the conventional sources of energy. A large number of organizations of national and international repute, working in the field of environmental awareness, education and conservation have also been established in the last century.

IN-TEXT QUESTIONS

6. Who was the author of "Silent Spring"?

7. Ramsar Convention is related to

(a) Wetlands

(b) Ozone

(c) E-Waste

(d) Pesticides

8. World Environment Day is celebrated on _____ of every year.

9. In which year did Bhopal Gas Tragedy happen?

(a) 1984

(b) 1982

(c) 1972

(d) 1994

10. Brundtland Commission's report was named as _____.

1.9 Concept of Sustainability and Sustainable Development

It was the global perception that environmental conservation and economic development cannot be pursued together. With the onset of the 1980s, the world started finding the middle path so that long-term economic development may be pursued without harming the environment. With this aim, the United Nations established World Commission on Environment and Development (WCED), under the chairmanship of Geo Harlem Brundtland (former Prime Minister of Norway) in December 1983. Hence, this

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commission is commonly known as the Brundtland Commission. The task of the commission was to formulate "A global agenda for change". Brundtland Commission submitted its report entitled "Our Common Future" in 1987 which gave the concept of Sustainable Development to the world. The report defines Sustainable Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainability (Latin: *sustinere* means to hold up) is a long-term idea that means making the entire world sustainable. However, sustainable development refers to pathways by which the goal of sustainability and a sustainable world can be achieved.

Sustainable Development Goals (SDGs): these are the seventeen goals set as the '2030 agenda for sustainable development. It was adopted by the United Nations state members in 2015 as a blueprint for peace and prosperity for people and the planet, now and into the future.' All the developed and developing countries have been called to achieve the goals by the global partnership.

Society, environment and economy, are collectively considered the three pillars of sustainable development. When the three pillars harmonically interact with each other, sustainability and sustainable development is achieved. A brief description of the three pillars is given below:

- **Environmental Sustainability:** It means that we should consume environmental goods and services in a sustainable manner. Mahatma Gandhi, once rightly said, "Earth provides enough to satisfy every man's need but not everyone's greed". The present rate of over-exploitation of natural resources exceeds manifolds the rate of replenishment of the same, which is causing environmental degradation at an exponential rate. Therefore, natural resources should be utilized sustainably. Sustainable Development Goals 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 13 (Climate Action), 14 (Life below Water) and 15 (Life on Land) indicate environmental sustainability.
- **Social Sustainability:** It defines a society as having fair and equal opportunities for its population with gender equality, good health

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and education facilities and people's participation in nation-building. Sustainable Development Goals 3 (Good Health and Well-Being), 4 (Quality Education), 5 (Gender Equality), 7 (Affordable and Clean Energy), 16 (Peace, Justice and Strong Institutions) and 17 (Partnerships for the Goals) indicate social sustainability.

- **Economic Sustainability:** Economic sustainability means the equitable distribution of resources. No one should be deprived of the basic needs to sustain a healthy life. Benefits should be earned from the resources but not at the cost of irreversible loss to the environment. Sustainable Development Goals 1 (No Poverty), 2 (Zero Hunger), 7 (Affordable and Clean Energy), 8 (Descent Work and Economic Growth), 9 (Industry, Innovation and Infrastructure), 10 (Reduced Inequalities), 11 (Sustainable Cities and Communities) and 12 (Responsible Consumption and Production) indicates economic sustainability.

The three pillars intersect each other giving the concept of a bearable, equitable and viable globe, which collectively forms a sustainable world.

- **Social Sustainability + Economic Sustainability = Equitable**
- **Social Sustainability + Environmental Sustainability = Bearable**
- **Economical Sustainability + Environmental Sustainability = Viable**
- **(Social + Economical + Environmental) Sustainability = Sustainable Development**

IN-TEXT QUESTIONS

11. Sustainable Development Goal 1 is for "No Poverty". (True/ False)

12. Three Pillars of Sustainable Development are: _____.

13. Sustainable Development Goal 5 is for _____.

14. Zero Hunger is mentioned in Sustainable Development Goal _____.

15. Sustainable Development Goal 11 is for _____.

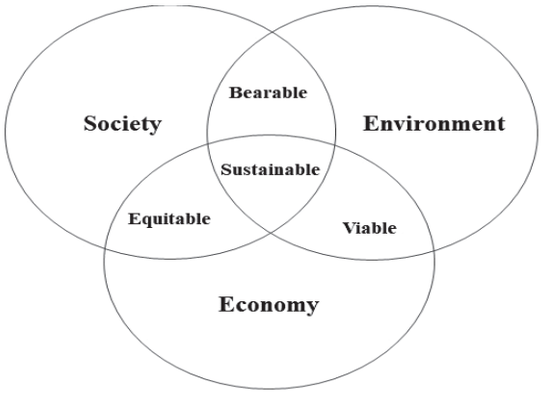

Figure 1.7: Venn Diagram of Pillars of Sustainable Development

Figure 1.8: Sustainable Development Goals

(Source: https://www.un.org/sustainabledevelopment/blog/2015/12 /sustainable-development-goals-kick-off-with-start-of-new-year/)

1.10 Summary

Nature supports life. Man must realise the value of the environment and help to maintain it healthy and productive. The environment gave him this wonderful world. Before industrialization, urbanisation, and population increase, mankind's natural environment was healthy and robust.

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Nature refilled its scarce supplies. After modern civilization began, the health and efficiency of the natural environment began to deteriorate, to the point that nature has lost its potential to restore man-made resource losses. Environmentalists, geographers, and biologists worldwide work to restore a sustainable ecosystem. Environmental management, pollution regulations, recycling of non-biodegradable material, etc., require more attention. Present-day sustainability in nature requires careful utilisation of natural resources. Modern environmental concepts like biodiversity conservation and ecological balance require more discussion. Environmental studies educate us to utilise natural resources more effectively and live sustainably. It reveals the natural behaviour of organisms and their population and community interactions.

1.11 Answers to In-Text Questions

1. Troposphere

2. False

3. *(a)* Biosphere

4. False

5. Lapse Rate

6. Rachel Carson

7. *(a)* Wetlands

8. 5th June

9. *(a)* 1984

10. Our Common Future

11. True

12. Society, Environment and Economy

13. Gender Equality

14. 2

15. Sustainable Cities and Communities

Notes

1.12 Self-Assessment Questions

1. What do you understand by the multidisciplinary nature of Environmental Studies? How does the multidisciplinary approach help to solve various environmental problems?
2. Describe the various components of the atmosphere.
3. Discuss important landmarks in the history of environmentalism in the World.
4. Discuss Sustainable Development. Write a short note on Sustainable Development Goals.
5. Define sustainable development, lithosphere, hydrosphere and biosphere.

1.13 References

- Dey, A. K. (1990). *Environmental Chemistry*. Wiley Eastern Ltd.
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1.14 Suggested Readings

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LESSON

2

Ecosystem: Concept, Structure, Pyramids and Succession

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STRUCTURE

2.1 Learning Objectives

- Know the concept, definition and structure of the ecosystem.
- Distinguish between biotic and abiotic components of the ecosystem.
- Understand the role of interaction among biotic and abiotic components.
- Explain the different types of ecological pyramids.
- Understand the term ecological succession.

Notes

2.2 Introduction

We are not alone in this world. We share our resources with other life forms. There are non-living things around us as well. Throughout our lifetime we keep on interacting with other living beings and non-living things and act as part of ecosystems. The study of the ecosystem includes a complete analysis of the structure, regulation and role of each component functioning there. Once we know it, in detail, the study of the ecosystem and its importance to the equilibrium of the environment will be understood easily.

2.3 Concept of Ecosystem

The ecosystem is the basic structural and functional unit of the environment. Both the living and non-living component of nature, when interact with each other to establish a stable living community, it is called an Ecosystem. That means there is a constant exchange of something between these living & non-living, which is called an Ecosystem. Without the living component, the establishment of an ecosystem is not possible and vice versa. Both are two sides of a coin or very much complementary to each other.

The study of all the physical as well as biological processes including the distribution and abundance of living organisms and the interaction between them with their surrounding environment is known as the Ecosystem. In simpler words, if any environmental changes occur in the physical or abiotic factors, they, in turn, change the type and number of the organisms that are both the plants and the animals, present in that particular area. The ecosystem is very complex in nature and human beings are a part of ecosystem also.

The theme of the ecosystem is “energy flow”. Sustenance of the ecosystem is possible due to the energy dependence as well as energy transfer between various components of an ecosystem may it be living or non-living. Examples of Ecosystems are terrestrial or land-based ecosystems, Aquatic or water-based ecosystems etc.

Notes

2.4 Structure of Ecosystem

It is very easy to study or understand the structure of the ecosystem from the flow chart described (see Figure 2.1) below.

2.4.1. *Biotic Components*

Biotic components are also divided into 3 categories based on their food-fed relationships (see Figure 2.2).

(i) **Producers:** Producers are the autotrophs (*auto* means self, *troph* means to nourish) of the ecosystem. They are the green plants and green microorganisms that can make their own food material by using carbon dioxide and water in presence of sunlight with the help of chlorophyll present in them e.g. all green plants, algae, cyanobacteria etc.

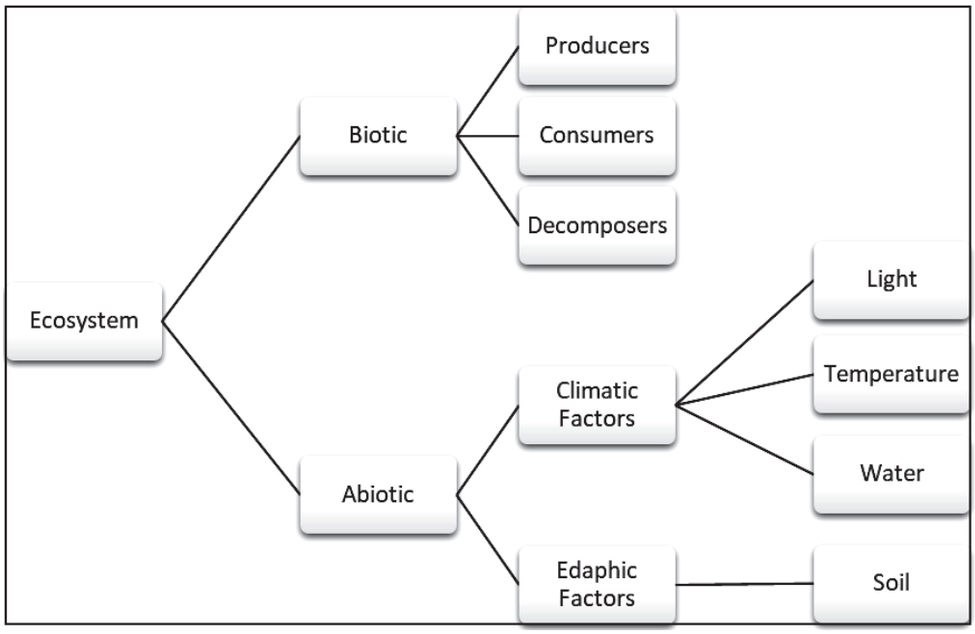

Figure 2.1: Schematic Representation of Structure of an Ecosystem

(ii) **Consumers:** Consumers are the heterotrophs (hetero: not self troph to nourish) of an ecosystem. They depend on the producers of nature to get energy. Consumers are also different types like:

Notes

(a) **Primary Consumers:** They are the herbivores who eat directly the autotrophs/plants. They cannot eat any animals e.g. grasshoppers, rabbits, goats etc.

(b) **Secondary Consumers:** They cannot directly eat the producers of the ecosystem, that is the plants. They can eat only herbivores e.g. frogs, jackals, snakes etc.

(c) **Tertiary Consumers:** They are carnivores in nature means they are meat eaters. Thus, they depend on secondary consumers for their food. They are top-level carnivores e.g. Tigers, Lions, Vulture, Kite etc.

(iii) **Decomposers:** Decomposers are also to some extent heterotrophic in nature. They do not contain chlorophyll, so depend on other materials for food and energy. These organisms can grow on the dead and decaying materials of the environment. That is why they are known as the decomposers or saprophytes, or scavengers of nature or they can be called the detritivores (Detri means dead particulate organic material). They can live in any type of soil with organic waste. They play a very important role in the completion of the Biogeochemical Cycle in the environment e.g. Bacteria, Fungi, Earthworm etc.

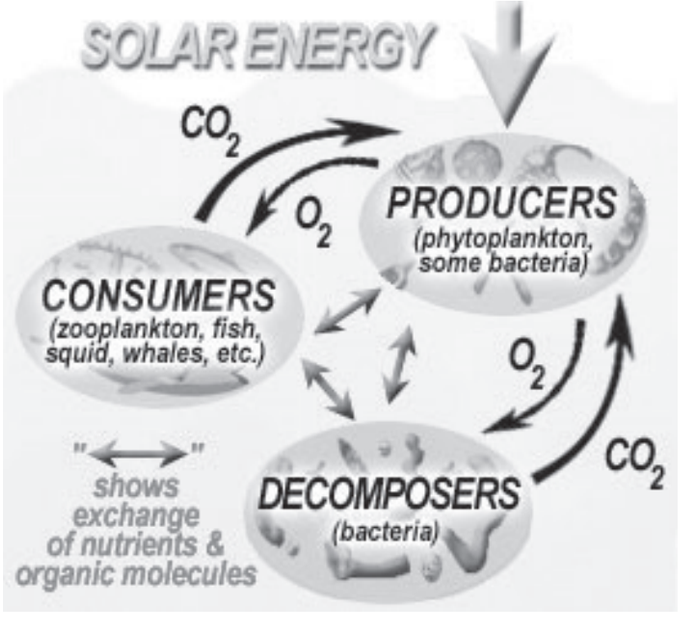

Figure 2.2: Relation between Producers, Consumers and Decomposers

(*Source: https://archive.bigelow.org/bacteria*)

Notes

Table 2.1: Different biotic factors in consumer forms in different Ecosystems

Sr. No.	Type of Ecosystem	Primary Consumer	Secondary Consumer	Tertiary Consumer
1	Grassland Ecosystem	Grasshoppers, Rabbits, Deer, Sheep, Goats etc	Frogs, Lizards, Birds, Snakes	Hawks, Eagle, Tiger etc
2	Forest Ecosystem	Leafhoppers, Bugs, Flies, Squirrels, Insects, Deer, Fruit bats, Nilgai, Elephants etc.	Birds, Owls, Lizards, Wolves, Jackals, etc.	Tiger, Lion etc.
3	Desert Ecosystem	Insects, Rats Birds, Camel, Squirrel	Scorpions, Fox, Jackal, Rattle Snakes, Mongoose etc	Snakes, Fox, Striped Hyena, Sand Cats, Viper, Saharan Cheetah, Eagles, Kites etc.
4	Pond or Lake Ecosystem	Insects, Frogs, Larvae, Beetles, Zooplanktons, Crustaceans etc	Insects, Larger fishes, Cranes, Other Birds	Largest Fishes, Water Snakes, Hawks etc.
5	Marine Ecosystem	Zooplanktons, Crustaceans, Small fishes	Bigger Fishes, Mackerel etc	Giant Carnivorous Fish, Sharks, Whales, Snakes, Hawks etc

2.4.2 *Abiotic Components*

These are the non-living factors in form of solids, liquids or gas found in nature (ice, water, moisture). They can be categorised into two types.

I. Climatic factors: e.g. Light, Temperature, Humidity, Rain etc.

II. Edaphic factors: e.g. Soil, Organic and Inorganic components of soil, Substratum etc.

Let's discuss the importance of each abiotic factor and its limitations in an ecosystem.

A. Climatic Factors

A.1 Light

It is an essential factor for all living organisms like producers, consumers as well as decomposers. In presence of the sunlight, plants can

Notes

prepare their food material, which in turn is eaten by the heterotrophs & ultimately by the decomposers. Without sunlight, photosynthesis is not possible thus it is one of the most important abiotic factors of an eco-system. Quantity, as well as the quality of light, has a different impact on different organisms. Let's discuss:

(i) Importance of light for plants

(a) Chlorophyll production

(b) **Distribution of Plants:** The vegetation or the types of plants that grow on the earth depend on the amount of sunlight they are getting. Thus the vegetation of temperate, tropical as well as Tundra regions is different from each other.

(c) Light thus decides the physiology of the plants of different regions.

(d) **Temperature:** When light increases, temperature also increases and vice versa. When temperature increases, the rate of transpiration in the plant increases. Thus, the absorption of water from the underground also increases. It clearly explains that temp also plays an important role and decides the type of plants to grow in a particular area.

(e) **Stomatal Movement:** The stomata are present in the leaves of the plants. They control the evaporation of water from a plant body. Thus, by opening and closing, stomata keep the plant body in a stable physiological status.

(f) **Duration of Light:** During the summer and winter months the types of flowers, and what we can observe in nature are different. The basic theory behind it is some plants that can bloom in the summer months are long days (based on the exposure to sunlight) plants and some are short-day plants (less exposure to sunlight or natural light).

(ii) Importance of Light for animals

(a) **Metabolism:** Light controls the physiology & metabolism of animals by affecting their enzymatic activity.

(b) **Vision:** Without light, it is very difficult to see anything. So it is required by all animals.

Notes

(c) **Pigmentation:** The process of pigmentation on the skin colour depends on the natural light source.

(d) **Reproduction:** Different animals respond to different duration of light exposure for their breeding activities.

(e) **Circadian Rhythm:** Daily response of the animals toward the light condition is known as circadian rhythm. This is an important physiological action of all living organisms. Thus, it is a light-dependent process.

A.2 Temperature:

Temperature affects animals and plants in the following ways.

(i) Importance of temperature for plants:

(a) **Metabolism:** Temperature increases physiological activity. Thus, the types of plants that grow in a desert ecosystem are different from the types of plants in a forest ecosystem and an aquatic ecosystem.

(b) **On Growth & Development:** Different types of plants need a different range of temperatures for their growth. Summer growing plants are different from winter season growing plants. This is self-explanatory.

(c) **Thermal Stratification:** The best example is an aquatic ecosystem. The organisms growing at the surface layer are different as they need more temperature and light than the organisms that grow at a deeper level in an aquatic ecosystem.

(ii) Importance of Temperature for Animals:

Based on the need for temperature, animals are categorised into two types. Like:

(a) Warm-Blooded or Endothermic animals

(b) Cold-Blooded or Ectothermic animals

Warm-blooded animals maintain their body temperature at a constant level. Their body temperature does not change with the environment's temperature. e.g.: Mammals, Birds, etc. The body temperature of the organism when changes with the temperature of the environment, then they are known as Cold Blooded animals. e.g.: Frogs

Notes

(c) **Migration:** Temperature is also a factor in the migration of animals. It is known as thermal migration. If temperature changes the locomotory animals or birds may change their places for a temporary period & their comeback to their original ecosystem when the weather changes.

A.3. Water:

Life is never possible without water. So, water is a very important abiotic factor in an ecosystem. The amount of water present in an area decides the type of ecosystem to be developed there. In this regard sometimes aquatic ecosystems also develop e.g. Pond & Lake ecosystems. If for a longer period, due to any reason, a huge amount of water got deposited & replenished repeatedly due to rainfall etc., then through the process of succession an aquatic ecosystem develops and gets established there. Besides photosynthesis & other metabolic activity plants needs water for the circulation of minerals throughout its body. Water is also an essential requirement of animals for their metabolic activity. Water regulates the body temperature of both plants and animals. Water in the form of rainfall is also needed by the ecosystem. It maintains the humidity & content of moisture in the atmosphere. The amount of rainfall also decides the kind of plants to grow over there. For example, Deciduous forests, Evergreen forests, Deserts etc. With the type of vegetation, different types of animals also started living in that particular geographic area. Water in form of humidity also affects plants and animals lives. Some plants can grow in a less humid area whereas some other plants need more moisture in their environment. Some plants can use atmospheric moisture directly from the environment e.g. Epiphytes, Orchids, Lichens, Mosses etc. Some other needs it in liquid form from underground by the process of absorption e.g.: Higher plants.

B. Edaphic Factors

B.1. Soil:

Soil is a natural resource and provides a platform for plants to grow and animals to dwell on it. Thus, the fertility and quantity of soil decide the type of vegetation in that area. To be more specific, the pH of the soil is the deciding factor. If the pH of the soil is less than 7, then it is acidic soil & if the pH is more than 7 it is alkaline. Thus, the acidity & alkalinity of the soil decides the number & kind of plants & animals to stay

Notes

over there (Figure 2.3). But needless to say, neutral soil, i.e. when the pH ranges from 6.5-7.5 is the preferred condition for most living organisms.

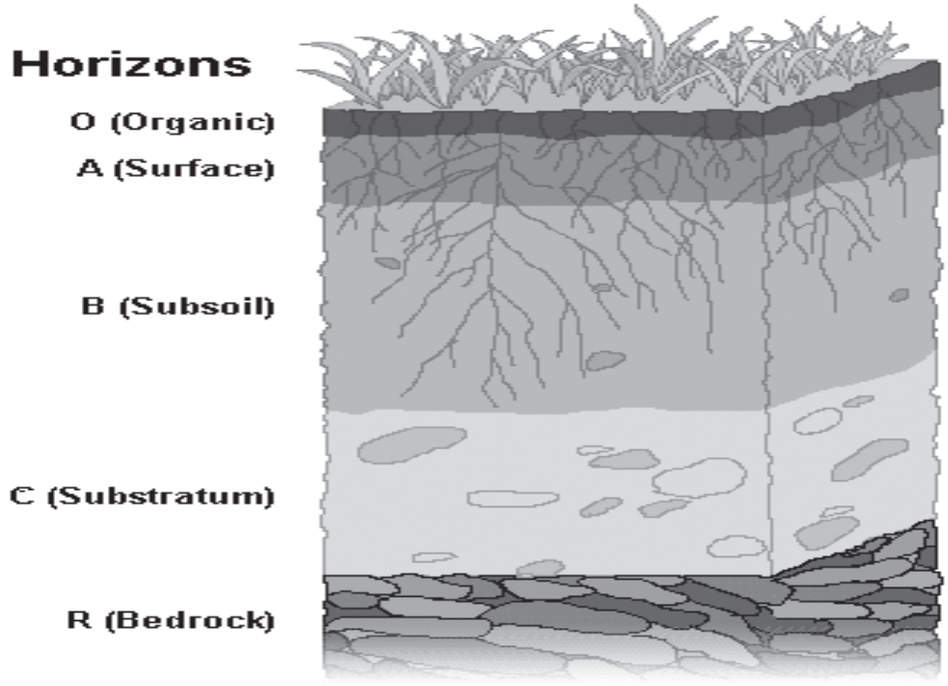

Figure 2.3: Schematic representation of different textures of the soil

(*Source: https://upload.wikimedia.org/wikipedia/commons/4/45/Horizons.gif*)

Soil is also associated with different kinds of minerals & nutrients. Some are required in more quantities and are called macronutrients and some are micronutrients which are required in small quantities. They also play a vital role in the development and sustenance of an ecosystem. The texture of the soil is also playing a key role, e.g. Rocky areas, Swampy areas, Mining areas etc. Different textured soil will allow different types of biotic factors or organisms to grow and establish themselves in that ecosystem.

ACTIVITY

Enlist the biotic and abiotic components of an aquarium ecosystem. Also, write down the importance of each component in that ecosystem.

Notes

IN-TEXT QUESTIONS

1. The ecosystem is classified into biotic and _____ components.
2. Water is a type of biotic component. True/False
3. An example of an abiotic Component is:
   (a) Horse
   (b) Ashoka Tree
   (c) Whale Fish
   (d) Air
4. In the soil profile, R horizon stands for _____.
5. _____ animals maintain their body temperature at a constant level.

2.5 Ecological Pyramids

By now we are clear that the ecosystem can sustain itself if there is a balance between the producers, the consumer and the decomposers. Energy is a major link which binds all the above components in an ecosystem. Thus, there is a fixed position or level of a particular type of organism in an ecosystem. How we can know or decide on that position? To explain it, a graphical structure has been proposed by environmental biologists, known as a pyramid or Ecological Pyramid (Figure 2.4).

An ecological pyramid is a graphical representation of the relationship between various trophic levels of organisms in a Food Chain. It was first designed by Charles Elton and is called Eltonian Pyramid or Food Pyramid. Ecological Pyramids are of three types:

1. Pyramid of Number
2. Pyramid of Biomass
3. Pyramid of Energy

1. **Pyramid of Numbers:** As the name says, in this type of pyramid number of organisms is counted and accordingly respective volume to each trophic level is allotted in the pyramid. Characteristic features of the pyramid of numbers are.

Notes

(i) The number of producers is higher in number than the consumers present in other trophic levels.

(ii) The number of individuals in each trophic level decrease when we go from bottom to top in a pyramid.

(iii) Collectively the living organisms present in each of the trophic levels are known as standing crops.

(iv) Normally the pyramid of numbers is upright (Figure 2.5) e.g. Grassland ecosystem, Aquatic ecosystem.

(v) Sometimes inverted pyramids (Figure 2.6) are also found in this case.

(vi) A mixed or spindle-shaped pyramid is also observed in the case of the forest ecosystem.

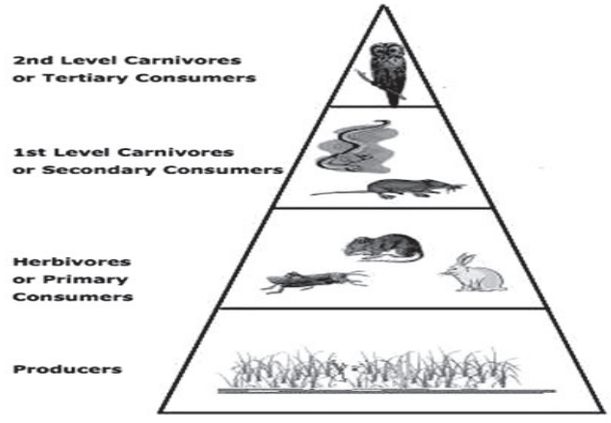

Figure 2.4: Schematic representation of an Ecological Pyramid

(*Source: https://sites.google.com/site/vhs2015environmentalscience/biodiversity/ecological-pyramids*)

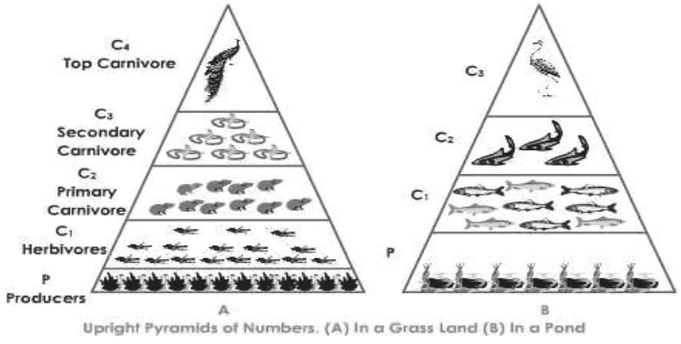

Figure 2.5: Upright Pyramid of Numbers

(*Source: https://www.pmfias.com/ecological-pyramids-pyramid-numbers-biomass-energy/*)

Notes

2. **Pyramid of Biomass:** Biomass is the total dry weight of the animals as well as plants present in the ecosystem at any point in time. Like a pyramid of numbers, it may be upright or inverted. In the case of a forest and grassland ecosystem, it is upright and in the cases of a pond ecosystem, inverted pyramids (Figure 2.7) are observed. The Figure shows the position of different organisms at different trophic levels.

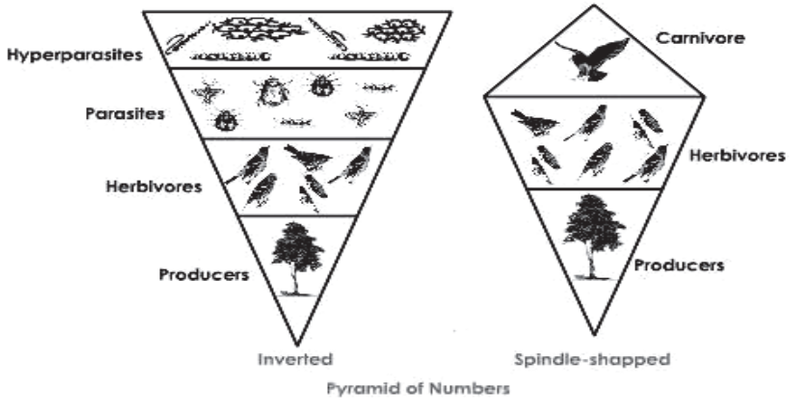

Figure 2.6: Inverted and Spindle-Shaped Pyramid of Numbers

(*Source: https://www.pmfias.com/ecological-pyramids-pyramid-numbers-biomass-energy/*)

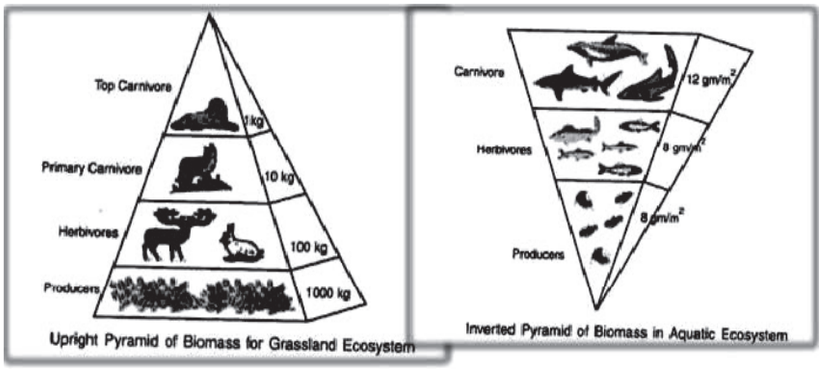

Figure 2.7: Upright and Inverted Pyramid of Biomass

(*Source: https://www.tutorialspoint.com/environmental_studies/environmental_studies_ecological_pyramid.htm*)

3. **Pyramid of Energy:** As already mentioned, the Food Chain and Food Web systems have existed for energy requirements and energy transfer between the living organisms in an ecosystem. It is the most important type of ecological pyramid. The amount of energy being transferred from the lower trophic level towards the upper ones becomes less and less. Thus, the longer the pyramid in height, the

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lesser will be the amount of energy to reach the organisms present at the topmost trophic level. Only 10% of the energy is transferred to the subsequent upper trophic level organisms (Figure 2.9). For example, if the producers generate a 1000 kilo-calorie amount of energy, the primary consumers will receive 100 kcal, the secondary consumer will get 10 kcal and only 1 kcal amount of energy will reach the tertiary or topmost level of consumers.

In this way, a pattern of an upright Pyramid of Energy (Figure 2.8) will be developed for all types of ecosystems found in Nature. This is the universal formula. An energy pyramid can never be inverted or spindle-shaped found in other types of ecological pyramid structures. The shape of the pyramid of energy is not affected by the size, biomass, number or metabolic rate of the organisms.

Some limitations are also observed in the studies of ecological pyramids. That can be described as follows:

1. The position of certain organisms is not fixed in one ecological pyramid. That may vary in the same or maybe in a different ecosystem.
2. There is no consideration of seasonal changes while studying the pyramids
3. The role of detritivores is not represented in an ecological pyramid.

At last, it can be said that the pyramid of energy is very accurate and gives a true picture of the ecosystem.

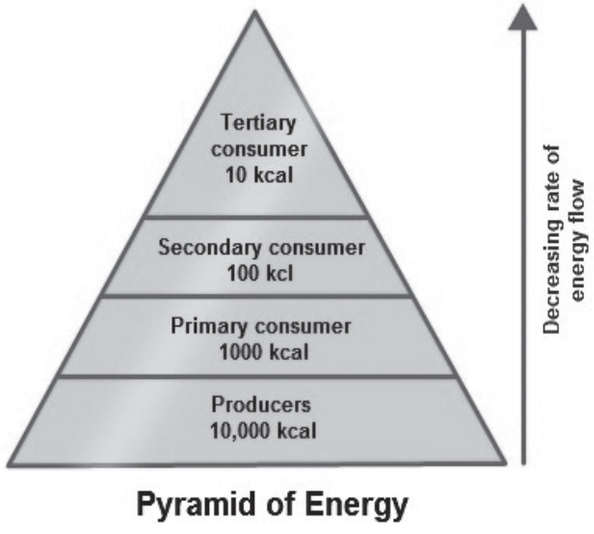

Figure 2.8: Structure of Pyramid of Energy

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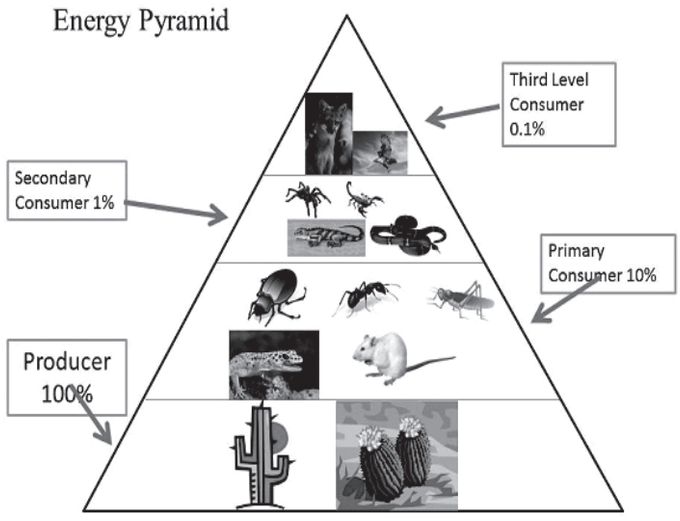

Figure 2.9: Energy Flow 10% rule in an Ecosystem

(*Source: https://www.tutorialspoint.com/environmental_studies/ environmental_studies_ecological_pyramid.htm*)

IN-TEXT QUESTIONS

6. What is a graphical representation of the relationship between individuals at various trophic levels of a food chain called?

7. An energy pyramid can never be an inverted one. (True/False)

8. Only 10% of the energy is transferred to the subsequent upper trophic level organisms. (True/False)

9. Who formulated the ecological pyramids?

(a) Charles Darwin

(b) Raymond Lindemann

(c) Charles Elton

(d) Gregor Mendel

10. Which pyramid depicts the numbers at each level?

(a) Pyramid of energy

(b) Circular pyramid

(c) Pyramid of age

(d) Pyramid of numbers

Notes

2.6 Ecological Succession

The ecological succession term was coined by Ragnar Hult (1885). Famous ecologist Clement defined Ecological Succession as *"the natural process by which the same locality becomes successively colonised by different groups or communities of plants*".

Characteristics of Ecological Succession:

1. The species types and the community change in an orderly process
2. The physical structure of a community changes by the biological action of the biological factors that grow there.
3. At last a stable ecosystem gets established in an area. Both biotic, as well as abiotic factors, interact there to establish equilibrium in that ecosystem.
4. Then the climax community gets established there, which in turn maintains an equilibrium with the environment.

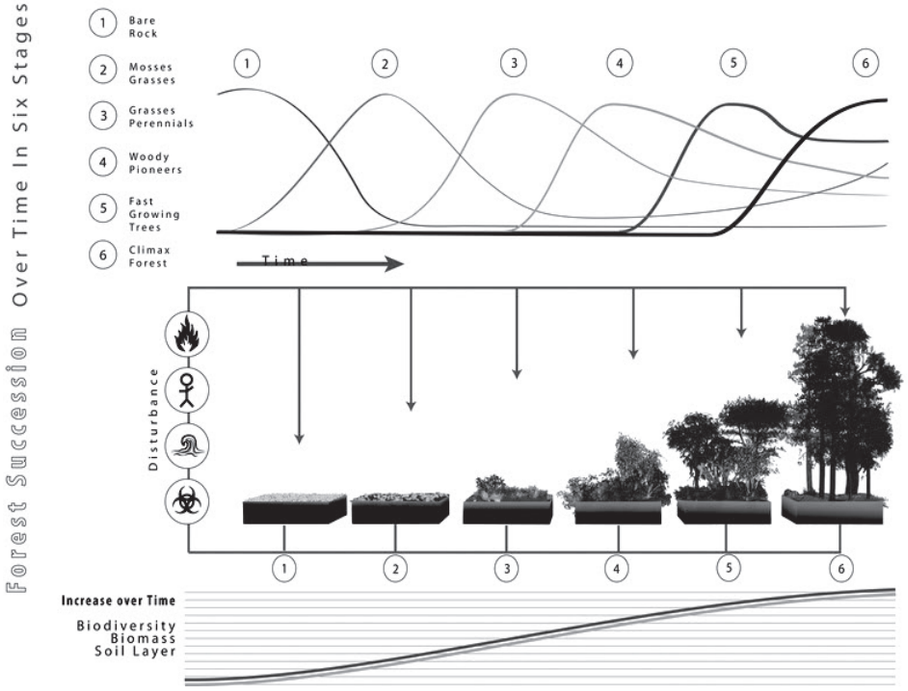

Figure 2.10: Schematic Representation of a Forest Succession

(Source: https://upload.wikimedia.org/wikipedia/commons /4/41/Forest_succession_depicted_over_time.png)

Notes

Causes of Ecological Succession

(a) **Initial Causes:** It happens to the destruction of existing habitat. It is two types.

