Basics of Environmental Studies

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Dedicated to…

My beloved parents

Contents

Preface

We and our surrounding constitute the environment. Human activities have been interfering with nature since the beginning of civilisation on earth. Population explosion, rapid industrialisation and urbanisation have degraded the environment by polluting air, water and land. Thus, the impact of technology and development have caused numerous global environmental problems and various climatic changes. At international levels, various steps have been taken to reduce the impact of human activities on the environment. In 2009, President of Maldives and his cabinet arranged an underwater meeting to highlight the threat of climate change and demanded global cuts in the carbon emissions to be presented in the UN climate summit. Most importantly, people at large need to be made aware about the consequences of environmental problems in order to make such efforts successful. Therefore, basic knowledge of environment is very essential for every human being. Keeping this aspect in mind, the University Grants Commission (UGC) has mandated to include a core module syllabus of environmental studies in all undergraduate courses.

About the book

This book entitled ***Basics of Environmental Studies*** is written for studying a first course in the subject. It will be a useful read for all first year engineering students. The present book is an attempt to impart basic knowledge of environment to the readers and students not only from the examination point of view but also acquire skills to motivate the common public for developing a sense of responsibility towards the environmental protection. The book is organised into four chapters:

1. **Introduction to Environment:** This chapter includes components of environment, ecological factors influencing environment, the interaction between man and environment, importance of environmental education and environmental degradation. The emphasis has been given on the impact of advancement and technology on the environment.
2. **Ecology and Ecosystems:** This chapter describes the structure and functions of ecosystem, biogeochemical cycles, food chains and food web with examples and all three types of ecological pyramids. The chapter ends with detailed description of all major types of ecosystems.
3. **Population and Natural Resources:** This chapter describes the habitation pattern, population growth, population structure and demographic projections. The chapter also includes the detailed description of main natural resources, Indian scenario of all these resources and the problems caused due to over-exploitation of natural resources.

4. **Environmental Pollution:** This chapter describes air pollution, water pollution, land pollution and noise pollution. The emphasis was given to the main global environmental problems like global warming, green house effect, acid rain and depletion of ozone layer.

Salient Features of the Book

The contents of the book are full of thorough, comprehensive and broad ideas related to the subject matter. The salient features of the book are given below.

- Every concept has been explained in a **lucid** manner and the text is written in **student-friendly language** to make comprehension easy for nonenglish medium students also
- Includes **systematic and simplified diagrams**, graphs, **pictures** and **examples**
- Startling **facts/notes on the environmental issues** within the chapters, especially in the separate boxes, increase general awareness of students
- **Case studies** related to problems faced at national and international levels have been included at the end of each chapter
- **Lists important terminology** for quick reference
- **Comprehensive pedagogy**

  Review Questions: 47

  Multiple Choice Questions: 94

The author hopes that the present book will be very useful to the readers, especially to the students to understand the subject with completeness without any need to refer to other books.

Acknowledgements

Dr Khare is heartily thankful to all those environmentalists whose ideas and opinions helped him while writing the book. He is also thankful to the Principal, HOD (Civil) and his colleagues of Government Engineering College, Dahod for their support and encouragement as well as to his friends specially Dr R K Jain who have supported and encouraged him during the preparation of the script. Dr Khare would specially like to express his thanks to his father-in-law Dr D P Srivastava for his constant inspiration and encouragement.

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Jadavji Patel—*BVM Engineering College, Vallabh Vidyanagar*

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Umesh Kumar Khare

Feedback

Even after the best effort, it is possible that some errors and misprints have gone unnoticed. The author will be grateful to the faculty members and students who kindly bring such mistakes to the author's or publisher's notice.

Publisher's Note

Do you have a suggestion or an opinion on this present edition? Then, don't forget to write to us at ***tmh.corefeedback@gmail.com***, mentioning the title and the author's name along with your feedback. You can also write to us in case of any piracy related problems.

Chapter 1

INTRODUCTION TO ENVIRONMENT

Contents

"We have modified our environment so radically that we must now modify ourselves to exist in this new environment".
–Norbert Weiner (1894–1964)
American Mathematician

1.1 INTRODUCTION

We and our surroundings constitute the environment which includes all physical, chemical and biological factors influencing the living and nonliving beings. The environment varies with space and time so the organisms need to adjust their self as per the changes in the environment. This chapter defines that and describes the components of environment in detail with ecological factors influence the environment. The chapter also describes the interaction between man and environment with emphasis on the impact of advancement in technology on the environment. The definition of environmental degradation and factors causing environmental degradation are discussed in the chapter with the importance of environmental education and role of environmental engineer.

1.2 ENVIRONMENT – MEANING AND COMPONENTS

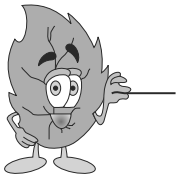
1.2.1 What is meant by Environment?

The meaning of the word *environment* is the surrounding of an organism. Therefore, environment can be defined as 'sum total of all conditions which surround an organism at a given point of time and space'. As per the Environment Protection Act, 1986, the legal definition of environment is "*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*". The environment has two parts:

1. **Biotic part**: It is also called the living component of environment which includes plants, animals, birds and all micro-organisms.
2. **Abiotic part**: This is also called nonliving component of environment and it includes most of the physical factors like temperature, humidity, light, water, air and gases, minerals, and soil.

The environment can also be divided into two categories:

1. **Natural environment**: It is the environment gifted by God and is operated by self regulation mechanism.



DID YOU KNOW?

The biotic and abiotic components of an environment are together known as the *biome environment*.

2. **Man-made environment**: It is the environment created by man through modifications in natural environment for fulfilling their needs.

The environment changes from place to place as well as with time. Therefore, in order to survive in this changing environment, the species are required to adjust themselves with the changes in the environment, otherwise they will become extinct. The ecological factors which cause changes in the environment are:

1. **Biotic factors**: These include all factors governing the ecological balance between living beings and their nonliving environment while interacting with each other.

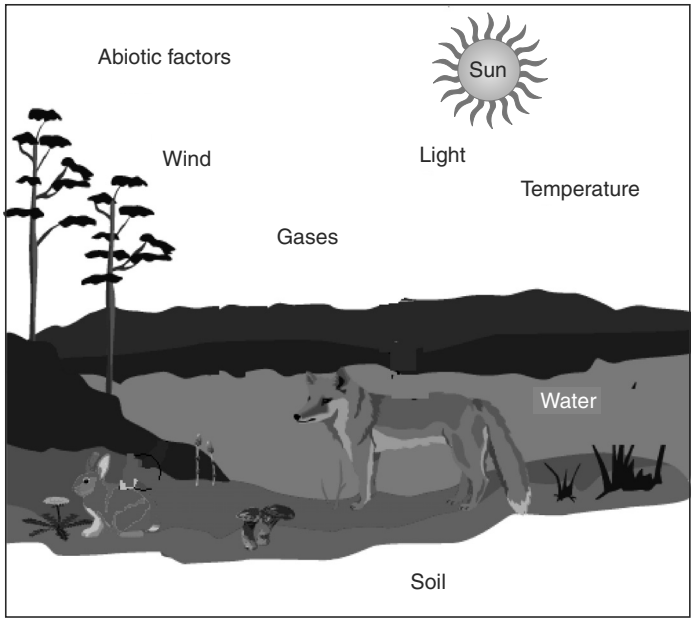


Fig. 1.1 Picture showing biome environment
Source: Google.com

2. **Edaphic factors**: They comprise of those factors which are responsible with the formation and properties of soil and earth.
3. **Topographical factors**: These factors are related to mountains, plains, lakes, oceans, forest, deserts and their interaction with living beings.
4. **Climatic factors**: These factors include the effect of parameters like temperature, humidity, light, water, air movements, etc.

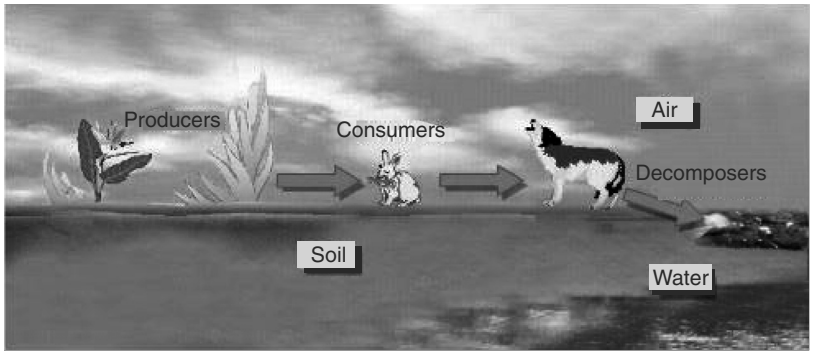


Fig. 1.2 Picture showing biotic and abiotic parts of environment
Source: Google.com

1.2.2 Components of Environment

Basically environment has two components abiotic or physical component which comprises of atmosphere, hydrosphere and lithosphere and biotic component which cons of biosphere.

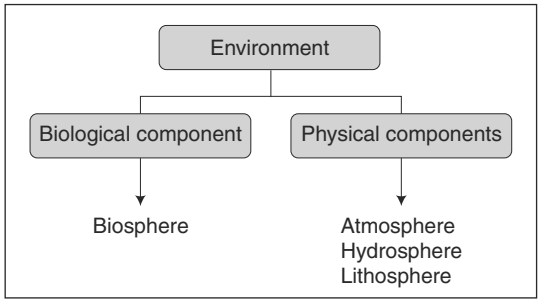


Fig. 1.3 Components of Environment

Thus, there are four main components of environment which are described below.

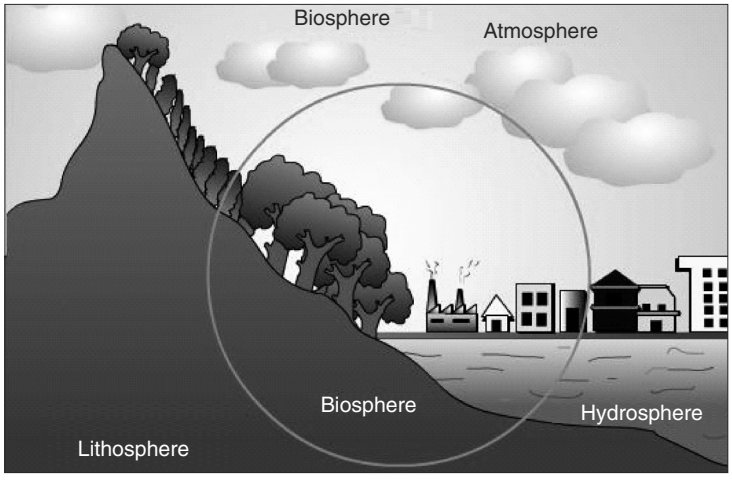


Fig. 1.4 Picture showing Components of Environment
Source: Google.com

1. **Atmosphere**: It is a pool of different gases and water vapours between earth and outer space. Various activities like filtration of radiant energy received by sun, insulation of heat and climatic changes take place in the atmosphere. At a given place, short term variations like hourly, daily and weekly variations in the properties of atmosphere (sun radiations, temperature, humidity, rainfall, wind and clouds) is termed as *weather*. When the weather remains almost constant for long duration like in seasonal variations, it is called *climate*. The compositions of atmosphere are given in Table 1.1.

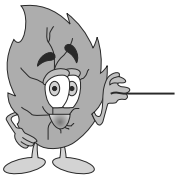
Table 1.1 Composition of Atmosphere

Sr. No.	*Names of gases*	*Concentration by % Volume*	*Category in atmospheric gases*
1.	Nitrogen (N_2)	78.09	Major gases
2.	Oxygen (O_2)	20.95	
3.	Argon (Ar)	0.93	
4.	Water vapours	0.1	Minor gases
5.	Carbon dioxide (CO_2)	0.032	
6.	Neon (Ne)	0.0018	
7.	Methane (CH_4)	0.0002	
8.	Helium (He)	0.0005	
9.	Ozone (O_3), CO, H_2, NH_3, NO, NO_2, SO_2, and H_2S	Concentration by % Volume less then 0.000006	Trace gases

The atmosphere can be divided into five regions as given below.

(a) ***Troposphere*** – It is the first layer over the ground in which the most living organism exist. In this layer temperature decreases with altitude. This rate of temperature change is called *lapse rate*.

Troposphere is known for pollution, presence of water vapours, dust, air movement and clouds. This layer is very important, as all climatic changes take place in this layer itself. It extends from ground up to about 8 – 16 km towards polar and equator region.



DID YOU KNOW?

Total mass of atmosphere is around 5×10^7 tonnes which accounts around one millionth of earth total mass of 5×10^{21} tonnes and troposphere is roughly 70% of mass of atmosphere.

(b) ***Stratosphere*** – It is the next vertical layer after troposphere from the ground. In this layer, temperature increases with altitude (positive lapse rate). *Stratosphere* is known for the presence of ozone which is found at around 20 kms from ground. This layer of ozone formed by photochemical reactions is called *ozonosphere* and acts as a protective shield against the harmful effects of ultra violet radiations (wavelength-190–380 nm) on living organism.

The formation of ozone in the stratosphere is cyclic as it is continuously formed as well as destroyed as shown below.

$$O_2 + h\nu \longrightarrow O + O \quad \text{(Atomic oxygen)}$$
$$O_2 + O + N_2 \longrightarrow O_3 + N_2 \quad \text{(Formation of ozone)}$$
$$O_3 + h\nu \longrightarrow O_2 + O \quad \text{(Atomic oxygen)}$$
$$O + O_3 \longrightarrow 2O_2 \quad \text{(Destruction of ozone)}$$

(c) ***Mesosphere*** – It exists over stratosphere and in this layer, temperature decreases with altitude (negative lapse rate) because of low concentration of ozone and low absorption of radiations. This layer is very special as all sound waves as well as short radio waves coming from earth are reflected from this layer.

(d) ***Thermosphere*** – After mesosphere, *thermosphere* starts and extends up to 500 kms above earth's surface. Temperature rises in this zone with altitude and this trend continues further. Ionisation of elements like oxygen and nitric oxide take place in the uppermost portion of layer. Therefore, the upper layer of thermosphere is also called *ionosphere*.

(e) ***Exosphere*** – The upper most layer of atmosphere which extends up to 1600 km and gives way to space is called *exosphere*. In this layer, very high temperature (> 1200°C) is found.

Table 1.2 Structure of Atmosphere

Sr. No.	*Name of Layer*	*Altitude from earth's surface in km*	*Temperature Range (°C)*	*Remarks*
1.	Troposphere	0–12	20 to –56	Presence of O_2, CO_2, N_2, NOx, SOx, and water vapours. Known for pollution.
2.	Stratosphere	12–50	–56 to –2	Presence of O_2 and O_3. Aeroplane flying zone.
3.	Mesosphere	50–85	–2 to –90	Presence of N_2 and O_3. Sound and radio waves reflected by this zone.
4.	Thermosphere	85–500	–90 to 1200	Presence of O_2 and O_3, NO. Ionisation of elements.
5.	Exosphere	500–1600	> 1200	Air less and contains hydrogen gas in ionised state

2. **Lithosphere**: It is basically that portion of the earth which is made up of soil, minerals, rocks and other organic as well as inorganic matter. Lithosphere has mainly three layers whose compositions are given below.

(a) ***Crest*** – It is top layer of the earth which extends up to approximately 17 km in depth. It is composed of different rocks, minerals and soils. Earth's crest also acts as shelter for biotic communities. Compositions of crest include oxygen 46.5%, silicon 28%, aluminium 8%, iron 5%, calcium 4%, sodium 3%, potasium 2.5%, and magnisium 2%.

(b) ***Mantle*** – It is the next layer after crest which comprises around 68% of total mass of earth. The upper layer up to around 500 km of mantle predominantly contains silicate materials while lower portion up to 2900 km consists basically a mixture of oxides. Compositions of mantle include oxygen 44%, silicon 23%, magnesium 19%, iron 10%, calcium 2%, aluminium 1.5%, sodium 1%, chromium 0.4%, manganese 0.3%, potassium 0.1%, and phosphorus 0.1%.

(c) ***Core*** – It is the main layer of the earth, over which other two layers are supported. This extends from 2900 km to the centre of earth (up to 6370 km). The outer core which is in liquid form contains iron and nickel alloys while the inner core contains basically of pure iron. Temperature in the core of the earth is around 5000–5500 °C.

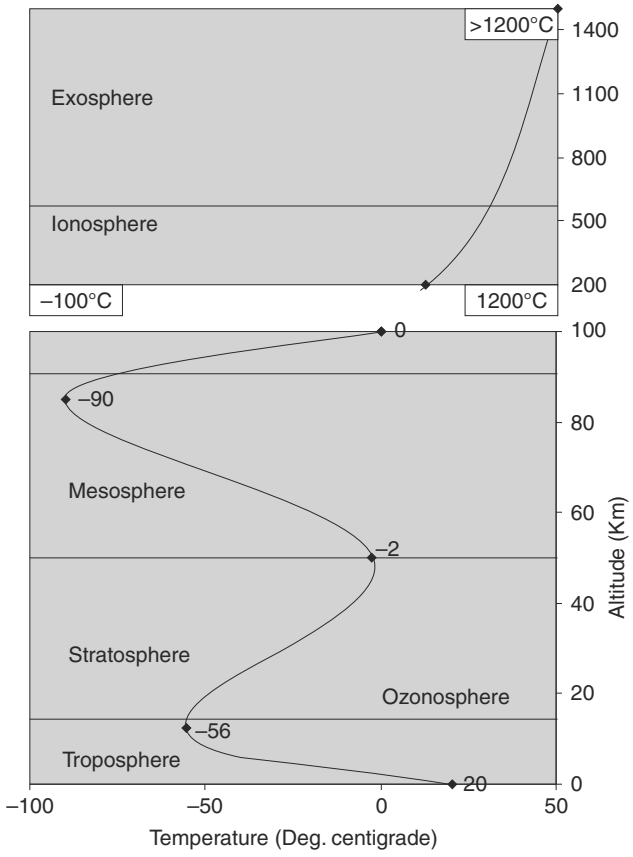


Fig. 1.5 Temperature Profile of Atmosphere

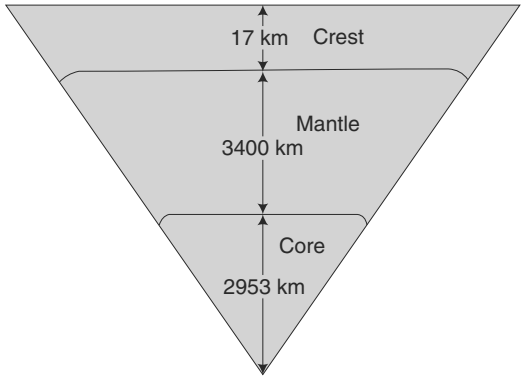
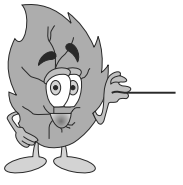


Fig. 1.6 Lithosphere

3. **Biosphere**: It is that portion of earth's surface, hydrosphere and atmosphere where life exists. As biosphere is life bearing layer so it has close interactions with other layers of hydrosphere and atmosphere. The soil of the earth's crest has organic matter and minerals to support *micro flora and fauna* (bacteria, fungi and algae) and *macro flora and fauna* (herbs, shrubs and trees). Oxygen and carbon dioxide levels of atmosphere depend upon balancing of different species on earth. Green plants are responsible for accumulation of oxygen which is must for life by means of photosynthesis. Hydrosphere also acts as the greatest sink for pollutants.