(i) **Climatic Factors:** e.g. Soil Erosion, Soil deposition due to heavy wind, Continuous flood, Heavy rainfall, Fire, Drought, Land Slides, Oil Deposition etc.

(ii) **Biotic Factors:** e.g. Deforestation, Overgrazing, Jhum cultivation etc.

(b) **Continuous Causes:** It is responsible for the changes in the population composition in that area. The factors responsible for population compositions are migration for safety, migration due to urbanization, migration due to industrialization, migration for better life etc.

(c) **Stabilizing Causes:** Stabilization of an ecosystem happens due to the climatic condition of that area, availability of minerals, fertility of the land for agriculture as well as the growth of different types of producers for a continuous flow of food and energy as discussed earlier.

The order of basic processes involved in succession is: nudation, invasion, completion and coaction, reaction, stabilization

Types of Ecological Succession

1. **Primary Succession:** It begins from the primitive substation where there was no living factor before. e.g. Volcanic eruptions, Rocky Areas etc.
2. **Secondary Succession:** It begins from a previously sustained living matter, but the vegetation got damaged due to any climate factors like flood, fire, acid rain etc.
3. **Autogenic Succession:** (Auto means self or same, and genic means producing/causing) The developing plant community brings a change in the condition of a particular place, which is not suitable for them, but creates or produces an environment for the growth of a different community. It is a succession driven by the biotic components of an ecosystem.
4. **Allogenic Succession:** (It is caused by abiotic factors) In contrast to autogenic succession, allogenic succession is an abiotic factor-driven

Notes

condition. The habitat of the ecosystem is changed due to volcanic eruptions, climate change, comet strikes, earthquakes, floods, drought etc.

5. **Induced Succession:** It is a man-made process, developed for the benefit of humankind. e.g. Cultivation of Crops in a field.
6. **Autotrophic Succession:** When a place is rich in inorganic content & poor in organic matter, the development of a succession of plants over that area is called autotrophic succession.
7. **Heterotrophic Succession:** If a succession begins in an area which is rich in organic contents like forest litter, sewage etc, and dominated by saprophytes like fungi, mushrooms etc is called heterotrophic succession.
8. **Retrogressive Succession:** Sometimes due to heavy biological or biotic interferences, the succession goes backwards instead of progressing. e.g. Forest community changes to shrubland or grassland or barren land due to deforestation and overgrazing.

IN-TEXT QUESTIONS

11. Who coined the word Ecological Succession?

(a) Hult (1885) *(b)* Reiter (1885)

(c) Haeckel (1869) *(d)* Odum (1951)

12. Induced Succession is a man-made process. (True/False)

13. When succession goes backwards instead of progressing, it is known as _____.

14. The order of basic processes involved in succession is

(a) invasion → stabilization → completion and coaction → reaction → nudation

(b) nudation → stabilization → completion and coaction → invasion → reaction

(c) invasion → nudation → completion and coaction → reaction → stabilization

(d) nudation → invasion → completion and coaction → reaction → stabilization

Notes

2.7 Summary

The ecosystem is the study of living organisms with their surroundings. Thus, it's an interdependence of biotic and abiotic factors in an area. The presence of only one factor cannot create an ecosystem. In an ecosystem positions of different organisms are different. This has been explained through ecological pyramids. The principle of the ecological pyramid depends on the food habit of the organisms present in that ecosystem. The development of a new ecosystem on barren land is known as succession. Sometimes reverse succession also happens when a well-functioning ecosystem may get destroyed due to some artificial i.e. man-made or due to natural calamities and gets converted into barren land.

2.8 Answers to In-Text Questions

1. Abiotic

2. False

3. *(d)* Air

4. Bedrock

5. Warm-blooded

6. Ecological Pyramid

7. True

8. True

9. *(c)* Charles Elton

10. *(d)* Pyramid of Numbers

11. *(a)* Hult (1885)

12. True

13. Retrogressive Succession

14. *(d)* nudation → invasion → completion and coaction → reaction → stabilization

Notes

2.9 Self-Assessment Questions

1. What do you mean by an Ecosystem?
2. What are the ecological pyramids in an ecosystem?
3. Explain different types of ecological pyramids in an ecosystem.
4. What is the succession in an ecosystem? Explain in detail what you know about it.
5. Explain consumers, the pyramid of energy and the edaphic factor.

2.10 References

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2.11 Suggested Readings

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LESSON

3

Ecosystem: Biogeochemical Cycles, Functions, Energy Flow and Productivity

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STRUCTURE

3.1 Learning Objectives

- Know the categories and their respective sub-categories of the biogeochemical cycle.
- Understand the working of the food chain.
- Distinguish between grazing and detritus food chains.
- Give a schematic representation of the food web.
- Explain energy utilization in an ecosystem.
- Know the various concepts of productivity.

Notes

3.2 Introduction

Function means the working of a particular ecosystem of a particular area. It includes the interlinking of organisms, their nutritional requirements, the circulation of nutrients, energy flow, and again decomposition of all the chemicals, both organic as well as inorganic and their release into the atmosphere. Mainly all these activities have been explained under three major categories as follows

1. Biogeochemical Cycle
2. Food chain and Food Web
3. Energy flow in the Ecosystem
4. Productivity

3.3 Biogeochemical Cycles

As the name indicates, in an ecosystem, both biological as well as physical components, pass/roll through the underground and above the ground to complete a cycle. Through Nutrient Cycling various, inorganic and organic compounds are formed and decomposed (normally forty elements are required by the living organisms in nature). These are also called nutrient cycles of the ecosystem. "*Nature is self-sufficient by nature*". Biogeochemical Cycle has been divided into two major categories atmospheric and edaphic cycling based on the types of substance they are dealing with.

(I) Atmospheric Nutrient Cycle
- *(a)* Water Cycle
- *(b)* Carbon Cycle
- *(c)* Oxygen Cycle

(II) Edaphic Nutrients Cycle
- *(a)* Nitrogen Cycle
- *(b)* Sulphur Cycle
- *(c)* Phosphorous Cycle

Notes

3.3.1 *Atmospheric Nutrient cycle*

(a) **Water Cycle:** Water is an essential compound for photosynthesis in plants. Plants absorb water from the underground through the roots, to their upper or aerial parts. This water is used for the process of photosynthesis. Some water gets back to the atmosphere from the plant body through the process of transpiration and some are utilized by the plants for their metabolic activity (Figure 3.1).

The driving force for a water cycle is solar radiation which is 15% of the total radiation reaching the earth. Though the radiation water gets evaporated from the surface of the water bodies, it comes back to the surface of the earth as rain. Figure 3.1 clearly shows us how the cycling of this vital resource occurs on the earth.

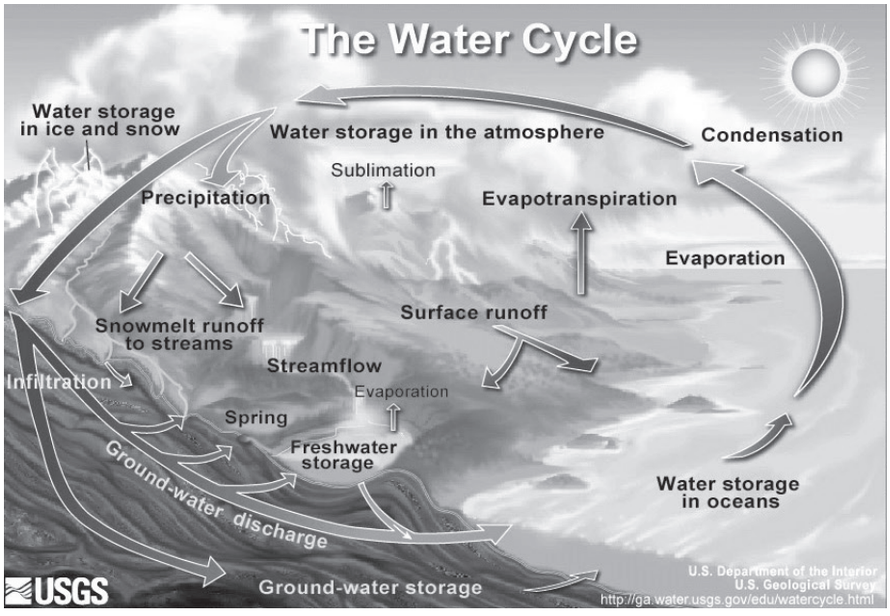

Figure 3.1: The Water Cycle

(*Source: https://upload.wikimedia.org/wikipedia/commons /9/94/Water_cycle.png*)

(b) **Carbon Cycle:** Carbon Dioxide is an important gas present in nature. Plants need it for the process of photosynthesis to prepare the food material that is carbohydrates for its own as well as for heterotrophs. That means it gets locked into the organic matter through the process of photosynthesis. Carbon Dioxide is released

Notes

into the atmosphere by the respiration of all the living organisms on the earth. Earth's Crusts also release carbon which is present in the forms of Calcium Carbonates ($CaCO_3$) and Magnesium Carbonates ($MgCO_3$) which come from the skeletons of marine organisms in the process of mineralization. By subsequent weathering, these Calcium Carbonates and Magnesium Carbonates get mixed with the soil and add to the soil nutrition. In this way ultimately these carbon-rich organic matters accumulate in the ecosystems. By the burning of fossil fuels, coal & wood large amount of carbon dioxide gets released into the atmosphere. These carbon dioxides get assimilated by the plants. The animals consume these carbohydrates, that is photosynthetic products. The carbohydrates consumed, in this way reach the heterotrophs. When these heterotrophs die, carbon again goes back to the earth's crust. Through the process of respiration also carbon dioxide is released from the biotic components into the atmosphere (Figure 3.2).

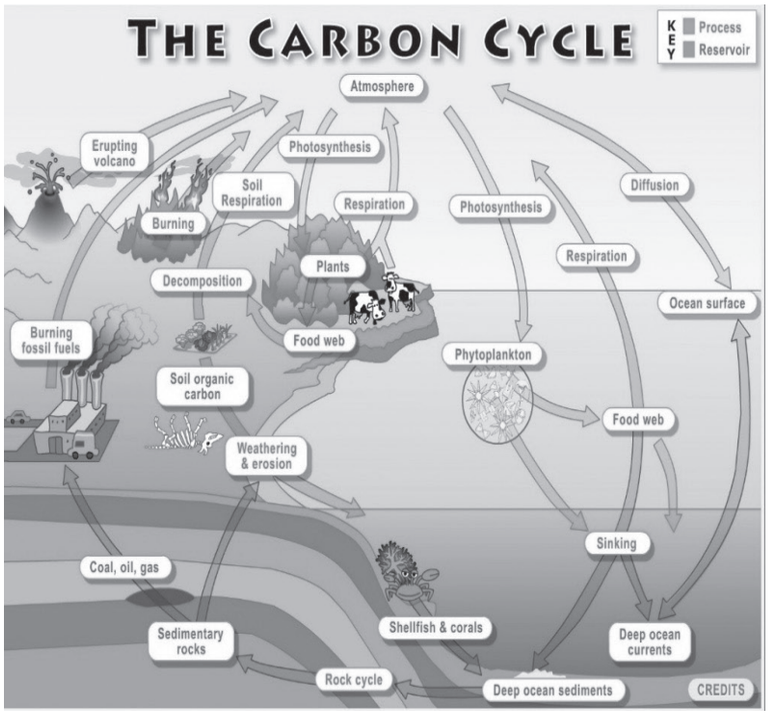

Figure 3.2: Carbon Cycle

(Source: https://d32ogoqmya1dw8.cloudfront.net/images/clean/literacy/tlp/carbocycle/carbon_cycle_diagram_1466775306722780178.jpg)

Notes

(c) **Oxygen Cycle:** In the atmosphere, the dry air contains 20.94% of oxygen. Oxygen is required by all living organisms for respiration. It is also associated with moisture content. It is the simplest but inevitable nutrient cycle in ecosystems (Figure 3.3).

3.3.2 *Edaphic Nutrient Cycle*

(a) **Nitrogen Cycle**: It is a complex cycle that occurs in nature through various steps. About 79% of the atmospheric air is Nitrogen. It enters the biotic world and got assimilated then again goes back into the atmosphere. The following steps are involved in the completion of the Nitrogen cycle (Figure 3.4).

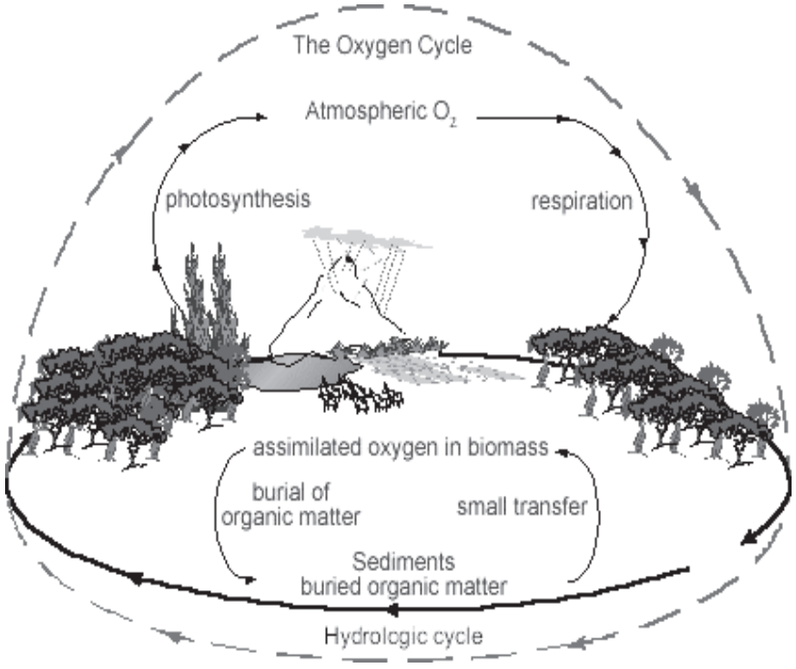

Figure 3.3: Oxygen Cycle

(*Source: https://www.universetoday.com/61080/oxygen-cycle*)

(A) ***Nitrogen enters the living organisms*:** Pure nitrogen gas cannot be used by green plants. Only Nitrate & Ammonium forms of Nitrogen can be utilized by them. Thus, nitrogen gas is first fixed into Nitrous oxide, Nitric oxide and Ammonium in nature. The production of nitrates from nitrogen is called nitrification.

Notes

The production of ammonia is called ammonification.

1. **Nitrification:** It can be done both in a non-biological (physical) and biological way.

   (i) **Non- Biological fixation of Nitrogen or Nitrification:** During lightening, nitrogen gets combined with the oxygen in nature, this reaction needs a high amount of energy.

   (ii) Artificially nitrogenous compounds are also get produced in industries. They are chemical fertilizers. Farmers use these fertilizers to enhance the yield of the crops and soil fertility.

   (iii) **Biological Nitrogen Fixation:** As the name indicates biological nitrogen fixation is carried out by the living organisms known as nitrogen-fixing organisms. e.g. Blue-green algae, Bacteria, Fungi etc.

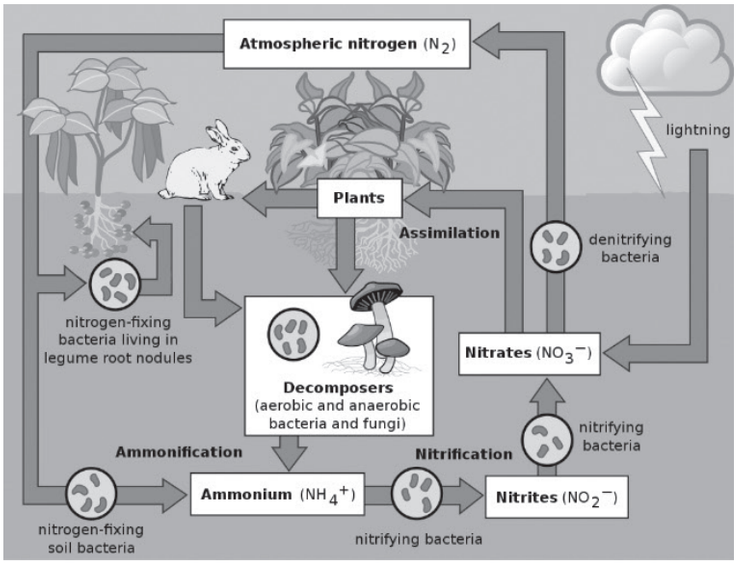

Figure 3.4.: Schematic Representation of Nitrogen Cycle

(*Source: https://en.wikipedia.org/wiki/Nitrogencycle#/media/File:Nitrogen_Cycle_2.svg*)

Biological Nitrogen Fixation is of two types:

(i) **Non-Symbiotic Nitrogen Fixation:** It is carried out by organisms, that live freely in the soil or water. e.g. *Azotobacter, Anabaena, Nostoc* etc.

Notes

(ii) **Symbiotic Nitrogen Fixation:** Some microorganisms live inside the root nodules of different plants in a symbiotic association. They can fix atmospheric nitrogen. This process is called symbiotic nitrogen fixation. In the roots of the higher plants, primarily in legumes (beans, peas, soybeans), the nitrogen-fixing organisms form nodules, multiply inside these nodules and carry out the process of nitrogen fixation. e.g. Bacteria, *Rhizobium* etc.

The nitrogen gas from the atmosphere gets converted into Ammonia (NH_3) which is then converted into amino acids. Amino acids are the building blocks of nucleic acids (DNA and RNA). Due to the symbiotic association legumes are regarded as a good biofertilizer for other crops which in turn reduces the use of chemical fertilizer in the crop fields.

Without root nodules also some symbiotic associations are there for nitrogen fixation in nature.

Example: *(i) Anabaena – Azolla* association

(ii) Cycas Coralloid roots etc.

(B) Ammonification: Ammonification is an important step in the nitrogen cycle. It is the process of production of ammonia ($NH_{3)}$ or ammonium (NH_4) compounds from the decomposition action of bacteria on organic matter. Thus, on the death and decay of the plants as well as animals the complex organic compounds are released into the soil where they are again decomposed into simpler compounds by the microorganisms and release energy.

Examples of bacteria – *Nitrosomonas* bacteria*, Nitrosococcus* bacteria

(C) Nitrification: When ammonium gets converted into nitrates, it is called nitrification. Nitrates can be directly absorbed by plants & incorporated into proteins, nucleic acids & other nitrogenous organic compounds. Some nitrates may be stored in the humus of the soil, immobilized by the bacteria & some may reach into the water bodies with the runoffs.

(D) Nitrogen Gas back to the Atmosphere: Through the process of denitrification, nitrogen gas goes back to the atmosphere.

Notes

Some bacteria there can convert Nitrates (NO_3) to Nitrites (NO_2). They are called denitrifying bacteria e.g. *Pseudomonas*. Ultimately Nitrates, Nitrites & gaseous Nitrogen are then released into the atmosphere.

(b) Sulphur Cycle

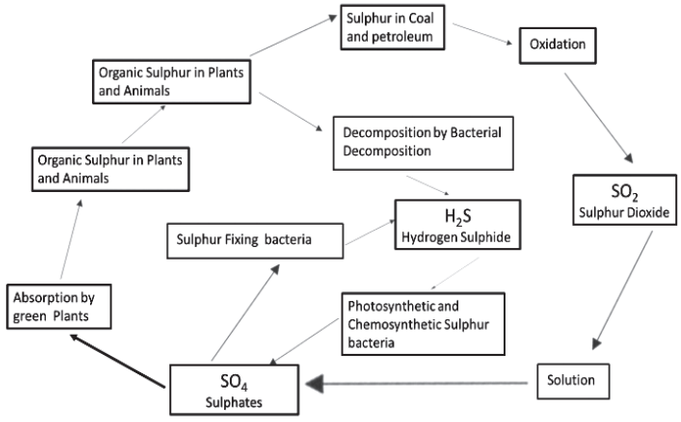

Figure 3.5: Schematic Representation of Sulphur Cycle

Like other Nutrient Cycles, the movement of sulphur in the biosphere and the underground is called the "Sulphur Cycle" (Figure 3.5). Sulphur Cycle is a sedimentary type of nutrient cycle as the reserve pool is buried underground in rocks, minerals as well as sulphates (SO_4) in sea sediments. Sulphur is found in nature in the following forms: Hydrogen sulphide (H_2S), Sulphur dioxide (SO_2), and Sulphates (SO_4).

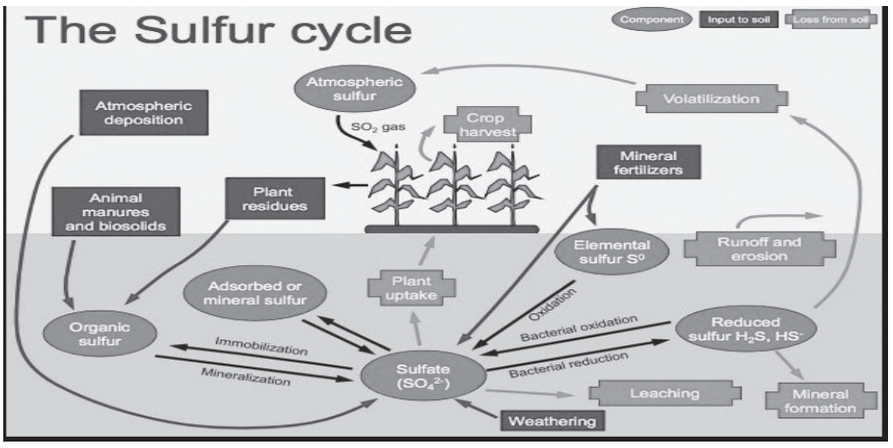

Figure 3.6: Schematic representation of Sulphur Cycle in detail

(*Source: https://en.wikipedia.org/wiki/Sulfur_cycle#/media/File:SulfurCycle_copy.jpg*)

Notes

It enters the living system as

(i) The soluble form is present in the soil and passes on to the plants through the plant's roots.

(ii) It is assimilated by the plant to synthesize protein, vitamins & some other important products.

(iii) Then the above compounds are passed to the animal bodies through the food chain.

Within plants & animal bodies the organic sulphur is decomposed by aerobic bacteria into sulphate (SO_4) or hydrogen sulphides (H_2S). Hydrogen Sulphides then get converted into elemental sulphur by anaerobic bacteria (these bacteria do not require oxygen). In this way, sulphur gets back to the soil & sulphur cycle gets completed. Sulphur Dioxide (SO_2) is also released into the atmosphere by vehicular exhaustion i.e. the burning of fossil fuels (Figure 3.6). Example: Petroleum, Coal etc.

(c) **Phosphorus Cycle:** In the ecosystem, more phosphorous is available in plants and animal bodies in comparison to the abiotic system. In the abiotic system phosphorous is abundant in rocks and other natural deposits, formed during geological processes. Phosphorous is desired for the structure of DNA, as coenzymes and for the conversion of foods to release usable energy. It is a simpler cycle.

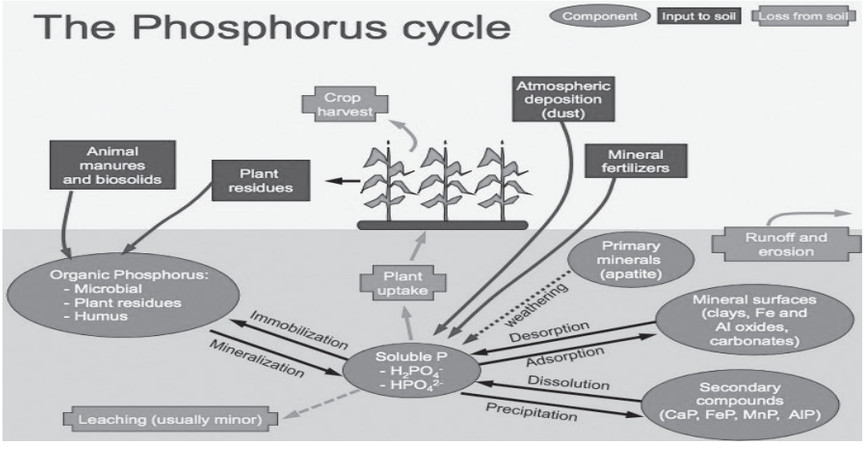

Figure 3.7: Schematic representation of Phosphorous Cycle

(*Source: https://en.m.wikipedia.org/wiki/File:Phosphorus_Cycle_copy.jpg*)

Notes

The roots of the plants absorb Phosphorous present in a soluble form in the soil and assimilate it. Through the food chain, it then gets transferred to the animal bodies and by the death and decay of the plants and animals, or animal excreta it goes back to the atmosphere (Figure 3.7).

The runoff from the soil and the loss of phosphorous to the sea is greater than the availability on it the land. Only 60,000 tons of phosphorous is returned to the soil through the birds, fishes of the sea and the algae. A major amount of phosphorus gets lost in the sea.

IN-TEXT QUESTIONS

1. The driving force for a water cycle is solar radiation which is _____ of the total radiation reaching the earth.
2. Carbon Dioxide is released into the atmosphere by _____ of all the living organisms on the earth.
3. In the atmosphere, the dry air contains _____ of oxygen.
4. Only _____ and ammonium forms of Nitrogen can be utilized by green plants.
5. During lightening, nitrogen gets combined with the _____ in nature, this reaction needs a high amount of energy.

3.4 Functions

3.4.1 *Food Chain*

The transfer of food energy from the source in plants through a series of organisms with repeated eating & being eaten is referred to or called the food chain.

How the Food chain works:

The green plants are the autotrophs or the producer of the ecosystem. With the help of chlorophyll, and by using CO_2 and H_2O from nature in presence of sunlight the plants can prepare their own food known as carbohydrates. The process is known as photosynthesis.

$$\text{Plants} \xrightarrow{\text{Sunlight}} CO_2 + H_2O + \text{Chlorophyll} \rightarrow \text{Carbohydrates}$$

(Photosynthesis Process)

Notes

That's why plants are called autotrophs (auto-self; troph means to nourish). Thus, plants are the first step in a food chain. The heterotrophs (hetero means other; troph means to nourish) are the organisms that depend on the autotrophs for food and energy. Heterotrophs are of two types: Herbivores and Carnivores. Herbivores are herb /plant eaters. They can only eat green plants/autotrophs e.g. Grasshoppers, Rabbits, Goats etc.

Carnivores are the meat eaters in an ecosystem. They cannot have the ability to eat herbs e.g. Frogs, Snakes, Hawks, Lions, and Tigers. Thus, in an ecosystem, a chain-like structure is found based on the ***"to eat and being eaten"*** scheme, which is also called the ***"Pray-Predator relationship***" in an ecosystem (Figure 3.8).

Plants (Autotrophs) → Herbivores (Heterotrophs) → Carnivores (Heterotrophs)

or

Plants → Primary consumers → Secondary consumers → Tertiary consumers

Types of Food Chain

Two types of food chains are observed in different ecosystems, known as

1. Grazing Food Chain
2. Detritus Food chains

Grazing Food Chain

It is recognized by the starting level organisms of a food chain. They are living green plants. Then if we see the examples, in a grassland ecosystem the chain will start with Greengrass, then Grasshoppers, then Frogs then Snakes then Hawks as shown in the above figure.

Detritus Food Chain

Here the starting point is dead plants or animals. This type of Food chain does not depend on sunlight e.g. Dead plants and animals, Scavengers, and microorganisms.

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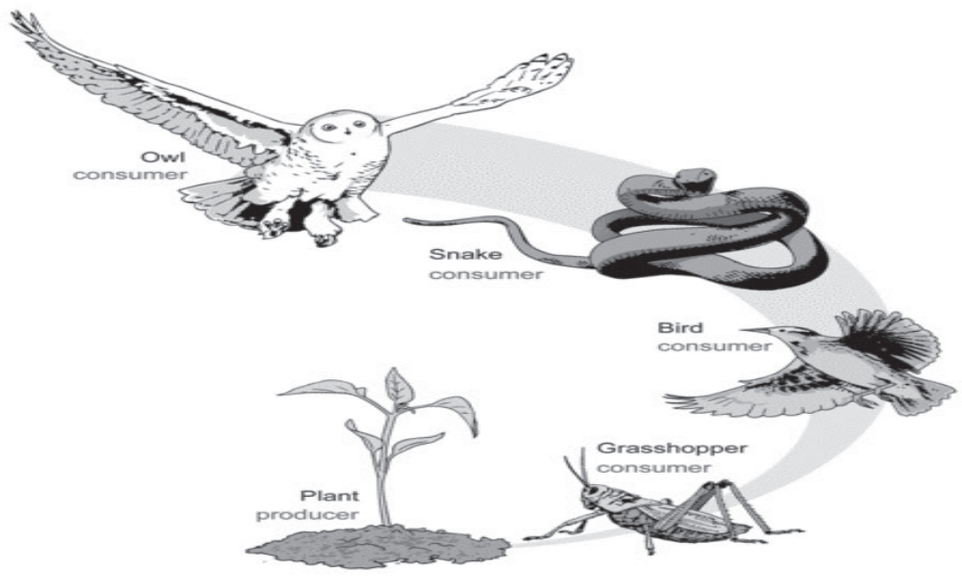

Figure 3.8: Schematic representation of a Food Chain

(*Source: https://www.ck12.org/ biology/food-chain/lesson/Food-Chains-and-Food-Webs-BIO/*)

This should be noted that the Grazing and Detritus Food Chain perform independently of each other but as different parts of a single ecosystem. More energy is transferred in a grazing food chain than in a detritus one. Combinedly the grazing and the detritus Food chain complete the nutrient cycle in an ecosystem.

3.4.2 *Food Webs*

In a natural system, the linear structured food chain does not happen always. Sometimes, if a particular species is absent in a particular area, that species is replaced by another species so that the "to eat and to be eaten" system will be maintained. For example, in a grassland ecosystem, if frogs will remain constant and the eagle, food will also be available. In addition to this, in Nature, a more complicated network of food chains exists which are interconnected. That is known as Food Webs (Figure 3.9). Though Food Webs are very complex in nature. It plays a significant role in the balance and stability of an Ecosystem. If deer will be eliminated from nature, then the number of grasses will increase, and they

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will invade the croplands. In turn area of the croplands will be reduced resulting in reduced products. Similarly, the upper trophic level animals like tigers will not get their food and will die ultimately. So, Food Web networking is an important creation of nature to maintain and sustain a balance in the ecosystems.

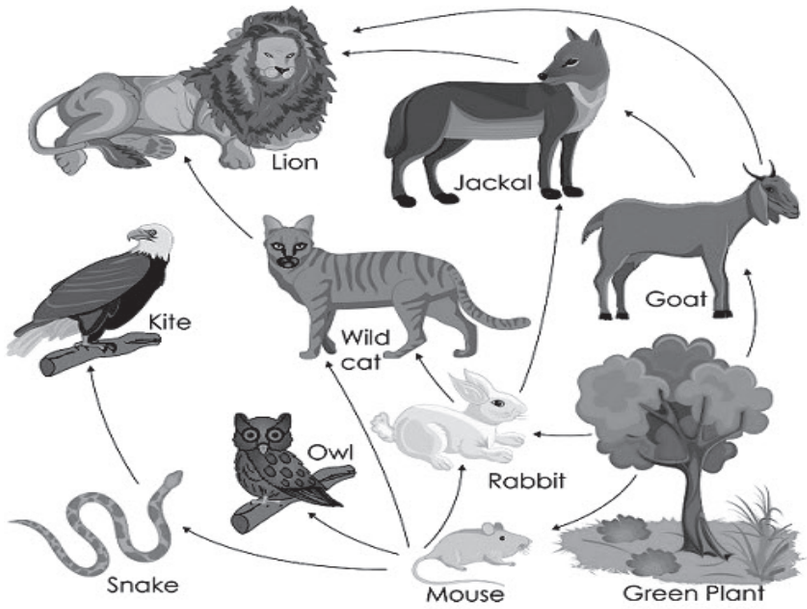

Figure 3.9: Schematic representation of a Food Web

(*Source: https://www.tutorialspoint.com/environmental_studies/environmental_studies_functions_of_ecosystem.htm*)

IN-TEXT QUESTIONS

6. The transfer of food energy from the source in plants through a series of organisms with repeated eating & being eaten is referred to or called as _____.

7. _____ can only eat green plants/autotrophs.

8. The detritus food chain starts with dead plants and animals. (True/False)

9. More energy is transferred in a grazing food chain than in a detritus one. (True/False)

10. The food chain is more complex than Food Web. (True/False)

Notes

3.5 Energy Flow in an Ecosystem

According to the first law of thermodynamics, energy cannot be created nor destroyed, it can be transferred from one form to another. In an ecosystem, the energy gets fixed in other words, in presence of sunlight, the autotrophs or the producers prepare their food material. The heterotrophs get their food/energy from the autotrophs that is the plants. Energy is required by all living organisms to perform their work or metabolism (Figure 3.10).

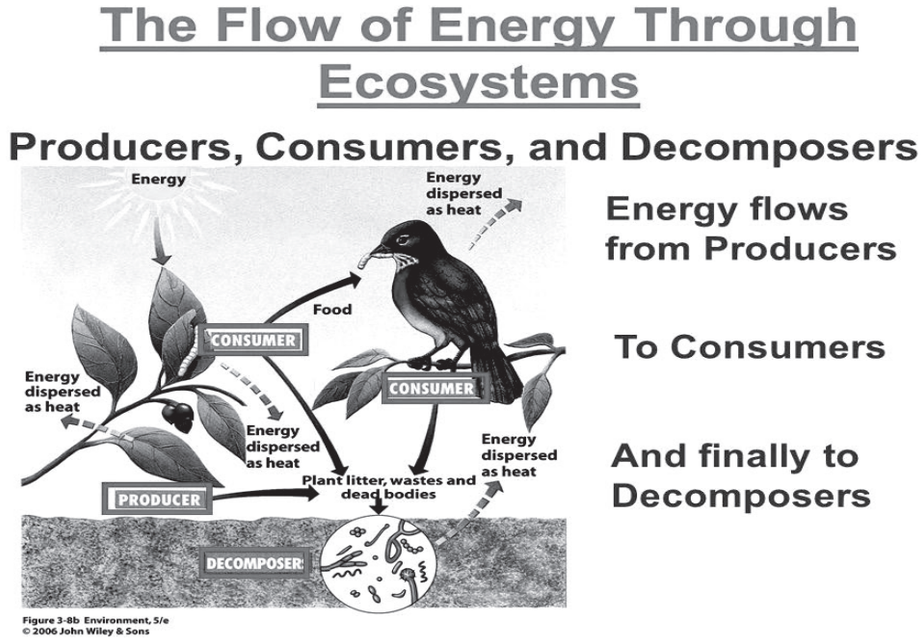

Figure 3.10: Relationship between producer, consumer and decomposers

(*Source: www.tes.com*)

Energy utilization in an ecosystem occurs in two ways.

(i) Quantity of solar energy the plants receive from the sun for photosynthesis

(ii) Quantity of energy flow occurs from the plants to the consumers.

This behaviour of energy transaction in an ecosystem is known as energy flow. Energy flow occurs in two models within the ecosystem

(a) Single Channel Energy Flow Model

(b) Y- Shaped Energy Flow Models

Notes

(a) **Single Chain Energy Flow Model:** This type of energy flow works as per the food chain of the ecosystem. For example, in a grassland ecosystem, grasses are the producers. They fix carbon dioxide$_2$ from the atmosphere and produce carbohydrates as the gross productivity. It is a one-way direction of energy flow. This clearly indicates that, if the food chain is longer in length then the energy that reaches the top carnivores are less and if the food chain is a shorter one, more energy will be available to the topmost trophic level organisms.

(b) **Y-Shaped Energy Flow Model:** In nature besides the single chain model, another way of energy transfer is found. The Food web shows a realistic picture of the flow of energy which is more complex with more combinations. The Y-model explains the connection between grazing & a detritus food chain (Figure 3.11).

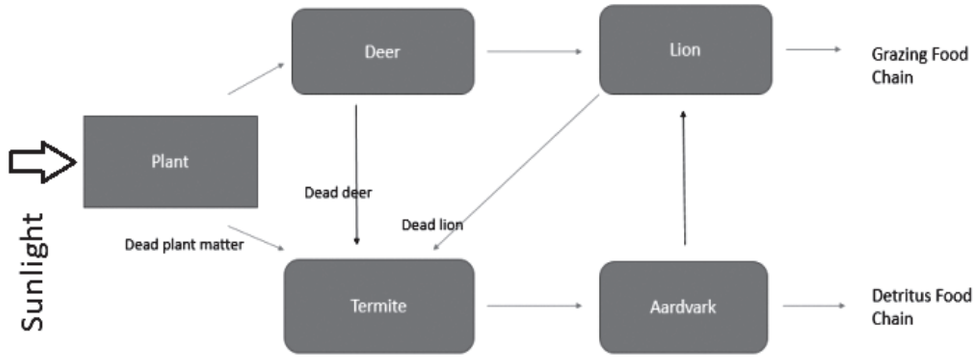

Figure 3.11: Y-Shaped Energy Flow Model

(*Source: https://eco-intelligent.com/2016/11/17/y-shaped-model-of-energy-flow-who-eats-whom-in-nature/)*

In the above figure at every stage, the two food chains are linked. The herbivores can be eaten up by the decomposer or the top predator in the detritus food chain. The other links are when the herbivore or the top predator died. They get decomposed by the decomposer and are again used up as nutrients by the plants. In a nutshell, in a balanced ecosystem, hardly anything goes to waste. Sometimes, the decomposers are also eaten up by the top predators of the grazing food chain. e.g. Earthworms in a grassland ecosystem can be eaten up by hawks or eagles. It is called so because it looks like the English alphabet 'Y'.

Notes

3.6 Productivity

Concept of Productivity:

The amount of organic matter i.e. the food prepared by a plant is known as productivity. When it is measured at any unit of time, it is known as the rate of productivity of that ecosystem.

Productivity is of the following types:

A. Primary Productivity

B. Secondary Productivity

C. Net Productivity

A. Primary Productivity: Productivity is the production capability of a plant. Thus, primary productivity is always associated with autotrophs or photosynthetic organisms i.e. green plants. Some microorganisms also can carry out this process and are known as photosynthetic microorganisms.

Thus, primary productivity is the rate of fixation of solar energy from the sun by the photosynthesis activity of the organisms.

Primary Productivity are 2 types

1. **Gross Primary Productivity (GPP)**
2. **Net Primary Productivity (NPP)**

1. **Gross Primary Productivity:** It is the total rate of photosynthesis or food production by a photosynthetic organism. It depends on the chlorophyll content of a plant. Thus, it is calculated as the amount of CO_2 fixed per gram of chlorophyll per hour. This can be represented as

   GPP = amount of CO_2/gm Chl/hr.

2. **Net Primary Productivity (NPP):** We know, that energy is required for each activity they do, by living organisms. Thus, for respiration work, plants also need energy. So, the energy that was fixed during photosynthesis is being used here. As a result, the remaining energy after loss in respiration utilization is known as the Net Primary Productivity. In simple words, NPP = GPP – Respiration energy

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B. Secondary Productivity: This is related to the heterotrophs in contrast to Primary Productivity. Secondary Productivity is the energy stored at the consumer level. Ecologist Odum (1971) prefers to use the term assimilation rather than production at this level. Secondary production is not a fixed level of energy utilization of production but rather moves from one consumer level to the other through the food chain.

C. Net Productivity: Net Productivity is the storage of energy by the consumers. That means it is the energy which remains in the body of the consumer after utilization in respiration or any other work done by the consumer. Thus, it can be measured as biomass. Net productivity can be expressed as the production of carbon mg/meter^2/ day. It can then be calculated how much energy per/biomass the consumer gets in a year.

IN-TEXT QUESTIONS

11. As per the _____ law of thermodynamics, energy cannot be created nor destroyed, it can be transferred from one form to another.

12. The behaviour of energy transactions in an ecosystem is known as _____.

13. NPP = _____ – Respiration energy

14. _____ can be measured as biomass.

3.7 Homeostasis

Homeostasis is defined as *"The ability to maintain a constant internal environment in response to the environment changes"*. This is a unique principle of biology. In the same way, natural ecosystems are also capable of maintaining their internal regulations i.e. self-regulations or self-maintenance at any point in time. This is called the stable steady state of an ecosystem (Homeo means same, and stasis means standing). Odum (1971) defined Homeostasis as the tendency of a natural ecosystem to resist change and to remain in the state of equilibrium, which implies that within an ecosystem there always stays a balance between the production, consumption, as well as decomposition and in all the living

Notes

organisms within a particular ecosystem in a particular time, follow this kind of equilibrium.

3.8 Summary

The abiotic factors in an ecosystem maintain a dynamic role. Different components of the atmosphere, like oxygen, hydrogen, carbon, nitrogen, Sulphur etc. cannot be used by living organisms in their elemental form. Thus, these elements form different compounds as nutrients for the living world. In that way, a cycle of "elements to compounds and again back to elemental form" happens in nature. That cycle is known as Biogeochemical Cycle. Each organism has a place in an ecosystem pyramid. That is based on their food habit. This characteristic can be easily understood by the food chain of an ecosystem. But if one of the organisms is absent in an ecosystem. Then some other organism with the same kind of food choice will replace that place. Thus, the chain of *"to eat and to be eaten"* habit remains maintained. So, instead of only one chain, a web-like structure is found for the self-sustenance of an ecosystem. That is known as Food Web.

Energy Flow is the theme of the ecosystem. Through different channels, energy flow occurs between the producers, consumers and decomposers. We know that the external environment or climate has an impact on the living organisms, growing in that area. But side by side Nature also provided a system to them that, the internal environment or the system within the body of the living organisms does not change with the disturbances of the outside environment. This is a gift of Nature to the biotic factors of an ecosystem and is called Homeostasis.

3.9 Answers to In-Text Questions

1. 15%

2. Respiration

3. 20.94%

4. Nitrate

5. Oxygen

Notes

6. Food Chain
7. Herbivores
8. True
9. True
10. False
11. First
12. Energy Flow
13. GPP
14. Net Productivity

3.10 Self-Assessment Questions

1. What is the nutrient cycle found in an ecosystem?
2. Explain the Oxygen Cycle and Nitrogen Cycle.
3. Describe the food chain and food web in an ecosystem, with proper examples.
4. How energy flows in an Ecosystem.
5. What is Productivity? Differentiate between Gross Productivity and Net Productivity.

3.11 References

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3.12 Suggested Readings

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LESSON

4

Ecosystem: Types and Services

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STRUCTURE

4.1 Learning Objectives

- To understand the importance and types of various ecosystems. In addition to this threat to these ecosystems and conservation strategies.
- To understand concepts of ecosystem services.
- To understand ecosystem preservation and conservation strategies.
- To understand the basics of ecosystem restoration.

4.2 Introduction

Ecosystems can range from small water bodies to an ocean, similarly on land from a patch of woods to a forest. Ecosystems can be natural or anthropogenic (human-created like farm-

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lands). Broadly Ecosystem is classified into terrestrial and aquatic ecosystems, which are further classified into several kinds. The ecosystem sustains mankind on earth by providing various products and services. There are several kinds of ecosystem services which maintain the basic functioning of the planet. Due to the exploitation of resources by the ever-growing human population ecosystems are getting degraded. Therefore, it is essential to understand various concepts of preservation, conservation and restoration of the ecosystem.

4.3 Types of Ecosystems

4.3.1 *Terrestrial Ecosystems*

Diverse kinds of terrestrial ecosystems are present on the earth. Both climate and relative contribution of general plant life forms (trees, shrubs, and grasses) contribute to the diversity.

1. **Forest Ecosystem:** The forest ecosystem mainly consists of the community of plants, animals and microorganism and their non-living environment functioning collectively to exchange material and energy, where trees, shrubs, climbers and ground cover forms the main component**.** Due to the expansion of human settlements and industrial areas since the last century, the pristine forest is only left in protected areas like National Parks and Wildlife Sanctuaries. The appearance of different types of forests differs greatly from each other. Each forest type forms a habitat for a community of animals that are specifically adapted to live in it.

   The forest ecosystem also consists of the abiotic or non-living component which includes factors like temperature, rainfall, topography, soil properties, etc. Due to the variation of these abiotic factors biotic or living components of the forest also varies in different types of forest. Forests also differ in their plant communities in response to the type of soil.

   Forest Types in India: Forests in India can be broadly classified into coniferous forests and broadleaved forests. In addition to this, the forest is also classified according to the kind of tree species they have which includes evergreen, deciduous, xerophytic or thorn trees,

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mangroves, etc. Forests are usually named after the most abundant species of trees such as Sal or Teak forests. In many cases, a forest is named after the first three or four most abundant tree species.

Coniferous forests are found in the high-altitude Himalayan mountain ranges. These ranges remain snow-covered for many months of the year with the temperature dipping below zero. These forests usually have tall trees with downward-sloping branches so that the snow can slip off the branches. The coniferous forest has trees having needle-like leaves. Many trees are gymnosperms which have cones instead of seeds. Pine and deodar trees are found in the Himalayan coniferous forest. Many animals are found adapted to these types of forests. Animal species found in coniferous forests include wild goats, sheep and Himalayan black bears. Some rare species of animals are also found in this forest including the snow leopard, hangul and Himalayan brown bear.

Broadleaf forests are a category of forest further classified into evergreen forests, deciduous forests, thorn forests, and mangrove forests. **Evergreen forests** are found in the Western Ghats, North Eastern India and the Andaman and Nicobar Islands. These regions receive a high amount of rainfall during the long monsoon period. Evergreen forests in southern India receive two monsoons. Trees in evergreen forests keep shedding some leaves throughout the year instead of having a dedicated dry leafless phase as in a deciduous forest. This is why the evergreen forest appears green throughout the year. Evergreen forests have a dense canopy because a high number of trees are present adjacent to each other with their branches overlapping. Due to this less amount of sunlight reaches the forest floor where some shade-loving plants grow. Species richness in the evergreen forest is the highest. Several orchids and ferns are found in these forests. High diversity of mammals, reptiles, and insects are found adapted to these forests. Some of the animals found in the evergreen forest of North-eastern India, Western Ghats and Andaman and Nicobar Islands include tiger, leopard, sambar, Malabar pied hornbill and tree frogs. Rare animals like Pigmy Hog and Lion-tailed macaque are also found in the evergreen forests. **Deciduous forests** are found in regions with a moderate amount of

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rainfall during the monsoon season. Deciduous forests are found in the central highlands and the Deccan peninsula. These forests have a specific season in which trees shed their leaves. At the onset of the monsoon, they regain their leaves. The appearance of these forests varies with the season. These forests have thick undergrowth as light easily reaches the floor. Teak (*Tectona grandis*), Sal (*Shorea robusta*) and Ain (*Terminalia elliptica*) are some examples of trees found in the deciduous forests of India. Animals like tigers, cheetal, barking deer, flycatchers and hornbills are also found in the deciduous forests of India. **Thorn and scrub forests** are found in the semi-arid and arid regions of India. These are regions of low and very low annual rainfall. Here trees are distributed sparsely and are surrounded by grasslands. Xerophytic plants are found in these forests which can survive in the scarcity of water Trees have several adaption-like small leaves, coating wax on their leaves which helps them conserve water. On the other hand, many trees have long and deep roots which help them access water below the ground. Tree species like Babool (*Acacia nilotica*), Khejdi (*Prosopis cineraria*) and Ber (*Ziziphus mauritiana*) are a few examples of plants found in thorn forests. Animals like Blackbuck, chinkara, sambar and monitor lizards make up the fauna of the thorn forests. **Mangrove forests** consist of trees and shrubs found in coastal-intertidal zones in the tropics and subtropics. All these trees grow in areas with low-oxygen soil, where slow-moving waters allow fine sediments to accumulate. In the mangrove forests, there is a dense web of prop roots that gives the impression of trees standing on stilts above the water. This web of prop roots allows the trees to withstand the daily rise and fall of tides. These roots slow the speed of the tidal water, due to this sediment settling out of the water and building up muddy water bottom. Sundarban in West Bengal is an example of a mangrove forest in India. Mangrove forests help in the stabilization of the coastline and prevent erosion from storm surges, currents, waves, and tides. The dense and complicated root system of mangrove forests makes these forests ideal habitats for fish and other organisms.

The forest ecosystem provides us with several products for direct consumption like fruits, medicine, and fuel wood. Forest products

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are also used as raw materials for making furniture and construction material for buildings. Similarly, forest products are also used as raw materials for medicines and industrial products. In addition to this, the forest ecosystem also provides us with several ecosystem services like purification of air, regulation of climate, and prevention of soil erosion. We are continuously losing our forests. Major threats to the forest ecosystem include deforestation and forest fragmentation due to ever-increasing urbanization, industrialization and intensive agriculture. In addition to this, overconsumption or exploitation of forest resources, and invasive species are also some threats to the forest ecosystem. We can conserve the forest ecosystem through afforestation programs, sustainable use of forest resources and making a network of protected areas.

2. **Tundra Ecosystem:** Tundra ecosystems (arctic tundra) are found in extreme northern latitudes where snow melts seasonally. On the other hand, the alpine tundra is found in the higher elevation of mountains, specifically above the tree line. Winters in arctic tundra are long and severe on the other hand, summers or growing season is short. Precipitation is also poor in the tundra ecosystem and mostly occurs in summer. Tundra ecosystems are characterized by low species richness and low primary productivity. The dominant vegetation is tundra including mosses, lichens, grasses and grass-like sedges. Only dwarf willows, dwarf birches and other dwarf trees are found in the tundra. Some of the animals found in tundra include lemmings, voles, weasels, arctic foxes and snowy owls. Oil and natural gas exploration and military use is harming the tundra ecosystem. In addition to this, climate change is posing a serious threat to the tundra ecosystem. As the temperature is rising, causing the permafrost melts resulting in the replacement of tundra vegetation by coniferous trees.
3. **Grasslands:** A wide variety of landscapes where the predominant vegetation is grasses and small annual plants present in various climatic conditions are called grasslands. Grasslands have been given different names on different continents like prairies in U.S. Midwest, pampas in South America, steppes in central Eurasia and savannas in Africa. Grasslands are found in regions where rainfall is not adequate to support forests but now as less as to

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form a desert. Broadly there are two different types of grasslands tropical and temperate (i) Tropical Grasslands and (ii) Temperate Grasslands. **Tropical grasslands** remain warm throughout the year. They have a dry and rainy season. One example of tropical grassland is Savanna in Africa. Animals like giraffes, zebra, rhinos, lions, hyenas and elephants are found in these grasslands. **Temperate grasslands**, on the other hand, receive less rainfall in comparison to tropical grasslands. Grasses of short lengths are usually found in these grasslands. These grasslands also have two seasons growing and dormant. Grasslands have a seasonal appearance because of flowering in the rainy season and during the winter season, only underground storage organs and thick stem bases remain.

Examples of grasslands in India include the Himalayan pasture belt that extends to the snow line. They are also found in patches along coniferous forests or broad-leaved forests. The Himalayan animals need both grasslands and forests as their habitat. Another example is the Terai which has patches of tall grasses interspersed with Sal forest. These grasslands are usually found in the foothills of the Himalayas. Another type of grassland is found along the thorn forest in semi-arid plains of western India, central India and the Deccan. In addition to this, India also has Shola grasslands which consist of patches of grasses on the hill adjacent to the Shola forests on the Western Ghats, Nilgiris and Annamalai ranges.

Grasslands have been used by humans as pasturelands for their cattle. In addition to this, certain grasses are also a source of fuelwood. They also provide habitats to pollinators. Having said that grasslands have been degraded severely as they are overused or exploited. The ever-increasing population along with conspicuous patterns of consumption has increased the demand for dairy products, wool and meat. Consequently, increasing the number of cattle results in overgrazing. Similarly, the expansion of agricultural land has also occurred at the cost of grasslands.

4. **Desert Ecosystem:** A Desert is an ecosystem which receives less or extremely less (less than 12 cm per year) rainfall. Deserts and semi-arid regions in India are found in western India and Deccan Plateau. The climate in these vast tracts is extremely dry. The Thar

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Desert of Rajasthan is an example of a typical desert in India which has sand dunes. Rainfall in these areas is sporadic. Sparse grasses and some shrubs grow in these arid regions. In the adjacent semi-arid regions some species of shrubs and trees like Babool (*Acacia nilotica*) and khair (Senegalia *catechu*) are found.

In addition to the Thar Desert, India has two more desert ecosystems. Cold desert is found in Ladakh, which is situated on the high plateau of the Himalayas. On the other hand, highly specialized arid regions are found in the Great and Little Rann of Kutch in Gujarat. During the summers these regions have conditions similar to a desert but during the monsoon, these regions get converted into salt marshes because they are low-lying areas adjacent to a sea. In terms of bird diversity Greater and lesser flamingos are found in the Great Rann of Kutch. Similarly, Little Rann of Kutch is the only region where the wild ass is found in India. Highly specialized insects and reptiles are found in the desert and semi-arid regions. These regions are home to several species of rare animals desert cats, desert foxes, Indian wolves and birds like the Great Indian Bustard and the Florican.

4.3.2 *Aquatic Ecosystems*

Diverse kinds of aquatic ecosystems are present on the earth. Broadly aquatic ecosystems can be classified as freshwater (ponds and lakes i.e. lentic ecosystems; streams and rivers lotic ecosystems i.e. lotic ecosystems), brackish water (estuaries) and salt water (oceans) ecosystems based on the salinity levels of the water. **Ponds and Lakes** are called lentic ecosystems which means stagnant water ecosystems.

1. **Pond Ecosystem:** Ponds are the smallest and simplest aquatic ecosystems. Many pond ecosystems become dry long after the monsoon is over and terrestrial plants grow on it till the arrival of the next monsoon. As the monsoon arrives organisms like algae, zooplanktons, insects, snails and worms come out from the bottom of the pond where they spent the dry phase. Slowly large animals like amphibians, crabs and large fishes also return to the ponds. In addition to this now, floating weeds and rooted vegetation at the

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periphery of ponds also start growing. Now a large number of food chains are formed.

2. **Lake Ecosystem:** Lakes on the other hand function like large permanent ponds as water remains in the lakes throughout the year. Organisms like algae, microscopic animals, and both herbivorous and carnivorous fishes form several food chains in the lakes. Fishes like catfish are also found in the lakes which specifically feed on detritus on the bed of the lakes. These fishes are called bottom feeders. Both ponds and lakes play a crucial role in the conservation of water and biodiversity. Pollution from industries and agricultural field are degrading these ecosystems.
3. **Streams and Rivers:** Streams and rivers are examples of lotic water ecosystems which means a running water ecosystem. A stream is significantly smaller in size than a river. These ecosystems are open systems, exchanging nutrients and energy with larger areas than lentic ecosystems. In these ecosystem currents is an important ecological factor. Two zones can be identified in these ecosystems which are the rapid zone and the pool zone. In the rapid zone, the current is fast which cleans the silt and other material from the bottom making it firm and hard. On the other hand, in the pool zone speed of the current is slow, water is deep resulting in the deposition of sand and silt. Here the bottom is soft. Different kinds of organisms are adapted to these two zones.

   Rivers originate from glaciers in the mountains and carry the sediments enter the plain areas making the soil fertile with sediments before ending in the oceans. Rivers provide water for drinking, domestic purpose, industries and agriculture and power generation to mankind. Pollution originating from the sewage drains (Urban areas), effluent drains (Industries) and agriculture fields are polluting the river ecosystems. In addition to this destruction of floodplains and catchment areas is causing loss of property and life during floods.
4. **Estuaries:** Estuaries are an example of a brackish water ecosystem where salinity levels are intermediate i.e. more than the freshwater ecosystem and less than the saltwater ecosystem. Estuaries, where the rivers enter the ocean. It is a complex ecosystem of high

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productivity having both salt marshes and mud flats connecting the freshwater communities and oceans. Estuaries have both plankton and detritus-based food webs. Most fisheries are directly or indirectly dependent on this ecosystem.

5. **Ocean:** The Indian Ocean, Bay of Bengal and Arabian Sea are examples of the ocean or marine ecosystems in India. 70% of the earth's surface is covered by oceans. These ecosystems are extremely deep and living organisms occur at all depths even beyond 5000 meters. Although density and diversity of organisms in the ocean in the peripheral zones. All oceans are connected with each other. Oceans have salinity levels much higher (35 parts per 1000 parts of water (by weight) or 3.5%) than freshwater ecosystems (0.5%). Ocean waters continuously move horizontally by the action of strong winds such as trade winds are called waves. On the other hand, ocean water also rises and falls by the action of different interactions of gravitational forces exerted between the moon, the Earth and the sun. This vertical movement is called the tide.

   The ocean ecosystem consists of several communities like littoral, marine sandy beaches and marine mudflat communities. Estuarine, mangrove and coral reef communities are important both ecologically and economically. In addition to this, Continental shelf (Neritic) Benthos communities, Marine surface Pelagic communities and Deep open benthos communities are also found in oceans. A great diversity of organisms is found in each of these communities. **Littoral communities** occur in coastal belts which are continuously affected by waves and tides. Some of the organisms found in these communities include oysters, branches, limpet and kelp.

   Coral reef communities are formed by the symbiotic relationship between coelenterate animals and endozoic algae dinoflagellates. The animals contribute to the coral, a colonial structure embedded in calcium carbonates. The animal gives support structure and nutrients to the algae. On the other hand, algae form food for them. Coral reef communities are found in warm waters of tropical and subtropical oceans. These communities have huge species diversity and richness. Some of the organisms in the coral reef communities

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include sponges, molluscs, crabs and snails. Coral reef communities in India are found in the Gulf of Kutch, Andaman and Nicobar Islands, Lakshadweep islands, and the gulf of Munner near Sri Lanka. The world's largest coral reef is called the great barrier reef in Australia.

Continental shelf (Neritic) Benthos communities are found below the littoral zone on the bottom. There is variation in the community with changing depth. Since light penetrates this part of the ocean, it has several organisms like diverse algal communities, fish and crustaceans.

Marine surface Pelagic communities have plankton and large swimming animals that are present in the open waters. These communities are further divided into surface pelagic and deeper water pelagic communities. Organisms in the surface pelagic communities include phytoplankton (dinoflagellates and diatoms) due to the availability of light. Other organisms existing in these communities include Zooplankton (Copepods) shrimp, arrow worms, comb jellies, tunicates, etc. Not much of the light reaches the marine deep pelagic communities because it occurs below the lighted surface waters and these communities are heterotrophic organisms. The Source of food for these organisms is settling plankton and dead organic particulate matter from the surface water.

Deep Open Benthos Communities: These communities are present between the boundary of the continental shelf to the deep oceans. Since light does not reach this region, therefore, only heterotrophic organisms and some bacteria are part of these communities.

Ocean ecosystems are a source of marine food for many human communities. In addition, these oceans are also used for travel and transportation of goods. Ocean ecosystems are also threatened by water pollution from sewage drains and industrial drains. Also, waste dumped into the rivers reaches the oceans threatening marine life. In addition to this, many ocean communities like coral reefs are getting degraded due to climate change.

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IN-TEXT QUESTIONS

1. Forest Ecosystem is a type of aquatic ecosystem. (True/False)
2. Grassland Ecosystem is a type of terrestrial ecosystem. (True/False)
3. _____ grasslands remain warm throughout the year.
4. Grasses of _____ lengths are usually found in these grasslands.
5. _____ desert is found in Ladakh, which is situated on the high plateau of the Himalayas.
6. Ponds and Lakes are not lentic ecosystems. (True/False)
7. Oceans have salinity level of _____.
8. Arabian Sea is an example of a marine ecosystem.

4.4 Ecosystem Services

Ecosystem services are direct and indirect benefits humans get from nature. These are essential for the maintenance of the basic functioning of the earth and consequently, support life on this planet. Changes in ecosystem services can significantly affect the quality of human life on earth. These services can be categorized into four main types

Provisioning Services: These include materials and products which we get from nature like fruits, vegetables, crops, honey, fish, marine food, livestock and other food material, freshwater, fuelwood, timber for furniture and construction, fibre, medicines, oil, natural gas, plant material for clothes and genetic resources.

Regulating Services: These are the services that humans obtain by the maintenance of the basic functioning of the ecosystem. It includes purification of air and water, climate regulation, flood control, carbon storage, prevention of soil erosion, natural hazard regulation, pollination, pest control and decomposition of waste by microbes. All these processes collectively work making the ecosystem functional, sustainable and resilient to change which in turn supports the life of humans on this planet.

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Cultural Services: Humans live in nature and constantly interact with it. They change it and in turn nature changes them. Cultural services are the non-material benefit that contributes to the progress and cultural advancement of people. It includes the role of ecosystems in local, national and global cultures. It also includes spiritual enrichment, intellectual development, the recreation of aesthetic values and creativity born by interacting with nature like art, music, and architecture.

Supporting Services: These services include processes which are essential for the sustenance of the ecosystems which in turn sustain life on the planet. It includes processes like biogeochemical cycles, photosynthesis, creation of soils and water cycle. Supporting services are essential for the existence of provisioning, regulating and cultural services.

4.5 Ecosystem Preservation and Conservation

Ecological Restoration: It is a process of assisting the recovery of an ecosystem that has been partially or completely degraded. In simple words, ecological restoration means restoring the ecosystem, to a former state or to a perfect condition. Ecological restoration focuses on the recovery of many aspects of the ecosystem which are as follows:

- The health of the ecosystem: purification of air, sequestration of carbon dioxide, filtration of water.
- The integrity of ecosystem: Species composition and community structure.
- Sustainability: Resistance and resilience to disturbance.

Rehabilitation: It means returning degraded land to a fully functional ecosystem irrespective of its original state but according to a prior land use plan. Examples of the rehabilitation process are a partial recovery of species diversity and ecological complexity, reducing the livestock grazing from the riparian zone, allowing natural growth of vegetation or restoring fluvial processes.

Remediation: It is a process in which using physical and biological methods, chemical contaminants are cleaned from the polluted ecosystem to protect human and ecosystem health.

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Reclamation: It is a process by which the biotic function and productivity of severely damaged land are restored.

Mitigation: It is defined as the restoration, rehabilitation or reclamation process to reduce the effect of the source of degradation.

IN-TEXT QUESTIONS

9. Purification of air and water is the _____ service of the ecosystem.

10. _____ is a process of assisting the recovery of an ecosystem that has been partially or completely degraded.

11. _____ means returning degraded land to a fully functional ecosystem irrespective of its original state but according to a prior land use plan.

4.6 Summary

- The ecosystem is the basic functional unit of nature. There is a great diversity of ecosystems present in nature.
- The terrestrial ecosystem includes forests, grasslands and deserts. These ecosystems provide several products and ecosystem services to mankind. These ecosystems are threatened by deforestation and forest fragmentation due to industrialization, urbanization and expansion of agricultural land.
- The aquatic ecosystem is categorized based on salinity level into freshwater and marine water ecosystem. These ecosystems provide us with water for drinking, domestic purposes, industries and agriculture. We also get food from aquatic ecosystems. Pollution from urban areas, agricultural lands and industries is severely polluting the aquatic ecosystems.
- In addition, the products ecosystem also provides us with several services which are essential for the sustenance of life on the planet. These services include Provisioning, Regulating, Cultural and Supporting services.
- It is essential to understand the concept of ecological restoration in order to restore degraded ecosystems.

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4.7 Answers to In-Text Questions

1. False
2. True
3. Tropical
4. Short
5. Cold
6. False
7. 3.5 %
8. True
9. Regulating
10. Ecosystem Restoration
11. Rehabilitation

4.8 Self-Assessment Questions

1. Differentiate between terrestrial and aquatic Ecosystems.
2. Explain the producers and consumers of the grassland ecosystem.
3. Explain the producers and consumers of the desert ecosystem.
4. Differentiate between Lentic and lotic ecosystems.
5. Explain the producers, consumers and decomposers of the ocean ecosystem.
6. Explain the rehabilitation of an ecosystem.

4.9 References

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LESSON

5

Natural Resources: Land Resources

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STRUCTURE

5.1 Learning Objectives

- To explain the importance, use, threats and problems related to land resources and the impact of dams and mines on forest resources.

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- To understand concepts of soil erosion, land degradation, desertification and land use change.
- To identify the problems of related land misuse, land mismanagement, deforestation, and desertification.
- To seek a solution to address how the land resource can be managed in a better and sustainable manner.

5.2 Introduction

Land is one of the most valuable resources for mankind as well as one of nature's most precious gifts. It is that part of the lithosphere that sustains life as well as provides various existential resources to human beings. The land is a mixture of inorganic and organic materials. It provides various kinds of resources like food, fibre, medicine, and minerals as well as services like agricultural productivity, biological diversity, carbon sequestration etc. The most basic use of land is to support vegetation of various kinds, thereby providing a place for all the terrestrial fauna to exist.

The land resource is under huge threat due to misuse and mismanagement by humans. Various anthropogenic activities have led to land losing its productivity leading to and becoming degraded and polluted. Land degradation and soil erosion are impacting the various resources and services that we humans obtain from land. It is impacting our quality of life and in many cases our very survival, as we are directly and indirectly dependent on it. An extreme case of land degradation is desertification wherein semidry regions of the world are losing their productive capacity to such an extent that they are becoming barren and desert-like due to anthropogenic activities and climate change issues.

5.3 Land Resources

From a human point of view, land resource includes all those aspects and functions of the land, which can be used to fulfil human needs. Humans have been exploiting the land for agriculture, mining, grazing animals and settlement purposes. The land resource can be divided into three categories

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(a) *Very stable resources*, like relief, geological formations and minerals;

(b) *Moderately stable resources*, like soil and water

(c) *Very unstable resources*, like vegetation and biodiversity

Some of the important resources and services provided by land to humankind are:

(a) **Minerals:** The mineral is a pure inorganic substance that occurs naturally in the earth's crust. Almost all minerals are found in the earth's crust. Minerals are non-renewable resources and include metals like iron, copper, aluminium etc. and non-metals like phosphates, gypsum, clay, sand etc. Minerals are extremely valuable to humans as they are the essential raw material in industries and play a major role in the overall development of the nation. Minerals available in the earth's crust can be divided into three categories

(i) Metallic minerals like Iron, aluminium, lead, zinc etc.

(ii) Non-metallic minerals like graphite, feldspar, asbestos, limestone etc.

(iii) Mineral fuels like coal, natural gas, petroleum etc.

India is rich in mineral resources and has sufficient quantities of iron, aluminium, titanium copper, lead and zinc ores.

(b) **Soil:** Soil is defined as the outermost thin layer of the earth's crust which serves as the natural medium for the growth of plants, providing them with a substrate for anchorage and essential nutrients for their growth. Soil is a complex mixture of organic and mineral content which is constantly being formed by the chemical decomposition and mechanical disintegration of rocks. Soil is a renewable resource which is constantly being formed and destroyed, mainly by the erosion process. The topmost layer of soil rich in organic matter is called humus and is the most fertile layer. Soil forms a fundamental part of the human environment and is as essential as water. Soil provides the substrate to support the productivity and cycling of biological resources, it is the source of nutrients and water for agricultural and forestry ecosystems and acts as a complex buffer against environmental variability. Soil is very rich in microbial biodiversity and is also a major reservoir of carbon. The soil across the world varies with respect to its characteristics and properties

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which forms the basis for its classification. The major soil groups found in India are alluvial soil, black soil, red soil, laterite soil, desert soil and acid soil.

(c) **Agriculture:** The most dominant use of the land resource by humans has been in the form of agriculture in order to meet the food demand of the growing world population. Agricultural ecosystems cover nearly 40% of the land surface. The total world land area suitable for cropping is 4.4 billion hectares out of which 1.6 billion hectares are currently under cultivation. Agriculture is the dominant driving force for the economy of a number of the world's developing countries, which includes India as well. Agricultural productivity has increased manifold globally over the last 70-80 years due to the increased use of fertilizers and pesticides. But this highly chemical-intensive agriculture has also adversely impacted the land and its associated resources.

(d) **Natural Forest Products:** Forest products are materials derived from forests for consumption and profitable use. These mainly include timber, firewood, wood pulp for paper and forage for livestock. There are also other non-wood products that are derived from forests which include nuts, resins, gum, medicinal plants, edible fruits, oils etc. which are collectively called Non-Timber Forest Products (NTFPs). These NTFPs are considered to have relatively lesser negative effects on the forest ecosystem. Forest products are used extensively worldwide for a number of purposes including cooking, animal feeding, medicines for healing, household subsistence, income generation as well as cultural traditions. These products are also an extremely important source of revenue generation for all countries.

(e) **Medicinal Plants:** Medicinal plants are valuable natural resources obtained from land (mainly forests) which have been used by human communities since prehistoric times. The immense diversity of medicinal flora in tropical forests is an invaluable source of new pharmaceutical products. About 80% of the world's developing countries are dependent on these traditional medicinal plants for primary health care. For a majority of people living in rural and urban areas in developing countries, medicinal plants are the only available treatment for various minor and major diseases. Moreover,

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the demand for medicinal plants is continuously on the rise as more people are understanding their importance as compared to allopathic medicines.

(f) **Forest-based Industries and Livelihood:** Forests have played a significant role in building up the economy of various countries and have provided a means of living to millions of people. Forest serves as a source of raw materials for large, medium and small-scale industries. Globally, about two billion people use fuelwood and charcoal as their main source of energy for cooking and for heating their homes. Millions of rural households obtain income by collecting and selling forest products like food, fuel, medicinal plants and construction materials. Many sell timber from their land areas to logging companies or make and sell furniture and handicrafts. And industrial logging provides employment and earnings for people in countries like Brazil, India, China and Indonesia. Forests also contribute to livelihoods in an indirect manner as they provide soil nutrients and forage for crops and livestock. They also help in pollinating crops, reduce soil erosion, and provide protection from natural disasters. Globally, it is estimated that between about 1.5-2 billion people depend on forests for their livelihoods and income and about 200 million people from indigenous communities are almost fully dependent on forests.

IN-TEXT QUESTIONS

1. Forests are part of water resources. (True/False)
2. The _____ is a pure inorganic substance that occurs naturally in the earth's crust.
3. Zinc is a non-metallic mineral. (True/False)
4. Agricultural ecosystems cover nearly _____ of the land surface.
5. NTFP stands for _____.

5.4 Land Cover and Land use Change

Land cover refers to the observed biophysical cover on the surface of the earth whether vegetation, water, bare soil or urban infrastructure.

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Land cover can be determined either by field survey or by analysing satellite and aerial images. The International Geosphere-Biosphere Programme (IGBP) has categorised land cover into 17 classes that include different types of forests, woodlands, shrublands, grasslands wetlands and deserts. The global land area is 13.2 billion ha. Of this, 12% (1.6 billion ha) is under cultivation, 28% (3.7 billion ha) is under forest and 35% (4.6 billion ha) comprises grassland and woodland ecosystems. On the other hand, land use is different from land cover. Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture. To illustrate this with an example, 'grassland' is a term used for land cover, while 'agricultural land', a 'horse ranch' or a 'tennis court' refers to the land use of grassland.

Land use change means the conversion of terrestrial land surface for anthropogenic uses. The use of land results in changes in the structure and functioning of ecosystems. Since the start of human civilization (ca 3500 BC onwards), land has been increasingly used for settlements, agricultural purposes, grazing of animals, mining, urbanization and industrialization which have drastically altered the land cover. The rapid and large-scale human intervention in converting natural landscapes for our own usage has resulted in devastating effects on both biotic and abiotic components of the ecosystem. The increased demand for water, waste disposal and food requirements has resulted in land being used in an unsustainable manner, leading to its degradation. Forest cover and composition, cropland expansion, agriculture intensification, urban development and desertification are key drivers of land use change. The major environmental impacts of land use change are:

- Climate Change and global warming
- Biodiversity loss
- Pollution of various kinds
- Large scale deforestation
- Land degradation and Desertification
- Waste aggregation

All these concerns have greatly impacted human health, well-being and livelihoods.