4. **Hydrosphere**: It is the portion of earth's surface which is covered by water and which may be held on/in the earth surface as gas, liquid and/or solid depending on the temperature.



DID YOU KNOW?

Total quantity of water available on the earth is about 1.4 billion km^3 and if this amount is spread over the earth surface then it will form 2.5 km deep water mass.

Hydrosphere accounts for around 70% of earth surface in which about 97% water is in oceans and seas. Water available in oceans and seas is not fit for human consumption, so only the remaining 3% water is available as fresh water for use.

Out of 3% fresh water, around 2.3% is locked in icecaps at polar regions. Therefore only 0.7% water is available for human consumption. Surface water through lakes, ponds, rivers and streams accounts for around 0.03% while 0.67% is available as ground water.

1.2.3 Interaction Among Components of Environment

All the components of environment are interrelated with each other. Any change in one of the components effect other components also, for example, changes in the temperature of atmosphere, cause changes in the rate of evaporation, humidity in atmosphere and after saturation of humidity when rainfall takes place, it affects lithosphere as flood may occur causing erosion of earth. This also affects the biosphere as different types of plants grow differently according to the amount of rainfall they receive. Thus, there is a dynamic interaction among different components of environment. Lithosphere is almost static component of environment while atmosphere and hydrosphere are dynamic components of environment. Different types of movements in air due to wind and storms and movements of river water as well as ocean water cause changes on the land surface and thus affect

lithosphere. Thus, all components of environment are interrelated and have capacity to change the structure and composition of other components of the environment.

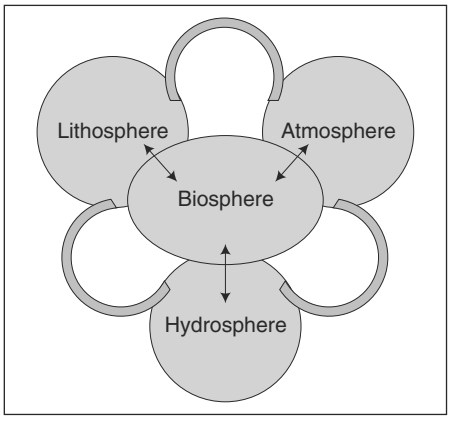
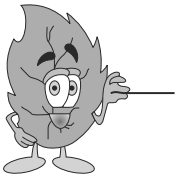


Fig. 1.7 Interaction among components

1.3 MAN AND ENVIRONMENT RELATIONSHIP

Right from the evolution of human beings on this earth, men have resided in forests and have consumed food from plants, by hunting and fishing. They began moving from place to place in groups to cultivate crops and in search of shelters. They started cutting forest for fuel and shelter and thus began the pollution of natural resources.

Living beings are affected by their environment. At the same time, environment also gets affected by the activities of living beings. Human being is basically dependent on his natural environment for fulfilling his basic needs for food, water and shelter. As per the Indian tradition, bodies of plants, animals and human beings are made up of five essential elements (earth, water, fire, air and *Akash*) and after death/decay these bodies again converted to those five essential elements. Sincs ancient times, Indians have worshipped their natural resources in the form of God for example, sun as Surya dev, water as Varun dev, air as Pawan dev, soil as Prathvi devi, trees as Van dev, other planets as Navagraha and animals like cow as Mata and elephant as Ganesh.



DID YOU KNOW?

Destruction of forest not only drastically reduces carbon storage capacity of the atmosphere but also releases additional carbon into the atmosphere through decay and burning.

With the increase in population, man started interfering with the environment by means of cutting trees to get wood and open land for shelter. Man started throwing wastewater to pollute water resources and burning fuels to pollute air.

But all natural resources can withstand all these pollutions, only up to a certain limit and assimilating capacity. Increase in human activities due to urbanisation and industrialisation, may have resulted in progress and advancement, but at the same time, they have also become a danger to other life-forms on earth.

In order to fulfill their basic needs quickly, human beings have modified the environment more, compared to other organism using advanced technologies. After the eighteenth century, lot of advancement in technologies and science took place especially after the invention of steam engine and automobiles. Consumption of fossil fuels increased which led to high air pollution and global warming. The invention of concrete and heavy construction machineries caused rapid industrialisation and rapid urbanisation by means of construction of quality industrial and domestic buildings, dams, power plants, road and railway networks, etc. Production of chemical fertilisers and pesticides increased the food production but same time polluted the land, water and air.

Thus, the interaction between man and environment is a two-way process. It is basically how we affect and in turn, are affected by the environment, and also how we disturb the natural environment. Here are some examples of human-environment interaction:

1. Instead of going up and over a mountain, humans and animals went around, using the path of least resistance which made them tired and difficult but eventually, people realised that it would be easier to go through a mountain than to go around it on longer paths. So they blasted through the mountain to create tunnels that we see today. But, looking at the history, we find these changes occurred over many thousands of years.
2. As trade between people from different areas increased, they needed other ways to reach different places quickly with their goods. This led to the use of aeroplanes as airways and ships as waterways along with the roads and railways. People constructed bridges, big dams, airports, docks and harbors so that they could have speedy trade relationships among different states and different countries.

1.3.1 Importance of Environmental Education

The subject of environmental studies includes the scientific study of the environmental system and interrelationship of environment with organisms. It deals with social and cultural factors along with the effects of biotic and abiotic factors which impact the environment.

The objective of environmental education is to make public aware about environmental problems, importance of environment protection. Environmental education is important because of the following reasons:

1. It gives us the basic understanding about environment and its associated problems.
2. It imparts the knowledge of eco-friendly techniques to be used in different fields.
3. It helps us to understand about ecological imbalance and the various ways to maintain ecological balance.
4. To learn about the beneficial use of natural resources without damaging it much.
5. To train people about proper use of natural resources using the concept of conservation of energy and natural resources.
6. It lays emphasis on motivation of public to participate in the programs of environmental protection.
7. It gives the knowledge of interdependency of man and nature.
8. It develops skills to identify environmental problems and their solutions.
9. It makes people aware about common pollution problems like getting safe and clean water, and healthy and hygienic food.

Even after Bhopal gas tragedy (1984), no efforts have been done to impart environmental education. Honorable Supreme Court had issued directive to central government (1991) to include environmental education at UG level. No significant changes were brought even after this measure. Therefore, Honorable Supreme Court once again issued orders in 2003 to all states and institutes like IIT's to introduce a course on environment from higher secondary level to UG level compulsorily. There are several ways to impart environmental education to public.

1. **Formal ways**: In this environmental education is given at school, college and university level.
2. **Nonformal ways**: It imparts environmental education by means of organising exhibitions, seminars, audio and video shows and documentaries and arranging nature camps. This also includes the activities of NGO's who organise the programs for environmental conservation, environment protection, pollution problems, deforestation, rehabilitation, plantation and cleaning water bodies. The world environmental day is celebrated every year on 5^{th} June to make public aware about current status of environmental problems and solutions.
3. **Public representation**: This includes (a) participation of individuals by research and development for solving environmental problems, (b) establishment of centers for environmental education, (c) arranging short term and long term training courses, and (d) by giving awards and fellowships for excellent workers.

1.3.2 Role of Environmental Engineer

Environmental engineers are the technocrats who are committed to protect human beings from the harmful effects of environmental degradation caused by the pollution in the environment due to population growth, rapid industrialisation and urbanisation.

Environmental engineers must have knowledge of mathematics, physics, chemistry, biology and microbiology. The environmental engineer generally acts to build a bridge between engineering technology and biology. Following are the basic duties of an environmental engineer:

1. Environmental engineers basically make environmental strategies like evaluation of environmental quality, steps for improvement in quality of water, air and food as well as suggestions regarding the proper collection and disposal of solid and liquid wastes from the city.
2. Environmental engineers do the design, construction and operation of treatment facilities for water, air and solid waste. These treatment facilities, which are designed by the environmental engineers are mainly based on the assimilating capacity of lithosphere, atmosphere and hydrosphere.
3. Environmental engineers design the different processes to handle large volumes of pollutants with the principles of optimisation, socio-economic effects and rapid treatment to convert any objectionable material to a less objectionable material.
4. Environmental engineers also keep in their mind to protect natural resources from the effects of disposal of hazardous waste, toxic chemicals and radioactive waste.
5. Environmental engineers have a special role of having good co-ordination with other technocrats and engineers to make rapid advancement in cleaning up the environment with eco-friendly techniques.
6. The basic challenging role of an environmental engineer is to make public aware about the environmental degradation and also to impart training in such a way, so that people participate in the programs of keeping the environment clean.

1.4 RELATION BETWEEN ANTHROPOGENIC ACTIVITIES AND ENVIRONMENT

The word environmental pollution is not new for our society. It has been present and existed since the origin of life on earth. In the beginning, people lived in forests near to the river banks to have easy access of food, water and shelter and used to throw waste on land and downstream of river which caused pollution in the environment. At present, the only change

is in the magnitude of pollution and spread of pollution, which is increased drastically in the last few decades. Rapid advancement in education, technology and industrialisation has changed the living standard of people but at the same time, this has become the cause of environmental degradation. There is a world wide concern over the disposal of toxic wastes, green house gases, climatic changes and disposal of nuclear and radioactive wastes. Impact of technologies in different fields on the environment can be summarised as below.

1. **Agricultural activities**: In the beginning, farmers used bio fertilisers and manual methods of farming but with advancement in technologies now, chemical fertilisers, chemicals for crop protection and mostly machines are used for farming to increase production. This has increased the discharge of pesticides and harmful chemicals in water bodies.
2. **Irrigation activities**: Advancement in irrigation methods (like drip irrigation, sprinkler irrigation) and construction of dams has improved the water management for irrigation but has led to the degradation of environment due to submergence of forest and land, causing rehabilitation problems. This has also caused water logging problems and spreading of water related diseases.
3. **Transport Activities**: Technological advancement in all modes of transport system (roadways, railways, waterways and airways) has provided the facility to reach from one corner to another not only in the country itself but also from one country to another within a very short period of time. This has caused deforestation and improper utilisation of agricultural land due to construction of roads, railway tracks, airports and docks. Higher consumption of fuel in all these transport facilities has also caused air pollution and noise pollution. Nowadays due to the rise in vehicular pollution in most of the big cities, public and government vehicles have been replaced with CNG fuel.
4. **Mining activities**: These activities involve the extraction of fossils from deep deposits to be used for the generation of electrical energy at thermal power plants. These activities cause soil erosion, subsidence of land, deforestation, air pollution, deposition of huge amount of fly ash at power plants, water pollution and occupational health hazards like asthma, bronchitis and silicosis, etc.
5. **Industrial activities**: All types of industries like pharmaceutical, textile, manufacturing, automobile, distilleries, dyes and pigment, leather and other chemical industries have now advanced technologies to minimise quantity and intensity of waste and for proper functioning of effluent treatment. Pollution control boards are also set by central and state governments to tackle with industries to minimise pollution but due to indiscipline and lack of awareness, these activities continue to create soil, water and air pollution.

6. **Construction activities**: Since the last few decades, huge construction activities that are taking place particularly in metro and big cities have converted the cities into jungle of concrete. These activities have created deforestation, stress on water recourses, water drainage problems, and energy problems.
7. **Tourism and religious activities**: In such activities, lots of people gather at a particular place at particular time which poses a transport problems, sanitary and water supply problems, solid and plastic waste problems and the danger of spreading of diseases like swine flu.

1.5 ENVIRONMENTAL DEGRADATION

It is the direct and indirect deterioration of the environmental quality due to different activities of living beings that pollute the key elements like air, water and soil. Environmental degradation can occur naturally or through human activities.

1. **Natural factors**: Natural factors causing environmental degradation are draughts, storms and floods, earthquakes, tsunami and volcanic eruptions. These factors not only cause physical and agricultural damage but are also responsible for disruption of property and essential services like electricity, and water supply.
2. **Man made factors**: These human factors include deforestation, industrialisation and urbanisation. Environment is degraded because of the following reasons:
   (a) High growth of human population and poverty is mainly responsible for environmental degradation.
   (b) Unplanned and heavy consumption of natural resources in which even renewable resources are not given sufficient time to renew.
   (c) Ecological imbalance created by human and animal activities.
   (d) Over use of resources like water, forest, land and energy which lead to solid, liquid and air pollution.
   (d) Heavy industrialisation leads air and water pollution which causes respiratory infections, toxic chemicals and heavy metals, contamination of water, use of pesticides and release of high amount of green house gases contributes for cause of cancer, birth defects, low immune power, global warming, climatic changes and other health hazards.

Famous physicist John Holdren and biologist Paul Ehrlich studied environmental degradation and pollution in detail. These scientists developed a model using three factors to assess the impact (I) on the environment which is called IPAT equation. It was one of the earliest attempts to describe the role of multiple factors in determining environmental

degradation. IPAT equation describes the multiplicative contribution of population (P), affluence (A) and technology (T) to environmental impact (I) as below.

$$\text{Impact } (I) = P \times A \times T$$

where, P = Size of the human population

A = The level of consumption by population (P)

T = Processes used to obtain resources and transform them into useful goods and wastes.

On the basis of this model they concluded the following things:

1. In developing countries basically population, poverty and pollution are three key factors responsible for rapid environmental degradation which is called as P^3 syndrome.
2. In developed countries, use of natural resources with very high rate (high per capita use) is the main reason of environmental degradation.
3. Different applications suggest that different types of impacts relate differently to changes in population, affluence and technology.
4. IPAT applications are used to evaluate single variable measure of environmental impact, such as air pollution. For example, the *Intergovernmental Panel on Climate Change* has applied IPAT to studies of CO_2 levels.

1.5.1 Sustainable Development

Sustainable development is a process of betterment of life in all the sectors like economic, social, educational, health and sanitation, national security, food and housing, etc. In 1987, the *World Commission on Environment and Development* made sustainable development on the theme of its entire report (Brundtland report) "Our Common Future". As per this report, sustainable development is defined as a form of development or progress that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable development has three important components that are also highlighted in the Brundtland report. They are discussed below.

1. **Economic development**: This includes utilisation of natural resources, agricultural developments, industrialisation, creating job opportunities and raising the quality of life.

2. **Social development**: This includes providing the basic needs of life, like food, drinking water, shelter, fresh air, cloths, education, health and sanitation.
3. **Environmental protection**: This includes providing safe environment by means of providing clean air, water and soil.

The idea of sustainable development was strongly supported by the Earth Smmit 1992, held at Rio de Janerio, Brazil. In this summit, UN general assembly asked for a report on progress made towards sustainable development. It was the largest environmental conference ever held attracting 30,000 people and more than 100 heads of states. The biggest challenge involved in this summit was finance, consumption and population growth.

Sustainable development must be a part and parcel of our national development plan. It can be achieved by keeping the following points in consideration:

(a) (b)

Fig. 1.8 Picture showing environmental degradation by (a) Industrial effluent and air pollution, (b)Air pollution by power plant

Source: Google.com

1. Controlling population and reducing substantially the population growth rates.
2. Reducing the over-exploitation of resources and enhancing the conservation of water, soil, energy and forest, etc.
3. Minimisation of waste production by performing recycling and reuse.
4. Enhancing the use of nonconventional energy resources.
5. Providing housing, health care and education to poor people, particularly in villages.

6. Encouraging the empowerment and education of women.
7. Arranging plantation programs in cities and villages and increasing people's participation in conservation of natural resources.
8. By making strategies for eradication of poverty.

(a) (b)

Fig. 1.9 Picture showing environmental degradation (a) By floods, (b) By Tsunami at Sumatra
Source: Google.com

(a) (b)

Fig. 1.10 Picture showing environmental degradation (a) By Earth quake, (b) By Volcanic eruption
Source: Google.com

CASE STUDIES

National Environment Awareness Campaign (NEAC): Environmental ministry launched major awareness program in 1986 to inform people of India about different environmental issues. Ministry also provided financial assistance to NGOs, Colleges, Universities, other organisations and army units for performing activities like padyatras, rallies, public meetings, exhibitions, completions, seminars, workshops, and training courses. A wide range of groups are been covered in campaign like students, teachers, common public, journalists and professionals.

Eco-Clubs: It is a special scheme designed to encourage the participation of school children in the activities related to preservation and conservation of environment. Its objective was not limited to impart environmental education but also to take efforts to protect the environment at the local community levels. The ministry gives the financial support to NGOs and professional bodies who set up such Eco-Clubs.

Environmental Brigade: This scheme was launched by the government in 1992 to encourage the participation of common people in environmental protection activities which is also called *Paryavaran Vahini*. Vahinies have to report the illegal acts pertaining to forests, wild life, pollution and cruelty to animals, etc., along with the feedback regarding the afforestation programs, monitoring of air and vehicular pollution and quality of water.

Important Terminology

1. *Environment*: Surrounding in which living beings (organisms) live.
2. *Ecological factors*: Factors affecting ecology like biotic, edaphic, topographical and climatic factors.
3. *Edaphic factors*: Related to the types and properties of soil.
4. *Climate*: Average weather remains constant for long time.
5. *Assimilating capacity*: Carrying capacity to absorb pollution.
6. *Volcanic eruptions*: It is molten magma coming out from hills at high temperature
7. *Global warming*: Rise in the temperature of globe due to green house gases and pollution.
8. *Atmosphere*: It is a mixer of various gases, water vapours and dust particles covering the earth and extends several kilometers above ground.

9. *Lithosphere*: Solid portion of earth which contains minerals and support living things.
10. *Hydrosphere*: It is the area on the earth surface, covered by water.
11. *Biosphere*: It is portion of environment which support life.

Review Questions

1. Define the term 'Environment' and describe the objectives of environmental education.
2. Why environmental education is necessary? Discuss the ways of environmental education.
3. Explain the meaning of 'Environment' and discuss its parts.
4. What are the components of environment? Describe the relationship between each.
5. What is the role of an environmental engineer?
6. Discuss the impact of advancement in technology on the environment.
7. Explain the structure of atmosphere and describe it using schematic diagram.
8. Describe the compositions of atmosphere and lithosphere.
9. Discuss the relationship between man and environment.
10. What is environmental degradation? Discuss the factors responsible for degradation of environment.
11. Write short notes on
    (a) Hydrosphere (b) Biosphere
    (c) Natural and man-made environment
12. Define the term 'environment' as per EPA and describe the different ecological factors which are responsible for changes in the environment.
13. Discuss the different components of atmosphere and draw the temperature profile of atmosphere.
14. What do you mean by sustainable development? Discuss how it can be achieved.
15. Describe schematically the interaction among different components of environment.