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5.5 Land Degradation

Land degradation is defined as the deterioration of the productive capacity of land due to overexploitation by humans. Land degradation affects soil chemistry and soil biodiversity and alters the natural ecological processes and ecosystem of the affected area. Land degradation has put the world's ecosystems under intense pressure as their capacity to provide vital resources and services is rapidly decreasing. Degraded lands have reduced the capacity for the supply of goods (food, timber, fibre, fuel etc.) for humankind.

The major causes of land degradation are:

(a) Deforestation

(b) Soil erosion

(c) Unpredictable weather patterns or climatic conditions

(d) Droughts and floods

(e) Modern agricultural practices

(f) Soil pollution

(g) Increasing urbanization

Land degradation is a major challenge that needs to be addressed quickly, not just to restore the ecosystem and biodiversity of the affected area but also for maintaining economic growth and social structure in human society.

5.6 Soil Erosion

Soil erosion is the loss or removal of the top layer of soil due to natural physical agents like wind, water and even gravity. As the topmost layer of soil is the most fertile layer, being extremely rich in organic matter and nutrients, erosion leads to reduced productivity of the soil, which in turn results in the soil being unable to support vegetation. Soil formation is a very slow process with 1 cm of soil taking 200-300 years to form from the bedrock. Hence frequent soil erosion takes years to restore naturally. When soil erosion is intense, the natural soil profile is destroyed and may never attain its original capacity. Extensive cultivation, overgrazing and deforestation expose the precious topsoil to wind and water erosion.

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The various natural and anthropogenic (human-originated) reasons for soil erosion are:

(a) **The Slope of the Surface:** Soil erosion is more common on hill slopes which get aggravated with the removal of natural vegetation.

(b) **Soil Content:** Soil with higher content of sand is more prone to erosion as compared to soil with a higher clay amount.

(c) Weather and climatic conditions: natural factors like high-intensity rainfall, floods and droughts also increase soil erosion in affected areas. With global warming and climate change as major threats, such natural disasters are becoming more frequent leading to soil erosion in many areas.

(d) **Deforestation:** Deforestation leads to a reduction in tree roots, which performed a major function of holding the soil together. In absence of a stronghold, the soil is prone to erosion

(e) **Extensive Agriculture and Cultivation:** Modern-day chemical-intensive farming practices lower soil organic matter levels, and soil biodiversity, and also reduce the soil water content, thus making soil prone to erosion. Excessive irrigation also is a major reason for erosion.

(f) **Overgrazing:** In order to feed cattle and cater to the meat and dairy needs of people, large areas of vegetation are exploited for grazing. Thus, overgrazing exposes soil to erosion.

Soil conservation has attained great importance today. The remedial measures suggested to arrest soil erosion include:

(a) Erosion control technologies in farming such as no-tillage or low tillage, crop rotation, and use of mulch cover can greatly reduce erosion of soil by water

(b) Adoption of terrace farming, contour farming and setting up structures like windbreaks, live fences, sand fences etc. reduce soil erosion in areas that are naturally prone to erosion.

(c) Reforestation in areas where large-scale vegetation has been removed is an extremely important step as trees are natural binding agents of soil.

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IN-TEXT QUESTIONS

6. The global land area is _____.
7. Biodiversity loss is an impact of land use change. (True/False)
8. The deterioration of the productive capacity of land due to overexploitation by humans is known as _____.
9. Increasing urbanization is one of the causes of land degradation. (True/False)
10. Crop rotation farming is one of the methods of soil erosion control. (True/False)

5.7 Desertification

Desertification is an extreme case of land degradation in which semidry regions, become increasingly arid resulting in the loss of water bodies, vegetation and wildlife. It is caused by a variety of factors, which includes both anthropogenic activities as well as climate change. Desertification is one of the most significant global ecological and environmental problems that we face today. According to UNESCO, one-third of the earth's land surface, categorised as drylands, is facing the threat of desertification. This would ultimately affect the livelihood of millions of people who are dwelling in these regions and are dependent on goods and services provided by these drylands. One of the major problems that arise out of desertification is the migration of people towards presumably resource-rich regions like cities, in search of better living conditions. However, large-scale migration to cities not only causes economic loss of land that could be cultivated but also puts an additional burden on the resource crunch and pollution in cities.

Desertification begins with land slowly getting degraded due to deforestation, overgrazing, modern agricultural practices, increasing urbanization, mismanagement of water resources, exploitation of groundwater and destruction of wetland regions. When such degraded land when faces climate change issues, like drought, erratic weather conditions, and rainfall deficiency for a continuous period, it results in the land losing its productivity to such an extent that it resembles desert-like conditions. Desertification thus leads to the loss of farmlands (economic loss), increase

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in hunger and poverty, social inequality and crowding and overpopulation in towns and cities.

In order the prevent drylands from facing desertification, there is a need for an integrated approach with help from multiple stakeholders. There is a need to implement policies and rules that help in better land and water management, educate and spread awareness among people (especially the farming community), provide all necessary support to farmers and local communities, and formulate and promote sustainable methods of agriculture.

5.8 Deforestation

Deforestation is the clearing or permanent removal of forest areas so that it is available for other uses. Deforestation is the root cause of land degradation, soil erosion and desertification. According to the United Nations Food and Agricultural Organization, the annual rate of deforestation is estimated to be about 1.3 million square km per decade. Extensive deforestation has taken place in tropical regions as compared to temperate forests. The depletion of forest areas not only results in the loss of trees, which act as a major carbon sink (storage reservoir), but it also leads to the release of billions of tons of carbon from the dead and decomposing trees. Both these factors significantly impact global warming and climate change, two of the major challenges faced by humanity today.

Causes of Deforestation

Forest lands are cleared mainly to provide for human needs. The major causes or reasons for deforestation are:

(a) **Agriculture and Plantations:** The most significant threat to forests are their conversion to agricultural and plantation areas, in order to fulfil the needs of the growing human population. Agriculture is the direct cause of 80% of deforestation in tropical and subtropical regions. Agriculture patterns have changed significantly since the 1950s, as the focus has shifted to more intense agriculture involving new technology, machinery and chemicals in order to meet human requirements. This agricultural intensification, often called industrial agriculture, has significantly increased the rate of deforestation,

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impacted terrestrial and aquatic ecosystems, and resulted in large-scale biodiversity loss as well.

(b) **Urbanization:** Urbanization is another major cause of deforestation which is a result of increasing population, capitalism and globalization. Forests are cleared for setting up residential areas, industries, commercial hubs, and development projects like roads, railways etc. The clearing of forests for such activities has led to habitat degradation, habitat loss and habitat fragmentation, all of which have significantly impacted the ecosystem and biodiversity.

(c) **Harvesting Wood for Use as Firewood and Timber:** Millions of families still rely on fuelwood as an energy source for various household activities (cooking, heating etc.) and forests are still the main source of fuelwood. Expanding urbanization has also increased the demand for wood (for use in furniture, industries, sports goods, equipment etc.) resulting in large-scale timber extraction from forests.

(d) **Illegal Logging:** Illegal logging is very common across various forest regions of the world. Wood is harvested illegally for various purposes, especially decorative and medicinal, and this illegally harvested wood has huge markets in the US and Europe.

(e) **Forest Fires:** Every year, fires destroy millions of hectares of forests across the world. Forests may catch fire naturally or through humans. Natural forest fire includes an unplanned burning of forest due to lightning, long spells of high temperature and drought which can spread quickly in warm and windy conditions. On the other hand human-induced forest fire results from the unauthorized burning practice of forests for attaining farmland. The recent bushfires that occurred in Australia are a prime example of the destruction caused by forest fires, that not only destroyed thousands of hectares of forests but also released large amounts of greenhouse gases into the atmosphere.

(f) **Mining:** With the increasing demand for metallic resources, mining has become a major economic activity. Large-scale mining operations, especially those using open-pit mining techniques, have resulted in significant deforestation. Mining projects also require the construction of new roads, settlements and townships for people working in the mines which results in the clearing of more forest areas. Industrial

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mining operations have thus caused large-scale deforestation, especially in tropical countries.

5.9 Impacts of Mining and Dam Building

Since the industrial revolution, mines and dams have become essential drivers for economic growth. The second half of the twentieth century witnessed a massive increase in mining operations and dam constructions, especially in developing countries. Although both mining and dams are of many benefits to human society and development, they have devastating impacts on the environment and people living in the vicinity. It is now well-proven that large-scale industrial mining and hydroelectric projects destroy ecosystems, cause pollution and impact vulnerable human communities.

The major impacts of mining and deforestation are:

(a) **Deforestation or Loss of Vegetation:** Both mining and dam construction lead to large-scale loss of forests and vegetation. While Industrial mining, especially open pit mining, requires the clearing of large areas of forest, large dam construction leads to the submergence of huge tracts of forests and vegetation.

(b) **Pollution:** Mining operations result in air, water and soil pollution that impacts the people living in the vicinity of mines. While air pollution is caused due to harmful gases from heavy machinery and equipment and the release of toxic gases from inside the mines, water pollution is caused due to mine waste rock and tailings getting mixed with surface and underground water. Air pollution is also caused during the construction period of dams when heavy machinery is in use. Dams are also one of the sources of methane gas emissions (greenhouse gas) that are released from the dead and decaying vegetation inside the reservoir.

(c) **Land Degradation and Water Loss:** Mining activities lead to the depletion of surface and groundwater supplies as water is extensively used during the processing stage. Groundwater withdrawal can harm streams and rivers that are many miles away from the actual mine site. Moreover, mines left open after the mining can also lead to loss of groundwater through evaporation leaving the area barren and degraded and susceptible to desertification.

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(d) **Siltation:** One of the most serious technical problems faced by the dam industry is that of siltation, which is the increased deposition of sediments brought along by the river at the bottom of the dam reservoir. The sediments gradually accumulate in the reservoir, reducing the ability of the dam to store water, the very purpose for which it was constructed. The intensity of siltation varies depending on the sediments that a river brings along. The silt-laden water also causes abrasion of turbines and other dam components thus reducing their electricity-generating efficiency.

(e) **Impact of Ecosystem and Biodiversity Loss:** Both mining and dams result in deforestation leading to habitat loss and habitat fragmentation thus affecting the biodiversity that dwells in the affected area. Dams submerge large areas of the terrestrial ecosystem where reservoirs are formed, while also impacting the aquatic ecosystem due to obstructed/ reduced water flow. Mines also impact terrestrial ecosystems due to the clearing of vegetation as well as any aquatic ecosystem that are in the vicinity of the mines due to pollution.

(f) **Displacement of Local and Indigenous Communities:** One of the biggest social problems caused due to large-scale mines and dam construction is the way it impacts local and indigenous communities dwelling in those areas. More often than not, these vulnerable communities are victims of injustice as they are not rehabilitated and compensated in an appropriate manner. They have to go through many emotional upheavals as they face the task of being displaced from areas where they have resided for long periods of time. Families lost their traditional ways of livelihood as they are shifted and had to struggle very hard to find similar living and livelihood conditions in the newly displaced area

(g) **Health Problems and Social Issues:** Mining operations have huge health impacts on the people working in mines, as they are constantly exposed to toxic metals, wastes and poisonous gases emanating from the mines. In many countries, mine workers don't have proper safety gear and work in deplorable conditions. Fatal accidents are also common in mines. The pollution caused due to mines and dams affects people living in nearby villages and towns. Dams and mines

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also open up remote areas to developers, road builders, loggers, and farmers accelerating deforestation further. Local people also face the problem of people migrating from other regions into the areas that can increase social instability due to issues like unemployment, increase in crimes, shortage of resources etc.

5.10 Steps for Sustainable Management of Land Resources

(a) **Afforestation:** Planting trees is one of the best ways to overcome the issues of land degradation, soil erosion and desertification. Afforestation, as well as reforestation in deforested areas, can improve the quality of human life by absorbing pollution and dust from the air, mitigating global warming, establishing natural habitats and ecosystems and providing timber and non-timber forest products. They play an essential role in diluting the effect of natural disasters and are essential life support systems for local and indigenous communities

(b) **Forest Management:** Our existing forests must be managed in a wise and sustainable manner rather than sacrificing them in the name of developmental projects. Governments across the world need to enact and implement rules and policies to protect the existing forests and also ensure to increase in forest cover through afforestation and reforestation. It is the responsibility of both government and citizens to protect existing forests from the threats of illegal logging, invasive species, diseases and overutilization. Programs like Joint Forest Management and Social forestry are good models wherein multiple stakeholders have worked together to protect the forests in India and have been able to increase the green cover. The emphasis also should be on the use of technology in order to find solutions to various threats to forests.

(c) **Farming Methods:** new farming methods need to be constantly devised in order to reduce the usage of pesticides, fertilizers and excessive irrigation. Mixed farming, organic farming, Rice fish farming, developing nano-fertilizers, improving irrigation technology to conserve water, use of mulch and manure, and using a wild

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variety of seeds are all ways which can be used to conserve the fertility of the soil and improve the agricultural output as well.

(d) **Water Management:** Water is an important constituent of soil and very important for soil formation, maintaining soil fertility and preventing soil erosion. Both surface and groundwater need to be monitored regularly as loss of groundwater make the soil susceptible to erosion and degradation. Overutilization of groundwater needs to be addressed by a coordinated effort of both government and the citizens in order to prevent soil erosion, land degradation and desertification. Better irrigation technology, judicious crop management, understanding soil characteristics, and reducing surface water pollution are all important steps to the proper management of existing water resources.

(e) **Waste Management:** Developing effective solid waste management technologies and practices are important to reduce the dumping of waste in landfills and other areas on land and to reduce the quantity of non-biodegradable and other toxic compounds mixing into the soil.

IN-TEXT QUESTIONS

11. According to UNESCO, _____ of the earth's land surface, categorised as drylands, is facing the threat of desertification.

12. Deforestation is the root cause of land degradation, soil erosion and desertification. (True/False)

13. Pollution is not the impact of mining. (True/False)

14. The annual rate of deforestation is estimated to be about _____.

5.11 Summary

- Land provides various resources (like minerals, and metals) that support vegetation, provide habitat, support agriculture and store carbon.
- Forest cover has decreased drastically, especially in tropical countries, due to various anthropogenic activities like agriculture, industries, urbanization, overgrazing etc.

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- Since the invention of agriculture, land use has changed considerably. The land is now used or exploited for a variety of purposes to satisfy ever-growing human needs.
- Land degradation is a major problem wherein land is losing its productive capacity. Land degradation affects soil chemistry and soil biodiversity and alters the natural ecological processes and ecosystem of the affected area. Several anthropogenic causes have been attributed to land degradation
- Desertification is an extreme case of land degradation in which semidry regions, become increasingly arid resulting in the loss of water bodies, vegetation and wildlife. It is caused by a variety of factors, which includes both anthropogenic activities as well as climate change. According to UNESCO, one-third of the earth's land surface, categorised as drylands, is facing the threat of desertification. One of the major problems that arise out of desertification is the migration of people towards presumably resource-rich regions like cities, in search of better living conditions.
- Deforestation is the clearing or permanent removal of forest areas so that it is available for other uses. Deforestation is the root cause of land degradation, soil erosion and desertification. Extensive deforestation has taken place in tropical regions as compared to temperate forests. The major causes of deforestation are the conversion of forest areas for agriculture, plantation and urbanization, illegal logging, forest fires and mining.
- Although both mines and dams are of many benefits to human society and development, they have devastating impacts on the environment and people living in the vicinity. Large-scale industrial mining and hydroelectric projects destroy ecosystems, cause pollution and have a socio-economic impact on vulnerable human communities.
- It is important to devise steps and strategies for the sustainable management of land resources. Afforestation, reforestation, sustainable agricultural practices, water management, Forest management, and waste management are important measures to utilize land and the services it renders to humanity for a long period.

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5.12 Answers to In-Text Questions

1. False
2. Mineral
3. False
4. 40%
5. Non-Timber Forest products
6. 13.2 billion ha
7. False
8. Land degradation
9. True
10. True
11. One-third
12. True
13. False
14. 1.3 million square km per decade

5.13 Self-Assessment Questions

1. What are natural resources? Explain the types of natural resources.
2. Differentiate between renewable resources and non-renewable resources.
3. Explain medicinal plants as land resources.
4. Elaborate on the challenges in front of forest-based industries and livelihoods
5. Explain methods to control soil erosion
6. Differentiate between soil degradation and desertification.
7. Explain the impacts of mining and dam building on the environment.
8. Elaborate on the steps for sustainable development of land resources.

Notes

5.14 References

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LESSON

6

Natural Resources: Water Resources

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STRUCTURE

6.1 Learning Objectives

- To explain the importance of hydrological cycles.
- To understand the distribution of water among the various sources.
- To identify the different challenges for the different water sources.
- To seek a solution to address the sustainable water management.
- To understand importance of water harvesting.
- To realize the disbalance between water demand and water supply.

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6.2 Introduction

Our planet Earth is known as a blue planet because of the water that covers three-fourths of its surface. Water has a remarkable influence on various aspects of the structure and function of our planet including shaping the continents, and moderating our climate and the survival of organisms. Without water, Life on Earth is impossible. All life forms including bacteria, plants and animals have 60-70% of water by their body weight. We rely on water not only for our convenience and usage but also for our survival. It is essential for ecosystem health. Although Earth has ample water, most of it is saline and not suitable to drink, agriculture or other purposes. The vast amount of the remaining three per cent of fresh water is locked up out of practical human reach in the form of glaciers, icecaps and deep groundwater aquifers. The very small fraction of freshwater that is accessible to us is distributed extremely unevenly in space and time. This results in serious water-related problems, including interregional conflict over access and quality, competition between rural, urban and environmental uses, severe human health problems and constraints on the economy. Society spends billions of dollars every year to move water from wet areas to drier areas, to store it for dry periods or to clean otherwise undrinkable sources. Conflicts often arise over water use because one application decreases the amount available for others. Even regions with readily available freshwater have problems maintaining the quality and quantity of water.

The World's renewable fresh water supply is relatively constant; the average amount of water available per person in 1850 was about 43,000 cubic meters per year. By 2014, this figure had dropped to around 5,900 cubic meters per year which may be further reduced because of the increase in population. Worldwide, freshwater use is increasing as population expansion, human activities, and climate change pose increasing pressure on a limited water supply and resulting in a situation where a growing number of countries experience water shortages.

6.3 Hydrological Cycle and Distribution of Water

Water exists in any of three forms: solid (ice/snow), liquid (marine/freshwater), and vapour (water vapour/steam). Water continuously circulates

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through the environment, from the ocean to the atmosphere to the land and back to the ocean through the **hydrologic cycle**. The result is a balance among water in the ocean, on the land, and in the atmosphere. This way hydrologic cycle interrelated various forms of water available on the earth's surface and also continually renews the supply of fresh water on land, which is essential to terrestrial organisms. However, approximately 97.5% of Earth's water is in the ocean and contains a high amount of dissolved salts. Seawater is too salty for consumption and other uses like agriculture and industries. For example, if you watered your garden with seawater, your plants would die. Most fresh water is unavailable for easy consumption because either it is frozen as polar or glacial ice, about 1.97%, or is present in form of groundwater, about 0.5%.

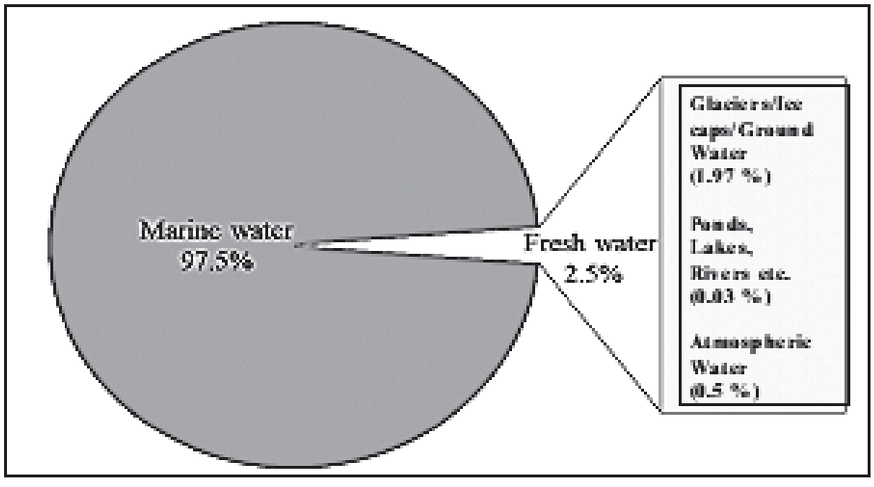

Figure 6.1: Distribution of water resources on Earth

Lakes, creeks, streams, rivers, and atmospheric water account for only a small portion. about 0.03% of Earth's freshwater (Figure 6.1). The underground establishments of the earth contain constructions that collect and store water. Groundwater flows through permeable sediments or rocks slowly—typically covering distances of several millimetres to a few meters per day and is ultimately, discharged into rivers, wetlands, springs, or the ocean.

Aquifers are underground reservoirs that are either unconfined or confined. Aquifers have a recharge area, the land from which water percolates to replace groundwater. In **unconfined aquifers**, the recharge area is directly

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above them because the layers of rock above are permeable and allow surface water directly seep downward, replacing the aquifer contents. The upper boundary of an unconfined aquifer is called the water table. The water table is sandwiched between the upper soil surface and the lower rock surface. The latter, rock surface has sediments and cracks saturated with groundwater. The water table varies in depth depending on the amount of precipitation occurring in an area e.g. in the case of deserts, the water table is generally far distant from the surface. In contrast, wetlands, lakes and streams have a water table that intersects with the surface. In dry conditions, the water table of a well is dropped lower than the depth of the well. A **confined aquifer** is also known as an **artesian aquifer**. It is a groundwater storage area between impermeable layers of rock. The water in a confined aquifer is trapped and often under positive pressure. In contrast to unconfined aquifers, the recharge area may be hundreds of kilometres away (Figure 6.2). Generally, groundwater resources are considered nonrenewable because they have taken hundreds or sometimes thousands of years to accumulate, and typically only a minor portion of it is replaced every year by the percolation of precipitation. The confined aquifers are recharged particularly slowly.

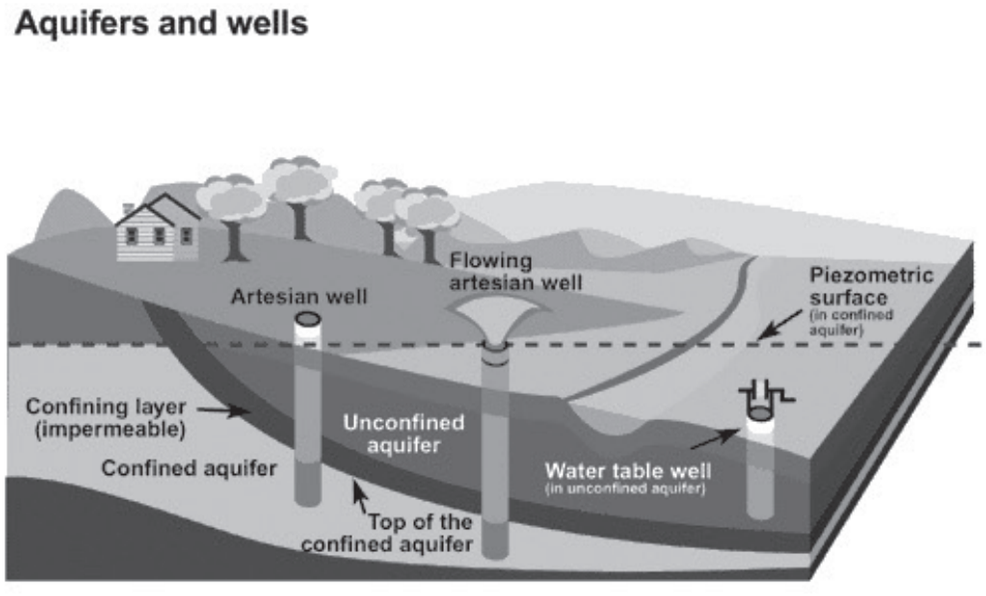

Figure 6.2: Schematic presentation of groundwater aquifers

(*Source: usgs.gov*)

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IN-TEXT QUESTIONS

1. Our planet Earth is known as a _____ planet.
2. All life forms including bacteria, plants and animals have _____ of water by their body weight.
3. _____ are underground reservoirs that are either unconfined or confined.
4. A confined aquifer is also known as an _____ aquifer.
5. Lakes, creeks, streams, rivers, and atmospheric water account for only a small portion of about _____ of Earth's freshwater.

6.4 Water Resources of India

India accounts for about 2.45% of the world's surface area, 4% of the world's water resources and about 17.7% of the world's population. Water in India is available from three chief sources- surface water (rivers, lakes, ponds), groundwater (wells, springs), and wetlands. The water availability in India is reducing due to the increasing population. The average annual water availability in 2001 was 1816 cubic meters per capita and had reduced to 1545 cubic meters per capita in the year 2011 which had further decreased to 1486 cubic meters per capita in the year 2018.

(a) **Surface Water Resources:** In our country, the surface flow takes place through 12 major rivers namely Ganga, Yamuna, Indus, Brahmaputra, Cauvery, Godavari, Krishna, Mahanadi, Mahi, Narmada, Pennar and Tapi. The mean annual flow in all the river basins in India is estimated to be 1,869 cubic km. However, due to various geographical and environmental constraints, only about 35% of the available surface water can be exploited. Water flow in a river depends on the size of the catchment area of the river and rainfall within the catchment area. The precipitation in India has very high spatial variation, and it is mainly concentrated in the Monsoon season. Some of the rivers in the country like the Ganga, the Brahmaputra, and the Indus have huge catchment areas. Much of the annual water flow in south Indian rivers like the Godavari, the Krishna, and the Cauvery has been harnessed, but it is yet to be

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done in the Brahmaputra and the Ganga basins. In addition to rivers, other surface water resources in India include canals, ponds, lakes, tanks, and wetlands. They are distributed unevenly over the country and retain about 50% of these inland surface water resources.

- **Surface Water:** It is the water found on Earth's surface in streams and rivers; lakes, ponds, reservoirs, and wetlands.
- **Wetland:** An area of land covered with water for at least part of the year.
- **Runoff:** It is renewable and finite resource precipitated water on land that replenishes surface water.
- **Drainage Basin:** It is the area of land drained by a single river or stream.
- **Watershed:** It is an area of land that drains snowmelt and rainfall into streams and rivers. It ranges in size from less than 1 km2 for a small stream to a huge portion of the continent for a major river system such as the Mississippi River.
- **Groundwater:** It is the form of water which originates as precipitation that percolates into the soil and goes down through cracks and spaces in sand, gravel, or rock until it is settled by an impenetrable layer and accumulates as groundwater.
- **Aquifers:** It is an underground layer of rock that holds groundwater.

(b) **Groundwater Resources:** India has about 432 cubic km of total annual replenishable groundwater resources. The Ganga and Brahmaputra basins have about 45% of the total replenishable groundwater resources. The groundwater utilization is relatively high in the river basins lying in the northwestern region and parts of south India. Groundwater utilization is very high in the states of Punjab, Haryana, Rajasthan, and Tamil Nadu. States like Bihar, Gujarat, Uttar Pradesh, Maharashtra and Tripura are utilizing their groundwater resources at a moderate rate. However, the utilization of groundwater had increased over the period of time due to the increase in population. If the present scenario continues, the demands for water would definitely require additional supplies and such a situation, will act as the deciding factor in the development and social, economic and environmental balance all over the world.

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(c) **Lagoons and Backwaters:** India has a vast coastline which is the basis for the presence of a large number of lagoons and estuaries are present. A lagoon is defined as a water body separated from larger bodies like a river by a natural barrier like barrier reefs and islands etc. The lagoons in India are very confined to a few states like Kerala, Orissa and West Bengal. Although, water is usually brackish in these water resources and is generally used for fishing and irrigation of certain varieties of paddy crops, coconut, etc. However, a backwater can be defined as a water body or a branch of the main river that lies alongside the main river or is backed up by some kind of obstruction which may be natural or manmade.

IN-TEXT QUESTIONS

6. India accounts for about _____ of the world's surface area.

7. _____ is an area of land covered with water for at least part of the year.

8. A drainage Basin is the area of land drained by a single river or stream. (True/False)

9. The precipitation in India has very low spatial variation. (True/False)

6.5 Water Demand and Utilization

India has traditionally been an agricultural country. Agriculture and its related activities are the leading sources of livelihood for about two-thirds of its population. Besides this, water is also required in large amounts for domestic, industrial, energy and other needs. Unlike land, the availability of water varies from time to time and from place to place in India. Being a monsoon land, the bulk of rainfall is confirmed to be a brief period of 3-4 months of monsoon season. However, due to the increase in population and changing lifestyles, water consumption increases dramatically with season and time. In addition, the conversion of agricultural land to residential or commercial purposes reduces the open area available for the natural recharging of groundwater during monsoon periods. More than 90 % of India's water demand is for agriculture. Hence, to meet the increased agricultural production, the development of irrigation has been

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consigned very high priority in our Five Year Plans. For this, various multipurpose river valleys projects like the Damodar River Valley project, Bhakra-Nangal project, Kosi Project, Hirakud Dam project, Nagarjuna Sagar Project, Narmada Valley Project, Indira Gandhi Canal Project, etc. have been taken up to fulfil the need. The share of the agricultural sector in total water utilization is much higher than in other sectors (Table 6.1).

Table 6.1: Trends of water demands in the country (km^2)

Sector	Year		
	2000	**2025**	**2000**
Domestic	42	73	103
Irrigation	541	910	1072
Industry	8	22	63
Energy	2	15	130
Others	41	72	80

Water is central to any developmental process. The link between quantity and quality of water should be kept in mind in all water-related issues. Due to water pressure, the availability and quality of freshwater are a matter of concern all over the world. According to a United Nations (UN) study, the availability of fresh water in Asia is only 3,000 m^3 /person/ year, the lowest of any continent. Rapid population growth with poor management has led to the situation of water stress.

6.6 Emerging Water Resource Problems

Water availability is diminishing day by day due to the increase in population. In addition, the presently available usable water resources are deteriorating in terms of quality due to the addition of agricultural, industrial and domestic effluents into the water resources and this is further limiting the accessibility to water resources. Now and then anthropogenic activities worsen the seriousness associated with water resources. Humans often court disaster when they make environmentally unsound decisions, such as building in an area prone to flooding.

(a) **Deterioration of Water Quality:** Water quality refers to standard biological, chemical and physical characteristics of water that represent the suitability of water to endure various uses. The mixing

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of any foreign particle or material like microorganisms, agricultural, chemical, industrial and other kinds of wastes into water disturbs the standard characteristics of water and pollutes it. This makes the water unsuitable for human use. Such problems worsen the quality of water and made it unfit for human usage. When toxic substances enter the water bodies, they either get dissolved in water as it is a great solvent or lie suspended in water. Both situations lead to water pollution and disturb the aquatic systems. Sometimes, these pollutants also seep down and pollute groundwater. The Ganga and the Yamuna are the two highly polluted rivers in the country.

ACTIVITY

Find out the major towns/cities located on the bank of the major rivers like Ganga, Narmada, Brahmaputra etc. and its tributaries and major industries in the towns/cities.

(b) **Enhanced Demand for Water for Irrigation:** In agriculture, water is mainly used for irrigation. In India, irrigation is needed because of spatial and temporal variability in rainfall. The large tracts of the country are deficient in rainfall and are drought-prone. Deccan plateau and North-western India come under drought-prone areas. Except for the monsoon season, summer and winter seasons are usually dry in most parts of the country. Hence, irrigation is a basic necessity in our agriculture during dry seasons. Even in areas of plentiful precipitation like Bihar and West Bengal, discontinuities in monsoon or its failure resulted in dry spells unfavourable for agriculture. Water requirements of certain crops also make irrigation indispensable. For instance, the water requirement for sugarcane, rice, jute, etc. is quite high which can be achieved only through irrigation. Irrigation makes multiple cropping systems possible. It is reported that in comparison to unirrigated land, irrigated land has shown increased agricultural productivity. Further, the high-yielding crop varieties demand a regular moisture supply, which can be made possible only by an efficient irrigation system. Additionally, a major share of irrigation is done by exploitation of groundwater through tube wells and wells which ultimately results in the depletion of groundwater.

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(c) **Increasing Water Conflicts:** The indispensable nature of water and its uneven distribution over time and space has often led to inter-regional disputes. These disputes may be internationals or inter-states or inter-districts. Issues over sharing of common water resources have been largely affecting not only the regional people but also the governments. Some major water conflicts include; the Cauvery water dispute (between Karnataka and Tamil Nadu), the Krishna river water dispute (between Karnataka, Maharashtra & AP), the Vamsadhara river water dispute (Between Orissa and Andhra Pradesh), The Indus water treaty (between India and Pakistan over the sharing of water of five rivers, the Jhelum, Chenab, Ravi, Satluj and Beas), and the water conflict in the Middle East (among Middle East countries like Ethiopia, Sudan, Egypt, Jordan, Syria etc. for the sharing of three river basins, Jordan, Nile and Tigris-Euphrates). All these conflicts over sharing of water resources need to be resolved with greater understanding and impartiality.

(d) **Flood and Drought:** Countries like India and Bangladesh where rainfall is majorly confined to the monsoon season, are prone to water-related problems like floods and drought. Heavy rainfall during the monsoon season often caused floods, especially in low-lying areas. Persistent downpour causes the overflowing of rivers and lakes resulting in floods. Nowadays, anthropogenic activities are majorly responsible for a flood-like situation and every year one or other state in India experiences severe flooding like that in 2017, 2018 and 2019 affecting mainly Gujarat, Kerala and Maharashtra, respectively. Interlinking of rivers and their networking at a national level is being proposed as the remedial solution to deal with this problem.

Drought is another problem associated with water resources. Whenever the annual rainfall is lower than normal and less than the annual evaporation, the resultant situation is called drought. Globally, about 80 countries, lying in semi-arid and arid regions frequently experience drought. Various anthropogenic activities like deforestation, overgrazing and mining etc. lead to desertification and more areas come under drought-affected areas. Social forestry, wasteland reclamation, careful selection of mixed cropping and the use of indigenous knowledge are a few effective solutions for dealing with the problem of drought.

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6.7 Sustainable Water Management

For sustainable development, it is important to effectively manage freshwater due to its declining availability and ever-increasing demand. India has to take steps and make effective policies and adopt effective measures for its conservation due to the high cost of desalination making seawater usage to a minimum. Attempts to prevent pollution ought to be made besides using water-saving techniques. There is a need to adopt practices such as rain-water harvesting, water recycling & reuse for sustained supply in the long run.

(a) **Prevention of Water Pollution:** There is a rapid deterioration of water quality alongside its quantity getting reduced. While rivers contain better quality in upper stretches of hilly areas than in plains river water is deteriorated owing to the solid/liquid wastes, fertilizers, insecticides and industrial effluents getting into it through drains. The pollutants are more enriched in summer due to the low momentum of the water. The water quality of 507 national aquatic resources is being monitored by central and state pollution control boards. Some of the most polluted ones are the Yamuna between Delhi and Etawah, the severely polluted rivers Sabarmati at Ahmedabad, the Gomti at Lucknow, the Vaigai at Madurai and the Musi of Hyderabad and the Ganga at Kanpur and Varanasi etc. Groundwater also got polluted over time due to high concentrations of heavy/ toxic metals, fluoride and nitrates. While The Water (Prevention and Control of Pollution) Act 1974, and the Environment Protection Act 1986 need to be adhered to, awareness for low usage of pollutants in agricultural and industrial sectors and also towards low waste generation need to be created in the general populous.

(b) **Sustainable Water Use:** Sustainable water use refers to the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle. The utilization of reclaimed wastewater is a smart option for fulfilling the demand of industries. Similarly, in urban areas, water from household drains can be used for gardening. Water used for washing vehicles can also be used for gardening. This would conserve the better quality of water for drinking purposes. Currently, the recycling of water is practised on a limited scale. However, we

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need to encourage the replenishment of water through recycling. United Nations Environment Programme has launched an Integrated Water Resources Management (IWRM) to promote coordination in the management and development of water, land and related resources. It will help to improve economic and social welfare in a justifiable manner without compromising the sustainability of vital resources.