Objective Type Questions

1. The environment consists of
   (a) Living organisms
   (b) Nonliving things
   (c) Living organisms and their Nonliving things
   (d) None of these
2. The layer of atmosphere which is harmful due to the presence of pollution is
   (a) Stratosphere (b) Troposphere
   (c) Ionosphere (d) Exosphere
3. Hydrosphere is defined as
   (a) Layer of soils
   (b) Layer of air and gases
   (c) Oceans, seas and other water bodies
   (d) None of these
4. Layer of atmosphere have lowest temperature is
   (a) Stratosphere (b) Troposphere
   (c) Mesosphere (d) Exosphere
5. Ozonosphere exists in
   (a) Stratosphere (b) Troposphere
   (c) Ionosphere (d) Exosphere
6. Presence of ozone is treated as pollutant in
   (a) Stratosphere (b) Troposphere
   (c) Ionosphere (d) Exosphere
7. Ozone present in ozonosphere protects us by
   (a) Infrared radiations (b) Ultraviolet radiations
   (c) Visible radiations (d) None of these
8. The range of temperature variations in troposphere is
   (a) 20 °C to –56 °C (b) –56 °C to –2 °C
   (c) –2 °C to –90 °C (d) –90 °C to 1200 °C
9. The range of temperature variations in stratosphere is
   (a) 20 °C to –56 °C (b) –56 °C to –2 °C
   (c) –2 °C to –90 °C (d) –90 °C to 1200 °C

10. The range of temperature variations in mesosphere is
    (a) 20 °C to –56 °C (b) –56 °C to –2 °C
    (c) –2 °C to –90 °C (d) –90 ^{o}C to 1200 ^{o}C
11. The range of temperature variations in ionosphere is
    (a) 20 °C to –56 °C (b) –56 °C to –2 °C
    (c) –2 °C to –90 °C (d) –90 °C to 1200 °C
12. The range of temperature variations in exosphere is
    (a) 20 °C to –56 °C (b) –2 °C to –90 °C
    (c) –90 °C to 1200 °C (d) >1200 °C
13. Meaning of lapse rate is
    (a) Rate of increase in temperature with altitude
    (b) Rate of decrease in temperature with altitude
    (c) Increase in humidity
    (d) Both (a) and (b)
14. The ambient lapse rate is
    (a) –6.5 °C per km (b) –9.8 °C per km
    (c) –5 °C per km (d) None of these
15. Negative lapse rate exists in
    (a) Stratosphere (b) Troposphere
    (c) Ionosphere (d) Exosphere
16. Lithosphere consists of
    (a) Earth crest (b) Mantle
    (c) Core (d) All of these
17. Earth core temperature is about
    (a) Around 5500 °C (b) 1000 °C
    (c) 0 °C (d) None of these
18. The inner core of the earth consists mainly of
    (a) Alloys (b) Pure iron
    (c) Rocks (d) Oxides
19. The component of environment which supports life in air, water and land is
    (a) Biosphere (b) Troposphere
    (c) Lithosphere (d) Hydrosphere

20. The world environmental day is celebrated on
    (a) 15th June (b) 5th June
    (c) 5th January (d) 15th February
21. Environmental study is a type of subject which is
    (a) Interdisciplinary (b) For civil engineering
    (c) For environmental engineering (d) For civil and environmental engineering
22. The biggest pollutant receptor or sink on the earth is
    (a) Biosphere (b) Atmosphere
    (c) Lithosphere (d) Hydrosphere
23. The least pollutant receptor or sink on the earth is in
    (a) Hydrosphere (b) Atmosphere
    (c) Lithosphere (d) None of these
24. The environment is basically degraded by
    (a) Only Industrialisation (b) Urbanisation
    (c) Deforestation (d) All of above

ANSWERS

1. (c)	2. (b)	3. (c)	4. (c)	5. (a)	6. (b)	7. (b)
8. (a)	9. (b)	10. (c)	11. (d)	12. (d)	13. (d)	14. (a)
15. (b)	16. (d)	17. (a)	18. (b)	19. (a)	20. (b)	21. (a)
22. (d)	23. (b)	24. (d)				

List of questions asked in Gujarat Technical University Examinations from this chapter

Q. No.	Details	Marks
Q1.	Explain the impact of technology and development on the environment. **GTU, Jan 2009**	7
Q2.	Give the compositions of environment. **GTU, Jan 2009**	7
Q3.	What are the components of environment? Explain with the help of a sketch.	7

Q4.	What are the objectives and guiding principles of environmental education? **GTU, Jan 2009**	6
Q5.	Define environment. **GTU, Jun 2009**	1
Q6.	Why environmental education is provided to engineers? What is the relationship between man and environment? **GTU, Jun 2009**	4
Q7.	Why environmental education is important? Explain the impact of technology and development on the environment. **GTU, Jan 2010**	7
Q8.	Define environment and give the compositions of atmosphere and lithosphere. **GTU, Jan 2010**	7
Q9.	What is the meaning of environment? Discuss the relationship between different components of environment. **GTU, Jun 2010**	7
Q10.	Explain the impact of technology and development on the environment. **GTU, Jun 2010**	7
Q11.	Answer in single line: (a) What is ozonosphere? (b) When is world environmental day celebrated? **GTU, Jun 2010**	2

Chapter 2

ECOLOGY AND ECOSYSTEMS

Contents

"We have to shift our emphasis from economic efficiency and materialism towards a sustainable quality of life and to healing of our society, of our people and our ecological systems".

– Janet Holmes a Court (1943 – present)
American Businesswoman

2.1 INTRODUCTION

The study of inter-relationship between living and nonliving is called *ecology* while a system in which both living and nonliving beings interact with each other as a self supported complete unit is called an *ecosystem*. An ecosystem has basically two components, biotic and abiotic. The biotic components include the producers, consumers and decomposers while abiotic components comprise physical elements like air, water, soil, temperature, humidity, etc.

This chapter describes the structure of ecosystem and the functions of producers, consumers and decomposers. Organisms need nutrient (CHONPS) along with the food for their proper growth and reproduction which they get from their biotic and abiotic environment. The cycles which recycle nutrients back to the environment after the consumption of nutrients are called *biogeochemical cycles*. All biogeochemical cycles are described in detail in this chapter. In an ecosystem, transfer of food energy takes place from one trophic level to another through a series of interconnected organism called *food chain*. The chapter describes the different food chains and food web with examples. When ecological parameters are plotted for different trophic levels they take the shape of pyramid so called ecological pyramid. The chapter also includes the description of all three types of pyramids (number, biomass and energy pyramid) with schematic diagrams. The chapter ends with detailed description of all major types of ecosystems.

2.2 ECOLOGY AND ITS CLASSIFICATION

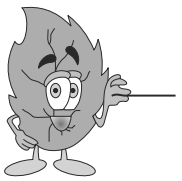
Ecology is the science which deals with the study of relationship of living organism with each other and with their nonliving environment. Hanns Reter (1885) combined the word *oikos* (meaning house) and *logos* (meaning study of) to form the term ecology. Ecology can be defined in a number of ways as described below.

1. Ecology is the scientific study of the interaction that determines the distribution and abundance of organisms – by Charles Krebs.

2. Ecology is defined as the study of structure and function of nature – by EP Odum.
3. Ecology is defined as the scientific natural history concerned with the sociology and economics of animals – by Charles Elton.
4. Ecology is defined as "the science of the environment" – by Karl Friederichs.

2.2.1 Classification of Ecology

1. **On the basis of aspect**
   (a) ***Autecology*** – It is ecology of an individual species and its population. It deals with study of inter relationship between individual species and its environment, e.g., a fish in pond, a tree in a forest.
   (b) ***Synecology*** – It is a study of communities and their behaviour and relations with abiotic environment. It has three types – population ecology, community ecology and ecosystem ecology, e.g., tribal belt, a pond, a forest.



DID YOU KNOW?
Individual populations can not sustain life indefinitely because a single specie can not produce all the food it needs and can not decompose all its wastes.

2. **On the basis of type of environment**
   (a) ***Aquatic ecology*** – It includes marine, fresh water and stream ecology.
   (b) ***Terrestrial ecology*** – It includes grassland, forest and desert ecology.

2.2.2 Objectives of Ecology

Main objectives of ecology are given below.

1. To study the inter-relationship between single and species in communities.
2. To study the behaviour of different species in natural environment.
3. To study the adjustment of species (structurally and functionally) with change in physical environment.
4. To study development, productivity, energy and material flow in natural system.
5. To study the effects of temporal changes on the activities of different species.
6. To study the parameters which affect ecological balance (balancing between production and consumption of each component in ecosystem which impart stability to ecosystem) and functioning of ecosystem for performing modeling.

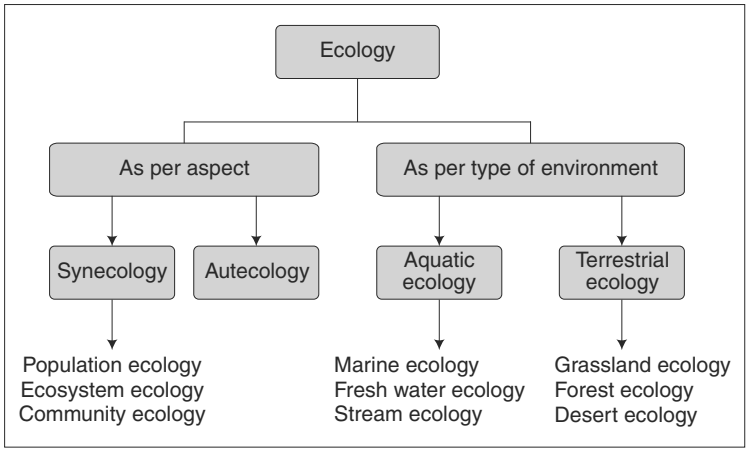


Fig. 2.1 Classification of Ecology

2.3 ECOSYSTEM AND ITS COMPONENTS

Living organism always require their physical environment (nonliving) like air, water, soil, temperature, humidity, etc., because living components get material and energy flow for its survival from nonliving environment. Therefore, the interaction of living and nonliving environment produces a stable self sustained system which is called the *ecosystem*. An ecosystem consists of habitat and its ecological niche with abiotic environment. An *ecological niche* is basically a role that specie plays in its ecosystem i.e., its movement, its food, its inter-relationship with other species. Thus, niche denotes the environment of single specie. Ecosystem can be defined as natural self supported system in which there is proper interaction between living organism and their nonliving environment. Ecosystem may be natural ecosystem like forest, lake, desert, grassland, pond, etc., while examples of man made ecosystems are aquarium, crop field, etc.

2.3.1 Structure of Ecosystem

Structure of ecosystem is characterised by its two basic components–

1. Abiotic
2. Biotic

1. **Abiotic components**: Abiotic components of ecosystem consist of:
   (a) ***Inorganic substances*** – Carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and all micro and macro nutrients which links biotic and abiotic components.

(b) ***Organic substances*** – It includes carbohydrates, proteins and lipids.

(c) ***Other climatic and edaphic factors*** – These factors include rain, temperature, light, humidity, pH, soil and its properties and topography.

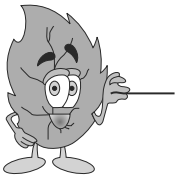
2. **Biotic components**: It includes all living organisms, plants, animals and microorganisms. As per the role of these organisms in ecosystem, biotic components can be classified into three main groups.

(a) **Producers** – Producers are basically green plants which generate their food for getting energy in presence of water and carbon dioxide using solar energy (sunlight). This process by which all green plants generate their food is called *photosynthesis*. As producers generate their food by self so they are also called *autotrophs* (auto means self and trophs means feeder). Sun radiant energy which is converted to chemical energy during the photosynthesis process by plants is utilised for their biomass growth and repair and maintenance.

(b) **Consumers** – Consumers are basically animals which depend upon producers for getting their food. As consumers feed on producers so they are called *heterotrophs* (hetero means other and trophs means feeder). Consumers are divided into four categories.

- **Primary consumers**–Primary consumers are also called *first order consumers*. They are basically *herbivores* because they derive nutrition directly from plants. Some examples of herbivores are deer, goat, grasshopper, etc.
- **Secondary consumers**–They are also called *second order consumers*. They are basically primary carnivores because they feed on herbivores. Some examples of primary carnivores are snakes, fox, etc.
- **Tertiary consumers**–They are *third order consumers*. They are basically large carnivores because they feed on secondary consumers. Some examples of large carnivores are wolves, hawks, etc.
- **Forth order consumers**–They are basically top level carnivores because they feed on both tertiary consumers and herbivores. Some examples of top level carnivores which are not eaten by other animals are lion, tiger, etc. This class also includes *omnivores*. Omnivores are also called opportunistic feeders (survive by eating what is available). They have neither carnivore nor herbivore specialisations for acquiring or processing food but are capable of consuming both animal protein and vegetation. Humans are classic examples of omnivores as there is no base for the assumption that humans are naturally fitted in herbivores. For that reason, the best arguments in support of a meat-free diet remain ecological, ethical, and health concerns.

(c) Decomposers–Decomposers are microorganisms which breakdown dead organic material of producers and consumers to simple organic substances and by-products to get their food. Decomposers convert complex organic material into simpler one with reduction in volume of material so they are also called *reducers*. Decomposers are basically saprophytes like bacteria and fungi. Generally, bacteria attacks on animal tissues while fungi prefer plant tissues.



DID YOU KNOW?

Scavengers are animals which feed on the dead bodies of other organisms like beetles, worms and termites.

Decomposers secrete enzymes during digestion of dead organic material and convert it into little organic and inorganic nutrients which is called *mineralisation*. These released minerals are utilised by producers as micro and macro nutrients.

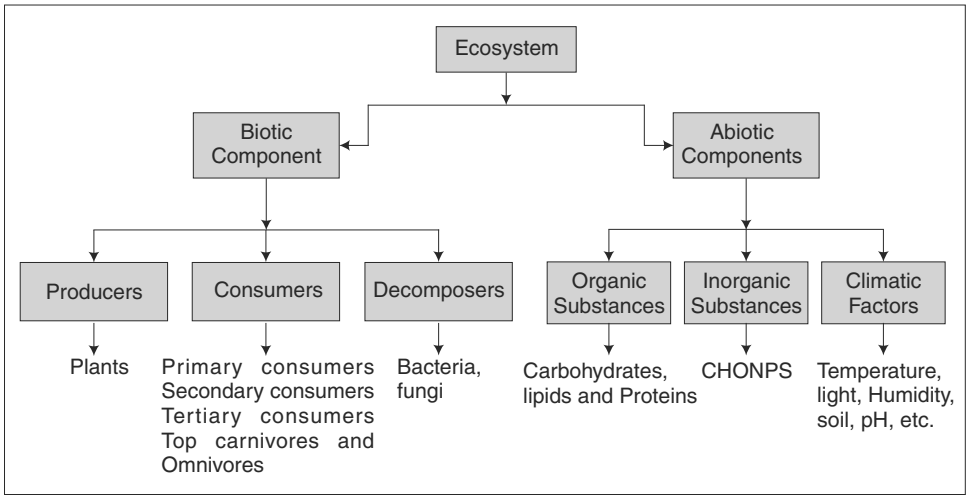


Fig. 2.2 Components of Environment

Nutrients needed in relatively large amount (> 0.2% of dry weight) are called *macro nutrients* like *C*, *H*, *N*, *P*, *O*, *S*, *K*, *Na*, *Ca*, *Mg*, *Fe*, *Mn*, *Cu*, etc., which are required for growth and reproduction of organisms. *Micronutrients* are those which are needed in less than 0.2% amount and play a role in enzymatic activities, cell division and nitrogen fixing. Main micronutrients are *Al*, *Ar*, *Bo*, *Br*, *Co*, *Mn*, *Mo*, *Ni* and *Zn*, etc.

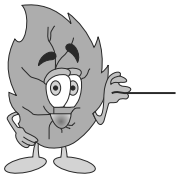
2.3.2 Functions of Ecosystem

All components of ecosystem run together to make our ecosystem functional. For example, in common forest system, green plants prepare food by the process of photosynthesis and roots absorb nutrients from the soil. A part of plant production utilised by herbivores are in turn eaten by carnivores. Decomposers breakdown the complex dead organic matter into simple organic and inorganic material, which are available as nutrients in the soil to be utilised by the producers. Thus, the main functions of ecosystem are as follows.

1. **Productivity**: Rate of biomass or energy production per unit area and time produced by producers is called *gross primary production* (GPP) while *net primary production* (NPP) is the rate of biomass or energy stored per unit area and time after respiration and maintenance. Secondary productivity is the rate of increase of biomass of consumers per unit area and time.

   GPP = NPP + loss of energy or biomass due to respiration and maintenance

2. **Energy flow**: Energy from solar radiations is converted by producers (plants, algae and microbes) into chemical form, a part of which passes from one trophical level to another level i.e., flow of energy from producers through herbivores to carnivores and the rest is lost as heat.
3. **Decomposition**: Decomposers convert the complex dead organic matter into simple organic and inorganic materials like carbon dioxide, water and nutrients.
4. **Nutrient cycling**: After decomposition of dead organic matter, the nutrients are accumulated on top of the soil which are again taken by the producers for their growth. These nutrients are cycled from one to other level (producers through herbivores to carnivores) and finally back again to soil.
5. **Stabilisation**: For a new ecosystem, it requires some time to become completely functional and after proper ecological balancing, the ecosystem becomes stabilised.



DID YOU KNOW?

Human beings have changed the earth's ecosystems more rapidly in last 50 years than any other period in human history. This degradation of ecosystem may even be worse in the begining of 21st century.

2.3.3 Energy Flow in Ecosystem

In the process of photosynthesis, green plants take energy from sunlight to convert carbon dioxide into glucose to get energy. This energy transfers from one trophical level to another. Flow of energy in ecosystem is governed by two basic laws of thermodynamics: (i) Energy can neither be created nor destroyed but can be transferred from one state to another, (ii) Each transfer of energy causes loss of energy within the ecosystem from one level to another i.e., from producer to primary consumer and from primary consumer to secondary consumer and so on. During respiration, carbon double bond is broken and carbon is combined with oxygen to form carbon dioxide. This process releases energy and around 90% energy is lost in between two trophical levels. This flow of energy within the ecosystem is unidirectional and does not recycle.

Salient features of energy flow in ecosystem are:

1. Sun acts as main source of energy.
2. Fate of energy is to be lost as heat lastly.
3. As one organism eats another as per food chain, so energy is transferred from one organism to another organism.

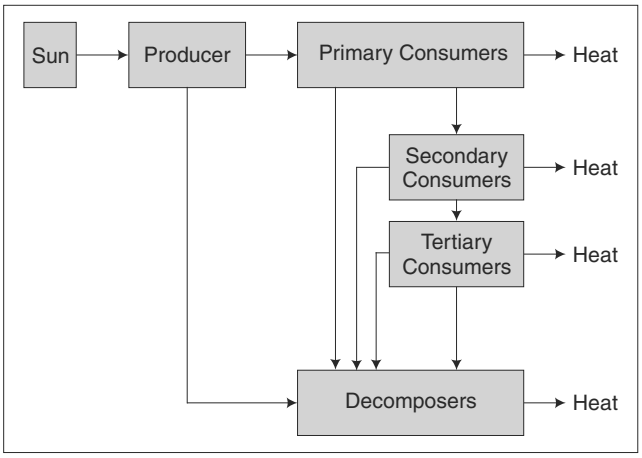


Fig. 2.3 Energy Flow in Ecosystem

Fate of Energy

Generally in the terrestrial ecosystem, producers utilise 1% of the energy incoming as solar radiations from sun. The energy transmitted further by the producers is distributed as given below.

Energy transmitted to herbivores = 27% (Then in each trophic level 10% energy is utilised)
Energy transmitted to top carnivores = 0.01%
Energy lost via respiration = 15%
Energy remains unused (wasted) = 57.99%

The sources of all the energy flowing through the detritus pathway is given below.

Leaves	= 83%
Root death	= 12%
Nonleaf litter fall	= 2%
Organic matter through precipitation	= 2%
Fecal material	= 1%
Animal death	= trace

2.3.3.1 Models for Energy Flow in Ecosystem

There are basically three types of models for energy flow through various trophic levels in the ecosystem.

1. **Single channel energy flow model**: This model depicts that energy flows in unidirectional manner from a single channel of producers to consumers. The energy is captured by producers through sun and that passes from producers to primary consumers (herbivores) but this energy can not revert back to producers but passes to secondary consumers. As flow of energy is one way so due to cut off of primary source of energy entire system collapses.
2. **Double channel or Y shaped energy flow model**: This model shows energy flow within the common boundary showing light and heat flows and import, export and storage of organic matter. Decomposers are also placed within the boundary to separate grazing and detritus food chains.
3. **Universal energy flow model**: This model depicts that there is loss of energy at each level so the available energy becomes less for the next level. This energy which is lost as heat is mainly used in respiration, for maintenance, locomotion and excretion etc. The remaining energy is utilized for production.

2.3.4 Nutrient Flow in Ecosystem

Like energy flow in ecosystem inorganic nutrients also flow from one to another trophical level. Finally all organisms die and become detritus food for decomposers who put all

nutrients back into soil and/or water which is called *nutrient pool*. These nutrients are further utilised by producers from nutrient pool.

Main inorganic nutrients are; (i) Phosphorus: It is required for growth of bones, teeth and cellular membranes, (ii) Nitrogen: It is found as amino acids which act as building blocks of protein and it plays important role in the functioning of DNA and RNA, (iii) Sulfur: Sulfur is required for synthesis of amino acids and proteins and it regulates other nutrients also and, (iv) Other micro and macro nutrients required essentially for growth of organisms.

Salient features of nutrient flow in ecosystem are:

1. Energy flow and nutrient flow proceed concurrently in ecosystems.
2. Energy flow is unidirectional flow and noncyclic while nutrient flow is cyclic.
3. Nutrient cycling must accompany energy flow and vice-versa.

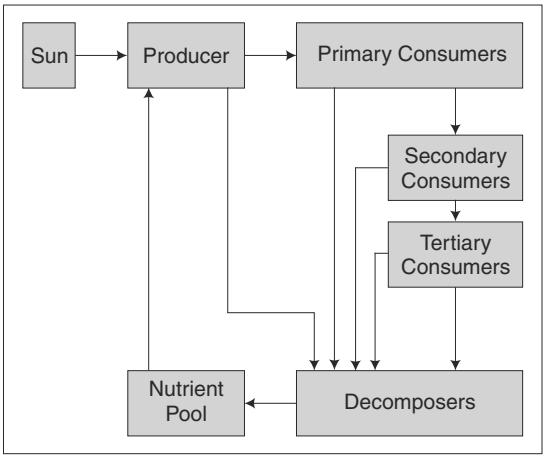


Fig. 2.4 Nutrient Flow in Ecosystem

2.4 FOOD CHAINS

It is a series of interconnected living organisms in which flow of food energy is shown by graphical representation from one organism to another organism. A food chain always starts with producer and ends with top level carnivores. In a food chain, each organism eats the smaller organism who in turn is eaten by the larger one. Each food chain has two to three levels of carnivores and three to five trophic levels in total.

2.4.1 Trophic Levels

Food energy is transferred from one to another level hierarchically and thus food energy passes from one group of organisms (plant) to other groups of organisms (animals) at different levels. These feeding levels of organisms are called *trophic levels*. Generally, there are four trophic levels but some times there may be five trophic levels also as given below.

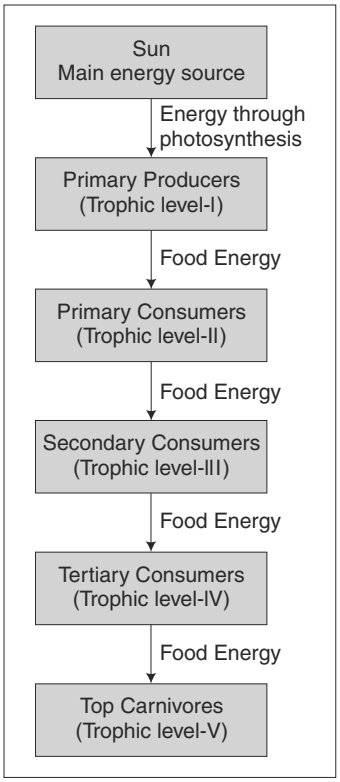


Fig. 2.5 Trophic Levels

1. **Trophic level-I**: This level belongs to producers (green plants) which are called autotrophs as they produce their food by own using solar energy.
2. **Trophic level-II**: This level belongs to primary consumers who depend upon producers for their food and are called herbivores like cow, goat, deer rabbit, etc.
3. **Trophic level-III**: In this level animals that are generally found are secondary consumers who depend upon other animals (herbivores) for their food and are called carnivores like snakes, foxes, etc.
4. **Trophic level-IV**: This level belongs to tertiary consumers like foxes, wolfs and hawks, etc. If only four levels are considered, then top carnivores also come in this trophic level.
5. **Trophic level-V**: This level belongs to top carnivores who feed on herbivores as well as carnivores but can not be eaten by other carnivores like tiger, lion etc. This level may also include humans who depend upon plants and animals for their food and come under the category of omnivores.

All ecosystems possess two types of food chains:

1. Grazing food chain
2. Detritus food chain

1. **Grazing food chain**: It starts from green plants and passes through herbivores to carnivores. It is again divided into two parts:
   (a) ***Terrestrial food chain*** – Food chain showing interconnections of living beings in terrestrial ecosystem are shown below.

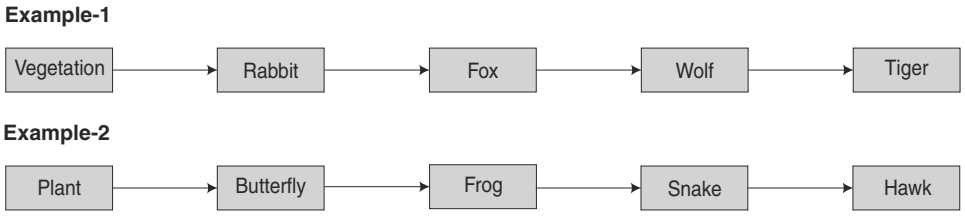


Fig. 2.6 Terrestrial food chains

(b) ***Aquatic food chain*** – Food chain showing interconnections of living beings in aquatic ecosystem are shown below.

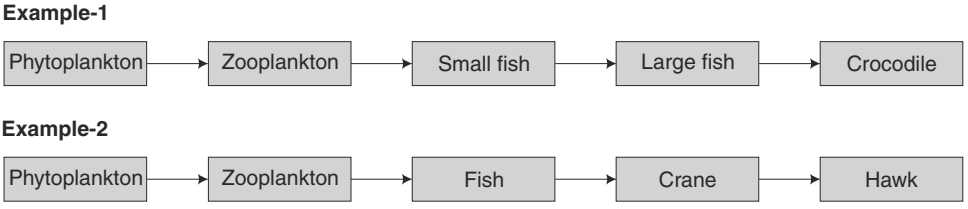


Fig. 2.7 Aquatic food chains

2. **Detritus food chain**: It starts from dead organisms and passes through micro-organisms to detritus feeding organisms and their predators.

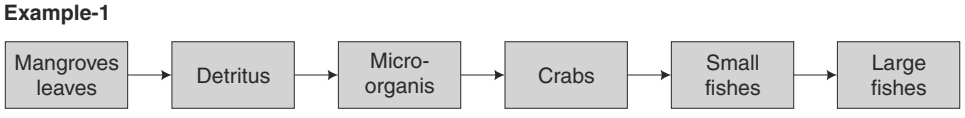


Fig. 2.8 Detritus food chain

Significance of Food Chain

The food chain in an ecosystem is very important and significant as it helps to maintain the biodiversity and feeding relationship of different species. The food chain also helps to maintain the energy flow and nutrient cycling in an ecosystem. Bioaccumulation and biomagnification are basically a part of food chain. Bioaccumulation refers to how pollutants enter a food chain while biomagnification refers to the tendency of pollutants to concentrate as they move from one trophic level to the next. Both these terms can be defined as given below.

1. **Bioaccumulation**: It is defined as increase in concentration of a pollutant from the environment to the first organism in a food chain.

2. **Biomagnification**: It is defined as increase in concentration of a pollutant from one link in a food chain to another.

2.5 FOOD WEBS

Like food chain, food webs also represent series of interconnected living organisms but here, the organisms become part of more than one food chain. In order to meet the energy and food requirements, most of the animals eat more than one kind of food and thus become part of more than one food chain. Such network of food chains which has interconnected food chains with more number of feeding connections among different organisms is called *food web*.

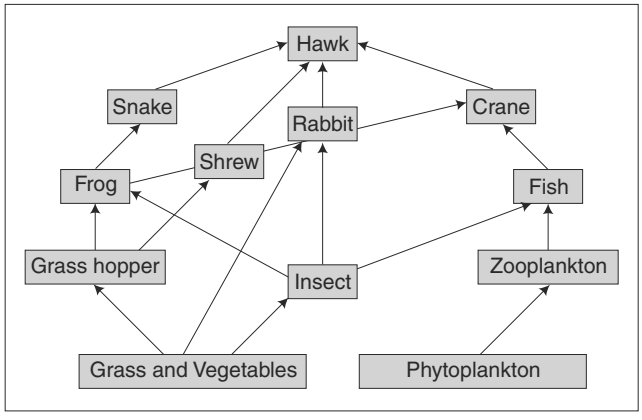


Fig. 2.9 Food web-1

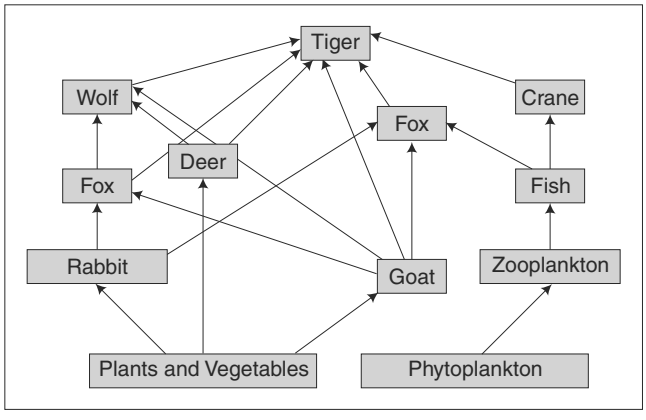
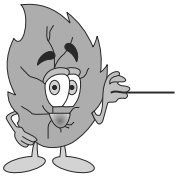


Fig. 2.10 Food web-2

2.6 BIOGEOCHEMICAL CYCLES

Out of the numerous elements some of the elements found on the earth are very much essential for living beings which are called *essential nutrients*. These nutrients which are also called biogeochemical are used by organisms from earth for their growth of biomass and metabolism. As described in food chain, the nutrients are taken by the producers and transferred to consumers from one level to other and finally by the action of decomposers returned back to soil and/or water to be used by producers.

This cyclic flow of material between biotic and abiotic environment is called *biogeochemical cycle*. In the biosphere, these nutrients exist as a pool either in lithosphere and/or in water in the atmosphere.



DID YOU KNOW?

The biogeochemical cycles are powered directly or indirectly by the sun and are subjected to disturbance by the human activities.

Common biogeochemical cycles are:

1. Hydrological cycle
2. Carbon Cycle
3. Nitrogen Cycle
4. Oxygen Cycle
5. Phosphorus Cycle
6. Sulfur Cycle

1. **Hydrological Cycle**: In this cycle, there is constant exchange of water among air, land and sea as well as between living and nonliving environment. Therefore, it is also called *water cycle*.

Step Wise Explanation of Hydrological Cycle

(a) Water evaporates from hydrosphere (i.e., oceans, seas, lakes, ponds and rivers) into the atmosphere as water vapours and form clouds.

(b) The evaporation of water from the leaves of the plants which is called transpiration and loss of moisture from earth and human activities also joins the atmosphere to become part of clouds.

(c) These water vapours condense and lead to the precipitation in the form of rain, snow and hail on earth to become again part of hydrosphere. A part of rain water infiltrates into the soil and percolate deep to join the water table and become part of unconfined and/or confined aquifer for the use of living beings. Rest of water content, flows on the ground as surface water called *runoff* which finally passing through different rivers reaches into the oceans and seas. Again, evaporation of water from hydrosphere forms clouds and cause precipitation and thus, the cycle continues.

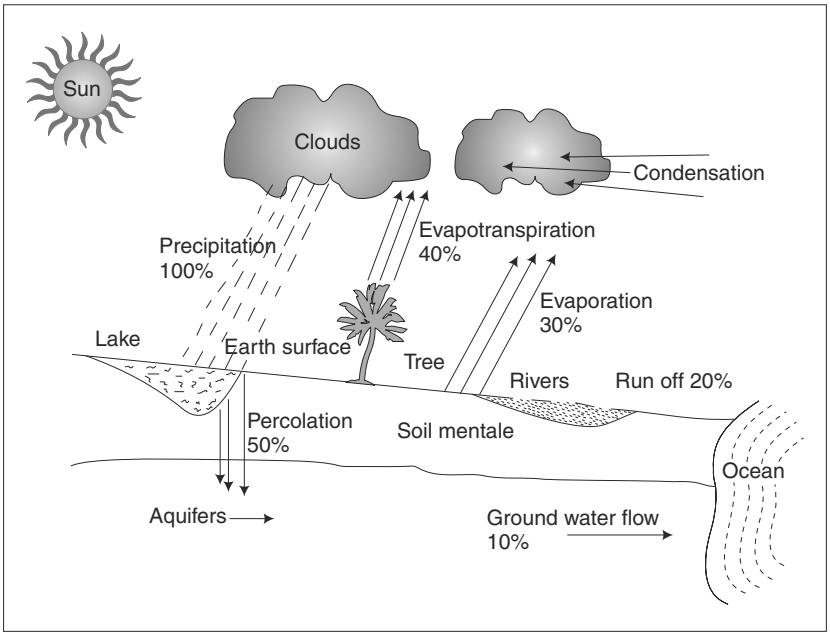


Fig. 2.11 Hydrological Cycle

Entry of water into living beings through physical environment and its return to the physical environment is called *biological water cycle*. Aquatic plants and animals obtain water from their surroundings and this water returns back to atmosphere by excretion process during their life and after their death.

2. **Carbon Cycle**: Carbon is one of the most essential compounds for all organisms. In biotic form, it is in forms, as carbohydrates, lipids, amino acids, enzymes and hormones, etc. In abiotic form, it is as carbon dioxide in air and carbonates and bicarbonates in water and as carbonates rocks (graphite), fossils and minerals in lithosphere.

Step Wise Explanation of Carbon Cycle

(a) Atmospheric carbon in terms of CO_2 is utilised by producers to get energy and biomass as explained below in photosynthesis process.

(b) Dead organic matters of producers and animals are decomposed by the microbes to liberate CO_2 back in the atmosphere.

(c) Respiration of living things and combustion of coal, oil and gas also returns CO_2 into the atmosphere.

(d) This atmospheric CO_2 is again utilised by producers to get energy and biomass through photosynthesis process and thus the cycle continues.

In photosynthesis process, carbon dioxide is utilised in presence of water and sun light by the green plants that contain chlorophyll in their leaves for the formation of their food.

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sun radiations}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2$$

$$CO_2 + 2H_2O \xrightarrow{\text{Chlorophyll and sun light}} \underset{\text{New algae cell}}{(CH_2O)} + O_2 + H_2O$$

Fraction of this carbon fixed by the producers, enters from one consumer to other consumers (as one trophic level to other trophic level) through the food chain and finally it joins the atmosphere as carbon dioxide after decomposition of dead organic matter. Oxygen is librated as by-product in the photosynthesis process which is again used by living beings (animals and plants) in respiration process. Carbon content in the abiotic environment returns by the following processes:

1. Decomposition of dead organic matter by microbes
2. Burning of fossil fuels
3. Respiration of living beings
4. Volcanic eruptions and forest fires

3. **Nitrogen Cycle**: Atmosphere consists of about 78% nitrogen which is in molecular form and can not be used directly by living organisms, therefore it is to be fixed or combined with other elements like carbon, hydrogen and oxygen to convert into usable form to plants. This process of making atmospheric nitrogen available for plants is called 'nitrogen fixation'.

Step Wise Explanation of Nitrogen Cycle

(a) Atmospheric nitrogen is fixed by bacteria and/or photochemical and electrochemical processes to make it usable to producers.

(b) Energy and biomass is transferred from producers to consumers as per food chain.

(c) Dead organic matters of producers and animals are decomposed by the decomposers by ammonification process to form ammonia.

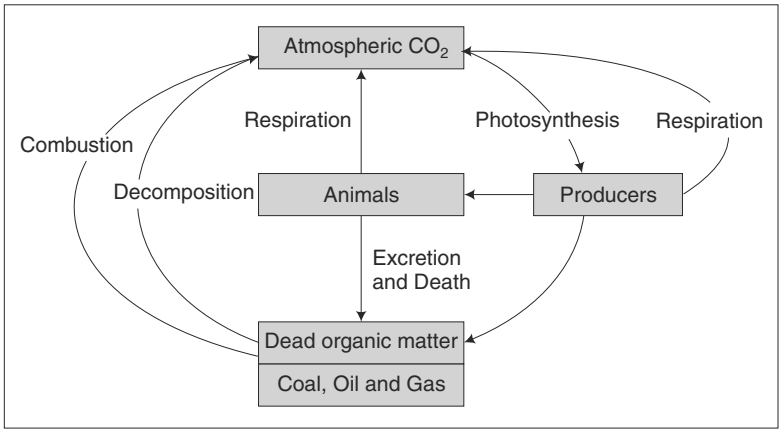


Fig. 2.12 Carbon Cycle

(d) Aerobic bacterial decomposition of ammonia forms nitrite which finally converts to nitrate which is used by the producers.

(e) Nitrate also converts to molecular nitrogen (N_2) by the denitrification process which can be fixed bacterially for the use of producers and thus the cycle of nitrogen continues.

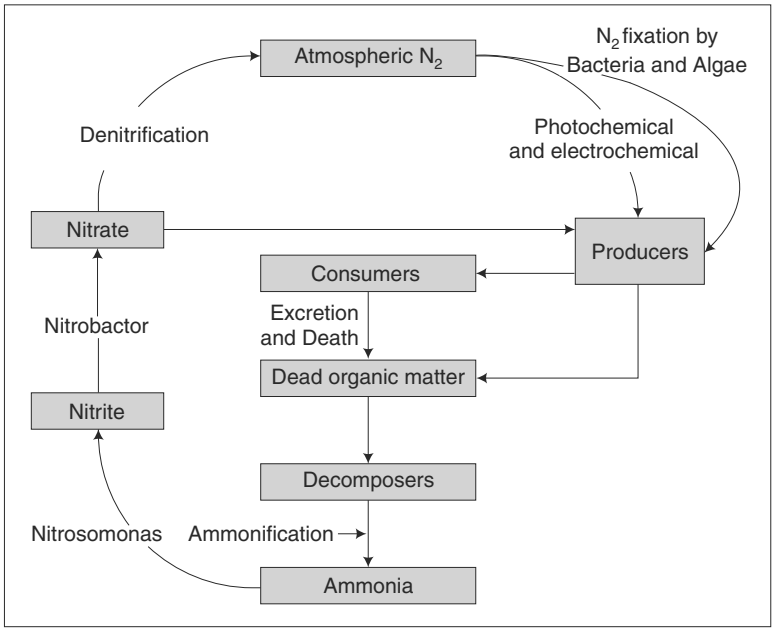


Fig. 2.13 Nitrogen Cycle

Major amount (around 70%) of the nitrogen is fixed by biological action as nitrifying bacteria like azatobactor, rizobium(symbiotic bacteria), and blue green algae (cynobacteria) convert molecular nitrogen of atmosphere into organic nitrogen which in turn are converted to ammonia by the process of ammonification. In physical action, atmospheric nitrogen combines with oxygen by photochemical and electrochemical reaction to form oxides of nitrogen and finally nitrates. Plants absorb nitrogen from soil in the form of nitrate or ammonia to form proteins and nitrogenous compounds. Part of these proteins also convert to animal protein as animals eat plants. These nitrogenous compounds pass through the food chain from producers to top carnivores and finally nitrogenous waste of dead plants and animals decomposed by micro-organisms (bacteria and fungi) to ammonia. Most of the ammonia in the soil produces nitrate by the action of nitrifying bacteria (nitrosomonas and nitobactor) in aerobic condition as shown below.