(c) **Watershed Management:** Watershed management implies the conservation and efficient management of surface and groundwater resources, especially in watershed areas. It comprises storage and prevention of runoff for groundwater recharge through various methods like recharge well, tanks and checks dams etc. The main objective of watershed management is to maintain the balance between the utilization of natural resources and their demand in society. The accomplishment of watershed development chiefly depends upon the participation of the local community. The States and Central Governments have started many watershed management programmes in India such as ***Haryali, Arvary Pani Sansad*** (Rajasthan), ***Neeru-Meeru*** (Andhra Pradesh) etc. It is essential to generate awareness about the welfare of watershed development and its management among local communities and this approach will ensure the sustainable availability of water.

(d) **Rainwater Harvesting:** Rainwater harvesting is used to capture and store rainwater. It is also helpful to recharge groundwater. It is an eco-friendly and cheap technique for preserving precipitated rainwater by guiding it to the storage tank or bore well or pits or wells. It increases water availability, sustains ground water table, and improves groundwater quality through the dilution of contaminants like arsenic, fluoride, phosphates, nitrates etc. It also prevents flooding, and soil erosion, and arrests saltwater imposition in coastal areas. Now a day, the Government is also encouraging the practice of Rainwater harvesting in residential, institutional and commercial areas. In our country, rainwater harvesting was a common traditional practice and is done by various methods in form of storage bodies like Kund or Tanka, ponds, lakes, etc.

(e) **Dam and Its Role in Water Conservation:** Storage of water by the construction of dams is regarded as an efficient component of water management for irrigation. In India, the high-level demand for water

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for irrigation can be achieved by building dams of various heights. It has already been done under several river valley projects like the Sardar Sarovar Dam project (in the Narmada river valley), Nagarjun Sagar Dam Project (in the Krishna River valley), and Tehri Dam project (in the Bhagirathi River valley) etc. The benefits of dam projects include;

(i) Generation of hydroelectricity.

(ii) Irrigation and flood control.

(iii) Industrial and municipal water supply.

The canal system from the dam can transfer a large amount of water over great distances. The most famous example is the Indira Gandhi canal which brought greenery to the desert areas of Rajasthan. However, mismanagement of water from a water reservoir of dams can cause many problems such as;

- Unequitable distribution of water in downstream areas
- People living close to the water sources grow crops which require heavy irrigation
- The sudden or accidental release of water from a dam result in flood-like situations.
- Disturbance of the ecosystem

IN-TEXT QUESTIONS

10. According to a United Nations (UN) study, the availability of fresh water is lowest in _____ continent.

11. IWRM stands for _____.

12. Neeru-Meeru watershed programme started in _____ state.

13. Nagarjun Sagar Dam Project is located in _____ river valley.

14. Sardar Sarovar Dam Project is located in the Bhagirathi River Valley. (True/False)

Since independence, more than 700 dams have been constructed. if the programmes go ahead as scheduled, there will be hardly any free-flowing rivers left in the country. That is why, environmentalists such as Sundar

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Lal Bahuguna, Medha Patkar, Chandi Prasad Bhatt and others have opposed the implementation of several river valley projects like the Tehri Dam project (Uttarakhand), Sardar Sarovar Dam (Gujrat), Narmada Sagar Dam project (Madhya Pradesh) etc. The reasons for this opposition are due to social, economic and environmental problems.

The Cauvery Water Dispute

Cauvery River has an inter-State basin including its origin in Karnataka and flowing through Tamil Nadu and Puducherry before terminating in the Bay of Bengal. The total catchment basin of the Cauvery river is 81.155 sq. km which is distributed among Karnataka (34,273 sq. km), Kerala (2,866 sq. km), Tamil Nadu and Puducherry (44,016 sq. km). The dispute over the distribution of Cauvery river water is about hundred-year-old. The river water is almost fully utilized by the upstream state, Karnataka and the downstream state, Tamil Nadu. Both states have increased demand for river water for agriculture and industries. To resolve the issue, the Cauvery Water Dispute Tribunal (CWDT) was constituted on June 2, 1990. CWDT passes an interim order in 1991 directing the Karnataka state to release water from its reservoirs to ensure 205 Thousand million cubic feet (TMC) of water into the Mettur reservoir of Tamil Nadu in a water year (1st June to 31 May) with weekly and monthly stipulations. But since 1995, delayed rain and the complex cropping pattern in the Cauvery basin resulted in a crisis-like situation over sharing of the water between these two states. In 2007, The Supreme Court (SC) reserved its decision on the appeals filed by states against CWDT's final award. The SC on 16 February 2018 delivered its verdict in the Cauvery water dispute, allocating more water to Karnataka state. As directed by SC, The Cauvery Water Management Authority (CWMA) and the Cauvery Water Regulation Committee (CWRC) were created to settle down the century-old dispute.

6.8 Summary

- 3/4th of the earth's surface is covered by water but only 2.5% is available fresh water.
- The freshwater resources include surface water and groundwater.

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- Population explosion, urbanization, industrialization and water pollution are the major causes of water-associated problems.
- Rainwater harvesting, watershed management, judicious use of water, construction of dams etc. are the key steps for sustainable water conservation and management.
- The problem of water scarcity can be solved by multipurpose river projects which can fulfil various objectives like irrigation, hydroelectricity, flood control, fish breeding etc.

6.9 Answers to In-Text Questions

1. Blue
2. 60-70%
3. 0.03%
4. Aquifers
5. Artesian
6. 2.45%
7. Wetland
8. True
9. False
10. Asia
11. Integrated Water Resources Management
12. Andhra Pradesh
13. Krishna River Valley
14. False

6.10 Self-Assessment Questions

1. Explain the hydrological Cycle and explain the distribution of water.
2. Define aquifer. Differentiate between confined and unconfined aquifers.
3. Write a note on the water resources of India.
4. Write a detailed note on the emerging water resource problems.

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5. Explain Sustainable Water Management.
6. Write short notes on
   (i) Rainwater Harvesting
   (ii) Watershed Management

6.11 References

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6.12 Suggested Readings

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LESSON

7

Natural Resources: Energy Resources

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STRUCTURE

7.1 Learning Objectives

- Define energy and identify the different types that exist.
- Analyse the energy demand due to the growing population, globalization and industrialisation.
- List the benefits of using alternate sources of energy sources instead of coal.
- Classify different energy resources as renewable or non-renewable.
- Describe the difference between renewable and nonrenewable energy resources.

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- Identify the benefits and disadvantages of using renewable energy resources.
- Understand the various forms of conventional energy resources.
- Identify the benefits and disadvantages of using conventional energy resources.
- Outline the technologies that are used to harness the power of solar energy using the case study.

7.2 Introduction

The term Energy was coined by Thomas Young (1737-1829), eighty years after Newton and applied it to what is now called kinetic energy. The term Energy can be defined as the "ability/capacity to do work". The two laws of thermodynamics describe the behaviour of energy.

- The first law states that Energy can neither be created nor destroyed however; it can be transferred from one form to another.
- The second law states that some energy is always dissipated into an unavailable form i.e. heat energy. There is no spontaneous transformation of energy from one form to another (in the context of protoplasm) that is 100 per cent efficient.

Energy is required by all living organisms and vegetation for the bio-chemical reactions of their cells. In fact, all living beings operate using energy. Energy moves the universe. About 99.8 per cent of our energy comes from solar radiation. It is the solar energy that plants use to make food which gets stored in plants as biomass. The consumption of energy is indicative of its development. It is because almost all developmental activities require energy either directly or indirectly. Also, there exists a wide range of disparities in terms of per capita consumption of energy among developed and developing nations.

7.3 Growing Energy Needs

The development and growth process of a country requires generation as well as consumption of energy. Thus, growing energy needs is an index of national development. Energy is derived from both conventional and non-conventional resources. Furthermore, it is expected that global energy

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needs will rise steadily in the next two and a half decades. If governments stick with current policies then according to the World Energy Outlook's Reference Scenario - the energy needs of the world would be 50% higher in 2030 than today with an average annual growth rate of 1.6%.

India is among the fastest-growing markets in the world and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. With limited fossil fuel reserves, the country has planned to increase its renewable and nuclear power industries. Fossil fuels to date continue to dominate energy supplies and are expected to remain the same in the coming years. Fossil fuels (coal, petroleum, natural gas etc.) are expected to cater for more than 80% of the projected increase in primary energy demand in this scenario. Natural gas demand is also growing at a very fast rate, which is driven mainly by power generation. Coal has been the largest energy source, especially in China and India.

Table 7.1: Consumption of Energy in various sectors

S. No.	Global Energy Usage (%)	Purpose
1.	24	Transportation
2.	40	Industries
3.	30	Domestic and Commercial purposes
4.	06	other uses including Agriculture

Reasons for the increase in worldwide energy demands:

We feel handicapped without the supply of energy. Can you think of life without electricity? Because of these rising demands and limited energy resources, these are under heavy stress. Attempts are continuously being made to develop alternate sources of energy. We meet our energy requirements to perform several activities every day from food, fuel and electricity. For a long, we have been exploiting fossil fuels on a large scale for this purpose.

(a) **Globalization:** Transportation is one of the largest consumers of energy in the world, accounting for more than 50% of liquid fuel consumption in countries. The energy required for transportation has inevitably increased with increased globalization.

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(b) **Industrialization, especially in emerging markets:** There is a large-scale requirement for energy in businesses and factories in the form of both electricity and petroleum-based fuels in order to operate. The energy demand is increased as soon as economies industrialize. In other words, Industrialization and Urbanization have multiplied the demand for energy resources several-fold.

(c) **Increasing wealth, especially in emerging markets:** With the growth of the economy, energy also grows. This leads to increased energy demand and consumption.

(d) **The rapid growth of the human population** is putting heavy stress on all resources of energy.

7.4 Sources of Energy

The source of energy can be defined as the one which can make available a sufficient quantity of energy in a usable form for a longer duration. Any energy source which provides an alternative to fossil fuel is called an alternate source of energy. All conventional mineral-based energy resources, such as fossil fuels, are exhaustible. It is estimated that if we continue to use coal at the present rate, the available coal reserve will exhaust in the present century itself. India produces petroleum which fulfils only half of our requirements and the remaining half is met by importing from other countries.

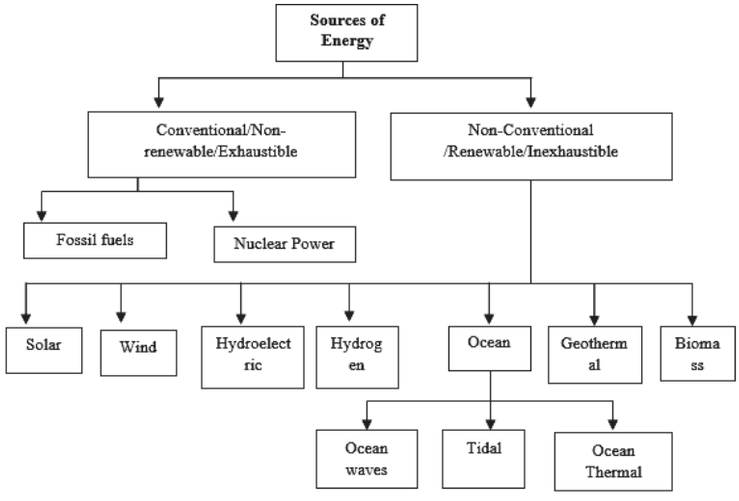

Figure 7.1: Sources of Energy

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7.5 Renewable and Non-Renewable Sources of Energy

In almost every part of the world, industrialization and agricultural development have increased the requirement for energy on a larger scale and the same can be directly related to the expansion of possible energy sources. These developments and expansions particularly in the field of industries as well as agriculture have caused a fall in their supply. Besides, traditional sources of energy have serious environmental concerns as these cause environmental pollution.

Renewable Energy Sources/Non-Conventional Energy Sources:

The increasing energy demands have compelled countries all over the world to think of a policy on energy and look into the possibility of having an energy system with no or very limited environmental impacts. The deposits of coal and oil will exhaust one day. The energy crisis has shown that for sustainable development in the energy sector, we must replace them with non-polluting renewable sources and conserve them. Efforts are being made to develop new sources of energy. These are called renewable sources of energy and include solar energy, wind energy, ocean energy, geothermal energy, urban waste, agricultural waste, energy plantations etc. These are non-polluting, environmentally clean and socially relevant. Moreover, no nation can afford to depend on only one form of energy there has to be a mix of various forms of energy.

Non-Renewable Energy Sources/Conventional Energy Sources:

The resources which have accumulated in nature over a long span of time and cannot be quickly replenished when exhausted are known as Non-renewable energy sources e.g. Coal, Petroleum, Natural gas, and nuclear fuels like uranium and thorium.

Advantages of Renewable Sources of Energy:

1. Renewable energy is available in abundant quantity and is free to use.
2. Renewable energy has low or zero carbon emissions, therefore they are considered green and eco-friendly.
3. Renewable energy develops self-reliance and minimizes the reliance on any third country for the supply of energy.

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4. Renewable sources can cost less than consuming the local electricity supply.
5. Renewable sources of energy help in economic simulations and creating job opportunities, through building such types of equipment, instruments or plants that provide jobs to many people.

Disadvantages of Renewable Sources of Energy:

Though renewable energy has many benefits and advantages it also has certain limitations, such as

1. High cost of initial investment to set up the plant.
2. Non-availability (Solar light only when days are sunny)
3. Loss of biodiversity and forest along with modification of local environment (Dam for hydroelectric energy).

Advantages of Non-Renewable Sources of Energy:

1. Non-renewable sources of energy are cheaper and easy to use.
2. Non-renewable sources release a great amount of energy from the small amount of resource use (uranium).

Disadvantages of Non-Renewable Sources of Energy:

1. Non-renewable sources of energy are limited and will end one day. Thus, their prices will keep rising and will not be accessible and available for everyone.
2. Their use is not eco-friendly as they release toxic gases that are creating serious environmental changes.

Table 7.2: Difference between Renewable and Non-Renewable Resources

S. No	Renewable Resources	Non-Renewable Resources
1.	Resources which can be renewed/ regenerated/replenished again and again within a given span of life are known as renewable resources.	Resources which cannot be re-newed/regenerated/replenished again and again within a given span of life are known as re-newable resources.
2.	The stocks or reserves of these resources are unlimited in nature.	The stocks or reserves of these resources are limited in nature.

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S. No	Renewable Resources	Non-Renewable Resources
3.	They are also called inexhaustible resources.	They are also called exhaustible resources.
4.	These resources are eco-friendly i.e. they do not cause pollution of the environment.	These resources are not eco-friendly i.e. they cause pollution of the environment.
5.	**e.g.** Water, Air, Sun etc.	**e.g.** Fossil Fuels: Coal, Petrol, Diesel, Nuclear Fuel etc.

7.5.1 *Renewable Energy*

1. Solar Energy

The Sun is considered to be the ultimate source of energy for all other forms of energy either directly or indirectly. The phenomenon occurring inside the sun releasing a tremendous amount of energy in the form of heat and light is nuclear fusion. The earth's space receives nearly 1.4 KJ/sec/m^2 of solar energy.

Advantages:

1. The energy produced by the sun is a renewable source of energy. The power source of the sun is absolutely free.
2. It produces electricity which doesn't cause pollution of the environment.
3. It can be used in remote and isolated areas where there is no power supply.
4. Most solar energy systems have a lifespan of about 30 to 40 years.
5. In the majority of solar energy systems, there is hardly any requirement for maintenance during their lifetime, indicating that one need not put additional money into them.
6. Solar energy systems are now being considered and designed to satisfy particular needs. For example, outdoor lighting can be converted to solar.
7. Solar energy has various other applications apart from producing Photovoltaic energy viz. Solar cookers, Solar water heating systems, passive solar heating of homes etc.

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Disadvantages:

1. Solar energy can be harnessed only during the daytime or when it is a sunny day. Cloudy skies reduce its effectiveness.
2. Solar energy can be unreliable at times.
3. The amount of sunlight reaching the Earth's surface varies with location, time of day, time of year and other weather conditions.
4. Transmission remains a barrier that has to be breached.
5. Installation cost is high as:
   - *(a)* Solar panels, solar cells as well as collectors are comparatively expensive to manufacture.
   - *(b)* It uses a special grade of Silicon which is expensive.
   - *(c)* Since silver is used for connecting the cells together it is more expensive.
   - *(d)* The current produced is DC and converting it to AC increases the cost.
6. Solar power stations are also very expensive to be built and also, and they fail to match the power output similar to sized conventional power stations.
7. The large-scale requirement of areas of land in order to capture solar energy.
8. In order to meet the requirement of energy during the night, batteries are charged during the day from solar energy. As a result, large storage space is required for these large and heavy batteries which need to be replaced at regular intervals.

2. Wind Energy

The high-speed moving winds due as a result of their motion possess a lot of energy in them in the form of kinetic energy. Sun is the main driving force for the wind. Wind energy can be captured by making use of wind-mills. The force of the striking wind is the main driving force that helps the blades of the windmill to rotate continuously. The revolving blades can be utilised to drive a number of machines like electric generators, flour mills and water pumps. Nowadays a large number of windmills are being installed in clusters known as wind farms that feed power to the utility

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grid by producing a large amount of electricity. The prominent areas where the winds are strong and steady comprise the coats, hilly regions mountain passes and ridges in particular, open grasslands are utilised for wind farms. The minimum wind speed that can rotate the blades of a wind generator for satisfactory working is **15 km/hr**. The largest wind farm in our country is near Kanyakumari in Tamil Nadu generating 380MW of electricity. Wind energy is considered to be the second fastest-growing source of energy since 1990 and probably the cheapest source.

Table 7.3: Wind speeds and the performance of the wind turbine

Average wind speed (Km/hr) (mph)	Performance of Wind turbine
Up to 15 (9.5)	No good
18 (11.25)	Poor
22 (13.75)	Moderate
25 (15.5)	Good
29 (18)	Excellent

Advantages:

1. The wind is free of cost and can be captured efficiently with the help of modern technology.
2. Wind energy could also be used to produce hydrogen by electrolysis of water.
3. It can be used in remote and isolated areas where there is no power supply.
4. It is utilized for par generation, pumping water and other domestic purposes such as threshing, winnowing, cutting wooden logs etc.
5. Wind energy can also be used for battery charging to run generators.
6. It is a decent method of supplying energy to remote areas.
7. The wind farm can be used to generate revenue as they can be tourist attractions.
8. The land beneath the wind turbines can still be used for farming, especially in agricultural areas as wind turbines can be very tall and each turbine takes up only a small plot of land.
9. The recurring cost is less.

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Disadvantages:

1. The main disadvantage of wind power is down to the wind's unreliability factor.
2. A minimum wind speed of **15 km/hr** i.e. **4.2 m/s** is required to rotate the wind turbine.
3. The installer has to face nature's problems because the wind doesn't blow all the time i.e. it is not always predictable, therefore, electricity needs to be stored until it is used. There is also the requirement for backup systems.
4. There is a large-scale requirement for multiple wind turbines to produce a sufficient amount of electricity as a single wind turbine produces much less electricity than the average fossil fuelled power station.
5. The blades of the wind turbine may interfere with television reception or with microwave communication used by various telephone companies.
6. There is a large-scale requirement for land for installation.
7. The blades of the turbine can kill birds and migrate flocks thereby causing a loss of biodiversity.
8. The wind generators are few and give an unattractive outlook to the landscapes and are extremely noisy: This disturbs the residents of the area.
9. Optimum areas for wind farms are often the open plains, and the coast, where the land is expensive.

3. Hydroelectric Energy

Hydropower is defined as "The electricity that is generated from the energy of falling water and running water that can be utilised for various useful purposes. Hydropower has been used in our country since ancient times for various purposes such as irrigation and the operation of various mechanical devices, such as watermills, sawmills, textile mills, dock cranes, domestic lifts, powerhouses and paint making. Hydroelectricity is considered to be the most widely used and accounts for nearly 16% of global electricity generation. The first hydropower station in India was a small hydropower station of 130 KW commissioned in 1897 at Sidrapong

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near Darjeeling in West Bengal. With the advancement in technologies and increasing requirements for electricity, emphasis was shifted to large-sized hydropower stations. Large hydropower projects in India are developed by the Ministry of power, the Government of India. Small and mini hydel projects have the potential to provide energy to remote and hilly areas where the extension of the grid system is uneconomical. The construction of mini/micro hydel plants with generation capacities between 3 MW and 15 MW is most suitable and avoids the socio-economic and environmental problems as occur during the construction of big dams.

Applications: Generating Electricity, Flood risk management and Enabling Irrigation.

Advantages:

1. Hydroelectricity is a clean source of energy.
2. The water can also be utilised for irrigation purposes.
3. The water can also be utilised as a source of drinking water provides drinking water to people living, particularly in the desert of Rajasthan and Gujarat.
4. It is absolutely non-polluting, has a long life, and has very low operating and maintenance costs, unaffected by inflation.
5. Help in controlling floods and making water available during non-rainy seasons for irrigation and other uses.
6. Once the dam is constructed, it produces electricity at a constant rate.
7. The gates can be opened and closed depending on the need for electricity. Also, the water saved during the closure of the gates can be utilised when the demand for electricity is high.
8. Dams and reservoirs are constructed to contribute to the production of electricity for many years and decades.
9. The build-up of water in the lake means that energy can be stored until needed when the water is released to produce electricity.
10. The production of electricity by dam systems doesn't result in the production of greenhouse gases thereby it does not pollute the environment.

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Disadvantages:

1. The construction of Dams requires a huge investment of money and they need to be constructed to a very high standard.
2. The natural environment gets destroyed as a result of large-scale flooding.
3. The dam sites are especially the forest and agricultural areas and get submerged during construction.
4. It causes water logging and siltation.
5. It causes a loss of biodiversity and the fish population and other aquatic organisms are adversely affected.
6. Displace local people and create environmental problems of rehabilitation and related socio-economic problems.
7. Increases seismicity due to large volume of water impounded.
8. Loss of prime agricultural land (flood plain area). The area beneath the river is the most fertile which gets lost as a result of the construction of dams.
9. The natural water table is altered as a result of the construction of a large dam.
10. The buildings of large dams can cause serious geological damage.

4. Hydrogen Energy

As hydrogen burns in the air, it combines with oxygen to form water with liberation of the enormous quantity of energy which is 150 kilojoules per gram. Hydrogen possesses the highest calorific value and therefore can serve as an excellent fuel. Hydrogen is a clean fuel and energy storage medium for various applications. The production of hydrogen is occurred by thermal dissociation, photolysis or electrolysis of water. Various organic effluents like a distillery, starch etc. can also produce Hydrogen by biological conversions.

Advantages:

1. At present, in the form of liquid hydrogen, it is used as a fuel in spaceships.

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2. H_2 can be used in the fuel cell to generate electricity. In a fuel cell, hydrogen is burnt in air or oxygen under the pressure of an electrolyte to produce electricity.
3. Being very light, it would have to be stored in bulk.

Disadvantages:

1. Hydrogen is highly explosive and inflammable and explosive. Therefore, in order to be used as fuel, it requires safe handling.
2. There is also great difficulty in storing as well as transporting hydrogen.

5. Ocean Energy

More than 70% of the earth's surface is occupied thereby making it the world's largest solar collector. The ocean forms a vital source of energy. Ocean Tides, produced by the gravitational force of the sun and moon, possess a tremendous amount of energy.

Tidal Energy

The rise and fall of water in the oceans are referred to as high tide and low tide. In order to rotate the turbine, there is a requirement of several meters difference between the high and low tide. This difference in the tides can be exploited to harness tidal energy by constructing a tidal barrage. The seawater will flow into the reservoir of the barrage during the high tide turning the turbine and producing electricity by rotating the generators. When the sea level is low during the low tide sea water which was stored in the barrage reservoir flows out into the sea turning the turbine and producing electricity by rotating the generators.

The potential of tidal power in India is estimated to be about 15,000 MW. In India, the Gulf of Cambay, Gulf of Kutch (1000 MW) and the Sunderban deltas (100 MW), Andaman and Nicobar Islands, Lakshadweep Islands, the coasts of Odisha, Kerala, Tamil Nadu, Karnataka and Maharashtra are the potential tidal power sites. The tidal power sites for harnessing tidal energy in the world are few. The Bay of Funday, Canada possess a potential of 5,000 MW of power generation with 17-18 m high tides. One of the first modern tidal power mills is located in La Rance, France.

Ocean Wave Energy:

The power of ocean waves, which operates on the principle of the oscillating water column, has not been exploited to its full potential except as

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power supplies for navigational aids. India has initiated a wave energy project at Vizhinjam Fishery Harbour near Trivandrum in Kerala as an indigenous effort. It was expected that on its completion, the project would be able to derive an energy output of 4.45 lakh units per year. The project resulted in a strict reality in 1991 when it started the generation of electricity to be fed to the grid of the Kerala State Electricity Board.

Ocean Thermal Energy:

As sunlight falls onto the surface of the ocean, the upper surface gets warmer while the lower layers have a relatively lesser temperature. This temperature difference between the upper and the subsequent lower layers of the ocean can be exploited to generate electricity through Ocean Thermal Energy conversion power plants. In order to produce electricity through the OTEC power plant, the minimum temperature difference between the surface and deeper levels is 20^{o} C.

Advantages:

1. Ocean wave energy and tidal energy is a free and clean source of energy.
2. The production of electricity by ocean systems doesn't result in the production of greenhouse gases thereby it does not pollute the environment.
3. The Energy capturing and conversion mechanism may help protect the shoreline.
4. There is a continuous generation of electricity as tides are active 24 hours a day, 365 days a year.

Disadvantages:

1. It causes the displacement of wildlife habitats. The barrage systems pose a risk of destruction of the ecosystem relying on the coming and going of tides. The barrage systems can kill the migrating fish passing through the turbine.
2. The energy from the oceans can only be harnessed from those areas where there is suitable wave motion or tidal flow. Therefore, cannot be used inland.
3. The energy can be produced during tidal surges only.
4. Recurring cost is high as barrage systems require salt-resistant parts.

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5. The movement of the large marine animals and ships through the channels on which the barrage is built is disrupted. The frames of the turbines can disrupt the movement of large marine animals and ships through the channels on which the barrage is built.
6. Waves of great intensity can be produced by extreme weather.

6. Geothermal Energy

Geothermal energy is the energy which is produced from the hot rocks present inside the earth. In many places below the surface of the earth, high-temperature and high-pressure steam fields are present. Radioactive materials naturally present inside the rocks produce this heat through the fission process. This energy in the form of steam or hot water either comes out to the ground from the earth's crust naturally through cracks in the form of **natural geysers** as in Manikaran, Kullu and Sohana, Haryana. The energy which does not find any place to come out can be taken out by artificially drilling a hole up to the hot rocks and by putting a pipe in it steam or hot water can be gushed out through the pipe at high pressure that will turn the turbine of a generator to produce electricity. Sometimes the steam or boiling water underneath the earth does not find any place to come out. In the USA and New Zealand, several geothermal plants are working successfully.

Advantages:

1. A lifetime energy resource. Geothermal energy can be used and reused again and again.
2. Geothermal energy is among the cleanest source of energy as it doesn't burn fossil fuel in order to produce electricity.
3. High heat source: The energy coming from the core of the earth is extremely powerful, which allows geothermal plants to generate electricity.

Disadvantages:

1. In order to harness geothermal energy one needs to find a good spot where there is a continuous and substantial amount of steam present that could be trapped into. So, to generate geothermal energy all the areas are not suitable.
2. For setting up a geothermal energy plant huge capital is required.

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3. In order to finalize a geothermal site drilling and testing are required that cost a lot of money.

7. Biomass Energy

The organic matter formed by the plants and animals that includes agricultural wastes, crop residues, wood, manure, cattle dung, sewage etc. is referred to as Biomass energy.

Types of Biomass

***Agricultural and Industrial waste biomass*:** Agricultural Crop Residues, Bagasse (Sugarcane Residues), Peanut hulls, Cotton stalks, Coconut shells etc. are a few common agricultural wastes that produce energy by burning.

Fishery and poultry waste, animal dung, and even human refuse are also examples of biomass energy. Thirty per cent (30%) of electricity in Brazil is produced by burning bagasse. Animal dung cakes are used in rural India to produce heat by burning. Agricultural waste, animal dung cakes and wood account for meeting nearly 80% of rural heat energy requirements. Open furnaces called "Chulhas" that usually produce smoke and are less efficient (efficiency < 8%) are used to burn waste biomass. Presently smokeless *chulhas* with improved efficiency and a tall chimney are used. The combustion of animal wastes and plant residues produces a lot of smoke thereby causing air pollution and producing a lot of ash as waste residue. Essential nutrients like N and P are also destroyed when we burn dung it is therefore advisable to convert biomass into biofuels or biogas.

***Energy Plantations*:** Green plants manufacture their own food by trapping solar energy trapped through the process known as photosynthesis. In this process, the solar energy of the sun is converted and converted into biomass energy. The energy from the energy plantations is produced either directly by burning or by converting into fuels by fermentation, or by converting into a burnable gas. Examples of energy plantations are crops like sugarcane, sugar beet, sweet sorghum, aquatic weeds like water hyacinth and sea-weeds and carbohydrate-rich potato, cereals and fast-growing trees like poplar, cottonwood and Leucaena leucocephala, non-woody herbaceous grasses.

***Petro-Crops*:** Some plants or algae are rich in hydrocarbons and produce oil-like substances under high temperature and pressure. This oily substance can actually act as a potential source of energy or may be refined

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to form gasoline and can be burnt directly in diesel engines. Examples of such petro-crops are oil palms and plants like Euphorbias.

Advantages:

1. It is sensible to use waste materials.
2. The fuel source is cheap.
3. Biomass doesn't emit additional carbon dioxide (CO_2), like fossil fuels.
4. Biomass can be utilised to manufacture a variety of fuels (biogas/ biofuel/heat) in order to produce electricity.
5. Biomass energy helps in reducing disposal costs.
6. The life of the landfills is increased as a result of this.
7. Energy generation from biomass has negative fuel costs as it uses waste products.
8. It reduces dependence on fossil fuels.

Disadvantages:

1. The main problem with the production of biomass energy is gathering fuel in sufficient quantities.
2. It is not available all year round.
3. The value of Biocrops is more than the food so it can detract from food production will result in food shortages and increased prices.
4. Emission of greenhouse gases. It releases pollutants into the atmosphere causing air pollution.

7.5.2 *Non-Renewable Energy Resources*

Fossil Fuels: Fossil fuels principally comprise hydrocarbons. Fossil fuels involve deposits of once-living organisms. This may take centuries to form. Fossil fuels for energy provision are of three types: Coal, Oil and Natural gas.

7.6 Energy Content of Fossil Fuels and Biogas

Coal: Coal was formed during the Carboniferous age around 255-350 million years ago, in hot damp regions of the earth. The plants and animals that occurred during this period, along the banks of rivers and

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swamps, getting buried alive or after their death in the soil and due to heat accompanied by pressures gradually got converted into peat and coal over millions of years of period. The vegetation which was partially decomposed and deeply buried in sedimentary environments got slowly transformed into solid, brittle, carbonaceous rocks commonly known as coal. Coal is the most abundant fossil fuel with a total recoverable resource of about 6,000 billion tonnes in the world. With the present rate of consumption, the coal reserves are likely to last during the next 200 years and if the use rate increases by 2% per year, then it will last within the next 65 years.

Table 7.3: Different types of Coal

S. No.	Type of Coal	(%) Percent Carbon	(%) Percent Oxygen	(%) Percent Volatiles	(%) Percent Moisture	Calorific Value (k cal gm^{-1})
1.	Lignite	60-70	16-18	45	35	5000-6000
2.	Anthracite	92-98	2-3	05	01	7500-8100
3.	Bituminous	78-90	9-10	20	06	6600-7500
4.	Sub-bituminous	75-83	14-15	40	17	6100-6500

Coal reserves are unevenly distributed in the country, with the bulk reserves located in the eastern states of Bihar, West Bengal and Odisha. Central India, including Madhya Pradesh and Andhra Pradesh, also possesses sizeable coal reserves of the order of 22 per cent of the total. Indian coal is not considered to be good coal in terms of heat capacity and India accounts for about 5% of the total world's coal. Bokaro, Jharia, Raniganj, Godavari valley and Singrauli are the major coalfields in India. Anthracite coal is found only in Jammu & Kashmir.

Peat is known as the precursor of coal. It is a soft organic material that consists of partly decayed plants and deposited mineral matter in some cases. When subjected to high pressure and heat peat becomes coal. Peat is composed of 60% organic matter, typically ferns and vegetation found in swamps or bogs. It has 55-60 per cent carbon and 30-35% Oxygen content. The moisture content is also high. The calorific value of Peat is 5400 kcal gm^{-1}.

Biogas has a high calorific value of 5000-5500 kcal kg^{-1} and **Natural gas** has a calorific value of about 13 kcal per gram.

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Advantages:

1. Coal is a readymade, tried and tested type of fuel.
2. It is relatively cheap to mine and converts into energy.
3. Coal is obtainable in abundance. Coal is in abundant supply – will last longer than oil or gas.
4. Capacity to generate huge amounts of electricity in just a single location.
5. They have a high calorific value.
6. It has vast potential to power the entire world.
7. Infrastructure to fossil fuel energy is entirely developed.
8. Easy transportation of liquid or gaseous fossil fuels.
9. Electricity can be produced by a simple combustion process.
10. They are highly stable in nature as compared to other fuels.
11. Cheaper source than non-conventional forms of energy.

Disadvantages:

1. Overexploitation has caused their considerable depletion.
2. Emission of sulphur dioxide, which causes acid rain**.**
3. Threatens the ecological balance and may be a cause of earthquakes.
4. The formation of fossil fuels takes millions of years.
5. When burned gives off atmospheric pollutants, including greenhouse gases, the main contributor to the global warming experienced by the earth today.
6. Only a limited supply.
7. Environmentally, the mining of coal results in the destruction of wide areas of land. Mining this fossil fuel is also difficult and may endanger the lives of miners. Coal mining is considered one of the most dangerous jobs in the world.

Petroleum:

Petroleum is considered to be the lifeline of the economy at the global level and is cleaner than coal. Sixty-seven (67%) of the total petroleum reserves are restricted to 13 countries in the world which together form OPEC (Organisation of Petroleum Exporting Countries). Saudi Arabia

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accounts for twenty-five (25%) of the oil reserves. If we continue to use crude oil at the present rate, then the world's crude oil reserves are expected to be exhausted in the next 40 years.

In India, crude oil was first recovered from Makum in North East Assam. Later, drilling for crude oil was done at Digboi, Dibrugarh, Narharlatiya and Surma valley in the northeast. The oil field also lies around the Bay of Cambay, Gujarat. The most important achievement was the exploration of oil in Bombay high on the continental shelf of Maharashtra, located at a distance of 167 km north-west of Mumbai. Recently oil has been located in the off-shore areas of the deltaic coasts of Godavari, Krishna, Cauvery and Mahanadi. Oil prospects in India are not so high as coal. But the demands are very high and the country has to import oil from OPEC countries at higher rates.

Natural Gas:

Natural gas, a fossil gift from nature, is composed of methane (95%) with small amounts of ethane and propane. Natural gas deposits are accompanied by oil deposits or they may also occur independently. Among fossil fuels, it is the cleanest source of energy. Natural gas can easily be transported through pipelines. It burns without smoke and has a high calorific value. It can be used as a source of energy for domestic as well as industrial purposes. It can also be used for power generation and as a raw material for petrochemical industries and fertilizer plants. Crude oil refining and fractional distillation plants yield natural gas as a by-product. About 40% of total natural gas is restricted to Russia followed by Iran (14%) and the USA (7%). In India, Natural gas reserves occur in association with oil fields. Some new areas have been discovered in Jaisalmer, Tripura, the off-shore area of Mumbai and the Krishna-Godavari Delta.

LPG (Liquefied Petroleum Gas):

It is widely used as a domestic fuel for cooking and has its main content as odourless butane to which other gases like propane and ethyl mercaptan are added to give a foul smell in order to identify leakage. It is produced by converting petroleum into liquid form under pressure. Indane and Bharat Petroleum are the chief distributing agencies of LPG. LPG emits negligible levels of particles which diesel does and even those emitted are not as toxic as those emitted from diesel. It is the ideal cleanest burning alternative fuel.