This nitrate becomes available to plants for absorption.

In anaerobic conditions denitrifying bacteria (pseudomonas and thiobacillus) convert nitrate into molecular nitrogen by the process called denitrification process as shown above.

4. **Oxygen Cycle**: Presence of oxygen is must for the existence of life on earth. The atmosphere is a major pool for oxygen where it is around 21% of the air.

Step Wise Explanation of Oxygen Cycle

(a) Atmospheric oxygen is taken by animals, humans and plants for respiration whose end product is CO_2.

(b) Oxidation of organic matter also consumes oxygen releasing CO_2.

(c) In presence of sun light, water and CO_2 green plants prepare their food and thus consume CO_2 and release oxygen by process of photosynthesis.

(d) This oxygen joins atmospheric oxygen which can be utilised by animals, humans and plants for respiration and thus the cycle continues.

During the respiration process, animals and plants take oxygen and release it in the form of carbon dioxide. In the process of photosynthesis, all green plants take carbon dioxide and water in the presence of sunlight to release molecular oxygen as by product. This whole process reaction is shown below.

Photosynthesis:

$$6CO_2 + 6H_2O \xrightarrow{\text{Chlorophyll and sun light}} C_6H_{12}O_6 + 6O_2$$

Respiration:

$$(CH_2O) + O_2 \longrightarrow CO_2 + H_2O$$

Thus, plants take oxygen during respiration at night while they release oxygen during day time by photosynthesis but production of oxygen by plants is almost ten times higher than the consumption. Aerobic bacteria utilise oxygen in oxidation process to oxidise organic waste and release carbon dioxide. Thus, the oxygen cycle continues.

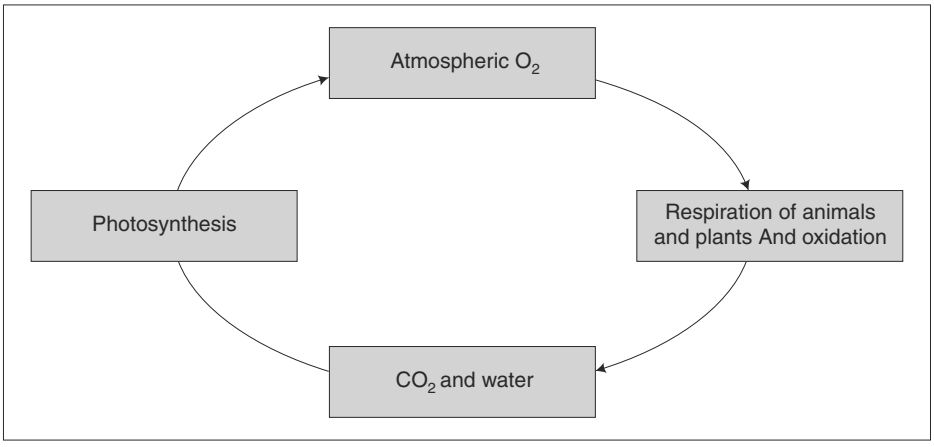
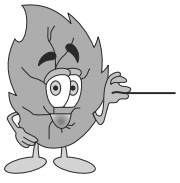


Fig. 2.14 Oxygen Cycle



DID YOU KNOW?

It is estimated that the forest spread in one hectare area absorbs about 30 tones carbon dioxide annually and produces about 10 tones of oxygen annually.

Symbiosis is the process in which two different species are mutually benefited as men get oxygen from plants and plants get carbon dioxide from men.

Human beings and animals thus consume the oxygen librated by plants so they are in symbiosis with plants.

5. **Phosphorus Cycle**: Phosphorus is one of the essential nutrients which is used for the growth, maintenance, functioning of DNA and RNA of the cell. It acts as a limiting or

regulating element in the productivity of organism. Phosphorus exists in soluble and insoluble forms in rocks and soil. Plants convert inorganic phosphate into organic phosphate which is supplied to consumers via food chain. After death and decay of living things, phosphate returns back to soil.

Step Wise Explanation of Phosphorus Cycle

(a) Phosphate is taken by living things for their growth and maintenance from either soil and/or water which is transferred as per food chain from one level to other.

(b) Dead matter and excretion of waste releases phosphate for accumulation in nutrient pool.

(c) Marine organisms also form phosphate rocks using marine sediments which join nutrient pool of water due to runoff.

(d) Living beings can now utilise phosphate from nutrient pool and thus, the cycle continues.

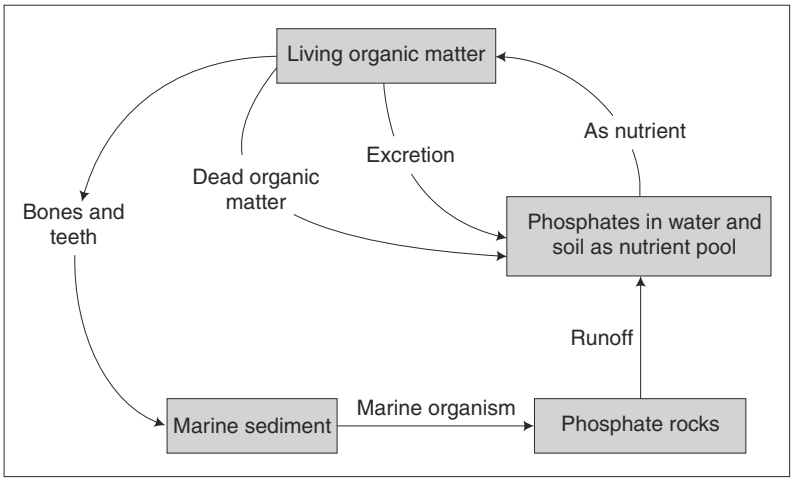


Fig. 2.15 Phosphorus Cycle

6. **Sulfur Cycle**: The sulfur is required for the organism for synthesis of amino acids and proteins. It plays an important role in the regulation of other nutrients including oxygen and phosphorus. Sulfur cycle involves uptake of SO_4^{-2} by producers largely through their roots to release and transform sulfur into H_2S, sulfides and molecular sulfur(S). Sulfur in the atmosphere comes from decomposition and/or combustion of organic matter, fossil fuels and volcanic eruptions. In atmosphere, its most common form is SO_2 which is washed out due to rain as H_2SO_4 and reaches into oceans and seas to form sedimentary rocks. Animals get sulfur from plants and water. Organic sulfur is mineralised after decomposition of dead

organic matter. Under anaerobic conditions, sulphides formation takes place which may be toxic to biological action but sulfur bacteria convert it to sulphates. H_2S is released into the atmosphere from marshy and water logged areas which are oxidised into SO_2 in atmosphere. Industrial processes also emit SOx and H_2S into the atmosphere which become a part of acid rain and enters in soil and water for the use by plants.

Step Wise Explanation of Sulfur Cycle

(a) Plants and animals use sulfur as sulphate for synthesis of amino acids and proteins.
(b) Combustion of dead organic matter and aerobic conversion of sulphides releases SOx in atmosphere which is finally converted to sulphates as shown below.
(c) Sulfur bacteria may convert sulphides to elementary sulfur and finally to sulphates.
(d) This sulphate is used by living beings and thus, the cycle continues.

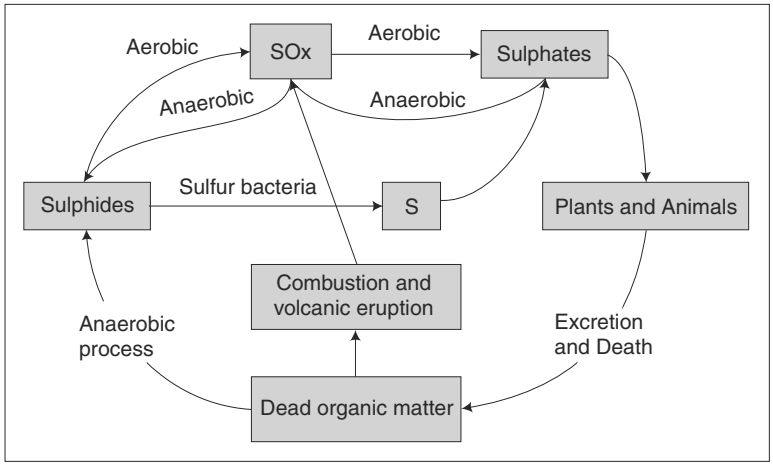


Fig. 2.16 Sulfur Cycle

2.7 MAJOR ECOSYSTEMS

An ecosystem is a system where living organisms and their corresponding physical environment interact together as a complete self supported unit. Different ecosystems present in the world are different from each other depending upon the existence of the types of species, amount of rainfall and intensity of radiant energy. An ecosystem may be a small aquarium to as big as the whole earth. Some of the important major ecosystems are forest ecosystem, grassland ecosystem, desert ecosystem, aquatic or marine ecosystem and estuarine ecosystem.

1. **Forest Ecosystem**: Forest ecosystems consist of a wide variety of trees, herbs, shrubs, climbers, grass, algae and numerous species of animals and birds. Forest ecosystems generally are known for having good productivity and diversity compared to other ecosystems.

Functions of Forest Ecosystem

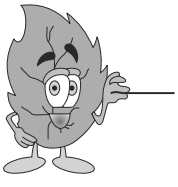
Following are the main functions of forest ecosystem:

- To regulate the hydrological cycle
- To give shelter and food directly and indirectly to animals and birds
- To control the atmospheric pollution and refreshing environment
- To reduce the abrasion of soil due to storms, floods and heavy winds
- To encourage the water absorption in soil and increase humidity

Forest ecosystem basically consists of both biotic and abiotic components interacting in the forest region with each other.

(a) ***Biotic components*** – It includes producers, consumers and decomposers present in the forest region.

- **Producers**–Producers in the forest ecosystem are mainly different types of trees like (i) Deciduous trees (trees which lose their leaves in winter) are found in the region of moderate rainfall, (ii) Evergreen trees (trees which keep their leaves through out the year) are found in the region of good and high rainfall, (iii) Coniferous trees (trees which grow in Himalayan region) are found in the region where temperature is low. (iv) Desert trees (trees which have thorns) are found in the region of low rainfall. (v) Mangrove trees are found in coastal and river delta regions and different types of shrubs, herbs and grasses.



DID YOU KNOW?

One tenth of world's known species of plants and animals are found in the Himalayas. If the Himalayas were not present, the rain clouds could pass over the subcontinent, leaving India a desert.

- **Consumers**–Main primary consumers found in forest area are small animals like grass hopper, ants, beetles, bugs, spiders, flies, moles and squirrels while big primary consumers includes deer, rabbit, rat, fox, mongoose, nilgai and elephant. Among secondary and tertiary consumers, the main animals are bird,

snake, lizard, frog, wolf, beer, etc. Top carnivores are hawk, lion and tiger while omnivores who feed on animals and plants are human beings.

- **Decomposers**–In a forest, wide varieties of microbes are generally found but main decomposers are bacteria, fungi and worms.

(b) ***Abiotic components*** – To make the forest ecosystem completely functional, abiotic component part is very important. It includes inorganic substances like carbon dioxide, water, air, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients; organic substances like carbohydrates, lipids and proteins, and physical factors like sun light, rainfall, soil, temperature and pH.

Fig. 2.17 Picture showing Forest Ecosystem
Source: Google.com

2. **Grassland Ecosystem**: Grasslands are basically areas covered by grass instead of big trees because of low rainfall (25–70 cm) compared to forest areas.

Functions of Grassland Ecosystem

Following are the main functions of grassland ecosystem:

- To increase the fertility of soil and to regulate the productivity of ecosystem.
- To give shelter and food directly and indirectly to animals, insects and birds.
- To have more cultivated grasses and grain crops.
- To reduce the leaching of minerals due to low rainfall.

Grassland ecosystem also consists of both biotic and abiotic components interacting with each other.

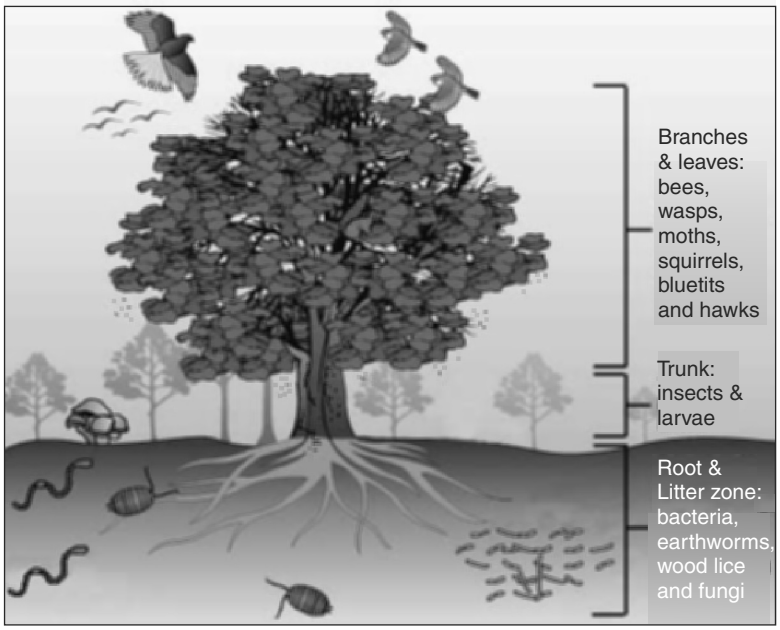


Fig. 2.18 Picture showing Tree Ecosystem
Source: google.com

(a) ***Biotic components*** – It includes producers, consumers and decomposers present in the grassland ecosystem.

- **Producers**- Producers in the grassland ecosystem are mainly different types of shrubs, herbs and grasses.
- **Consumers**- Main primary consumers found in grassland ecosystem are like grass hopper, ants, termites, bugs, deer, rabbit, sheep, cow, and buffalo. Among secondary and tertiary consumers main animals are bird, snake, lizard, frog, jackal, hawk, eagle and vulture.
- **Decomposers**- In grassland ecosystem, the main decomposers are bacteria and fungi which bring back minerals to soil.

(b) ***Abiotic components*** – It includes inorganic substances like carbon dioxide, water, air, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients; organic substances like carbohydrates, lipids and proteins, and physical factors, like sun light, rainfall, soil, temperature and pH.

(a) (b)

Fig. 2.19 Pictures (a) and (b) showing Grass Land Ecosystem
Source: google.com

3. **Desert Ecosystem**: Every desert is somewhat different from another from the point of view of presence of species and properties of soil. Almost all deserts receive less than 25 cm rainfall yearly. Desert areas are very hot during day time because intensive sun light heats the sand while at night they are cold because of absence of clouds. In India, deserts are located in western India and deccan plateau. Most typical desert in India is Thar in Rajasthan and cold desert in Ladakh. The basic components of desert ecosystem are biotic and abiotic components interacting in desert region with each other.

(a) ***Biotic components*** – It includes producers, consumers and decomposers present in the desert region.

- **Producers**–Producers in the desert ecosystem are mainly few varieties of trees like babul and kher, plants like cactus and lichen and some shrubs and grasses. Mainly wide varieties of cactus and other desert plants having thorns and flowers are found in desert.
- **Consumers**–Main primary consumers found in desert ecosystem are rabbit, squirrel and camel (*Jahaj* of desert) among secondary and tertiary consumers main animals are birds (like woodpecker, roadrunner, ostrich and galah etc), snakes, lizard, wolf, desert cat and desert fox, etc.
- **Decomposers**–Due to low rainfall and productivity, the amount of dead organic material generated in desert ecosystem is less. Therefore basically thermophilic bacteria and fungi act as decomposer to degrade dead organic matter.

(b) ***Abiotic components*** – It includes inorganic substances like carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates)

of calcium and magnesium as well as required micro and macro nutrients; organic substances and carbohydrates, lipids and proteins, and physical factors like intensity and speed of wind, sun light, rainfall, soil, temperature and pH.

Fig. 2.20 Picture showing Desert Ecosystem
Source: google.com

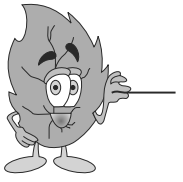
4. **Aquatic Ecosystem**: Aquatic ecosystems include the ocean, ponds, lakes, rivers and wetlands. There are three main types of organisms present in aquatic system (i) *Planktons*: Free floating microbes which could not swim in waves and current called Phytoplankton and tiny organisms feed on these Phytoplankton called *Zooplankton* (ii) *Nektons*: These are good swimmers which include small fishes, turtles and big fishes (iii) *Benthos*: Mostly resides at the floor of water bodies so called bottom dwellers like Sponges, crawfish, oysters and octopi. It also includes organisms like worms and crabs which burrows sand.

From the quality of water point of view, aquatic systems are of two types- (i) Salt water ecosystem which includes ocean or marine ecosystem and estuarine ecosystem, and (ii) Fresh water ecosystem which includes pond or lake ecosystem and river or stream ecosystem.

Ocean or Marine Ecosystem

Ocean or marine ecosystem is the largest ecosystem present on earth and it is characterised by the high concentration of salts and minerals which make it more stable. It includes major oceans like Atlantic, Pacific, Indian and Arctic. In ocean ecosystem, salinity, light, nutrients

and water current are crucial factors rather than temperature and rainfall. Large ocean ecosystems have two parts, (i) *Coastal zone*: The coastal zones have shallow depth so light can penetrate and hence coral reefs are found in this zone. Coral reefs are basically colonies of tiny organisms called Polyps which secrets calcium carbonate to made protective cell.



DID YOU KNOW?

Coral reefs are one of the natural wonders of the ocean. 60% of the world's coral reefs are threatened by the costal development, pollution and over fishing etc.

Coral reefs are colourful and aesthetically good looking and considered among highly productive ecosystem. Just inland of coral reefs mangroves are found which are salt tolerant trees grow in shallow marine sediments.

Mangrove forests are also found in Indian coastal areas particularly in Andaman and Nicobar Island, West Bengal (Sundarban) and Goa (ii) *Open ocean zone*: It has deep depth of water and is therefore more stable and consists of big fishes.

Basic components of ocean ecosystem are biotic and abiotic components interacting in salty water region with each other.

(a) ***Biotic components*** – It includes producers, consumers and decomposers present in the marine ecosystem.

- **Producers**–Producers in the marine ecosystem are mainly phytoplankton, large marine plants, mangroves and sea weeds.
- **Consumers**–Main primary consumers found in marine ecosystem are zooplankton, protozoa, crustacean and small fishes while among secondary and tertiary consumers main animals are big fishes like shark, whale, etc.
- **Decomposers**–It includes basically bacteria and fungi which act as decomposers to degrade dead organic matter.

(b) **Abiotic components**: It includes inorganic substances like carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients, organic substances like carbohydrates, lipids and proteins, physical factors like intensity and speed of current, cyclones and storms, sun light, rainfall, soil, temperature and pH.

Fig. 2.21 Picture showing Marine Ecosystem
Sources: google.com

(a) (b)

Fig. 2.22 Pictures showing (a) Well developed Coral reefs; (b) Destruction of Coral reefs
Sources: google.com

Estuarine Ecosystem

Estuarine is the area where fresh water from the river mixes with ocean water. Thus, estuarine basically exists on the ocean coast where the bay enters into the open sea and

therefore presence of high salt and mineral concentration is generally seen in estuarine ecosystem. Basic components of estuarine ecosystem are biotic and abiotic components interacting in estuarine and delta region with each other.

(a) **Biotic components** – It includes producers, consumers and decomposers present in the estuarine ecosystem.
- **Producers**–Producers in the estuarine ecosystem are mainly marsh grasses, seaweeds, mangroves and phytoplankton.
- **Consumers**–Main consumers found in marine ecosystem are zooplankton, protozoa, crustacean, oysters, crabs and small to medium fishes.
- **Decomposers**–It includes basically bacteria and fungi which act as decomposer to degrade dead organic matter.

(b) **Abiotic components** – It includes inorganic substances like carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients, organic substances like carbohydrates, lipids and proteins, and physical factors like intensity and speed of current, cyclones and storms, tides, sun light, rainfall, soil, temperature and pH.

Pond or Lake Ecosystem

Pond or lake ecosystem is the area where fresh water almost remains stagnant. Basic components of pond or lake ecosystem are biotic and abiotic components interacting in pond or lake with each other.

(a) **Biotic components** – It includes producers, consumers and decomposers present in the pond or lake ecosystem.
- **Producers**–Producers in this ecosystem are mainly phytoplankton, attached algae and other free floating plants like macrophytes (Hydrilla and Hyacinths).
- **Consumers**–Main consumers found in this ecosystem are zooplankton, protozoa, crustacean, insects, crabs and small to medium fishes like game fish, crocodiles and many birds like dove and crane.
- **Decomposers**–It includes basically bacteria and fungi which act as decomposer to degrade dead organic matter.

(b) **Abiotic components** – It includes inorganic substances like carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients, organic substances like carbohydrates, lipids and proteins, and physical factors sun light, rainfall, soil, dissolved oxygen, temperature and pH.

(a) (b)

Fig. 2.23 Pictures showing (a) Lake ecosystem; (b) Pond ecosystem
Sources: google.com

River or Stream Ecosystem

River or stream ecosystem is the area covered by the running water bodies where fresh water flows with high current in rainy season while in other seasons, the flow takes place calmly. Due to flowing conditions, dissolved oxygen and suspended solids are generally found more in these ecosystems. Basic components of river or stream ecosystem are biotic and abiotic components interacting in river or stream with each other.

(a) **Biotic components** – It includes producers, consumers and decomposers present in the pond or lake ecosystem.

- **Producers**–Producers in this ecosystem are mainly phytoplankton, floating and attached algae and water grasses.
- **Consumers**–Main consumers found in this ecosystem are zooplankton, protozoa, crustacean, flat worms, crabs, snails and small to medium fishes, crocodiles and many birds like dove and crane.
- **Decomposers**–It includes basically bacteria and fungi which act as decomposer to degrade dead organic matter.

(b) **Abiotic components** – It includes inorganic substances like carbon dioxide, water, dissolved oxygen, nitrogen and inorganic salts (phosphates, nitrates and sulphates) of calcium and magnesium as well as required micro and macro nutrients, organic substances like carbohydrates, lipids and proteins, physical factors like sunlight, rainfall, suspended solids, dissolved oxygen, temperature and pH.

Fig. 2.24 Pictures showing River Ecosystem
Sources: google.com

2.8 ECOLOGICAL PYRAMIDS

Ecological pyramid is a graphical representation of variations in ecological parameters like number of organisms, biomass of organisms and energy with different trophical levels. In ecological pyramid producers form the base of pyramid and top carnivores exist at the top or the vertex of pyramid and there is more than 90% loss in energy and biomass as well as in numbers at every level. Thus, there are three types of pyramids: (1) Pyramid of numbers, (2) Pyramid of biomass and, (3) Pyramid of energy. This concept was given by British ecologist Charle's Elton first in 1927, so these pyramids are also called *Eltonian pyramids*. Steep side slope of pyramid suggest high primary production, good energy transfer and utilisation.

1. Pyramid of Numbers

In this pyramid, the number of organisms per unit area is plotted with different trophical levels. Producers (plants) remain at the base with maximum numbers followed by herbivores which eat plants in the next level. Similarly, fewer primary carnivores are supported by these herbivores in the next level followed by lesser numbers of carnivores in secondary and tertiary levels. Top carnivores are very few in numbers like Lion and Tigers who eat other herbivores and carnivores but are not eaten by other carnivores when a live.

Advantages and Drawbacks of Pyramid of Numbers

This type of pyramid has all three types like upright pyramid, inverted pyramid and spindle shaped pyramid. Some of the main drawbacks are: (i) No account for individual size of specie, (ii) No consideration for biomass of individuals.

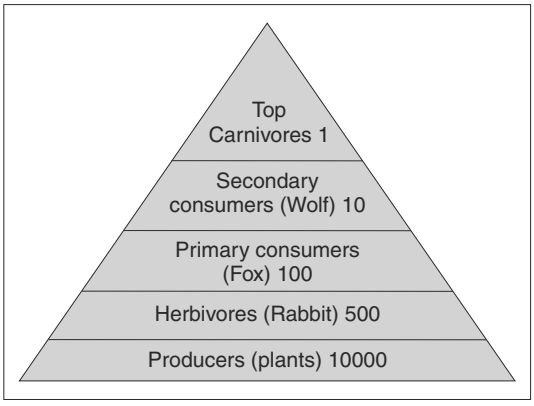


Fig. 2.25 Pyramid of numbers in forest

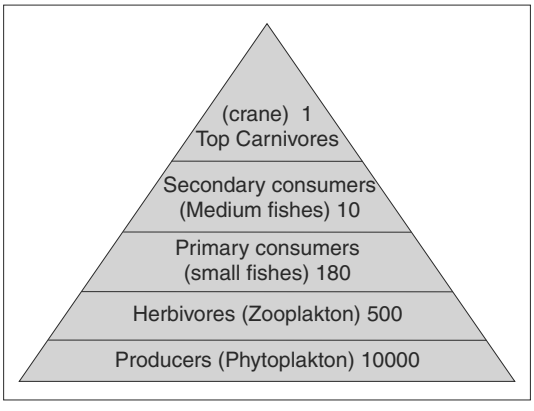


Fig. 2.26 Pyramid of numbers in pond

A huge tree provides shelter and food to several birds and organisms therefore in a tree ecosystem pyramids are inverted as shown below.

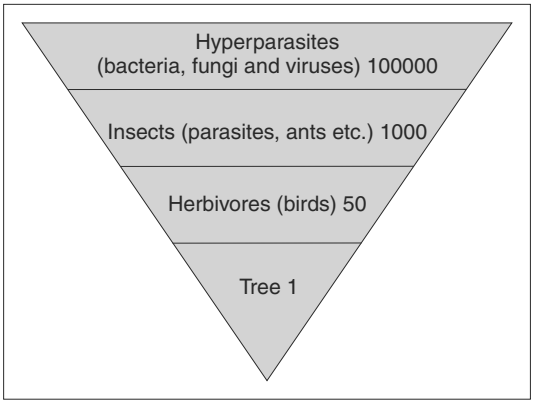
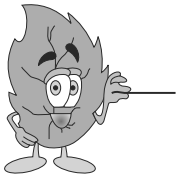


Fig. 2.27 Pyramid of Numbers in big tree



DID YOU KNOW?

Colombia is the world's most bird-diverse country with more than 1800 species of birds while India with 1250 species ranks among top ten.

Out of around 9800 bird species, about 1200 bird species are likely to become extinct by the end of this century. Around 800 species are already endangered critically.

2. Pyramid of Biomass

The amount of organic matter present in any organism at particular environment is called its *biomass* which can be measured as wet or dry weight per unit of specie. In this pyramid, biomass of organisms per unit area is plotted with different trophical levels. Producers (plants) remain at base with maximum biomass followed by herbivores which eat plants in the next level. Similarly, there is progressive decrease in biomass of primary carnivores to secondary and tertiary carnivores. Top carnivores are very few in numbers like Lions and Tigers, so their biomass per unit area is least in this pyramid.

Advantages and Drawbacks of Pyramid of Biomass

This type of pyramid is always upright pyramid for terrestrial ecosystem and inverted pyramid for aquatic ecosystem. Some of the main drawbacks are: (i) No account of age of individual specie, (ii) No consideration of seasonal effects on biomass of individuals and, (iii) Energy contents are different of different biomasses.

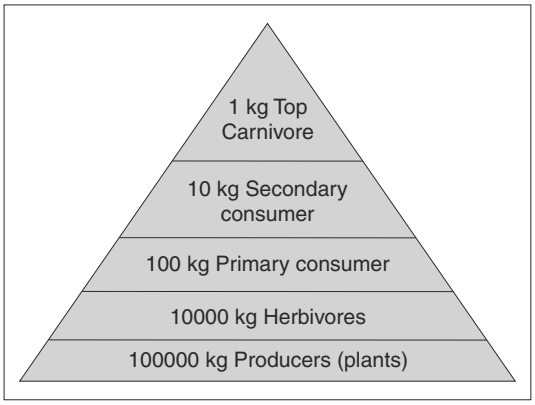


Fig. 2.28 Pyramid of Biomass in Terrestrial Ecosystems

In an aquatic ecosystem pyramid of biomass is inverted because of less biomass per unit area of producers compared to high biomass per unit area of carnivores as shown below.

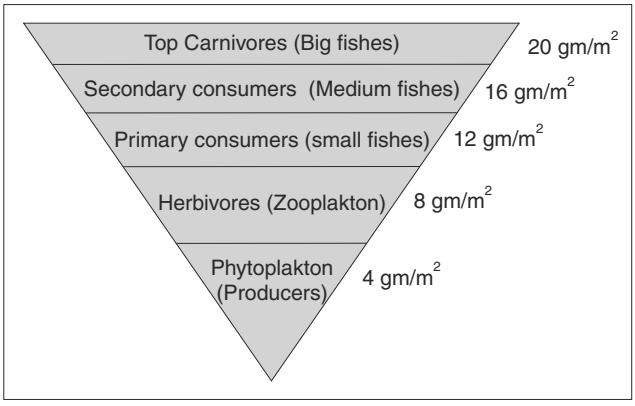


Fig. 2.29 Inverted Pyramid of Biomass in pond

3. Pyramid of Energy

All the organisms perform different activities, and to do those activities they are required to gain energy which they get from their food. Energy trapped by an organism is expressed as Kcal/m^2/yr. In this pyramid, energy trapped by different organisms per unit area and time, is plotted with different trophical levels. Producers (plants) remain at the base with maximum energy followed by herbivores which eat plants in next level. Similarly, there is progressive decrease in energy per unit area and time of primary carnivores to secondary

and tertiary carnivores. Generally it is assumed that each kilocalories unit is equivalent to 220 g body weight or around 4.5 calories equivalent to 1 g dry weight.

Advantages and Drawbacks of Pyramid of Energy

This type of pyramid is always upright pyramid and is based on productivity. This pyramid gives the idea of energy loss at each trophic level. Some of the main drawbacks are: (i) Huge loss of energy at each trophic level, (ii) Energy is lost as heat in each level and its flow is unidirectional and noncyclic.

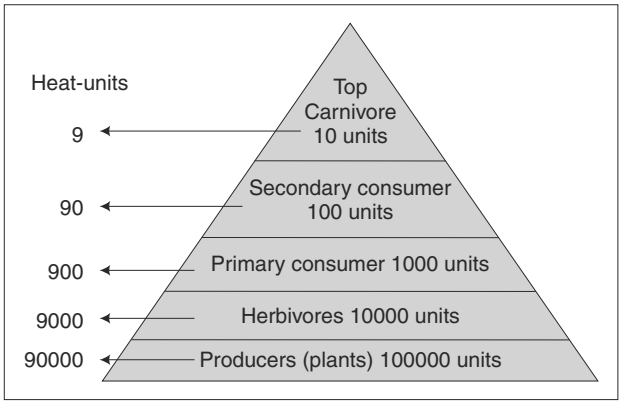


Fig. 2.30 Pyramid of Energy

CASE STUDIES

Biosphere Program: UNESCO (United Nations Educational Scientific and Cultural Organisation began the man and biosphere program in 1971. As per this program, the plan was to establish biosphere reserves in different countries and by the year 2008 there were 531 biosphere reserves in 105 countries. The four Indian biosphere reserves are in the Nilgiris, the Gulf of Mannar, Nanda Devi, and the Sunderbans.

Conservation of Ecosystem: The forest of Bhutan which covers about 72% area have immense biodiversity. This ecosystem supports 7000 species of plants, 165 species of mammals and 700 species of birds. The Bhutan government is also fully committed to conserve its rich biodiversity.

Tundra: The forest generally found in arctic regions are called Tundra. Tundra occurs in the extreme northern latitudes where there are long winters with very short summers. Diversity of species is low and generally mosses, lichens, grasses and dwarf trees are found in Tundra.

Important Terminology

1. *Aquifer*: Permeable or impermeable layer of sediment rock contains water within it.
2. *Ammonification*: Conversion of dead organic matter (proteins and amino acids) into ammonia.
3. *Biomass*: Mass of organic material of living beings.
4. *Biological nitrogen fixing*: Fixation of atmospheric nitrogen into soil by bacterial action.
5. *Detritus*: Dead plants and animals.
6. *Food web*: A network of food chains indicating multiple feeding connections.
7. *Macrophytes*: Rooted plants found in aquatic ecosystem in shallow water bodies.
8. *Productivity*: Rate of biomass production by organism.
9. *Respiration*: Process in which organisms use oxygen for maintenance purposes to release carbon dioxide.
10. *Coral reefs*: Formation of colorful protective layer of limestone by colonies of tiny organisms in coastal areas.
11. *Symbiosis*: Process in which two species are mutually benefited.
12. *Ecological Niche*: Role of a single specie in an ecosystem.

Review Questions

1. Define ecology and give its classification.
2. What is ecosystem? Discuss the different components of an ecosystem.
3. Define autotrophs and heterotrophs and discuss their role in an ecosystem.
4. Explain schematically, the energy and nutrients flow in ecosystem.
5. Differentiate (a) food chain and food web (b) Autotrophs and Heterotrophs
6. Explain at least two food chains using block diagram.
7. What is food web? Describe with examples.
8. What are biogeochemical cycles? Explain nitrogen cycle using sketch.
9. Explain with sketch (a) Carbon cycle (b) Oxygen Cycle
10. Describe with sketch the functioning of hydrological cycle.
11. What are ecological pyramids? Explain pyramid of numbers.
12. Why pyramid of biomass for aquatic ecosystem is inverted? Draw and discuss it.

13. What is Nitrogen fixation? Explain the functioning of nitrogen cycle with sketch.
14. What are essential nutrients? Describe with sketch functioning of phosphorus cycle.
15. Why is the sulfur required for proper functioning of an organism? Describe the sulfur cycle.
16. Enumerate different major Ecosystems and discuss the functions of forest ecosystem.
17. What are different marine ecosystems? Differentiate estuarine and lake ecosystem.
18. What is desert ecosystem? Describe its components parts.
19. Write short note on pyramid of numbers for a big tree.
20. Write advantage and drawbacks of energy pyramid.

Objective Type Questions

1. The basic components of an ecosystem are
   (a) Biotic (b) Abiotic
   (c) Biotic and Abiotic (d) None of these
2. The abiotic components of ecosystem are
   (a) Sunlight only (b) Soil only
   (c) Temperature and humidity only (d) All of above
3. The biotic components of ecosystem are
   (a) Producers only (b) Consumers only
   (c) All microbes (d) All of above
4. Ecology is defined as
   (a) Study of interaction between living and their nonliving environment
   (b) Study of human beings
   (c) Study of nonliving things
   (d) None of these
5. Autecology stands for
   (a) Study of population of single species (b) Study of communities
   (c) Study of physical environment (d) None of these
6. Synecology stands for
   (a) Study of population of single species (b) Study of communities
   (c) Study of physical environment (d) None of these

7. Edaphic factors are basically related to
   (a) Soil and its characteristics (b) Water and water pollution
   (c) Air quality (d) None of these
8. Autotrophs are defined as
   (a) Those who prepare their own food
   (b) Those who depend on producers for their food
   (c) Can do both things
   (d) None of these
9. Heterotrophs are defined as
   (a) Those who prepare their own food
   (b) Those who depend on producers for their food
   (c) Can do both things
   (d) None of these
10. Saprotrophs feed on
   (a) Dead microbes (b) Vegetables
   (c) Rotten organic material (d) None of these
11. Top level carnivores are
   (a) Microbes (b) Rabbits and foxes
   (c) Tigers and Lions (d) Deer and Elephants
12. Man comes in the category of
   (a) Decomposers (b) Producers
   (c) Carnivores (d) Omnivores
13. Symbiosis means
   (a) Mutual benefit between two species
   (b) Only on specie get benefit
   (c) None is benefitted
   (d) None of these
14. Autotrophs are
   (a) Green plants and vegetables (b) Viruses
   (c) Fungi (d) None of these
15. The process of nitrogen fixation by bacteria is
   (a) Exothermic (b) Endothermic
   (c) Both (d) None of these

16. Food web is defined as
    (a) One food chain (b) Parasitic food chain
    (c) All interconnected food chains (d) None of these
17. Micronutrients are
    (a) Carbon dioxide (b) Nitrogen
    (c) Phosphorus (d) Zinc and cobalt
18. Eutrophication means
    (a) Rich in nutrients (b) Poor in nutrients
    (c) Rich in carbon (d) None of these
19. Energy pyramid is
    (a) Upright (b) Inverted
    (c) Both (d) None of this
20. Number pyramid for a tree is
    (a) Upright (b) Inverted
    (c) Both (d) None of these
21. Biomass pyramid for aquatic ecosystem is
    (a) Upright (b) Inverted
    (c) Both (d) None of these
22. Main source of energy for most of the ecosystems is
    (a) Sun light (b) Trees
    (c) Glucose (d) None of these
23. Loss of moisture from leaves of trees and plants is called
    (a) Transpiration (b) Precipitation
    (c) Infiltration (d) None of these

ANSWERS

1. (c)	2. (d)	3. (d)	4. (a)	5. (a)	6. (b)	7. (a)
8. (a)	9. (b)	10. (c)	11. (c)	12. (d)	13. (a)	14. (a)
15. (b)	16. (c)	17. (d)	18. (a)	19. (a)	20. (b)	21. (b)
22. (a)	23. (a)					

List of questions asked in Gujarat technical University Examinations from this chapter

Q. No.	Details	Marks
Q1.	Explain by drawing a sketch of the Hydrological cycle. **GTU, Jan 2009**	7
Q2.	Write a short note on marine ecosystem. **GTU, Jan 2009**	7
Q3.	Explain in detail different components of ecology. **GTU, Jan 2009**	8
Q4.	Define (a) Ecology, (b) Ecosystem, (c) Trophic level, (d) Carnivores, (e) Ecological Pyramid, and (f) Decomposers **GTU, Jun 2009**	6
Q5.	How has an ecosystem evolved? Give the component parts of an ecosystem. **GTU, Jun 2009**	4
Q6.	Give classification of ecology and write in detail structure and functions of an ecosystem. **GTU, Jun 2009**	7
Q7.	Narrate in detail the energy flow in an ecosystem. Explain one of the models of energy flow you have learnt in class. **GTU, Jun 2009**	7
Q8.	Explain the term food chain and food web with examples of aquatic and terrestrial ecosystem. **GTU, Jun 2009**	7
Q9.	How is balance maintained in ecosystem? Why is ecosystem of large population of one species considered not healthy? **GTU, Jun 2009**	4
Q10.	Describe the importance of biochemical cycle in biosphere. Describe carbon cycle with sketch in detail. **GTU, Jun 2009**	5
Q11.	Give reasons for (a) Decomposers are important in ecosystem (b) Carnivores are more affected by biomagnifications of toxicant **GTU, Jun 2009**	2
Q12.	Describe the concept of ecosystem and explain its relationship among its different parts. **GTU, Jan 2010**	7
Q13.	What do you understand by biogeochemical cycle? Explain oxygen cycle with sketch. **GTU, Jan 2010**	7
Q14.	Give classification of ecology and explain in detail the structure of an ecosystem. **GTU, Jan 2010**	7
Q15.	What is an ecological pyramid? Describe pyramid of mass and energy with sketch. **GTU, Jan 2010**	7

Q16.	Differentiate food chain and food web and explain food chain and food web with one example of each. **GTU, Jan 2010**	7
Q17.	Explain (a) Hydrological Cycle (b) Pond ecosystem **GTU, Jan 2010**	7
Q18.	Answer (a) What are Heterotrophs? (b) What are Herbivores? **GTU, Jun 2010**	2
Q19.	Describe the concept of ecosystem using schematic diagram and explain the relationship among its components. **GTU, Jun 2010**	7
Q20.	What do you understand by decomposers? Describe different types of decomposers and explaining their functioning. **GTU, Jun 2010**	7
Q21.	What is ecological pyramid? Describe its types and explain pyramid of energy with sketch. **GTU, Jun 2010**	7
Q22.	Enumerate aquatic ecosystems and describe the structure of Pond ecosystem stating its characteristics. **GTU, Jun 2010**	7
Q23.	What do you understand by biogeochemical cycle? Explain oxygen cycle with sketch. **GTU, Jun 2010**	7

Chapter 3

POPULATION AND NATURAL RESOURCES

Contents

"The more we exploit nature, The more our options are reduced, until we have only one: to fight for survival."
– Morris K Udall (1922 – 1998)
American Democratic politician

3.1 INTRODUCTION

Population is defined as a group of organisms belonging to a particular type. The change in population per unit area at particular time is called *population growth*. The *birth rate* is defined as the numbers of child birth per 1000 people while *mortality rate* is expressed as the number of deaths per 1000 people. The *population density* is defined as the number of people per unit area in per unit volume of environment. This chapter describes habitation pattern, population growth, population structure and demographic projections in detail. *Natural resources* are basically resources gifted by nature to us like sun light, air, water, plants and animals, soil and minerals. This chapter also includes the detailed description of main natural resources i.e., water resources, forest resources and energy resources and their uses. Indian scenario of all these resources and problems due to over exploitation of these natural resources have been covered in this chapter.