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CNG (Compressed Natural Gas):

CNG is used as a substitute for petrol and diesel in vehicles. Delhi Transport Corporation (DTC) has totally switched over to CNG where buses, as well as auto-rickshaws, run on CNG. It has reduced levels of pollution in the city. CNG is a cleaner fuel than diesel, used currently in many cities and long-distance transport across the country. It contains mostly methane, compressed to 80 atmospheres. CNG also works out cheaper (one-third) than diesel in long run because of its stable price. Moreover, it is readily available, its carcinogenic potential is lesser, it cannot be adulterated and gives higher mileage i.e. 35-40 km per kg.

7.7 Nuclear Energy

Known for its high destructive value, as evidenced by nuclear weapons, non-renewable nuclear power can also be harnessed to produce energy of commercial value. Nuclear energy can be generated either by:

(i) Nuclear fission in which the nucleus of certain isotopes with a large mass number is split into lighter nuclei on the bombardment of neutrons in order to release a huge amount of energy through a chain reaction. In order to control the rate of fission, only one neutron released is allowed to strike for splitting another nucleus. Uranium-235 nuclei are most commonly used in nuclear reactors.

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3{}_{0}n^{1} + \text{Energy}$$

(ii) Nuclear fusion on the other hand is a process in which a heavier nucleus is formed from the two isotopes of a lighter element releasing enormous energy in the process. In order to fuse these nuclei extremely high temperatures of nearly 1 billion degree Celsius is required. The heat energy produced as a result of either of the processes is used to produce steam which runs the electric turbine.

Deuterium-deuterium Fusion

$$_{1}H^{2} + {}_{1}H^{2} \rightarrow {}_{2}He^{3} + 3{}_{0}n^{1} + \text{Energy (3.27 MeV)}$$

Deuterium-tritium Fusion

$$_{1}H^{2} + {}_{1}H^{3} \rightarrow {}_{2}He^{4} + 3{}_{0}n^{1} + \text{Energy (17.59 MeV)}$$

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Components of a Nuclear Reactor:

1. **Moderator: Heavy water, Graphite, Deuterium, Paraffin**

   When fast-moving neutrons collide head-on with the protons of moderator substances, their energies are interchanged and thus the neutrons are slowed down. Such neutrons are called thermal neutrons which cause the fission of U^{235} in the fuel.

2. **Control Rods:** Boron or Cadmium rods
3. **Coolant:** A substance which is used to remove the heat produced and transfer it from the core of the nuclear reactor to the surrounding is called coolant.
4. **Shielding:** Protected with concrete walls 2-25 m thick so that radiations emitted during nuclear reactions may not produce harmful effects on the persons working in the reactors.
5. **Nuclear Fuel**: Uranium 235 (U^{235}).

Advantages:

1. Emits very few greenhouse gases and hence does not contribute to global warming.
2. Readily available technology.
3. Generates a high quantity of electricity from a very small amount of nuclear fuel.
4. Low operating costs.
5. It is able to meet both industrial and domestic needs for energy.
6. Nuclear wastes may be reduced through reprocessing or recycling.

Disadvantages:

1. High installation cost due to radiation containment and procedures.
2. Needs a centralized power source with a large infrastructure.
3. High known and unknown risks.
4. Requires a large construction period.
5. Nuclear fuel is a finite source. Uranium may last for only 30 to 60 years.
6. Installation and operation new high expertise and skill.

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7. Mining involves health and other catastrophes.
8. Requires a huge amount of water.
9. Disposing of spent fuel is a problem. Wastes may last for 200 to 500 years.
10. The target for terrorist activities.
11. The average life span of nuclear reactors is usually 40 to 50 years.

7.8 National Solar Mission

The National Solar Mission is among the eighth key National missions which comprises India's National Action Plan on Climate Change (NAPCC). NAPCC was launched on 30th June 2008 and identified the development of solar energy technologies in the country as a National Mission. In order to promote ecologically sustainable growth and meet the challenge of India's energy security, the national solar mission was launched by the Government of India and State Governments as a major initiative. The Government of India approved National Solar Mission on January 11, 2010. As far as India is concerned undoubtedly, solar energy has got tremendous potential to reduce reliance on non-renewable and depleting energy sources as sunshine is available in great intensity and for a longer duration per day. Besides, it can also permit the decentralized distribution of energy for empowering people at the grassroots level.

Keeping in view this vision and the brand name "Solar India", The National Solar Mission was launched with the prime objective to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. The mission was launched following a three-phase approach extending till the period of the 11th plan and the first year of the 12th plan (up to 2012-13) as Phase 1, the remaining 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3.

The mission aims at establishing an enabling environment for solar energy in our country at both the levels centralized and decentralized. In June 2015 the ambitious target of 20,000 MW was revised to 1 lakh MW of grid-connected solar power by 2022. There is a provision for the midterm evaluation of the progress review of capacity and the targets for the successive phases in order to protect the government from the exposure of

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subsidies. The mission had two well-defined purposes: Long-term energy security and Ecological security.

Environmental Impact:

1. Solar energy is environmentally friendly as it has zero emissions while generating electricity or heat. It produces electricity which doesn't cause pollution of the environment.
2. The energy produced by the sun is a renewable source of energy. The power source of the sun is absolutely free.
3. It can be used in remote and isolated areas where there is no power supply.
4. Most solar energy systems have a lifespan of about 30 to 40 years.

7.9 Summary

- Energy is required by all living organisms and vegetation for the biochemical reactions of their cells. In fact, all living beings operate by means of energy. Energy moves the universe. About 99.8 per cent of our energy comes from solar radiation.
- Growing energy needs is an index of national development. Energy is derived from both conventional and non-conventional resources.
- According to the World Energy Outlook's Reference Scenario - the energy needs of the world would be 50% higher in 2030 than today with an average annual growth rate of 1.6%.
- India is among the fastest-growing markets in the world and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption.
- With limited fossil fuel reserves, the country has planned to increase its renewable and nuclear power industries.
- All conventional mineral-based energy resources, such as fossil fuels, are exhaustible. It is estimated that if we continue to use coal at the present rate, the available coal reserve will exhaust in the present century itself. India produces petroleum which fulfils

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only half of our requirements and the remaining half is met by importing from other countries.

- Any energy source which provides an alternative to fossil fuel is called an alternate source of energy. India is now promoting many alternate renewable energy sources in order to meet the increasing demands of the increasing population.

7.10 Self-Assessment Questions

1. Write short notes on the following: a) Energy Resources, (ii) Non-conventional sources of energy and (iii) Different types of Coal.
2. Explain geothermal energy.
3. Differentiate between Renewable and Non-renewable sources of energy.
4. What are the major energy sources of developed countries?
5. What are fossil fuels? Give three examples of fossil fuels.
6. Are fossil fuels renewable or non-renewable? Give reasons.
7. Explain the advantages and disadvantages of solar and wind energy.
8. Write an account of the growing energy needs with special reference to India.

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LESSON

8

Pollution: Air, Noise and Nuclear Pollution

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STRUCTURE

8.1 Learning Objectives

- The sources, causes and impacts of Air, water, noise and soil and Nuclear pollution.
- How various kinds of pollutants impact the ecosystem and human health.
- Various measures and steps can be employed for reducing pollution.
- Government initiatives and programs as mitigating measures for Pollution across India.
- Definition, types, sources of solid waste, the impact of landfills and importance of an integrated Solid waste management plan.
- Critically assess the various issues discussed above to relevant case studies.

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8.2 Introduction

E.P. Odum (1971) defined pollution as an alteration in the Physico-chemical and biological nature of air, water and soil that ultimately affects the whole environment. It also specifies its hazardous impacts on living organisms (both flora and fauna), other environmental systems and non-living material. Pollution is caused by anthropogenic (man-made) or natural activities. Examples of natural pollution are volcanic eruptions, forest fires, floods caused etc. Incomplete technology lacking close integrated systems is the main cause of man-made pollution.

Today, the problem of pollution has become a major challenge to scientists, environmentalists and humanists as the pollution of various components has gone to such an extent that we are unable to breathe fresh air, drink fresh water and eat pure food. If a man has to survive, he has to fight and overcome this gigantic problem before it swallows him and his very existence.

8.3 Sources of Pollution

Pollution may be caused by several sources depending upon the nature of the pollutants:

1. **Solid Wastes as a Source of Pollution:** Solid Wastes may be domestic or industrial in nature. Various solid wastes can be categorised as follows:
   - *(i)* Industrial wastes, e.g. particulate wastes from various industries such as glass fragments, leather pieces, rubber pieces etc.
   - *(ii)* Domestic Wastes, e.g. garbage in the kitchen, slaughterhouses etc. These may be combustible (such as leaves, twigs, papers etc.) or non-combustible (such as crockery, plastics, glass etc.) in nature.
   - *(iii)* Sewage, e.g. human and animal excreta, domestic effluents, detergents etc. (solid faecal is called sludge)
   - *(iv)* Agricultural Wastes, e.g. plant and animal residues, broken twigs, wood fractions, fruits, pesticides, fertilizers etc.

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2. **Liquid Wastes as a Source of Pollution:** Industrial effluents and domestic wastes in the form of liquid are the major sources of water and soil pollution. Industrial pollution may leach the lethal magnitude. Liquid discharges from chemical factories, refineries, breweries, tanneries etc. contain acids, alkalies, oil and dissolved heavy metals which enter the river water and adversely affect the aquatic life and impair its self-purification system. Liquid wastes from domestic sources may be of inorganic or organic nature. Inorganic liquid wastes include soap water and detergent water from bathing and washing clothes whereas organic wastes include kitchen garbage, faecal water, urine etc. Runoff from agricultural fields carries residual fertilizers, pesticides, biocides etc. which enter the water streams and harm the aquatic life.
3. **Gaseous Wastes as a Source of Pollution:** Common gaseous pollutants like carbon monoxide, sulphur oxides, nitrogen oxides, hydrogen sulphide etc. are frequently released from various industries and automobile exhausts. Pollution resulting from gaseous wastes is one of the most dangerous and lethal types. Life on earth is dependent upon the air we breathe and if this source of life is contaminated and polluted by lethal gaseous discharges, the very existence of all living organisms is threatened.
4. **Energy Wastes as a Source of Pollution:** A significant addition to the sources of pollution are the invisible pollutants i.e. pollutants without mass or weight and invisible to the eyes. Examples of such pollutants are heat and radioactive emissions. Radioactive emissions are the most hazardous, and their cumulative effects are far-reaching and damaging to the genetic makeup of living organisms.
5. **Noise as a Source of Pollution:** Unwanted sound or noise above a particular level in the atmosphere is an important pollutant. Indiscriminate and continuous use of radios, traffic horns, public broadcasting systems etc. is a common source of noise pollution. Aeroplanes and supersonic jets also produce noise of high intensity which may sometimes rupture the ear drum and cause irreparable damage to the brain.

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8.4 Classification of Pollution

Pollution has been classified in various ways based on different factors such as :

1. **Nature of Pollutants:** Two categories are recognised based on the degradability of pollutants:
   (i) **Biodegradable:** These are those substances which can be decomposed naturally in the presence of microorganisms. For example, any organic waste, leaf litter etc.
   (ii) **Non-biodegradable:** These are those substances which cannot be decomposed or broken down into simpler substances by any natural process. For example, plastic waste, metallurgical waste etc.
2. **Components of Environment:** Pollution has been classified based on the particular component of the environment being polluted, such as:
   - Air Pollution
   - Water Pollution
   - Soil Pollution
   - Radioactive Pollution
   - Noise Pollution
   - Thermal Pollution

8.5 Management of Environmental Pollution

At present what is required is not so much the ability of human beings to conquer nature, rather there is a need for a balanced and harmonious collaboration with its forces. The ultimate goal of environmentalists should be to manage the environment in such a way that it can contribute to man's happiness, health and enjoyment and improve the quality of human life. The various activities of civilisation invariably interact with the environment predicting various forms of environmental problems. These problems may be local, national or international and must be managed accordingly. Following are a few suggestions to combat pollution:

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1. Environmental education must be made compulsory in all education systems, from primary to university levels.
2. Awareness about general environmental issues should be circulated at a large scale through media services.
3. Formulation of quality standards should be implemented and breaking these standards should be a punishable offence.
4. Sustainable approach toward the environment should be made through community participation.
5. Relocation of industrial units, airports etc in the countryside to reduce the risk of air pollution.
6. Private and public enterprises should adopt pollution mitigation plans through laws and policies.
7. Nuclear testing should be restricted to the minimum by international agreements.

The entire world is now involved in combating environmental problems in various ways. National and International efforts, Important Environment Dates, Indian Centres for Environmental Studies, Centres for Excellence, Important National Awards etc. are also important pillars of environmental studies.

8.6 Air Pollution

It is defined as the pollution caused by anthropogenic and natural agents that degrades the quality of air and has an impact on living and non-living systems. The essential component of our life, "air", resides in one of the spheres of the environment, called as "Atmosphere". The envelope of air that surrounds the earth's surface is called as "atmosphere". It consists of both major and minor components which include gases, particles, water vapour and biological particles. It makes up nearly 80% of a man's daily intake by weight. Humans breathe almost 22,000 times per day, taking in almost 16 kg of air. So, the quality of air that we breathe is very important for our sustenance of life, otherwise, it leads to loss of lives and produces disturbance in ecological systems. The atmosphere has two natural detergents that can remove the pollutants from an air parcel: high mixing height plus high wind speed which favours high dispersion

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and high precipitation in the form of rainfall. Rainfall act as the best scavenging agent for the removal of air pollutants.

8.6.1 *Categorization of Air Pollutants*

Agents or carriers which cause air pollution are known as air pollutants. Air Pollutants are divided based on their origin, composition and kind of matter.

A. Origin:

(i) Primary air pollutants are those which have their own origin and have direct emissions into the atmosphere. For example, oxides of nitrogen, oxides of sulphur, oxides of carbon, volatile organic compounds and particulate matter (dust particles).

(ii) Secondary air pollutants are those which are derived from primary air pollutants. For example, O_3, PAN etc.

B. Chemical Composition:

(i) Organic compounds: These are those which contain carbon and hydrogen units. For example, aldehyde (formaldehyde) and ketone (acetone).

(ii) Inorganic compounds: These are those which are having mixed formations of compounds and don't contain carbon and hydrogen units. For example, carbonates, nitrogen oxide etc.

C. Kind of Matter:

(i) Size-segregated particles in micrometre size ranging from 10μm to less than 1 μm. For example, dust, aerosol, and total suspended particulate.

(ii) Gaseous air pollutants. For example, oxides of nitrogen, oxides of sulphur, oxides of carbon and volatile organic compounds.

8.6.2 *Types of Air Pollution*

Indoor Air Pollution: This type of air pollution has mainly an anthropogenic source. Domestic activities like cooking fuel burning, coal burning, crop residue burning etc. Most household women are severely affected due to emissions of indoor air pollutants. Approximately 2.5 Billion people,

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mostly in developing nations are exposed to high levels of indoor air pollution and consequently, suffer.

Outdoor Air Pollution: Vehicular and industrial emissions are major sources of outdoor air pollution. Overpopulation growth and industrialization are also major indirect contributors. Outdoor air pollution affects over 1,100 million people, predominantly in cities.

The London Smog, 1952

In the winters of the UK in the late nineteenth and twentieth centuries, on considerable occasions, in early December of 1952, the wind speed had fallen and temperature inversions were formed as stationary high-pressure systems developed over western Europe. With an increase in the concentration of pollutants, the fog became widespread. The condition was commonly referred to as smog. Initially, the term smog was coined by Harold Des Voeux, the treasurer of the Coal Smoke Abatement Society in 1905 to refer to an odd combination of smoke plus fog. Smog was formed from particulate emissions from the combustion of coal in industrial furnaces, kilns and boilers, domestic grates and steam locomotives, and canal ships. The visibility dropped, transport could not move, railways and air flights had to be closed and shops, stores and institutions were shut down completely paralyzing the city. PM went up by 56 times the normal level and the SO2 level went up by seven times. Some 8,000 young and old people were hit by bronchitis and heart disease. The number of deaths rose so high from this Sulphur laden sooty condition that it was popularly known as Great Smog. These profound events led to the enactment of the Clean Air Act of 1956.

The Los Angeles Smog

This event occurred in Los Angeles city in 1943. The Sulphur-laden sooty smog in time, however, eventually gave rise to photochemical smog with the development of the internal combustion engine as a prime source of transportation. Such smog is initiated by nitrogen dioxides, In the Presence of sunlight the free oxygen atoms react to form ozone. This was first evidenced in the Los Angeles region of the USA. It irritated the eyes, and damaged the plants, for example,

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tobacco. The major sources of nitrogen dioxides were vehicular emissions, and emissions from aircraft, ships, trains, industries and houses. The symptoms are aching lungs, wheezing, coughing and headache. 'Smog complex' involves irritation of the eyes and respiratory passages, chest pains, shortness of breath, nausea and headache. Lungs are ozone's primary target causing damage to cells in the airways, inflammation and swelling. It also reduces immunity. It poses a health risk to those people who already suffer from emphysema and chronic bronchitis.

8.6.3 *Sources of Air Pollution*

A. *Natural Sources:* The natural sources can be thunderstorms, emissions of gases and particulates from forest fires, methane emissions from marshy lands, bioaerosols from pollen grains, volatile organic compounds emissions from trees and plant species, and volcanic eruptions generate sulphur dioxides emissions and decomposition of organic matter emits carbon dioxide and methane.

B. *Anthropogenic Sources:* Along with natural pollutants, there are pollutants of anthropogenic origin too. The main anthropogenic sources are gasoline exhaust emissions, industrial emissions, mining activities, cooking fuels, construction works, fireworks etc. The details of each emission source category are as follows:

   (i) Household works: Coal combustion generates an enormous amount of smoke, soot, dust, CO, SO_2, and NOx. However, the burning of LPG releases fewer amounts of pollutants comparatively.

   (ii) Gasoline Exhaust: Different categories of vehicles like 2-wheelers, 4-wheelers, heavy-duty vehicles, etc. release a number of gaseous air pollutants and particulate matter. They mainly include NOx, SOx, VOCs, CO, O_3, PM_{10}, $PM_{2.5}$ and sometimes lead. Vehicles contribute approximately 70% of air pollution as they are the major source of primary and secondary air pollutants.

   (iii) Industries:

      (a) Chemical Industries: *They generate SOx, NOx, VOCs and PM.*

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(b) ***Coal Powered Plants:*** *SO_2, CO, NOx and PM.*

(c) ***Electroplating and Metallurgical Industries:*** *CO, CO2, NOx, PM, cooper, lead etc.*

(d) ***Gasoline-fuel Industries:*** *They include petroleum and diesel which emits VOCs, NOx, SOx, CO, PM, O_3 etc.*

(e) ***Paper Manufacturing Industries:*** *PM10, PM2.5, SO_2 etc.*

(iv) ***Agricultural Practices:*** agriculturally based chemical fertilizers which include pesticides and herbicides like chlorinated hydrocarbons, etc.

The Bhopal Gas Disaster

Commonly known as Bhopal Gas Tragedy, it is to date the ghastliest industrial disaster in the world. The incident took place on 2-3 December night, 1984 at the Union Carbide Industrial Plant in Bhopal, Madhya Pradesh, meant for the production of seven - a pesticide. Over 40 tons of Methyl Isocyanate (MIC) gas escaped from the Union Carbide Pesticide Plant, which instantaneously killed nearly 3,800 inhabitants and accused considerable despondency and early death for several thousand. Estimates from various sources vary on the death toll. Another agency claimed over 15,000 deaths. As per government sources in 2006, the leak caused 5.58.125 injuries with disabling injuries. The vent gas scrubber, a safety device had been turned off three weeks prior. It becomes apparent that a defective valve permitted a load of water that was meant for clean-up of the internal pipelines, which got mixed with 40 tons of MIC. When MIC is exposed to 200ºC heat, it formed more deadly Hydrogen Cyanide (HCN) gas. The evidence gathered does reveal the temperature of the storage tank reached that disastrous level.

The effects of this tragedy were: Ophthalmic (chemosis, redness, watering, ulcers, photophobia); respiratory (distress, pulmonary edema, pneumonitis, pneumothorax), psychological (neuroses, anxiety states, adjustment reactions); neurobehavioral (impaired audio-visual memory, impaired alertness and reaction time, impaired analysis, interpretation and spatial ability, dysfunctional psychomotor coordination), Visual (constant watering, corneal opacities, chronic conjunctivitis), respiratory (obstructive and restrictive airay disease, decreased lung function) etc.

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8.6.4 *Main Air Pollutants*

The air pollutants are divided into the following categories:

(a) Aerosols and VOCs

(b) Other Hydrocarbons

(c) Particulate matter (inorganic and organic)

(d) Oxides of carbon

(e) Oxides of Sulphur

(f) Oxides of Nitrogen

Aerosols are very small particles suspended in the atmosphere and have a crucial role in the formation of cloud condensation nuclei, radiative forcing etc. For example, pollen grains, haze, smog etc. The main source of aerosols in the atmosphere is anthropogenic sources. Most of the aerosols are concentrated in Northern Hemisphere due to wind patterns and other favourable meteorological factors. Crop residue burning and construction activities are major sources of aerosols.

Natural aerosols also contribute to altering the composition of air quality. The natural sources include sea salt spray, pollen grains, forest fires, dust storms etc. Aerosols have the tendency to block solar radiation and this will result in radiative heating. A high concentration of aerosols also affects the crop species and mainly biochemical and physiological processes and mechanisms. They are also responsible for photochemical smog formation.

Volatile Organic Compounds (VOCs) refer to those organic compounds which are having a vapour pressure of 0.1mm Hg and vaporise at or less than 25ºC. There are different classes of VOCs as non-methane hydrocarbons, aldehydes, ketones, aromatic compounds, amides, carbonyls etc. They are the only air pollutants whose maximum source contribution is from natural sources (80%) and the rest is from anthropogenic (20%). Natural sources are trees, plant species and animal breath. Trees have the major contribution of VOC emissions from leaves, stems, flowers etc. as compared to any other source. Anthropogenic sources include vehicular emissions from gasoline exhaust, industrial emissions like paints, mosquito repellents, adhesives, varnishes, cleansers and disinfectants and mining activities.

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POPs (Persistent Organic Pollutants) are organic compounds that adversely affect the lives of human beings all over the world. POPs including some pesticides and heavy metals evaporate from the soil in the equatorial and tropical countries; travel in the air towards comparatively cooler regions, where they condense with the falling temperature. The processes repeat in 'hops' and are thus carried across thousands of kilometres away within a few days. The more the volatility, the far they are carried and retained in the air. Such a mechanism of long-range atmospheric transport and subsequent deposition of POPs is called 'grasshopper or global distillation process. The process goes on and on with the highest concentrations in the circumpolar nations. Because of this, the Arctic Council was constituted by Denmark, Sweden, Iceland, Norway, Russia, Alaska, Greenland, Finland etc. to monitor and assess the source and pathway of POPs. The POPs remain in the environment for a long period and can easily transfer from one stage to another in an ecological chain. In 1992, under the United Nations (UN)/ECE (European Commission of Europe) the Convention on Long-Range Transboundary Air Pollution (LRTAP) was constituted to identify the chemicals of potential concern.

Particulate Matters: Particulate Matter (PM) or dust particles are those which remain suspended in the atmosphere and have a deleterious impact on human health. Particulate matter is divided based on its particle size. The finer the particle, the more dangerous it is for human health. Particles with an aerodynamic diameter of less than 10 μm are known as $\mathbf{PM}_{10}$. Particles with an aerodynamic diameter less than equal to 2.5 μm are known are $\mathbf{PM}_{2.5}$. PM10 particles are also called coarse particles, as they are bigger so they trap inside the nose and don't penetrate inside. Whereas $PM_{2.5}$ is also called fine particles and our nose doesn't have efficient filters to trap them, therefore, they penetrate inside the lungs and accumulate in the trachea. The particles having a size of less than 2.5 μm are also called nanoparticles and deep penetrate inside the lungs and settle inside the alveoli. They are the most dangerous particles for human health. Vehicular emissions, industrial emissions, construction activities, domestic activities, mining and religious activities are the main sources of particulate matter in the atmosphere. The symptoms of particulate matter emissions on human health are nausea, dizziness, respiratory illness, asthma, inflammation of lung tissue, chest pain and in most severe cases, lung cancer.

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Chlorofluorocarbons (CFCs) are those organic compounds which contain groups of halogen families and are produced as an important product of methane and ethane called freons. The main sources of CFCs are refrigerators, propellants etc. The examples of CFCs are hydrochlorofluorocarbons (HCFCs), dichlorodifluoromethane (R-12 or Freon-12) etc. CFCs.

Table 8.1: Summary of air pollutants, sources and impacts

S. No.	Pollutant	Source/Cause	Effect
1.	Carbon monoxide (CO)	Vehicular emissions, wood burning, coal burning, incomplete combustion etc.	Nausea, dizziness, severe headache, cardiac arrests, brain stroke, low blood pressure and CO poisoning. After inhalation due to incomplete combustion, CO inhales deep into the lungs and combines with haemoglobin as it has a high affinity to oxygen. The result is carboxyhemoglobin. When a large number of carboxyhemoglobin molecules increases in the human body then it decreases the oxygen level. Due to a high decrease in O_2 levels, the condition becomes fatal and leads to death.
2.	Carbon dioxide (CO_2), is declared a pollutant only at elevated levels.	Biomass burning	Global warming, greenhouse effect and climate change.
3.	Sulphur dioxide (SO_2)	Industrial processes, fossil fuel combustion, wildfire, thermal power plants, smelters and volcanic eruptions	Respiratory ailments, dizziness, bronchitis, reduced plant production, yellowing, necrosis and corrosion to marble, spoiling of leather, corrosion.

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S. No.	Pollutant	Source/Cause	Effect
4.	Polynuclear Aromatic Hydrocarbons (PAHs)	Gasoline exhaust emissions, emissions from garbage sites, coal tar lining.	Nausea, dizziness, lung cancer, respiratory disorders, eye irritation etc.
5.	Chlorofluorocarbons (CFCs)	Refrigerators, ACs, cleaning solvents, disinfectants.	Ozone layer depletion, formation of the ozone hole.
6.	Nitrogen Oxides	Biomass burning, forest fires, gasoline exhaust emissions, mining etc.	Nausea, dizziness, cardiovascular disorders, photochemical smog, acid rain etc.
8.	Peroxy Acetyl Nitrate (PAN)	Vehicular emissions, Chemical industrial emissions, domestic activities etc.	Irritation of the eye, throat and trachea, damage to clothing, paints and rubber etc.
9.	Particulate matter	Vehicular emissions, construction-based activities, industrial emissions, wood burning etc.	Respiratory disorders, bronchitis, emphysema, and asthma; some are carcinogenic.

8.6.5 *Air Pollution Control*

A. Source Emissions - Industries

- Low-sulphur fuels should be encouraged to use to reduce the emission of sulphur dioxide and a reduction in benzene in gasoline fuels (petrol) from 10% to 1% is implemented as per central pollution control board norms.
- Exhaust hoods are the latest modifications in industrial ovens which have good efficiency to recover the solvents that have the possibility to become air pollutants.

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- Cost-effective instruments are implemented to reduce air pollutant concentrations.
- Removal of pollutants at source reduction like a wet scrubber, cyclone separator, electrostatic precipitator etc.

B. Source Emissions - Vehicles

- Eradication of Old Vintage Vehicles. Vehicles, particularly cars, which are older than 15 years, should be discarded due to their low efficiency and malfunctioning engines. These vehicles are also one of the main reasons for emissions of air pollutants into the atmosphere.
- Catalytic converters are efficient devices fitted in engines of different sets of vehicles and play an important role in converting noxious gases into less harmful gases through a chemical reaction.
- Improvement in the quality of vehicular fuel will reduce tail-pipe emissions and further betters air quality. For e.g. sulphur content was reduced from 0.5 to 0.2 per cent in diesel to reduce the emission of SO_2 from the tail-pipe. Methyl Tert-Butyl Ether (MTBE) should be added as a gasoline additive for increasing the octane number and reducing the knocking of the engine
- Unleaded petrol is recommended for vehicular use, especially in Delhi to reduce the lead emissions from gasoline fuels.
- Alternative fuels should be used in place of gasoline fuels like CNG, LPG, biodiesel, vegetable oils, ethanol etc to curb the emission of air pollutants.
- To promote the use of electric vehicles

C. Legal and Policy Measures

For the control of air pollution, two main acts are implemented, The Air Pollution Prevention and Control Act, 1981 and the Environmental Protection Act, 1986.

Implementation of Air Quality Standards (NAAQS)

- The National Ambient Air Quality Standards (NAAQS) were first suggested under the Air Pollution Prevention and Control Act, 1981 for prescribing the standards of different hazardous air pollutants. In 1984, a statuary body called Central Pollution

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Control Board (CPCB), India adopted 12 parameters which are needed to prescribe air quality standards. The 12 parameters are particulate matter (PM10 and PM2.5), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ammonia (NH_3), ozone (O_3), lead (Pb), benzene (C_6H_6), benzopyrene, arsenic and nickel. CPCB initiated this programme and later called as National Air Monitoring Programme (NAMP).

National Air Quality Monitoring Programme

There are about 610 monitoring stations in 227 cities in India as on 1 January 2019. The air quality monitoring was undertaken under the supervision of CPCB, SPCB, DPCC, National Environmental Engineering Research Institute (NEERI), Nagpur and pollution control committees. Meteorological (weather-related) parameters are also carried out along with air quality data.

D. Greenbelt Development/Landscape Green Planning

- To plant tolerant species which are good absorbers of different air pollutants. These types of plant species are called sinks and help in purifying the air.
- These tolerant plant species will be screened by a biological method called as Air Pollution Tolerance Index (APTI) and planted around the periphery of the affected area.

E. Emission Norms and Emission Standards

Emission norms are the threshold or permissible limits set by the nodal agency for a particular category of vehicle. These limits are for those air pollutants which are emitted usually from the tail-pipe of vehicles like CO, NOx, VOCs, PM etc. If any vehicle emissions these air pollutants above the set permissible limit, it is considered an unfit vehicle. The Automobile Research Institute, Pune is the certifying authority for the vehicles fulfilling the standards. Euro norms are applied in Europe and also for setting up permissible limits for different categories of vehicles. In India, Euro I norms are referred to as INDIA 2000 because they have been effective since 4 January 2000. In 2016, the Indian government announced that the country would skip the BS V norms altogether and would adopt BS-VI norms by 2020.

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F. Air Pollution Control Equipment

***(i)* Control for Particulate Matter**

1. Wet Scrubbers are used to take away the pollutants from furnace flue gas. They consequently pass through scrubbing liquid and hence, particulate matter is removed.
2. An electrostatic Precipitator (ESP) is also a fine device for the removal of PM which is based on the principle of opposite charges attracting each other. The dust particles which are having a positive charge, get deposited on the negative charge electrode (cathode) and similarly, the negative charge dust particle is deposited on the positive charge electrode (anode).
3. Cyclone Separators: Particulate matter is removed by centrifugal force taking place in a rotator machine. It will remove particles 10 microns or larger.

***(ii)* Control for NOx**

1. Exhaust Gas Recirculation (EGR).
2. Catalytic converter.

***(iii)* Systems to Decrease VOC**

1. Gas Flare
2. Biofilters are devices that use living matter to trap biologically degradable pollutants.

Taj Mahal Issue

Taj Mahal, being one of the seven wonders and one of the most beautiful monuments of the world, attracts international tourists throughout the year. It was built along the bank of river Yamuna by Mughal Emperor Shah Jahan in memory of his beloved wife Mumtaz more than 350 years back in Agra. It is now included in the list of World Heritage due to its archaeological importance. In 1972, the Government of India established Mathura Oil Refinery in Mathura. This step was most resented by various environmentalists of the country who protested that its air pollutants were harmful to the Taj Mahal. During the oil refining process, Sulphur dioxide

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(SO_2) is released in large quantities along with the smoke. Air containing SO_2 blow all around and reacts with water during rains. SO_2 combines with water to form Sulphur acid (H_2SO_3) and sulphuric acid (H_2SO_4) and produces acid rain. Environmentalists protested that acid rain causes damage to the marble of the Taj Mahal. The white marble has yellowed and blackened in places. The government constituted a committee in 1974 to find out the fact and authorized Italian Company Technico to evaluate the changes occurring in the air due to the Mathura Oil Refinery of the Indian Oil Corporation. According to the report of the committee and determinations carried out by an Italian company, it was concluded that in Agra the quantity of SO_2 would increase up to 1-3 micrograms which is negligible and harmless to the Taj Mahal. However, WHO (1982) has recognized the 'Taj Trapezium Zone' (TTZ) (50 km radius area) to protect the monument from pollution hazards. The burning of coal and wood fuel has been banned in TTZ. Supreme Court has ordered to set up of a solar power plant for the energy requirement of TTZ.

8.7 Noise Pollution

Noise is an unwanted and unpleasant sound. Noise pollution may be defined as unwanted sound released into the atmosphere and may create some adverse effects or unwanted noise. The high-intensity sound may have great physical/physiological damaging effects which can be extremely damaging. The sound intensity has been measured in terms of decibels (dB). The various levels of the sounds with the loudness sensation are given in Table 8.2.

8.7.1 *Sources of Noise pollution*

There is a number of sources available indoors and outdoors for sound generation. The most common source in our houses are gadgets like a mixture/grinder, vacuum cleaner, washing machines, coolers, air conditioners, radios, and TV systems, whereas the outdoor sources are factories, vehicles, aeroplanes, trains, loudspeakers and crackers used in the various festivals.

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Table 8.2: Different Noise Levels

S. No.	Noise levels (dB)	Sensation	Source
1	0-20	Whisper	Rustle of leaves, Sound-proof room
2	20-40	Faint	Quit home, Private office, Empty auditorium
3	40-60	Moderate	Noisy home, conversation quit radio
4	60-80	Loud	Average radio, average street noise, average factory
5	80-100	Very Loud	Loud street noise, noisy factory, Police whistle
6	100-120	Deafening	Elevated train, Thunder, Nearby riveter
7	120-140	Physical Pain	Jet aircraft, Train horn

8.7.2 *Effects of Noise pollution*

Noise exposure causes a variety of adverse health effects and it depends on its intensity, frequency and periodicity.

1. **Effects of High-Intensity Sound:** The sound (80-100 dB) of such intensity is emitted by machinery, motorcycles, high-intensity music system etc. It may cause emotional and behavioural changes by producing nervous tension and cardiovascular problems like heart disease and blood pressure. Such regular exposure to machinery can cause complete hearing loss, and a rise in the blood cholesterol level and body plasma concentration.
2. **Effects of Explosive Sound:** The sound above 110 dB is referred to as the explosive sound which may be generated by crackers, trains, motorcycles etc. Such sound may easily cause vomiting, severe concussions of the internal ear and profound deafness.
3. **Effects of Loud and Sudden Noise:** A sonic boom produces startle effects and damages the brain. It may also damage the property such as window breaks.

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4. **Effects of Intermittent Noise:** Such sound is very disturbing and may cause psychiatric illness as found in the area having the regular sound of aeroplanes.
5. **Effects of Low Noise:** This is the common noise produced by crowed, roads, radios and TVs etc. Interfere with the conversation and causes emotional and behavioural stress. Such noise increases the consumption of alcohol, drug tranquillizers and sleeping pills.
6. **Effects of Absolute Silence:** Absolute silence is also undesirable for man. In a perfect anechoic room (sound levels 0-5dB), one can stay for a few minutes, he will be overcome by an uncomfortable sensation as a pounding of heart will be felt and ringing noises start in the ears. Mild sound (about 10 dB) was found very necessary for human existence and feel pleasant in such sound produced by nature like bird songs.

8.7.3 *Control of Noise Pollution*

Control of noise pollution is basically, a reduction of the sound intensity of any available sources. There can be three ways to reduce such type of noise pollution:

(i) Eliminate the noise at the sources,

(ii) Modify the path of the sound transmission

(iii) Provide the receiver with some form of protection

Some of the important ways for noise reduction are as follows:

1. **Noise Pollution Reduction in Industries:** Noise in industries can be reduced by replacing old machinery with newer and more efficient ones. The noisy generator must be located far from the work area. Factory workers must wear ear muffs (for sound above 90dB) or ear plugs (for sound below 90dB). Apart from this, some plants such as Ashok, Banyan, Neem, Kadamb etc. should be grown around the factory to minimise noise pollution.
2. **Reduction of Community Noise:** The use of loudspeakers in marriages or other occasions should be banned else permitted for a certain period of time. Measures should be taken to prohibit the manufacture, sale and use of crackers of high sound intensity.