3.2 HABITATION PATTERNS

In the beginning of life on earth, people started living in forests near the river banks to have easy access of food, water and shelter. Around 10,000 years ago, the population of human beings during that time was around five million among which most of the humans were hunters. People started agricultural activities and living in communities for their settlement. As population increased, people started moving from one place to an other, and so revolution in the field of transportation started. Due to pollution in surface water bodies like rivers, lakes and ponds, people start the use of ground water in terms of open well for drinking purposes.

Different environmental factors governing human settlement are given below.

1. **Land**: As population increased, so people started taking over more and more land for human settlements. Land was used to develop infrastructures like roadways, railways, public complexes and industries. These activities caused environmental degradation due to large amount of air, water and land pollution and deforestation.

2. **Food**: With the increase in population, there was a demand for more and more food and so more land was started to be used for agricultural activities. Development of advanced technologies in the field of agriculture caused use of fertilisers and pesticides for increasing productivity which deteriorated the quality of environment and health of common beings.
3. **Water resources**: High population and settlement of human beings in different places caused the problem of water scarcity due to unequal distribution of water resources and unplanned use of these resources for industrialisation and urbanisation.
4. **Energy resources**: Conventional energy resources started depleting due to high demand of increased population for energy.
5. **Forest resources**: Due to increased population, use of more land area for human settlement and industrialisation also increased. Thus, the areas of forest region reduced which caused diminished forest resources available for consumption.
6. **Shelter**: With the increased population, people started settling by constructing kuchcha and pucca houses in cities, towns and villages. By doing so, they separated themselves from the forest ecosystem and thus created an imbalance in the ecology of nearby forest area.

3.2.1 Population Pollution (Over Population)

Population is defined as group of individual species living in particular area at specific time. *Population pollution* is the pollution caused due to overpopulation. *Overpopulation* is the condition when the human population exceeds the maximum carrying capacity of the environment. The maximum carrying capacity of environment is the capacity to support human beings with the availability of food, water, air and shelter and proper waste assimilating system as well as protecting human beings against extremities in environment. Following are the reasons for over population:

1. **High Birth rate**: The crude birth rate is the number of child's birth per 1000 people per year. If the birth rate is high, it implies more number of people will be for human settlement and will therefore cause overpopulation.
2. **Low Death rate**: The crude death rate is the number of deaths per 1000 people per year. Low death rate is basically due to technological advancement in the field of medical science which reduced the mortality rate by providing better medical facilities to human beings.
3. **Migration**: People from towns and villages generally migrate to cities in search of jobs and better living standards which overpopulates the cities comrade to villages.

Similarly, people from developing countries try to migrate to developed countries making them overpopulated.

4. **Illiteracy**: People of lower and poor classes generally have larger families due to poor education facilities. In India, particularly in villages, due to religious reasons and/or due to eagerness to have a male child people tend to have big families which can be resolved by proper education.

Table 3.1 Population of four metro cities of India

Name of city	*Population in 2001 in million*	*Population in 2010 in million (Estimated)*
Mumbai	11.978	13.830
Delhi	9.879	12.565
Kolkata	4.572	5.138
Chennai	4.343	4.616

Source: US Census Bureau

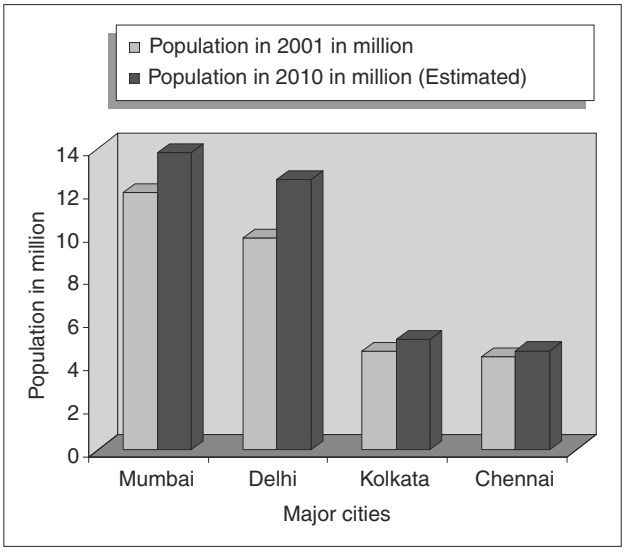


Fig. 3.1 Population of metro cities of India

3.2.1.1 Population Explosion and its Effects

When the human population increases, it is termed as *population explosion*. Similarly, if the population of human beings decreases, it is termed as *population crash*. The population of India which was around 350 million in 1947 has now crossed one billion after 2003. Following are the effects of population explosion:

Table 3.2 Population of top ten countries in 2010

Country	*Population in million*	*%age of world population*	*Rank*
China	1330	19.5	1
India	1173	17.3	2
United Nations	310	4.5	3
Indonesia	242	3.5	4
Brazil	201	2.8	5
Pakistan	177	2.5	6
Bangladesh	158	2.4	7
Nigeria	152	2.3	8
Russia	139	2.0	9
Japan	127	1.8	10

Source: World population data sheet

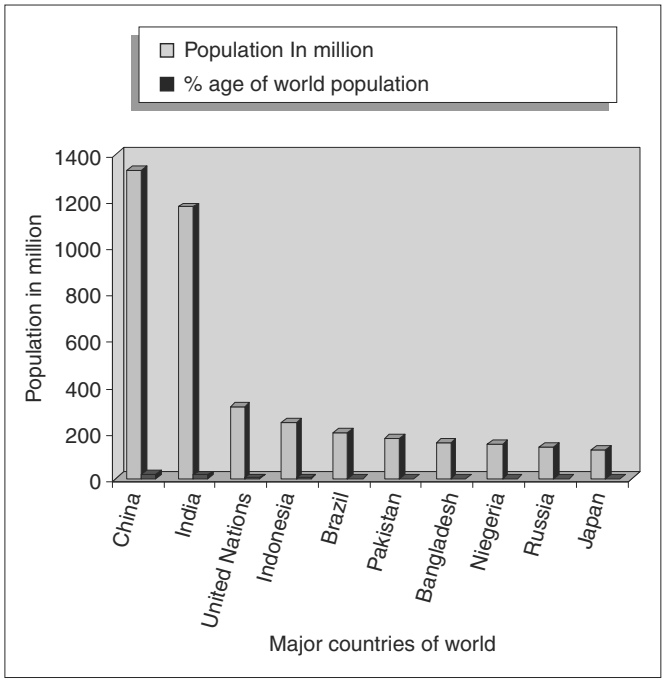


Fig. 3.2 Population of major countries of world

1. **High demand of basic needs like food, water and services**: Population explosion causes scarcity of food and increase in the prices of food items. Shortage in agricultural land and water may also cause starvation in some parts. Population

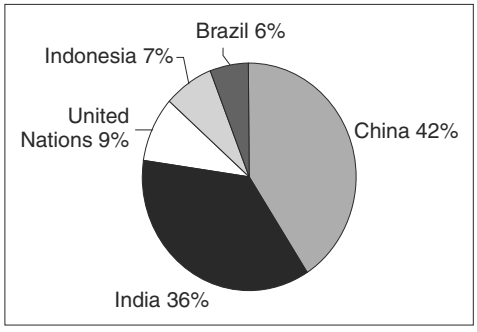
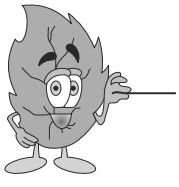


Fig. 3.3 Percentage population of top five major countries of the world in 2010

explosion results in high growth rate which causes problems related to shelter due to less availability of land and high cost of houses, particularly in cities. It also leads to the formation of slums in big cities. It sharpens the problem of availability of drinking water mainly in the summer season. This shortage of water poses other problems like unhygienic conditions and health problems. It creates problems like rush in transportation facilities, education facilities, medical facilities and other basic facilities required by the people in their day to day life.

2. **Reduction in natural resources**: Population explosion causes depletion of different natural resources due to more consumption of these resources by the people. It leads to high consumption of fossil fuels, minerals and forest resources.
3. **Generation of huge quantity of waste**: Population explosion results in generation of wastewater, industrial effluents and solid waste which poses the stresses over the facilities for disposal of wastewater.
4. **Other**: Population explosion also results in some other problems associated with the daily functioning of human life as mentioned below.
   (a) Increase in migration rate and reduction in living standard of people.
   (b) Reduction of agricultural land
   (c) Energy crisis
   (d) Increase in unemployment
   (e) Deterioration in the quality of environment due to pollution in soil, air, and water.



DID YOU KNOW?

Problem of unemployment is now become global problem. In India for every 10 workers there are 25 non working dependents for feed.

3.2.2 Population Growth

Population growth is the change in population at a particular time in a particular space. Population growth is positive when the rate of population increase is positive with time while it is negative when the rate of populations declines with time. *Doubling time* is the time when the population doubles. The population reached 500 million at the end of fourteenth century. This figure of population became six billion in 1999 and is expected to cross the nine billion mark by 2050. There are two theories related to population growth.

1. **Malthusian theory**: As per Malthusian theory, human population increased with exponential rate while the ability to grow food increased arithmetically. Malthus theory was based on the assumption that power of population is much more than the power of earth to provide subsistence for man. He concluded that human population will outgrow the assimilating capacity of land but natural disasters, famines, wars and epidemics will bring population under control.

Limitations/Criticisms of Theory

Following are some of the limitations/criticisms of this theory:

(a) Malthus did not consider migration of people.

(b) Malthus failed to recognise the potential of human population to increase food supply.

(c) He also did not consider man's ability to use science and technology, advancement in the field of agriculture to increase the food supply, family planning methods and advancement of medical facilities for fulfilling the needs of increased population.

(d) He proposed some preventive checks like delay in marriage, abortion and celibacy to check population growth rather than suggesting its implementation.

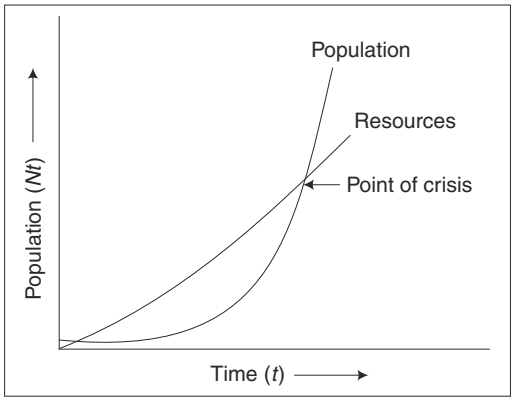


Fig. 3.4 Qualitative Presentation of Malthusian Theory

2. **Marxian theory**: Karl Marx believed that depletion of natural resources, existence of poverty and pollution as well other social ills present in the society are indicated by the population growth. Therefore, population increase is an indicator rather than a cause of these problems. His belief was that the social exploitation and oppression of poor and lower class people lead to poverty, unemployment, population explosion and degradation of environment.

Limitations/Criticisms of Theory

Following are some of the limitations/criticisms of this theory:

(a) Marx stated that poverty and unemployment is not only due to increased population but due to capitalist system which failed to provide jobs.

(b) He also said that in no country the population increases due to fertility only but increases only on account of capitalist policies.

The population growth can be measured for particular time by any one of the two ways:

1. By measurement of crude birth rate and crude death rate of a given year as shown below.

$$\text{Population Growth Rate} = \frac{(\text{Crude birth rate} - \text{Crude death rate}) \times 100}{1000}$$

2. By measurement of population between two censuses as shown below.

$$\text{The population Growth Rate} = \frac{(\text{Population of previous census} - \text{Population of current census}) \times 100}{\text{Population of previous census} \times \text{Number of years between census}}$$

On mathematical bases population growth rates are of two types:

1. **Exponential growth rate**: In this case, the rate of change of population is directly proportional to population at that time as shown below.

If after time 't' population is N_t and r is rate of population growth, then

$$dN_t/dt \propto N_t$$

or,
$$dN_t/dt = r\,N_t$$

It can be written as

$$dN_t/N_t = r d_t$$

Integrating this equation

$$\int dN_t/N_t = \int r d_t$$

or, $$\ln N_t = rt + C$$

When $t = 0$, initial population is N_0

$$\ln N_0 = r \times 0 + C \text{ or } C = \ln N_0$$

Now putting value of C in main equation, the equation becomes

$$\ln N_t = rt + \ln N_0$$

or, $$\ln N_t/N_0 = rt$$

Thus, $$N_t = N_0\, e^{rt}.$$

if we put $N_t = 2N_0$, then the time required to double the population i.e., doubling time (t_d) is calculated as shown below.

$$2\mathrm{N}_0 = N_0\, e^{rtd}$$

$$\text{Doubling time } (t_d) = \ln 2/r$$

$$\text{Doubling time } (t_d) = 0.693/r$$

Thus, approximately doubling time = $70/r$, where r is in percentage.

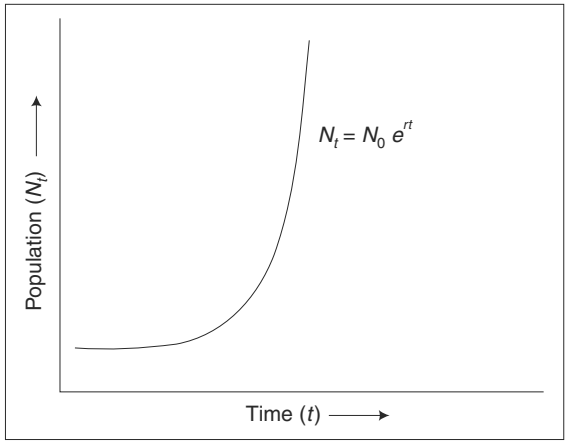


Fig. 3.5 Qualitative presentation of exponential growth

2. **Logistic growth rate**: Rate of increase of population never remains constant but varies with time as shown below in logistic growth curve. This curve is derived from the following deferential equation:

$$dN/dt = rN\{1 - N/K\}$$

where N is the population size and K is the carrying capacity and r is the logistic growth rate.

The factor $(1 - N/K)$ is called *environmental resistance* and it becomes negative when population exceeds carrying capacity and thus factor $(1 - N/K)$ is responsible for achieving logistic growth from exponential growth.

Logistic growth curve is divided into three phases:

(a) *Phase-I* In this phase, population size is much less than carrying capacity and rate of growth is proportional to population size i.e., $dN/dt \propto N$.

(b) *Phase-II* In this phase, increase in population is rapid compared to phase-I and growth is steady i.e., dN/dt = Constant.

(c) *Phase-III* Here population growth decreases as population approaches to carrying capacity i.e., $dN/dt = 0$.

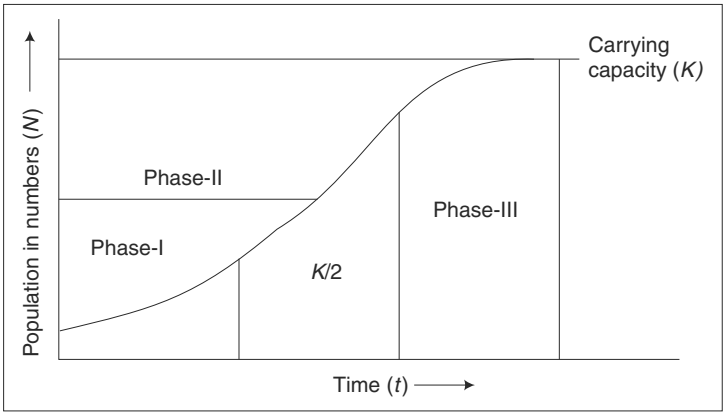


Fig. 3.6 Logistic growth curve

3.2.2.1 Factors Affecting Population Growth Rate

Growth rate depends on several factors as given below.

1. **Birth rate and Mortality rate**: Birth rate is defined as the number of children born per thousand people in a particular year. It is always positive and can never be negative. High birth rate can cause increased population growth rate which has come down in recent years by education, birth control and increased standard of living.

   Mortality rate is defined as the number of deaths per one thousand people in a particular year. High mortality rate reduces the population growth rate but in recent years, mortality rate is low because of the availability of good medical facilities.