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3. **Reduction of Traffic Noise:** Old and sound-producing motor vehicles should be banned on roads and denied operation. Hooting and blowing of horns needless should be restricted legally. All along the highways 50 feet wide plantation strips should be developed.
4. **Reduction of Aeroplane and Jet Noise:** Aerodrome should be located very far from the residential area. The heavy and thick green belts should be developed to reduce the noise pollution levels around the aerodrome.
5. **Planning of Cities and Housing System:** Well-planned cities should be developed to reduce the noise pollution created by industries and highways. There should be a sufficient number of green belts in between residential areas.
6. **Legal Control of Noise Pollution:** Recently, Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) have been given the power to frame certain rules and regulations to control noise pollution. Certain rules and regulations are:
   - *(i)* A silence zone should be created near hospitals and educational institutes.
   - *(ii)* The use of sound amplifiers should be strictly restricted.
   - *(iii)* All vehicles should have effective silencers and uncontrolled blowing of the horn should be declared illegal.
   - *(iv)* Mid-night aircraft flights should be restricted/minimised.
   - *(v)* Restriction on the factory noises should be handled legally and soundless machinery should be promoted.
   - *(vi)* Developmental authorities should have a legal procedure and protocol to establish a significant number of green belts in and around cities.

8.8 Nuclear Pollution

8.8.1 *What is a Nuclear Hazard?*

Nuclear hazards can be stated as potential risks arising due to exposure to radiation emanating from the atomic nuclei. The important process leading to the emission of radiation by different nuclei is known as radioactivity.

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The source of radioactivity is an emission of energy from radioactive isotopes such as Carbon-14, Uranium-235, Uranium-238, Uranium-239, Radium-226, etc. The energy from these sources is released in the form of alpha, beta or gamma radiation. All these radiations have a different impact on tissues. The alpha rays are highly ionizing but have low tissue penetration. If the alpha-emitting source is ingested it causes a severe problem. Beta rays have more penetration ability and can cause cell damage and mutagenesis. It is also used in radiation therapy for cancer patients. Gamma radiations have a high penetration value and can cause severe problems. These sources are also used for the sterilization of medical and scientific equipment and the treatment of food. Nuclear power plants using radioactive elements for energy generation (see Figure 8.1) have been among the cause of disasters affecting millions with radiation fallout.

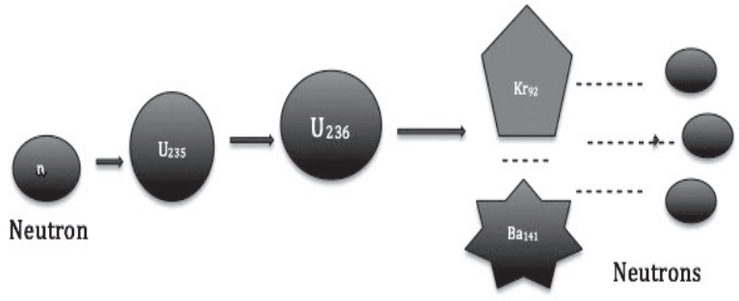

Figure 8.1: Nuclear chain reaction occurring in nuclear reactors also known as nuclear fission reaction.

Chernobyl Disaster

The Chernobyl Disaster took place in April 1986 in Ukraine formerly known as part of the USSR. The Chernobyl disaster is known to be the biggest disaster to have occurred in nuclear power plants. In routine maintenance of one of the four nuclear reactors of the plant, a sudden power surge caused an uncontrolled chain reaction in one of the reactors leading to explosions in the reactor. The explosion exposed the nuclear reactors causing the spread of radioactive material into the atmosphere. The initial response from the administration was to contain the fallout of the disaster but later it realized that too much irreparable damage has already happened. The explosion released around 30 per cent of the 190 metric tons of Uranium being used in reactors. The USSR government later informed the world of

the explosion and started evacuating people when they realized fall out couldn't be controlled. It is estimated that 335,000 people were evacuated and more than hundreds died due to the explosion. The periphery of the nuclear reactor approximately 19 miles wide was cordoned off as an "exclusion zone" with no human activity. The incident site has been covered with thick sheets of steel in order to limit radiation leakage. More than 34 years on, scientists opine that the area won't be habitable for the next 20000 years. The researchers predicted contamination of surrounding areas with high radiation which led to low and high-level radiation exposure to as many as 10,000 people causing radiation-related cancer which led to their death in later years. The disaster led to a global anti-nuclear movement discouraging the use of nuclear energy.

8.8.2 *Causes of Nuclear Pollution*

1. **Nuclear Accidents:** Nuclear energy is one of the important energy sources discovered in recent times. The high energy in nuclear substances is due to their high latent power, also responsible for a high level of radiation. Due to safety issues, the use of nuclear materials is not promoted much but research is still underway to determine its environmental safety. Nuclear power plant accidents such as the Fukushima Daiichi nuclear disaster, Chernobyl disaster, and Three Mile Island accident are very well-known nuclear disasters that left many dead and many more affected people and the contaminated environment by the radiation released.
2. **Weapons of Mass Destruction (WMD):** The Second World War ended up with the use of nuclear missiles and atomic bombs; a form of nuclear energy may easily explain the damaging nature of radioactive pollution. These two strikes in Hiroshima and Nagasaki in 1945 after which the children were reported with complications such as mental retardation, autism and other disorders. In the present situation, the number of cancer cases present in the two towns is more than those in the rest of Japan.
3. **Use of Radioisotopes:** These are radioactive isotopes since they have an unstable atomic nucleus and emit energy and particles when it changes to a more stable form. Each radioisotope has a definite half-life

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period and characteristic disintegration. Such type of energy is liberated mostly in the form of alpha, beta, or gamma rays. Radioisotopes are used to make detectors and in other industrial activities. Isotopes such as uranium have high concentrations of radiation. While common Isotopes such as carbon-containing radioactive material are easily found in waterways through sewage lines. Since most of the raw sewage is untreated before release, once released, the isotope combines with other compounds and elements in the water. Consumption of this water through any means is a potential intake of radiation.

4. **Mining:** Mining is related to the excavation of mineral ores. Radium and Uranium, for instance, are naturally occurring in the environment and are equally radioactive. Other minerals with a hint of radiation are thorium, plutonium, radon, potassium, carbon and phosphorus.
5. **Radiation Tests:** Due to the lots of interesting properties radiation grabs the attention of scientists to carry out research. It plays one of the important roles in the treatment of cancer. Chemotherapy is now widely used in the treatment of cancer in which radiation is used to prevent further growth of the cancer cells as well as keep the immune system strong.
6. **Cosmic Rays:** Radioactive pollution is also caused by cosmic rays coming from outer space to our Earth. Gamma rays, for example, are said to have the highest level of radiation and yet, depending on their intensity, some are not visible to the human eye.

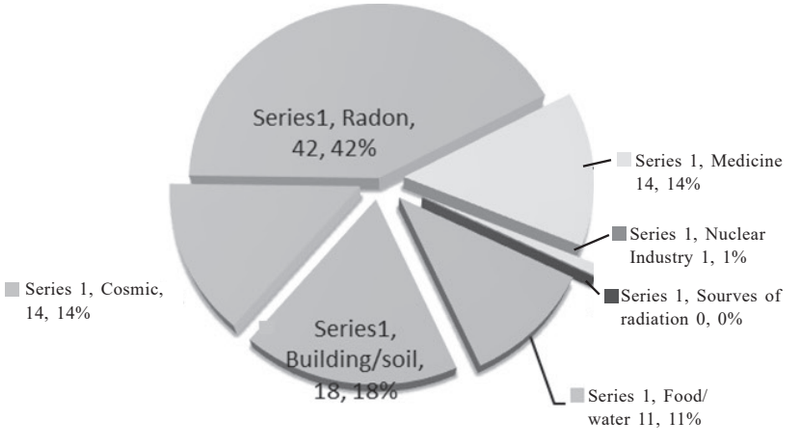

Figure 8.2: Contribution of harmful radiation from natural and human activities. The nuclear industry and medicine are the main man-made sources of radiation.

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8.8.3 *Impact of Nuclear Hazards*

The nuclear hazard can pose a great threat to the environment according to the spread of radioactive radiation. These are:

- The radioactive substances are known to be hazardous and when released into the environment can disperse or accumulate in living organisms by passing from one trophic level to another in a food chain.
- One of the radioactive substances known as Strontium-90 has properties similar to calcium and can be easily deposited in bones replacing calcium. Contaminated milk is regarded as a source entering the human body through ingestion.
- Nuclear power plants use tritium, which has a half-life of 12.3 years and emits radioactive Beta particles. These power plants are known to be routinely or accidentally releasing tritium into the air and water. If tritium enters a body by inhaling or swallowing, the beta particle released by it can bombard cells causing mutation.
- There are certain areas where exposure to nuclear radiation is high and poses threat, which are uranium mineworkers, radium watch dial painters, technical staff at nuclear power plants etc. The people working in these areas are exposed to radiation for a longer duration, which can cause cancer, mutations and teratogenesis (prenatal toxicity characterized by structural or functional defects in the developing embryo or foetus) in them.

8.8.4 *Effects of Radioactive Pollution*

The effect of radioactive pollutants depends upon:

(i) half-life time

(ii) energy releasing capacity

(iii) rate of diffusion and

(iv) rate of deposition of contaminants

Various atmospheric and climatic conditions also determine the pollution effects. The biological effects of ionising radiations may be:

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(a) **Short Range Effects:** The short-range effects are acute and expressed within a few days or weeks after exposure to radiation. The effects may be:

(i) Physical crippling or

(ii) Immediate death

(b) **Long Range Effects:** The long-range effects take a longer time to express. Such delayed effects of radiation are now centres of the World's interest. These include:

(i) Genetic changes

(ii) point mutation and chromosomal aberration

(iii) increase incidence of tumour and cancer

(iv) Shortening of the lifespan

(v) Loss of vitality

(vi) Anaemia

(vii) Haemorrhages etc.

8.8.5 *Mitigation of Nuclear Hazards*

Taking precautions for the safe disposal of nuclear waste should be the priority. The radioactive nuclear waste can be damaging to the environment and so the best way is considered to be the burial of wastes in deep trenches.

- **Delay and Decay:** The radioactive waste generated from nuclear reactors, and industries should be stored in airtight containers and allowed to decay deep beneath the ground in pits.
- **Concentrate and Contain:** The small amount of highly radioactive waste should be mixed with other components such as concrete and solidified and dumped deep in the ocean or beneath the earth.
- **Dilute and Disperse:** The moderately or weak radioactive waste should be released into the environment after diluting it with some inert materials.

Protective Measures

Some of the protective measures are listed as follows:

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1. While handling UV lamps, dark glass spectacles or goggles must be worn. UV rays can't penetrate dark glasses.
2. Visible light neutralises UV damage considerably. Thus exposure to sunlight for any individual exposed to UV could be a good remedial measure to treat the exposed individual.
3. Nuclear fallout Hazards must be minimised by adopting certain precautions, e.g.
   - ***(i)*** **High-level wastes** are long-lived and have high radioactivity per unit volume. These must be contained somewhere as follows:
     - *(a)* In underground tanks without treatments
     - *(b)* Liquid should be converted into solid like ceramic and then buried deep underground
     - *(c)* Stored in deep salt mines

Fukushima Disaster

The Fukushima disaster is considered the second biggest disaster in history after Chernobyl Disaster. The Fukushima disaster occurred in March 2011 in one of the islands in Japan. The accident was rated 7 on the INES scale due to high radioactive release for 5-6 days. Four nuclear reactors were damaged in the incident leading to radiation fallout in the region. The accident mainly happened due to a major earthquake followed by a 15 m high Tsunami causing damage to the reactors. There were no reports of death due to radiation sickness but more than a hundred thousand people were evacuated from the area as a precaution. The radiation mainly consisted of Iodine-131, Caesium-134, Caesium-137, strontium-90, and Plutonium-238.

8.9 Self-Assessment Questions

1. What is pollution? Describe the different types of pollutants and pollution.
2. What do you understand about air pollution? Describe its various causes.
3. What are various air pollutants? Discuss their effects on vegetation and human beings.

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4. Explain the following terms:
   (i) Air pollution Tolerant trees.
   (ii) Electrostatic precipitators.
5 Give a brief account of noise pollution.
6 Describe in detail about impacts of noise pollution on human health.
7 What are the causes of nuclear hazards? What is its impact on the human population?

8.10 References

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8.11 Suggested Readings

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LESSON

9

Pollution: Water, Thermal and Soil Pollution

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STRUCTURE

9.1 Learning Objectives

- Understand the sources, causes and impacts of Water, soil and thermal pollution.
- Realize the impacts of pollutants on the ecosystem and human health.
- Understand the solid waste management plan.
- Assess the various measures and steps that can be employed for reducing pollution.
- Gain knowledge of Government initiatives and programs for pollution across India.
- Assess the various issues discussed above with respect to relevant case studies.

9.2 Introduction

Nowadays, the problem of pollution has become a major task in everyday human lives. A high concentration of pollutants in any of the environmental systems like water, air, soil

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etc. poses a higher risk to environmental health. Apart from air, noise and nuclear pollution, there are other types of pollution too like water, soil and thermal pollution which also becomes a challenging task in day-to-day life. These pollutants are discharged or emitted from various natural as well as anthropogenic sources which ultimately harm the plant as well as human health.

9.3 Water Pollution

Nearly 50% of all marine pollution is caused by sewage and wastewater discharge. Annually, about 400 billion tons of industrial waste are produced globally, the bulk of which is discharged untreated into streams, rivers, seas, oceans and other water bodies. Water pollution means one or more substances building up in aquatic bodies to a limit that causes trouble to life forms. Water pollution also deals with the amount of polluting substance released and also the amount of water it is discharged into.

9.3.1 *Types of Water Pollution*

There are different perspectives on considering pollution.

A. Based on water bodies.

- **Surface Water Pollution:** The most evident type of water pollution affects surface waters like huge oceans, lakes, rivers and streams. For example, an oil slick from an oil tanker can affect a huge area of the marine region.
- **Groundwater Pollution:** All of Earth's water is not surface water. An immense amount of water is present in underground rock structures or aquifers that are not visible to one and people hardly ever think of. Water that is stored in aquifers is groundwater. The rivers and streams are not only nourished by aquifers but they also supply drinking water. Fertilizers applied in the fields often seep into the soil and contaminate the waters. Groundwater pollution though less evident than surface water pollution is also a mounting problem.

B. Based on the source.

- **Point Source:** If pollutants are discharged from one place or spot for e.g. an effluent pipe of a plant, oil spillage from a tanker, smoke

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stack discharge etc. The pollution from such a source is known as point source pollution.

- **Non-point Source:** A prodigious amount of water pollution also happens from a variety of speckled sources. This is called non-point source pollution.

C. Based on Chemical Composition:

- **Soft Water:** water with little or no dissolved salts of magnesium and calcium.
- **Hard Water:** In contrast to soft water, hard water has high mineral content. It primarily consists of calcium and magnesium metal cations, and sometimes other dissolved compounds such as bicarbonates and sulphates. Such water is unsuitable for use.
- Sometimes the pollution may enter the environment from one place and extort an outcome hundred or even thousands of miles away from that place. Such pollution is known as transboundary pollution. Examples include persistent organic pollutants and radioactive wastes that may travel across the oceans and national boundaries.

9.3.2 *Sources of Water Pollution*

Approximately 33% of water pollution is by domestic sources, followed by agriculture-livestock with 29%, 27% by industry and 11% from other sources.

A. Domestic: Domestic sewage is wastewater generated from household activities. It is 99.9% pure water; the remaining 0.1% are pollutants which are both organic and inorganic materials. Organic materials are food and vegetable waste, excreta, and faecal matter whereas inorganic materials such as phosphates and nitrates come from soaps and detergents.

Sewage is an entirely natural matter that should degrade blandly in the environment. Sewage also contains a host of chemical substances, from drugs, papers, plastics, and their drainage system. Soaps and detergents used in washing machines and dishwashers are finally drained into the sewage.

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B. Agriculture: It is undoubted that extensive use of fertilizers and pesticides, collectively called agrochemicals, increases agricultural output. These mostly artificial chemicals, move into the water bodies along with rainfall and groundwater by leaching. Such chemicals are persistent and may get entry into the food chain causing numerous problems for the animals.

C. Pesticides: Any chemical utilized in controlling pests is a pesticide. The pest can be insects, microbes, fungi, snails and slugs, worms, weeds etc. Consequently, the pesticide can be in the form of insecticides, fungicides, herbicides etc. Pesticides can cause a number of diseases like lung malignancy, chronic liver damage, cirrhosis and chronic hepatitis, hormonal and gonadal disorders, immune suppression, cytogenic effects, breast cancer, non-Hodgkin's lymphoma, polyneuritis etc.

Class of pesticides on the basis of their chemical nature are:

(a) **Organochlorine Compounds:** These are the most hazardous of all pesticides. There are three classes of organochlorines:

- Dichlorophenyl ethanes – DDT, methoxychlor. They are highly penetrable and soluble in fats.
- Cyclodienes – Aldrin, endosulfan, endrin, heptachlor, toxaphene, chlordane. The metabolites of these products are more toxic.
- Hexachlorocyclohexanes – Lindane or Benzene Hexachloride (BHC)

The best-known representative of this class is DDT, made by Swiss Scientist Paul Miller. He received the noble prize for Physiology and Medicine in 1948 for his discovery. DDT was announced on the market in 1944. Exposure to high doses of DDT can produce paresthesia, ataxia, dizziness, headache, nausea, and restlessness. Chronic exposure results in anorexia, anaemia, tremor, weakness and anxiety. They are potent carcinogens and damage the liver and endocrine organs.

(b) **Organophosphates:** They are frequently used in chemical warfare. Examples are Sarin, Tabun, Soman etc. Their toxic effects are additive; hence the toxicity amplifies with multiple

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exposures. The common organophosphates are malathion., parathion, diazinon and Tetra Ethyl Pyrophosphate (TEPP).

(c) **Organo-carbamates:** The mode of action of this class is quite similar to that of organophosphates. Their actions last for a smaller duration and are thus the least toxic among the three. Examples are Sevin, Baygon etc. Exposure to such compounds may cause salivation, lacrimation and convulsions.

(d) **Biological Insecticides:** The most common is *Bacillus thuringiensis*. It is used to kill the larva against diverse forms of caterpillars. BT toxin from *Bacillus thuringiensis* could be successfully inoculated into the plants through genetic engineering.

D. Industries: Most of the industries are situated along the banks of the river for convenience and disposal of effluents. Often these effluents comprise acids, bases, dyes, paints, and a range of other chemicals. Detergents form white foam. Industrial waste can be mercury, lead, cadmium, chlorides, fluorides, ammonia etc. Such an addition alters the pH of the water and turns it into a condition that is fatal to aquatic forms. The industries regularly discharge heavy amounts of superheated water used in thermal power plants, oil refineries, nuclear power plants, etc. such high-temperature injuries and kill the aquatic flora and fauna. High temperature also reduces the amount of oxygen dissolved in water which may harm or even kill aquatic life, the condition is called thermal pollution.

(i) **Mining Industries:** The process of extraction of minerals exposes heavy metals and sulphur that were earlier inaccessible. Rainwater further leaches these chemicals out of the uncovered portions, causing AMD along with heavy metal pollution that lasts for a long period even after the closure of mining operations. The act of rainwater on the tailings contaminates the freshwater bodies. Cyanide is deliberately dispensed on mined piles in the gold mines for the extraction of gold. Some of the cyanides used inevitably contaminate the close by water. Often, an enormous amount of mining waste or 'slurry' is stored behind contaminant dams. In case of any accident or dam leakage or bursting, water pollution is assured.

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(ii) **Oil Refineries:** Oil spill is a leading issue in the aquatic system. Oil seeps from the oil tankers and offshore oil refineries into the waters. Oil leakage from tanker accidents accounts for about 12%; more than 70% of oil pollution is from the usual shipping as well as from the oil that people drain out into the drainage system. Oil is lighter than water and thus floats on the surface of the water. Such a film blocks the aerial oxygen from dissolving in water. Oil can coat and smother the body of aquatic animals fatally. Oil can also find entry into the body while drinking. The oily beaches disturb the ecosystem balance and rigorously affect tourism.

(iii) **Radioactive Waste:** High concentrations can be lethal, whereas low concentrations of radioactive substances can cause malignancy and various forms of sickness. The two most important contributors in Europe are Sellafield and Ca La Hague.

Table 9.1: Major Types of Water Pollutants

S. No.	Substances	Sources or Applications	Impact or Effect
1.	Antimony – Sb	In electrical appliances, semiconductors, expectorants, manufacturing ammunition	In large doses, it can cause poisoning, stomach ulcers, and heart diseases.
2.	Mercury – Hg	Industrial wastes, dental fillings, fungicides, soldering, and various scientific instruments such as thermometers and barometers.	When ingested, mercury damages the Central Nervous System (CNS) leading to a disease called neuropathy. One of the famous cases is the Minnimata incident in Japan in 1953.
3.	Arsenic – As As_2O_3 and trivalent arsenic	As a component of animal feed, in treated wood, ceramics, medicines, pesticides, paints and fireworks.	70 mg of arsenic compounds are considered lethal if ingested. Lower doses of arsenic can result in a disturbance in peripheral circulation, black foot disease, damage to the liver and kidney, and various types of cancer, such as skin cancer, bladder cancer and lung cancer.

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S. No.	Substances	Sources or Applications	Impact or Effect
4.	Cadmium – Cd	In Ni-Cd batteries and part of various metallic alloys, electroplating, pigments, nuclear reactors, and the anticorrosion coatings of other metals, tyres.	Often deposited in the hepatic, renal, pancreatic and intestinal lining. Poisoning with cadmium causes headache, regurgitation, anaemia, pneumonia, diarrhoea, osseous deformation and renal necrosis. It results in bioaccumulation to interfere with the body's metabolism. It also leads to cancer, teratogenesis and Itai-Itai disease.
5.	Chromium – Cr	Used in tanning leather, treating wood, storing data in magnetic tapes, making pigments, photography and manufacturing iron-based alloys. The human body needs trace amounts of trivalent chromium to metabolize fats and carbohydrates.	Hexavalent chromium is dangerous, it causes dermatitis, gastrointestinal ulcers, lung cancer, weak immune system, and liver damage. It is also a teratogen.
6.	Lead – Pb	It is found in plastics, ceramics, glassware, paints, pigments and batteries. Lead is also a crucial component in antiknock agents.	Lead is easily absorbed in the blood. It affects the liver, kidneys, osseous system, central and peripheral nervous system; red blood cells leading to anaemia. This toxic heavy metal can cause brain damage, coma and even death.
7.	Nickel – Ni	Used in the steel industry, in making batteries, welding rods, and wires, adding pigments to paints, desalination plants, and producing dental and surgical prostheses.	Overexposure may cause allergic reactions, asthma-like symptoms, lung embolism and various organ problems.
8.	Beryllium – Be	Used mainly in defence and aerospace industries, used in the field of x-ray detection diagnostic and in the manufacture of a variety of computer equipment.	Breathing beryllium particulates is hazardous as it damages the pulmonary tossie causing pneumonia. The most common effect is berylliosis. Beryllium is an allergen for hypersensitive people, in severe conditions it causes a person to be seriously sick, a condition known as Chronic Beryllium Disease (CBD).

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S. No.	Substances	Sources or Applications	Impact or Effect
			The symptoms are weakness, fatigue and breathing problems; people suffering from CBD sometimes develop anorexia and blueness of hands and feet. In extreme conditions, CBD can cause death. Beryllium enhances the probability of malignancy and DNA damage.
9.	Aluminium – Al	Used in the aerospace industry and is very important in transport and construction where light weight, durability and strength are desirable. It forms alloys with many elements such as copper, zinc, magnesium, manganese and silicon. All present-day mirrors and telescopic mirrors are prepared by using a thin reflective coating of aluminium on the back surface of a sheet of float glass. Other applications are electrical transmission lines and packaging. Production of aluminium foam used in traffic tunnels and in space shuttles.	Health effects, such as damage to the CNS, dementia or loss of memory, lethargy, rigorous trembling and lung problems. Inhalation of aluminium is reported to cause pulmonary damage in the form of pulmonary fibrosis. This effect, identified as Shaver's disease, is complicated by the existence of inhaled silica and oxides of iron. Possibly it also contributes to Alzheimer's disease.
10.	Manganese – Mn	Iron and steel production. Manganese dioxide is also used as a catalyst. Used in decolourization of glass and craft violet-coloured glass. Potassium permanganate is a strong oxidising agent and is used to disinfect water. Used in making fertilisers and ceramics.	Effects occur mainly in the respiratory passages and in the brain. Symptoms of manganese poisoning are hallucinations, lack of memory and neuronal damage. Excess manganese causes Parkinson's disease, lung embolism and bronchial infection. A syndrome that is caused by manganese toxicity exhibits symptoms such as schizophrenia, dullness, weak muscles, headaches and sleeplessness.

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9.3.3 *Impacts of Water Pollution*

1. **Eutrophication:** It refers to the enrichment of freshwater bodies by the accumulation of nitrates and phosphates mostly due to the result of anthropogenic activities. It is predominantly found in sluggish rivers and shallow lakes. The number of coastal areas affected by eutrophication globally is over 500. High amounts of nitrates and phosphates are present in sewage, fertilizers and other organic matters. The waters at depth are usually deficient in oxygen, ranging from hypoxic to anoxic conditions. A number of algal blooms are identified by the discolouration of water bodies often due to the high density of pigmented cells. The water usually becomes greenish. This is known as an **'algal bloom'**. Rapid algal expansion leads to increased decomposers. All forms of aquatic life such as decomposers, other aquatic vegetation including algae, and aquatic animals including fishes, consume the oxygen that is dissolved in the water for respiration. This in turn seeks a great requirement for oxygen and leads to oxygen depletion. Some algal blooms are harmful for instance the dinoflagellates belong to the genus *Alexandrium* and *Karenia*. Such a bloom often assumes a red or brown colour and is conventionally known as red tide.
2. **Bioaccumulation and Biomagnification: Bioaccumulation** is the accretion of substances like pesticides, metals and various organic compounds into the body of a living organism over a period of time. This can occur either because the chemical gains entry faster than it can be utilized, or because the chemical cannot be metabolized by the organism.

   Bioconcentration is a more precise term that refers to the uptake and accumulation of a chemical substance from water alone. Compounds like DDT and tetra-ethyl lead, being lipids soluble, are stored in the body's adipose tissues, which are used for energy production, the compounds being released cause acute poisoning.

   Biomagnification also known as *bioamplification* or *biological magnification*, on the other hand, is the amplification of the concentration of a substance up the trophic level. Pollutants like DDT may also enter the body of humans through dietary milk

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provided the bovine animals get exposure to DDT-contaminated grass and water. The consequences are severe blood and nervous system disorders.

3. **Biological Pollution of Water or Water-Borne Diseases:** Water-borne diseases are caused by pathogens. Microbes can also be the source of food-borne diseases through the consumption of contaminated food. The most common water-borne diseases are summarized in the following tables.

Table 9.2: Few Important Protozoan Infections

Disease	Pathogen	Common Symptoms
Amoebiasis	*Entamoeba histolytica*	Discomfort in the abdomen, tiredness, loss of eight, diarrhoea, distension.
Cryptosporidiosis	*Cryptosporidium parvum*	Flu-like manifestations, diarrhoea, loss of hunger, distension.

Table 9.3: Few Important Parasitic Infections

Disease	Pathogen	Common Symptoms
Taeniasis	Taenia solium	Intestinal disturbance, neurologic manifestations, loss of weight, cysticercosis.
Ascariasis	Ascaris lumbricoides	Inflammation, fever and diarrhoea. Loffler's syndrome in the lungs along with nausea, vomiting, malnutrition and underdevelopment.

Table 9.4: Few Important Bacterial Infections

Disease	Pathogen	Common Symptoms
Botulism	*Clostridium botulinum*	Blurred vision, thirsty and dehydrated mouth, difficulty in swallowing, slurred speech, vomiting diarrhoea, difficulty in breathing, death may be caused by respiratory failure.

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Disease	Pathogen	Common Symptoms
Dysentery	*Shigella dysenteries*	Passing of faeces with blood and or mucus, in many a case vomiting blood.
E.coli infections	*Escherichia coli*	Diarrhoea and dehydration
Cholera	*Vibrio cholera*	Watery stool, nausea, cramps, nasal bleeding, rapid pulse, vomiting, haemorrhagic shock.
Typhoid	*Salmonella typhi*	Sustained fever up to 104ºF, profuse sweating, diarrhoea, rarely rashes, if untreated leads to splenomegaly and hepatomegaly, progressive delirium and sometimes death.

Table 9.5: Few Important Viral Infections

Disease	Pathogen	Common Symptoms
Hepatitis A	Hepatitis A virus (HAV)	Fatigue, fever, abdominal pain, nausea, diarrhoea, loss of weight, itching, depression, jaundice
Gastroenteritis	Astro virus, Calici virus, Enteric adeno virus, Parvovirus	Diarrhoea, nausea, vomiting, fever, malaise, abdominal pain.
SARS (Severe Acute Respiratory Syndrome)	Coronavirus	Pyrexia, myalgia, lethargy, cough, sore throat, gastrointestinal disturbance
Poliomyelitis	Poliovirus	Headache, fever, delirium, sporadic seizures, spastic paralysis, seldom aseptic meningitis and death.

4. Occupational Health Hazards

(a) **Itai-Itai Disease:** This was a famous case in Toyama Prefecture, Japan that was characterized by severe pain in joints and vertebral column. It was called as itai-itai disease by the local inhabitants and was found to be produced by cadmium poisoning. Several mining companies discharged cadmium

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into the rivers. The consequences are softening of the bones and kidney failure. It became one of the most prominent pollution-related diseases in Japan.

(b) **Chisso-Minamata Disease:** Also known as Minamata Disease, the root cause of such disease is mercury poisoning. Primary symptoms are ataxia (loss of muscular coordination affecting speech, eyeball movements, swallowing, walking etc.), lack of sensation in the palms and feet, weakness in the muscles, hearing impairment, reduced visual field, etc. Such a neurological syndrome, in extreme cases, can lead to insanity, paralysis, coma and death that might follow within a few weeks of the inception of the symptoms. Mercury may cross the placenta and affect the in-utero foetus.

(c) **Blackfoot Disease (BFD):** BFD is an endemic disease confined to the southwestern coast of Taiwan and is caused due to arsenic toxicity. The disease is initiated with people complaining about coldness or numbness in the appendicular extremities, especially in the feet along with irregular claudication (cramps and pain in the lower leg while exercising or walking) making progress over the course of time. This peripheral disease with severe systematic arteriosclerosis and gangrene-like symptoms affects the feet and occasionally the fingers.

(d) **Methemoglobinemia:** Excess release of nitrates from fertilizers enters the human body through water. Then nitrates are ingested or taken, they are transformed into nitrites in the alimentary system. The nitrites reacting with blood haemoglobin form methaemoglobin. The haemoglobin molecule being preoccupied with nitrites cannot bind to oxygen. The body is thus deprived of oxygen supply. This is fatal especially in infants as they have a very little amount of methaemoglobin reductase which could revert such an effect. The syndrome is called blue baby syndrome or methemoglobinemia. The symptoms are shortness of breath, vomiting and diarrhoea. After confirming the test for the syndrome, an injection of the required dose of methylene blue can help the baby's blood to return to normal.

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9.3.4 *Measurement of Water Pollution*

1. **Biological Oxygen Demand:** Pollution in water can usually be measured by estimating the biological/Biochemical Oxygen Demand (BOD) of water. A lower value of BOD indicates lesser pollution whereas a higher BOD value indicates higher pollution. It is one of the most useful parameters to indicate the organic strength of wastewater and can be defined as the amount of oxygen required by the aerobic bacteria to decompose the biodegradable matter in a given amount of water at 20ºC over a period of five days. In reality, it is an indirect measure to calculate the concentration of degradable matter present in the waste. The BOD value of raw sewage may run to several hundred. Till 1971, the recommended BOD limit by World Health Organization (WHO) for potable water was 6 mg/l, there is no prescribed limit at present.
2. **Chemical Oxygen Demand:** This is the most common method of measuring the strength of industrial water i.e. the amount of oxygen used for the chemical oxidation of the pollutants. It is expressed in mg/l and is the total measurement of all the chemicals in the water that can be oxidized. Higher COD values indicate higher values of pollution in the wastewater sample. COD can be employed for waters too toxic for the BOD test and usually takes a few hours for completion, an added advantage over the BOD test. The decomposition is brought out by adding and boiling with a powerful oxidant, usually potassium dichromate. The COD value is usually higher than the BOD value.

9.3.5 *Steps to Prevent or Control Water Pollution*

1. **Awareness:** Creating mass awareness is the foremost step toward preventing and controlling water pollution. Many NGOs have campaigned against the over-harvesting of fish and regularly demanded tough penalties against the industries and factories dispensing effluents in the water bodies.

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2. **Legislation:** The major problem with water pollution is mainly because of the flowing nature of water which results in transboundary pollution. Most rivers cross national boundaries whereas oceans and seas may span continents. The pollutants released by the factories in one nation with pitiable emission standards cause glitches in the neighbouring countries. In many a case, the countries that suffer have stringent environmental legislation and elevated environmental standards. Environmental laws make a situation difficult for people to foul, but it is more difficult to make such laws practically operative as they need to be implemented across national and international borders. To handle such transboundary issues several international negotiations and laws were negotiated and agreed upon:

   - The International Convention for the Prevention of Pollution of the Sea from oil tankers, London, 1954.
   - The International Convention for the Prevention of Pollution from Ships, 1973, (MARPOL 73/78),
   - UN Convention on the Law of the Sea, 1982 enforced in 1994.
   - London Dumping Convention, 1972.
   - Convention on the control of the transboundary movement of hazardous wastes and their disposal, 1989, Basel.
   - 1998 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic.
   - Nairobi International Convention on the Removal of Wrecks, 2007

   The GOI has enacted the following legislations:

   - The Water (Prevention and Control of Pollution) Act, 1974 was further amended in 1988.
   - The Water (Prevention and Control of Pollution) Cess Act, 1977, was last amended in 2003.

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Table 9.6: BIS drinking water – specifications for some of the important parameters IS 10500 – 2012 as per Ministry of Drinking Water and Sanitation (MDWS), GOI

S. N.	Characteristic	Unit	Requirement (Acceptable Limit)
1.	Total Dissolved Solids (TDS)	milligram/litre	500
2.	Colour	Hazen Unit	5
3.	Turbidity	Nephelometric Turbidity Unit (NTU)	1
4.	Total Hardness	milligram/litre	200
5.	Ammonia	milligram/litre	0.5
6.	Free residual Chlorine	milligram/litre	0.2
7.	pH	-	6.5-8.5
8.	Chloride	milligram/litre	250
9.	Fluoride	milligram/litre	1.0
10.	Arsenic	milligram/litre	0.01
11.	Iron	milligram/litre	0.3
12.	Nitrate	milligram/litre	45
13.	Sulphate	milligram/litre	200
14.	Selenium	milligram/litre	0.01
15.	Zinc	milligram/litre	5.0
16.	Mercury	milligram/litre	0.001
17.	Lead	milligram/litre	0.01
18.	Cyanide	milligram/litre	0.05
19.	Copper	milligram/litre	0.05
20.	Chromium	milligram/litre	0.05
21.	Nickel	milligram/litre	0.02
22.	Cadmium	milligram/litre	0.003
23.	E.coli or Thermotolerant coliforms	Number/100 ml	NIL

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9.3.6 *Ganga Action Plan*

River Ganga is so important and closely associated with Indian culture and civilization that it is often designated as 'Maa-the mother' and is worshipped in India and is now the National River of India (2008). The Ganga is the ninth largest river in the world and the second largest in India with a length of 2,525 km. from Gangotri to Ganga Sagar. It constitutes about 25.2% of the water source in India. Several Himalayan rivers including Mandakini, Alaknanda, Yamuna, Ghagra, Gandak, Koshi etc. join it during its course. About 692 cities/towns are located along its bank of which 27 cities have a population of more than 1 lakh. More than 600 km part of the river, particularly between Kanpur and Patna is highly polluted. Every day it receives about 1300 million litres of sewage and 250 million litres of chemical effluents. The main causes of pollution of Ganges water are the mixing of industrial effluents (20%) and domestic and municipal effluents (80%) into it. The following are the main causes of Ganga Pollution:

- Sediment load of the Ganga River and other associated rivers.
- Sewage disposal of villages, towns and cities.
- Discharge of industrial effluents.
- Release of dead bodies of animal and human beings.
- Cremation along the bank of river and disposal of cremation material and burnt and half-burnt dead bodies of human beings.
- Surface run-off of toxic chemicals, agrochemicals, pesticides etc.

Yamuna Pollution

River Yamuna after being originated from Yamunotri covers a passage of 1376 km before joining the river Ganga at Allahabad. The river has been divided into five segments from the point of view of pollution level. The pollution problem in the Delhi segment is acute and highly dangerous. About 1900 million litres of sewage is discharged every day in this segment of 22 km. The total treatment capacity of Delhi plants is about 1270 ml/day i.e. about 630 ml/day of it is still discharged directly to river Yamuna without any treatment. Moreover, the treated water is also not pure. It remains partially untreated. Further 2800 ml effluents per day are discharged into the river by eleven main

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nullahs which results in an increase of 200 BOD and 160 tones of suspended solids. Najafgarh and Shahdara nullahs are most problematic. In 1993, in the second step of the Ganga Action Plan (GAP) of the Government of India, Yamuna Action Plan (YAP) was also taken up. It included 127 working projects of which 48 are in UP, 76 in Haryana and 3 in Delhi. After 13 years of work on these projects, the pollution problem still remains serious. Pollution is further nurtured due to barrages built in Delhi, Mathura and Agra for civic water supply and the number of canals made for irrigation.

GAP helped in estimating the magnitude of Ganga Pollution. In an estimate, it was calculated that about 10,90,000 kg of toxic effluents and 13,00,000 kg of domestic and municipal effluents are discharged every year from the cities of UP only. The first step of GAP started in 1985 and the second in 1995 to complete the plan by the end of 1999. Despite, the 20,000 crores that have been spent to clean the water, the results achieved remain insignificant. Various other projects have also been subsidized by the governments of the Netherlands and Japan to clean the water of the Holy Ganges. Now Project of GAP includes cleaning the Yamuna and Gomti rivers. NGPRA has granted rupees 100 million to clean them. Technical experts (2014) have recommended 5 programmes for cleaning the National River of India, the Ganga, as follows:

- Formation of micro dams
- Planning for floating population
- Reduction in the number of riverside industries
- Limited storage of water in barrages and
- Development of organic farming

The present Prime Minister, Shri Narendra Modi has launched a new scheme called Namami Gange to clean the holy river Ganga (2015). The government has sanctioned rupees 20,000 crores for this project.

9.4 Thermal Pollution

Water pollution due to heat is popularly known as thermal pollution. Hot water from different sources when enters the water bodies and affects

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the water bodies adversely. Both plants and animals get affected by such type of pollution.

9.4.1 *Sources of Thermal Pollution*

Several industries, thermal power plants, and nuclear power stations use a large quantity of water as a cooling agent, resulting heating of water after the absorption of excess heat from these processes. In thermal power plants, about 70% of the heat is lost as waste which is absorbed by the cooling water. The water becomes hot and then released into the reservoirs. Such types of water often raise the temperature up to 10-15 degrees centigrade and became dangerous for the aquatic ecosystem. Sewage and industrial waste also rise of temperature of water bodies by 4-6 degrees centigrade.

9.4.2 *Effect on Aquatic Life*

Some of the major adverse effects on aquatic life are as follows:

(i) Small animals, phytoplankton, zooplankton, and small fishes get affected and killed by the hot water.

(ii) Cell walls of such types of animals and plants are severely damaged due to the hot water.

(iii) Hot water may adversely affect the enzyme and metabolic activities of plants and animals.

(iv) The quantity of dissolved oxygen is also affected by the presence of hot water as the oxygen present in the water body bobbles out from the water body. It is also called the gas bobble disease of water. This results increase in the BOD levels of the water and causes the suffocation of aquatic animals.

(v) The hot water makes the aquatic organism susceptible to toxic chemicals and bacterial/viral/fungal infections.

(vi) Thermal pollution adversely affects the overall ecological balance of the aquatic ecosystem, e.g. it affects the hatching of the eggs of some fishes, while other insects begin hatching with a slight rise in the water temperature.

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9.4.3 *Control of Thermal Pollution*

It is very hard to control thermal pollution because it is the result of the actions of many people. But in the case of an already known source location, the water should be allowed to cool down before being discharged. The cooling towers and fountains can be used for rapid cooling. A large tank and reservoir should be constructed to retain the water for a little longer time. It is also suggested to discharge such type of hot water system into the running water bodies instead of stagnant water bodies.

9.5 Soil Pollution

Soil is a natural medium of inorganic and organic nutrients and has an inbuilt system of spontaneous recycling of matter. It is affected by changes in the atmospheric conditions as well as water contents and microbial population. Soil pollution is defined as an undesirable change in the natural, physical, chemical or biological components of the soil.

9.5.1 Sources of Soil Pollution:

The various sources of soil pollution may be categorized into two groups:

1. **Natural Sources:** They are as follows:
   - ***(i)*** **Plant Residues:** Normally plants, on death and decay, contribute organic matter to the soil and thereby increase soil fertility. Sometimes residues from crops, fields and orchards carry plant pathogens and pests. Burning of crops yields residues with CO (8.3%), NO (1.5%), hydrocarbons (5.3%) and particulate matter (8.5%).
   - ***(ii)*** **Animal Residues:** Animal wastes, such as faecal matter, urine, blood, slaughterhouse waste in the form of liquid or particulate matter, bodies of dead animals etc. are all indiscriminately dumped into the soil. Excessive organic contents are harmful to the healthy growth of roots as they create hypertonic conditions in the soil causing wilting or stunted growth of the plants.

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2. Anthropogenic Sources

(i) **Domestic:** Domestic sewage is wastewater generated from household activities. It is 99.9% pure water; the remaining 0.1% are pollutants which are both organic and inorganic materials. Organic materials are food and vegetable waste, excreta, and faecal matter whereas inorganic materials such as phosphates and nitrates come from soaps and detergents.

(ii) **Agriculture:** It is undoubted that extensive use of fertilizers and pesticides, collectively called agrochemicals, increases agricultural output. These mostly artificial chemicals, move into the water bodies along with rainfall and groundwater by leaching. Such chemicals are persistent and may after gaining entry into the food chain cause numerous problems in the animals.

(iii) **Industries:** Most of the industries are situated along the banks of the river for convenience and disposal of effluents. Often these effluents comprise acids, bases, dyes, paints, and a range of other chemicals. Detergents form white foam. Industrial waste can be mercury, lead, cadmium, chlorides, fluorides, ammonia etc. Such an addition alters the pH of the water and turns it into a condition that is fatal to aquatic forms. The industries regularly discharge heavy amounts of superheated water used in thermal power plants, oil refineries, nuclear power plants, etc. such high-temperature injuries and kill the aquatic flora and fauna. High temperature also reduces the amount of oxygen dissolved in water which may harm or even kill aquatic life, the condition is called thermal pollution.

(iv) **Radioactive Waste:** High concentrations can be lethal, whereas low concentrations of radioactive substances can cause malignancy and various forms of sickness.

9.5.2 *Impacts of Soil pollution*

(i) Soil pollution decreases soil fertility. Loss of soil fertility makes the soil inhabitable for plants and other organisms.

(ii) Soil pollution has adverse effects on the soil microbial population that plays an important role in soil formation and keeping it fertile.

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(iii) Indiscriminate use of agrochemicals destroys the soil flora and fauna and soil properties.

(iv) SO_2, SO_3 and oxides of nitrogen in the atmosphere are washed down by rain in the form of H_2SO_4, HNO_2 and HNO_3 which reach the soil and increase the acidity. Increased acidity develops unhealthy conditions for plant growth.

(v) The dumping of radioactive wastes onto the soil is lethal to plants and microbial life. Such pollution has far-reaching effects and even human beings are not spared.

9.5.3 *Control measures for Soil Pollution*

1. Control of pesticide pollution can be carried out by:

(i) Lowering its use in agriculture.

(ii) Use of degradable insecticides like organic phosphates.

(iii) Use of short-lived chemical pesticides.

(iv) Adopting biological control

(v) Releasing sterile males into the natural population of insects.

(vi) Rotation and diversification of crops etc.

2. Control of fertilizer pollution

3. Control of pollution due to garbage

4. Control of acid rains

5. Control of radioactive-based soil pollution

6. Discharge of hot liquids and oil leakage in the soil should be avoided.

7. Sewage should be biologically treated and converted into manure instead of its uncontrolled release into the soil.

9.6 Self-Assessment Questions

1. What is water pollution? Describe various causes and methods of control.
2. Outline the different sources of water pollution.
3. Discuss the nature of pollutants and suggest remedial measures.

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4. Define the following terms:
   (i) Water pollution
   (ii) Biomagnification
   (iii) Algal blooms
   (iv) Black foot disease
5. Write short notes on:
   (i) Bhopal Gas Tragedy
   (ii) London Smog Disaster
   (iii) Minmata Episode
   (iv) Ganga Pollution
6. Write a brief account of soil pollution.
7. What is soil pollution? Describe their causes, effects and remedies.

9.7 References

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9.8 Suggested Readings

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LESSON

10

Solid Waste Management and Case Studies

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STRUCTURE

10.1 Learning Objectives

- The sources, causes and impacts of Nuclear pollution.
- How various kinds of pollutants impact the ecosystem and human health.
- Various measures and steps that can be employed for reducing pollution.
- Definition, types, sources of solid waste, the impact of landfills and the importance of an integrated Solid waste management plan.
- Critically assess the various issues discussed above with respect to relevant case studies.

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10.2 Introduction

Waste is known as a material or substance or its by-product that is not found useful after the completion of its process or use. The waste generated can be from residential, industrial, commercial or agricultural activity. Solid waste can be paper, metal, glass, organic matter or something else. Based on their hazard potential they are classified as toxic, non-toxic, flammable, radioactive or infectious.

In 2018 the per capita waste generation was highest in USA and Canada approx. 2.58 and 2.33 kg per day and in India, it was about 0.34kg per day. It is predicted with the current rate, global waste generation will rise to 2.2 billion tons per year by 2025. Municipal solid waste (MSW) contains organic waste (51%), recyclables (17%), hazardous (11%) and inert waste (21%). Waste segregation has been a very basic problem in solid waste management as about 40% of waste is not collected and litters the town, entering drains and water bodies-choking and polluting the environment. The unsegregated waste causes nuisance and various types of pollution and is spread to nearby areas and pollutes our environment. Burning of these wastes creates air pollution and releases gases that cause global warming.

10.3 Types of Wastes

1. **E-waste:** E-waste is defined as electronic waste, which has been rendered useless after fulfilling its use. These wastes consist of televisions, computers, copiers, mobile phones, fax machines, stereos and other equipment. Presently, e-waste generation is increasing at a very rapid rate throughout the world also supporting recycling, recovery and refurbishment and resale of this equipment. According to the Global E-Waste Monitor 2017, India generates about 2 million tons (MT) of e-waste annually and ranks fifth among e-waste producing countries (Global E-Waste Monitor -2017), led by USA and China. In India, 95% of the e-waste is treated in the informal sector. The e-waste-connected health risks are very high and mainly related to handling and direct contact with harmful materials such as mercury, chromium, lead, cadmium, flame retardants and polychlorinated biphenyls present in these wastes. The recovery and extraction of

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various elements in these wastes can lead to the inhalation of toxic fumes and accumulation of harmful chemicals in water, soil and food that can directly affect human health.

2. **Biomedical Waste:** Biomedical waste is classified as waste generated during the diagnosis, or treatment, of human beings or animals, research activities or testing subjects. According to the latest Biomedical waste (BMW) Rules, 2016, several changes and additions have been made in earlier rules to further improve the collection, segregation, processing, treatment and disposal of biomedical wastes in an environmentally sound manner. The waste consists of anatomical waste, soiled waste like plasters and bandages, medicines, chemical waste, discarded linen, syringes and needles, glassware etc. and they are incinerated or autoclaved to avoid infection in the environment. According to new rules, wastes have been colour coded into four colours (yellow, red, white, and blue) to address the issue of their handling and disposal.
3. **Plastic Waste and Management:** Plastic waste is considered one of the most persistent major wastes in the environment. According to the report from the Central Pollution Control Board (CPCB) in 2017-18, India generated 9.4 million tons of plastic waste annually. Only 60% of plastic is recycled through organized and unorganized sectors. 50% of plastic waste generated consists of single-use plastic like straws, plates, food packaging etc. The recycling rate is only 10% for single-use plastic and the majority ends up in the ocean affecting aquatic life and creating pollution. The plastics have been graded according to their thickness and used in different industries (Figure 10.1). Management of plastic waste has become a huge task for the government resulting in the banning of single-use plastics in many states of India. Plastics cannot be decomposed and slowly breaks down into micro-plastics and remain in the environment for thousands of years. Single plastic bottle cans stay in the environment for thousands of years. The plastic waste management rules of 2016 specify a minimum thickness of 50 microns for plastic use in order to easily reuse and recycle the product. It also promotes the use of plastic for road construction, energy generation and oil formation. Accordingly, CPCB has been entrusted to set the guidelines for

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thermoset plastics. The Plastic Waste Management Rules, 2018 by MoEFCC amended rules for phasing out Multi-Layered Plastic (MLP), which cannot be recycled, is non-energy recoverable and has no alternate use.

Figure 10.1: Different types of plastic used in day-to-day use.

(*Source: MoHUA-2019*).

1 – Polyethylene Terephthalate (PET or PETE), 2 – High-Density Polyethylene (HDPE), 3 – Polyvinyl Chloride (PVC), 4 – Low-Density Polyethylene (LDPE), 5 – Polypropylene (PP), 6 – Polystyrene (PS), 7 – Other.

10.4 Waste Management 5 R Principles

One of the widely used waste reduction strategies can be used by people in towns and cities and is known as the 5-R principle (Figure 10.2). This strategy can reduce waste and can also use for energy generation.

Reduce: The reduction of waste generation can be started by households by reducing the packages of commodities, increasing durability, avoiding disposable or single-use plastic items, usage of jute bags or cloth bags for marketing etc. Reducing paperwork in homes and offices and promoting e-mails or e-bills should be promoted.

Reuse: The habit of reusing commodities should be promoted. One can donate books, old clothes, and electronics by getting in touch with organizations that can direct you to the needful people who may find need of these resources.

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Recycle: Segregation of waste is paramount for recycling waste. Segregation of paper, metals, glasses and plastics from organic waste is very important. These wastes can be used for recycling and creating a new product that can be used widely. Recycling saves other resources and is good for our environment. A ton of recycled paper can save 25-30 trees, 25000 litres of water and 4000 kWh of energy.

Recover: Recovery is one of the methods where more resources are required i.e. mechanical, and technical to convert and reprocess the waste into energy. This means that energy can be generated in form of heat and can be converted into other forms as per requirements and resources.

Refuse: It is considered a last resort to get rid of the waste generated and is dumped accordingly in landfills and dumpsites. The waste collected from the city or town in these areas remains for a longer period of time. These landfill sites are a major concern for the human population as they are home to feral animals and also make the adjoining areas unfit for habitation due to foul smell, leachate affecting the water table and burning of waste causing air pollution.

Figure 10.2: Integrated method of solid waste management. Reduction is the primary concern and refuses to be last.

10.5 Incineration, Composting and Landfill

Incineration is a waste treatment process where combustion happens at very high temperatures converting them into ashes and releasing gases and heat. It is also considered a waste to energy processes like pyrolysis, gasification and anaerobic digestion. Biomedical waste and hazardous waste are treated through the incineration process as they cannot be treated with conventional methods. The disadvantage of the incineration process is the release of harmful gases like dioxins and furans that can cause severe health problems in humans.

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Composting is a natural process that involves using microorganisms for the decomposition of biodegradable waste. Organic waste consisting of agricultural or kitchen waste can be used for composting. This process requires aeration for proper and faster decomposition. In one of the methods of composting the earthworms are used to increase the rate of decomposition also known as vermicomposting. Earthworms such as *Eisenia fetida* are used which consume biomass and create vermicasts. The vermicasts are rich in nutrients (N, P, K) and growth-promoting substances required by plants. Vermicompost is good for the soil and does not contain pathogens and weeds. Vermicomposting needs to be promoted as it is beneficial for the soil and growth of plants and also reduces waste generation.

A sanitary landfill is a controlled reduction and disposal of waste away from human habitation in a designated area, which reduces the contact between waste and the environment. In a sanitary landfill, the garbage is compressed to reduce its volume and covered by a thick layer of soil in order to minimize odours, deter pests, limit rainwater runoff, prevent fire and discourage scavenging by feral animals. This process is repeated till the landfill is saturated with waste and covered with soil and the plantation is done. At various stages provisions for tapping landfill gas (methane) is established for use in furnace or generation of electricity. In many parts of the world, landfill sites have been successfully converted into community parks.

Ghazipur Landfill

Ghazipur landfill is one of the oldest and biggest landfill areas in the Delhi NCR region. The landfill area is more than 30 years old and highly saturated to its capacity. The 65 m high landfill is one of the towering structures in Delhi filled with municipal waste generated from various parts of the city. The landfill is releasing greenhouse gases together with leachate in the soil. More than 3 million people survive within a 10 sq km radius of the landfill. Despite using various management practices an early solution to this problem is not seen. Recently prime minister's office has shown interest in handling this problem and various institutions have been included to find a permanent solution in order to meet global sustainable development goals regarding health and the environment.

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CASE STUDIES

The London Smog 1952

In the winters of the UK in the late nineteenth and twentieth centuries, on considerable occasions, in early December of 1952, the wind speed had fallen and temperature inversions were formed as stationary high-pressure systems developed over western Europe. With the increase in the concentration of pollutants, the fog became widespread. The condition was commonly referred to as smog. Initially, the term smog was coined by Harold Des Voeux, the treasurer of the Coal Smoke Abatement Society in 1905 to refer to an odd combination of smoke plus fog.

Smog was formed from particulate emissions from the combustion of coal in industrial furnaces, kilns and boilers, domestic grates and steam locomotives, and canal ships. The visibility dropped, transport could not move, railways and air flights had to be closed and shops, stores and institutions were shut down completely paralyzing the city. PM went up by 56 times the normal level and the SO_2 level went up by seven times.

Some 8,000 young and old people were hit by bronchitis and heart disease. The number of deaths rose so high from this sulphur-laden sooty condition that it was popularly known as Great Smog. These profound events led to the enactment of the Clean Air Act of 1956.

The Los Angeles Smog Episode

This event occurred in Los Angeles city in 1943. The sulphur-laden sooty smog in time, however, eventually gave way to the photochemical smog with the development of the internal combustion engine as a prime source of transportation. Such smog is initiated by nitrogen dioxides, In the Presence of sunlight the free oxygen atoms react to form ozone. This was first evidenced in the Los Angeles region of the USA. It irritated the eyes, and damaged the plants, for example, tobacco. The major sources of nitrogen dioxides were vehicular emissions, and emissions from aircraft, ships, trains, industries and houses. The symptoms are aching lungs, wheezing, coughing and headache. 'Smog complex' involves irritation of the eyes and respiratory passages,

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chest pains, shortness of breath, nausea and headache. Lungs are ozone's primary target causing damage to cells in the airways, inflammation and swelling. It also reduces immunity. It poses a health risk to those people who already suffer from emphysema and chronic bronchitis.

The Bhopal Gas Disaster Episode

Commonly known as Bhopal Gas Tragedy, it is to date the most ghastly industrial disaster in the world. The incident took place on 2-3 December night, 1984 at the Union Carbide Industrial Plant in Bhopal, Madhya Pradesh, meant for the production of Sevin - a pesticide. Over 40 tons of Methyl isocyanate (MIC) gas escaped from the Union Carbide Pesticide Plant, which instantaneously killed nearly 3,800 inhabitants and accused considerable despondency and early death for several thousand. Estimates from various sources vary on the death toll. Another agency claimed over 15,000 deaths. As per government sources in 2006, the leak caused 5.58.125 injuries with disabling injuries. The vent gas scrubber, a safety device had been turned off three weeks prior. It becomes apparent that a defective valve permitted a load of water that was meant for clean-up of the internal pipelines, which got mixed with 40 tons of MIC. When MIC is exposed to 200ºC heat, it formed more deadly Hydrogen cyanide (HCN) gas. The evidence gathered does reveal the temperature of the storage tank reached that disastrous level.

The **early effects** (0-6 months) from this tragedy were: Ophthalmic (chemosis, redness, watering, ulcers, photophobia); respiratory (distress, pulmonary edema, pneumonitis, pneumothorax), gastrointestinal (persistent diarrhoea, anorexia, persistent abdominal pain); genetic (increased chromosomal abnormalities), psychological (neuroses, anxiety states, adjustment reactions); neurobehavioural (impaired audio-visual memory, impaired alertness and reaction time, impaired analysis, interpretation and spatial ability, dysfunctional psychomotor coordination).

The **delayed effects** (6 months onwards) from this tragedy were: Visual (constant watering, corneal opacities, chronic conjunctivitis); respiratory (obstructive and restrictive airway disease, decreased lung function); reproductive (increased abortion, increased child mortality, reduced placental/foetal weight); genetic (increased chromosomal abnormalities) and neurobehavioural (impaired associate learning, motor speed, precision).

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Taj Mahal Issue

Taj Mahal, being one of the seven wonders and one of the most beautiful monuments of the world, attracts international tourists throughout the year. It was built along the bank of river Yamuna by Mughal Emperor Shahjahan in memory of his beloved wife Mumtaz more than 350 years back in Agra. It is now included in the list of World Heritage due to its archaeological importance.

In 1972, the Government of India established Mathura Oil Refinery in Mathura. This step was most resented by various environmentalists of the country who protested that its air pollutants were harmful to the Taj Mahal. During the oil refining process, sulphur dioxide (SO_2) is released in large quantities along with the smoke. Air containing SO_2 blow all around and reacts with water during rains. SO_2 combines with water to form sulphurous acid (H_2SO_3) and sulphuric acid (H_2SO_4) and produces acid rain. Environmentalists protested that acid rain causes damage to the marble of the Taj Mahal. The white marble has yellowed and blackened in places.

The government constituted a committee in 1974 to find out the fact and authorised the Italian Company Technico to evaluate the changes occurring in the air due to the Mathura Oil Refinery of Indian Oil Corporation. According to the report of the committee and determinations carried out by an Italian company, it was concluded that in Agra the quantity of SO_2 would increase up to 1-3 micrograms which is negligible and harmless to the Taj Mahal. However, WHO (1982) has recognized the 'Taj Trapezium Zone' (TTZ) (50 km radius area) to protect the monument from pollution hazards. The burning of coal and wood fuel has been banned in TTZ. Supreme Court has ordered to set up of a solar power plant for the energy requirement of TTZ.

The Ganga Pollution

River Ganga is so important and closely associated with Indian culture and civilisation that it is often designated as 'Maa-the mother' and is worshipped in India and is now the National River of India (2008). The Ganga is the ninth largest river in the world and the second largest in India with a length of 2,525 km. from Gangotri to

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Ganga Sagar. It constitutes about 25.2% water source of India. A number of Himalayan rivers including Mandakini, Alaknanda, Yamuna, Ghagra, Gandak, Koshi etc join it during its course. About 692 cities/towns are located along its bank of which 27 cities have a population of more than 1 lakh. More than 600 km part of the river, particularly between Kanpur and Patna is highly polluted. Every day it receives about 1300 million litres of sewage and 250 million litres of chemical effluents. The main causes of pollution of Ganges water are the mixing of industrial effluents (20%) and domestic and municipal effluents (80%) into it.

The following are the main causes of Ganga Pollution:

- Sediment load of the Ganga River and other associated rivers.
- Sewage disposal of villages, towns and cities.
- Discharge of industrial effluents.
- Release of dead bodies of animal and human beings.
- Cremation along the bank of the river and disposal of cremation material and burnt and half-burnt dead bodies of human beings.
- Surface runoff of toxic chemicals, agrochemicals, pesticides etc.

In 1985, the Ministry of Environment and forests started the Ganga Action Plan (GAP) for preventing irreversible damage and restoring the water quality of the Ganga. GAP has the following objectives:

1. All round environmental improvements.
2. Installation of sewage treatment units and their proper operation and maintenance.
3. The basic facilities of sewage treatment are to be coupled with the production of energy and manure and the provision of pisciculture, aquaculture and irrigation-treated water.
4. Economic benefits to the local population.

GAP helped in estimating the magnitude of Ganga Pollution. In an estimate, it was calculated that about 10,90,000 kg of toxic effluents and 13,00,000 kg of domestic and municipal effluents are discharged every year from the cities of UP only. The first step of GAP started in 1985 and the second in 1995 to complete the plan by the end

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of 1999. Despite, the 20,000 crores that have been spent to clean the water, the results achieved remain insignificant. Various other projects have also been subsidised by the governments of the Netherlands and Japan to clean the water of the Holy Ganges. Now Project of GAP includes cleaning of Yamuna and Gomti rivers. NGPRA has granted rupees 100 million to clean them.

Technical experts (2014) have recommended 5 programmes for cleaning the National River of India, the Ganga, as follows:

- Formation of micro dams
- Planning for floating population
- Reduction in the number of riverside industries
- Limited storage of water in barrages and
- Development of organic farming

The present Prime Minister, Shri Narendra Modi has launched a new scheme called Namami Gange to clean the holy river Ganga (2015). The government has sanctioned rupees 20,000 crores for this project.

The Yamuna Pollution

River Yamuna after being originated from Yamunotri covers a passage of 1376 km before joining the river Ganga at Allahabad. The river has been divided into five segments from the point of view of pollution level.

1. Himalayan Segment from Yamunotri to Tajewala, 172 km, nonpolluted zone.
2. Upper segment from Tajewala to Wazirabad, 224 km polluted by agrochemicals used in Haryana.
3. Delhi segment from Wazirabad barrage to Okhla barrage, 22 km, highly polluted zone due to Delhi effluent discharges.
4. Eutrophicated segment from Okhla barrage to join a place with river Chambal, 490 km, highly polluted with microbes and with highest BOD, Mathura and Agra covered in the segment.
5. Mixed segment from Chambal Sangam to Allahabad 468 km, the pollution level decreases.

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The pollution problem in the Delhi segment is acute and highly dangerous. About 1900 million litres of sewage is discharged every day in this segment of 22 km. The total treatment capacity of Delhi plants is about 1270 ml/day i.e. about 630 ml//day of it is still discharged directly to river Yamuna without any treatment. Moreover, the treated water is also not pure. It remains partially untreated. Further 2800 ml effluents per day are discharged into the river by eleven main nullahs which results in an increase of 200 BOD and 160 tonnes of suspended solids. Najafgarh and Shahdara nullahs are most problematic.

The pollution indicator coliform test revealed the presence of 24,000,000 *Escherichia coli* per 100 ml in the downstream of Okhla region which is indicative of the magnitude of water pollution. Conditions become more severe during summer.

In 1993, in the second step of the Ganga Action Plan (GAP) of the Government of India, Yamuna Action Plan (YAP) was also taken up. It included 127 working projects of which 48 are in UP, 76 in Haryana and 3 in Delhi. After 13 years of work on these projects, the pollution problem still remains serious. Pollution is further nurtured due to barrages built in Delhi, Mathura and Agra for civic water supply and the number of canals made for irrigation. All this has made river Yamuna a *sewage Vahini.*

Chernobyl Disaster

The Chernobyl Disaster took place in April 1986 in Ukraine formerly known as part of the USSR. The Chernobyl disaster is known to be the biggest disaster to have occurred in nuclear power plants. In routine maintenance of one of the four nuclear reactors of the plant, a sudden power surge caused an uncontrolled chain reaction in one of the reactors leading to explosions in the reactor. The explosion exposed the nuclear reactors causing the spread of radioactive material into the atmosphere. The initial response from the administration was to contain the fallout of the disaster but later it realized that too much irreparable damage has already happened. The explosion released around 30 per cent of the 190 metric tons of Uranium being used in reactors. The USSR government later informed the

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world of the explosion and started evacuating people when they realized fall out couldn't be controlled. It is estimated that 335,000 people were evacuated and more than hundreds died due to the explosion. The periphery of the nuclear reactor approximately 19 miles wide was cordoned off as an "exclusion zone" with no human activity. The incident site has been covered with thick sheets of steel in order to limit radiation leakage. More than 34 years on, scientists opine that the area won't be habitable for the next 20000 years. The researchers predicted contamination of surrounding areas with high radiation which led to low and high-level radiation exposure to as many as 10,000 people causing radiation-related cancer which led to their death in later years. The disaster led to a global anti-nuclear movement discouraging the use of nuclear energy.

Fukushima Disaster

The Fukushima disaster is considered the second biggest disaster in history after Chernobyl Disaster. The Fukushima disaster occurred in March 2011 in one of the islands in Japan. The accident was rated 7 on the INES scale due to high radioactive release for 5-6 days. Four nuclear reactors were damaged in the incident leading to radiation fallout in the region. The accident mainly happened due to a major earthquake followed by a 15 m high Tsunami causing damage to the reactors. There were no reports of death due to radiation sickness but more than a hundred thousand people were evacuated from the area as a precaution. The radiation mainly consisted of Iodine-131, Caesium-134, Caesium-137, strontium-90, and Plutonium-238.

Indore: Global Model For Waste Management

Indore city is one of the big cities in India and has been named the cleanest city in India for a record third time in *Swachh Survekshan* 2019. The city has managed to segregate 100% of waste at source and successfully managed the organic waste through composting and other methods. The better implementation of cleanliness programs by Indore Municipal Corporation (IMC) had led to cooperation and participation from citizens. The IMC is a global model for the world, especially in big cities where the waste management is a huge

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task due to the quantity of waste and the number of people needed for its handling. The success of the IMC can be attributed to the following steps:

- Information, Education and Communication (IEC): This is key to behavioural change in the primary stakeholders-the citizens.
- Waste generation and segregation at source and at bulk in collection centres: Door-to-door collection of waste in the segregated form of dry waste and wet waste. Special attention is given to hazardous or biomedical waste.
- Waste collection and transportation: the waste is collected from all the sources and reaches a central facility where data is gathered from different localities and assessed.
- Waste processing: The wet waste is sent to a central facility for composting and dry waste such as hazardous or biomedical waste is sent to incinerators. The waste is also used to create bio-compressed natural gas (bio CNG) that is being used to run vehicles in the city.

Swachh Bharat Abhiyan (Clean India Mission)

This is a campaign launched by the prime minister of India on 2nd October 2014 to create awareness regarding cleanliness in our homes, streets, and infrastructure of the country. It is India's largest cleanliness drive where students, government employees and people from the private sector participate. This movement has been successful in creating awareness for cleanliness and discouraging open defecation by building toilets in rural and urban areas. The movement has also created awareness of health and sanitation among the communities.

10.6 Summary

- Substances that are not considered useful are categorized as waste. The origin of these can be domestic, industrial, construction or agriculture.
- Waste management is important for the categorization of different types of waste and their proper handling.

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- The increasing waste generation in the world has supported the 5R principle for waste management which consists of –reduce, reuse, recycle, recover and refuse.
- The hazardous wastes are generally treated by a method known as incineration and organic waste is treated by the method of composting.
- Special treatment is required for e-waste and biomedical waste as these can lead to serious health problems among people.
- Awareness and knowledge are the most important step in the reduction and management of waste.

10.7 Self-Assessment Questions

1. Explain E-waste, biomedical waste and plastic waste.
2. Explain the 5-R principles of solid waste management.
3. Explain landfill, composting and incineration.
4. What are leachate and vermicomposting?

10.8 References

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10.9 Suggested Readings

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Glossary

Aquifers: It is an underground layer of rock that holds groundwater.

Atmosphere: a thin blanket of gaseous mixture which envelops the planet and is essential for the survival of biotic components on earth.

Biochemical Oxygen Demand: When bacteria and other microorganisms decompose organic matter in an aerobic (oxygen present) environment, the amount of oxygen they consume is measured as Biochemical Oxygen Demand (BOD).

Biogeochemical Cycles: These include nutrient cycles such as the carbon cycle, nitrogen cycle, Sulphur cycle and phosphorus cycles.

Biosphere: sphere on and around the earth having life.

Brundtland Commission: World Commission on Environment and Development, commonly known as the Brundtland Commission, gave the concept of sustainable development to the world.

Compost: Organic matter rich in nutrients created by the decomposition of biodegradable waste.

Deforestation: Deforestation is the clearing or permanent removal of forest areas so that it is available for other uses.

Deforestation: Deforestation is the clearing or permanent removal of forest areas so that it is available for other uses.

Desertification: Desertification is an extreme case of land degradation in which semidry regions, become increasingly arid resulting in the loss of water bodies, vegetation and wildlife. It is caused by a variety of factors, which includes both anthropogenic activities as well as climate change.

Ecological Succession: the process by which the structure of a biological community evolves over time.

Edaphic Factor: These are the aspects of the soil that affect the different kinds of organisms that live there.

Environment: Every biotic and abiotic component that surrounds us forms the environment.

Notes

Environmental Studies: Environmental study is a multidisciplinary subject which studies various dimensions (scientific, social, cultural, economic, political etc.) of the environment, its issues and challenges and tangible solutions in a holistic way. It studies the human-environment interaction and its results at the micro and macro level.

Estuaries: These are the region where the river meets the ocean and are an example of a brackish water ecosystem.

GPP: It is the total rate at which material is produced.

Hydrosphere: depicts the area on earth covered with water

Incinerator: The furnace is designed to burn hazardous or infectious waste at high temperatures in controlled conditions.

Land Cover: Land cover refers to the observed biophysical cover on the surface of the earth whether vegetation, water, bare soil or urban infrastructure.

Land Degradation: Land degradation is defined as the deterioration of the productive capacity of land due to overexploitation by humans. Land degradation affects soil chemistry and soil biodiversity and alters the natural ecological processes and ecosystem of the affected area.

Landfills: Sites created for storage or dumping of municipal solid waste.

Leachate: The liquid consisting of dissolved harmful substances enters the environment by seeping into the soil from landfills.

Lentic Ecosystem: It means stagnant water ecosystem e.g. pond and lake.

Lithosphere: Solid surface part of the earth.

Lotic Ecosystem: It means running water ecosystems e.g. River.

Mangrove Forests: They consist of trees and shrubs found in coastal-intertidal zones in the tropics and subtropics.

Multidisciplinary: interaction of various subjects or disciplines to address a complex issue or subject.

Non-timber Forest Products: Non-timber Forest Products (NTFPs) are any product or service other than timber that is produced in forests. They include fruits and nuts, vegetables, fish and game, medicinal plants, resins, essences and a range of barks and fibres such as bamboo, rattans, and a host of other palms and grasses.

Notes

NPP: It is the rate at which material is accumulated in excess of respiration.

Polychlorinated Biphenyls: A group of toxic chemicals used for manufacturing various appliances and commodities including electrical appliances, adhesives, and fluids that are considered carcinogenic in nature.

Productivity: the rate of formation of biomass in the ecosystem.

Radioactive Waste: Nuclear medicine, research, power generation, rare-earth mining, and even the reprocessing of nuclear weapons all produce radioactive waste.

Radioisotope: A form of an element that is not stable and gives off radiation as it breaks down and becomes more stable.

Reforestation: Reforestation is the re-growing of forests that have previously been cut down using tree species that are native to the geographic area.

Siltation: increased deposition of sediments brought along by the river at the bottom of the dam reservoir.

Soil Erosion: Soil erosion is the loss or removal of the top layer of soil due to natural physical agents like wind, water and even gravity.

Sustainable Development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Tundra: These ecosystems (arctic tundra) are found in extreme northern latitudes where snow melts seasonally and on the high elevation of mountains.

Vermicomposting: The organic matter with high nutrient availability, good for soil and plants created with the help of earthworms by decomposition of biodegradable waste like kitchen waste.

Wetland: An area of land covered with water for at least part of the year.

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