Table 3.3 Population growth Rate of some countries in 2005

Country	*Population Growth rate (%)*
China	0.58
India	1.46
United Nations	0.97
Indonesia	1.16
Brazil	1.26
Pakistan	1.84
Bangladesh	1.67
Japan	–0.02
Niue	–1.85
Cook Island	–2.23

Source: US Census Bureau

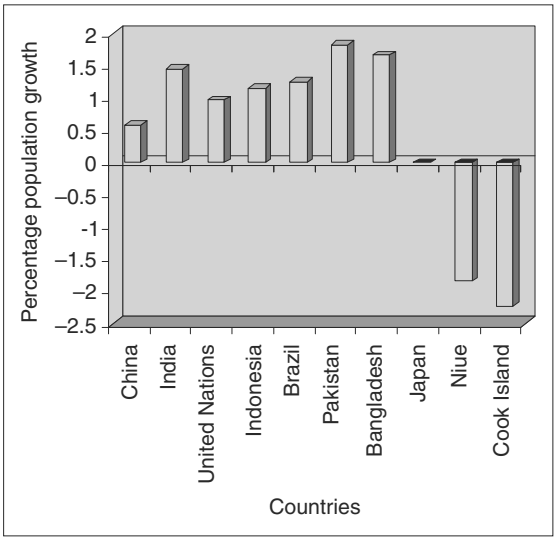
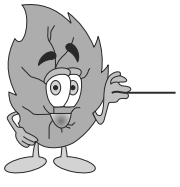


Fig. 3.7 Percentage population growth of some countries of the world in 2005



DID YOU KNOW?

Death rates have fallen faster than birth rates in current decades. There are 3.3 births for each death in less developed countries compared to 1.6 births for each death in more developed countries.

2. **Fertility**: Fertility is the capability of reproduction of human beings. *Total fertility rate* is represented by the number of children born to women during her life time. Total fertility rate varies region wise and is higher in developing counties rather than the developed counties. Advancement in technology and education leads to lower fertility rate.
3. **Migration**: It is movement of people from one place to another within a country or from one country to another country. Movement of people into country/city is called *immigration* while movement from the place to an other country/city is called *emigration*. Net immigration (immigration – emigration) which may be positive, negative or zero is only responsible due to growth rate.
4. **Sex ratio**: It is the number of females per 1000 males. Eagerness to have a male child in families have lowered down this ratio as people sometimes take steps to destroy the female embryo. This imbalance in sex ratio lowers the growth rate as less number of females results in more and more males being unmarried.
5. **Age group**: Reproductive group of people is considered to have an age between 18 to 45 years. Therefore, if more number of people belong to this group, more will be the growth rate.

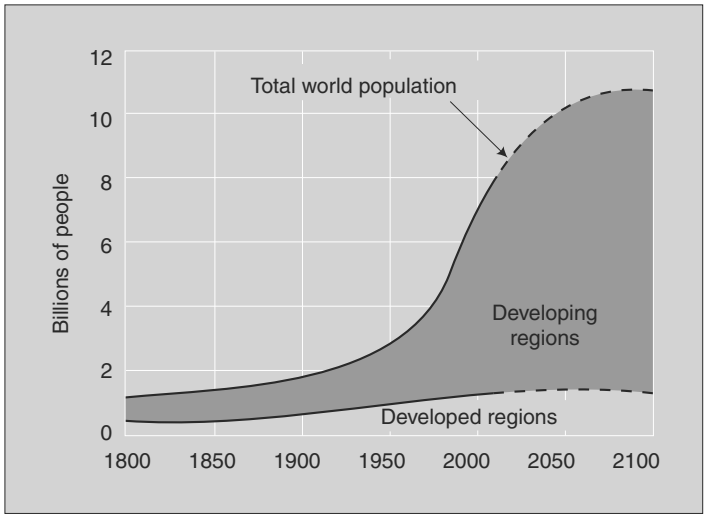


Fig. 3.8 World's Population-trend in developed and developing regions
Source: Google.com

3.2.2.2 Effects of Population Growth

Excessive population growth which puts extreme load on natural and artificial resources are always undesirable. The main effects on human beings due to this excessive growth are given below.

1. Increased demand of food due to high growth cause scarcity of food and increase in the prices of food items. Shortage in agricultural land and water may also cause starvation in some parts.
2. High growth also causes problems related to shelter due to less availability of land and high cost of houses, particularly in cities. It also leads to the formation of slums in big cities.
3. High growth rate sharpens the problem of availability of drinking water mainly in summer season. This shortage of water poses other problems like unhygienic conditions and health problems among people.
4. Depletion of different natural resources due to more consumption of these resources by people. Higher growth rate also leads to high consumption of fossil fuels, minerals and forest resources.
5. Rush in transportation facilities, education facilities, medical facilities and other basic facilities required by the people in their day to day life.
7. Problems regarding availability of electric energy, drinking water and disposal of wastewater facilities.
8. Unemployment problems and increase in crime rate in society.
9. Increase in migration rate and reduction in living standard of people.
10. Deterioration in the quality of environment because of pollution in soil, air, and water.

3.2.2.3 Control of Population Growth

Higher population growth always puts extreme load on natural and artificial resources. Therefore control of population growth is highly desirable. Following are the factors which can control the population growth:

1. **Education**: Improvement of literacy rate in villages and lower and middle class of people, particularly in women can control the population growth.

2. **Living standard and employment**: Employment will improve the living standard of people so there will be improvement in education and awareness of family planning which could control the population growth.
3. **Government benefits and incentives**: Implementation of government policies to give special incentives to people having only two children and benefits to such children in education later on, may play an important role in control of the population growth.
4. **Publicity**: Publicity by giving advertisements and incentives, stating importance, need and significance of birth control and family planning may also control growth.

3.2.3 Population Structure

India has 2.4% area to support 16.7% world population which has rural population – 70.5% and urban population – 29.5%. Population structure of India as per 2001 census is given below.

Table 3.4 Population structure of India

Sr. no.	*Name*	*Amount/ Quantity*
1	Population	1028 million (532.1 million males and 496.4 million females)
2	Growth Rate	1.93
3	Death Rate	8.93
4	Birth Rate	24.8
5	Life expectancy rate	63.9 years for male and 66.9 years for female
6	Literacy rate	total population: 68.84% (male: 75.26% and female: 53.67)
7	Density of population	324 inhabitants/ square km
8	Sex ratio	933

Table 3.5 Population, Birth rate, Death rate and Fertility rates of India

Year	*Birth rate*	*Death rate*	*Population in million*	*Fertility rate*
2005	22.32	8.28	1080	2.78
2006	22.01	8.18	1095	2.73
2007	22.69	6.58	1129	2.81
2008	22.22	6.4	1147	2.76
2009	21.76	6.23	1166	2.72
2010	21.72	7.6	1173	2.68

Source: Ministry of Environment, Planning Commission, Ministry of Health, Press Information Bureau, Census of India

3.2.3.1 Population Pyramids

Population pyramid is the graphical representation of the number of people and/or their percentage in each age group. In India, distribution of age wise population includes children, 40%, youth 33%, middle age persons 21% and old age 6%. Thus, in developing countries like India, structures have predominantly young people who favour fast population growth. In developed countries like USA, population has much less youthful age structure which slows the population growth. There are main three age groups in a population as per the ecological point of view as given below.

1. Pre-reproductive age group (0 to 14 years)
2. Reproductive age group (15 to 44 years)
3. Post-reproductive age group (45 years and above)

As far as population pyramids are considered there are three types of population variations.

1. **Expanding Population**: In this type, the birth rate is high and population growth is exponential. So in this condition, successive generations will be more numerous and the shape of age structure is like a pyramid.
2. **Stable Population**: In this type, pre-reproductive age group and reproductive age group becomes almost equal in size. Post-reproductive age group is found smallest in this condition and the shape of age structure is like a bell.
3. **Diminishing Population**: In this type, pre-reproductive age group becomes drastically low as compared to reproductive age group and post-reproductive age group. In this case, the birth rate is reduced and the shape of age structure is urn-shaped.

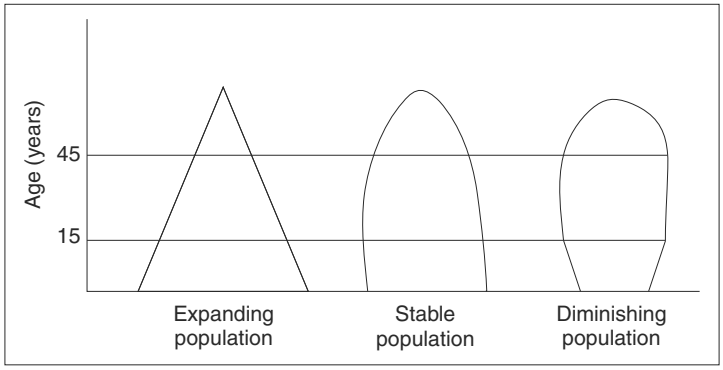


Fig. 3.9 Population Pyramids

3.2.3.2 Population Forecasting Methods

The data regarding present and past population of any city is always available from the records of municipalities or municipal corporations but to design a new water supply scheme and/or wastewater treatment plant, the current population should be forecasted for the design period of scheme. Following are some of the methods of population forecasting:

1. **Arithmetical increase method**: Principle of this method is that the rate of change of population with time is constant as shown below.

   $$dp/dt = \text{constant}$$

   For the past three to four decades, data for future population is calculated by the formula given below.

   $$Pn = P + nI$$

   where Pn is population forecasted for 'n' decades, P is present population and I is average increment of a decade. This method is used for big cities which have reached their saturation.
2. **Geometrical increase method**: Principle of this method is that the percentage growth rate of population with time is constant. For the past three to four decades, data for future population is calculated by the formula given below.

   $$Pn = Po\{1 + r/100\}^n$$

   where Po is the initial population, Pn is population forecasted for 'n' decades, r is the percentage growth rate of population. This method is used for cities of high population growth.
3. **Incremental increase method**: In this method, both arithmetic and geometrical increase of population is taken into account to have more accurate predictions. For the past three to four decades, data future population is calculated by the formula given below.

   $$Pn = P + nI + n(n + 1)r/2$$

   where P is present population, Pn is population forecasted for 'n' decades, I is average increment of a decade, r is the average incremental increase of a decade. This method is used for cities of medium population growth.
4. **Graphical extension method**: In this method, as per the past data, the growth curve is drawn between population and time and shape of the curve is obtained till the present population and then the curve is extended till the decade of population forecasting.
5. **Logistic curve method**: As per this method, the rate of increase of population never remains constant but follows logistic curve which is described above.

Example 1

The following data are available from municipality based on the census of last four decades, calculate the population after two decades i.e., forecasted population in 2021 by (i) Arithmetical increase method, (ii) Geometrical increase method, and (iii) Incremental increase method.

Year	Population
1971	8000
1981	12000
1991	17000
2001	22500

Solution

(i) Arithmetical increase method

Find out average increment (I) as shown below.

Year	Population	Increase in population
1971	8000	–
1981	12000	4000
1991	17000	5000
2001	22500	5500
	Total	14500
	Average Increase (I)	14500/3 = 4833

Population in 2021: $P_{2021} = P_{2001} + nI$

$P_{2021} = 22500 + 2(4833)$

$P_{2021} = 32166.$

(ii) Geometrical increase method:

Find out average increment (I) and percentage increase (r) in population as shown below.

Year	Population	Increase in population	Percentage Increase in population (r)
1971	8000	–	–
1981	12000	4000	4000 × 100/8000 = 50
1991	17000	5000	5000 × 100/1200 = 41.7
2001	22500	5500	5500 × 100/17000 = 32.4
	Total	14500	124.1
	Average Increase (I)	I =14500/3 = 4833	Percentage Increase (r) = 124.1/3 = 41.37

Population in 2021: $P_{2021} = P_{2001} \{1 + r/100\}^n$

$P_{2021} = 22500 \{1 + 41.37/100\}^2$

$P_{2021} = 44967.$

(iii) Incremental increase method

Find out average increment (I) and percentage increase (r) in population as shown below.

Year	Population	Increase in population	Average incremental Increase in population (r)
1971	8000	–	–
1981	12000	4000	–
1991	17000	5000	1000
2001	22500	5500	500
	Total	14500	1500
	Average Increase (I)	I =14500/3 = 4833	Average incremental Increase (r) = 1500/2 = 750

Population in 2021: $P_{2021} = P_{2001} + nI + n\,(n + 1)r/2$

$P_{2021} = 22500 + 2(4833) + 2(2 + 1)\ 750/2$

$P_{2021} = 22500 + 9666 + 2250$

$P_{2021} = 34416.$

3.2.4 Demographic Projection

Due to the change from pre industrialised era to industrialised era in the economy of the world, there has been an evident change in the birth rates and death rates in different areas. *Demographic projections* are used to represent the increase in the population, shift has been from high birth rates and high death rates to low birth rates and low death rates. *Rate of natural increase in population* is the difference between birth rates and death rates but if birth rates and death rates are equal then zero population growth rates are observed which is called *demographic transition*. There are four stages of demographic projection as discussed below.

1. **Phase-I**: Due to lack of awareness, poor medical facilities, low education levels and natural disasters, in pre-industrialised society, fluctuating high birth rates and high death rates were observed as shown in Fig. 3.10.
2. **Phase-II**: In developing countries, due to advancement in technologies and improvement in medical facilities and education system death rates dropped rapidly compared to corresponding birth rates. This caused high increase in population in countries.

3. **Phase-III**: In this era, due to urbanisation and industrialisation, reduction in natural resources, women's education and use of family planning scheme, high reduction in birth rates was observed which tried to level off the population growth.
4. **Phase-IV**: In this phase, both birth rates and death rates are low. High living standards and more jobs by women lead to reduction in fluctuating birth rates while death rates are also low because of high technologies and excellent medical facilities.

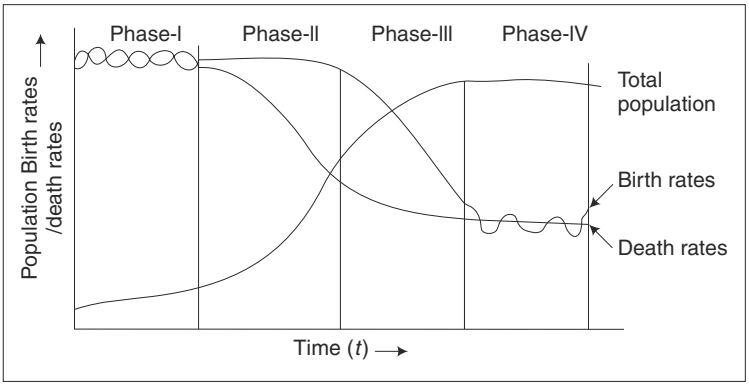


Fig. 3.10 Qualitative representations of different phases of demographic projection

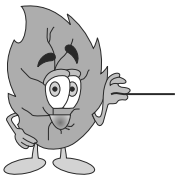
Conclusion or Inference

Demographers usually consider crude birth rate and crude death rate and the difference between these two is termed rate of natural increase. In demographic transition, birth and death rates are equal and this condition might occur in developing countries when they become developed. This theory is a model and effects of migration are not considered in this so it may not predict the correct future population. Another point is regarding the availability and credibility of results as the results are based on the data of birth and death rates. To get the exact and credible data of birth and death rates in developing countries are very difficult.

3.3 NATURAL RESOURCES

Natural resources are the resources utilised by the living organism for their survival and welfare directly from the natural environment. These are basically resources gifted by nature to us like sun light, air, water, plants and animals, soil and minerals.

These natural resources are abundant therefore even after their use since the beginning of life, they have not depleted. But from the last few decades due to increase in population,



DID YOU KNOW?

We are consuming our natural resources with very high rate and we do not give enough time to nature to regenerate these resources.

industrialisation and urbanisation, huge load is been put on natural resources. Natural resources can be divided in to two categories:

1. **Renewable resources**: These are the natural resources which can replenish themselves by recycling and/or reproduction within a reasonable time. These resources are also called inexhaustible resources like sunlight, air, plants and animals, birds, soil, water, wind, rainfall, tidal and hydro power and microbes.
2. **Nonrenewable resources**: These are natural resources which are found almost in fixed amount and that is why they are sometimes called as exhaustible resources. Practically, there is no completely exhaustible resource but its rate of formation may be so low that it becomes unavailable after a period of time due to high rate of consumption. Some of the nonrenewable resources are fossil fuels (coal, petroleum and diesel, and natural gas), oils, minerals and crops, etc.

   As per the possibility of recycling, nonrenewable resources may be again two types

   (a) ***Recyclable nonrenewable resources***- These resources include those things which can be reprocessed after collection to new products like ores of metals, nutrient rocks (phosphorus, sulfur and calcium).

   (b) ***Nonrecyclable nonrenewable resources***- These resources include those things which can not be reprocessed for recycling or reuse and are lost after giving energy like fossil fuels (coal, oil, petroleum and diesel and natural gas) and uranium, etc.

Importance of Natural Resources

Natural resources are considered as a gift of nature to human beings for fulfilling their needs and desires. Natural resources such as air, food, water and shelter are basic needs of all types and forms of life for their survival in biosphere. These resources are very important for living beings because:

1. Almost all living beings use natural air to breath.
2. All humans, animals, birds and other living beings use water to drink.
3. Every living beings use land for getting shelter.

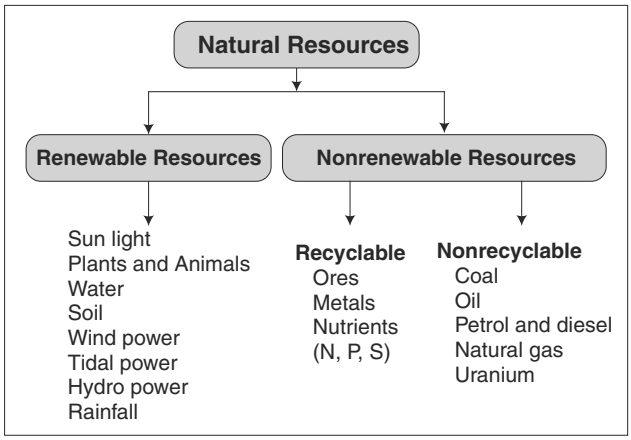


Fig. 3.11 Flowchart showing classification of natural resources

4. Natural resources like forests give food, timber, paper, medicines and fresh air.
5. Natural resource like coal mines give energy to us.
6. Natural gas and naturally available minerals and metals are also considered as natural resources.

3.3.1 Destruction of Natural Resources

Natural resources are needed in our daily life to fulfill our basic needs but over population and extreme desires for having high living standard has put a tremendous pressure on natural resources. Even in the case of renewable resources, this high pressure due to high rate of utilisation of resource than rate of its being renewed cause depletion of natural resources. Some reasons of destruction are given below.

1. High population growth causes very high use of natural resources like water, air, land, animals and plants which leads to destruction of water sources, pollution of air and land degradation.
2. Unplanned industrialisation and urbanisation also leads to degradation of environment by destruction of forest and release of effluent waste in air, water and land.

3.3.2 Conservation of Natural Resources

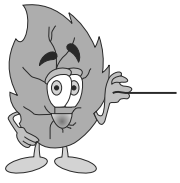
Conservation of natural resources means managing the use of these resources such as to have maximum benefit to common beings and maintaining the potential of resources to meet future demand. But excessive and unplanned use of these resources has depleted these resources so much so that there is an urgent need of stopping destructive practices

and to implement necessary steps for conservation of natural resources. All of us have some responsibility to contribute our share to conservation and protection of environment. The main objective of conservation is to preserve the quality of environment and allowing natural cycle of renewal.

Steps to be taken to conserve different natural resources are given below.

1. Water Conservation

(a) By installing rain water harvesting systems for all types of houses and making it compulsory particularly to all commercial and public buildings.
(b) By using advanced technologies (like drip irrigation and sprinkling system) in agricultural fields and giving education to farmers.
(c) By reducing the evaporation losses in ponds, lakes, wells and even in gardening.
(d) By improving operational and maintenance system to reduce leakages in joints and pipes.
(e) By stopping wastage of water and encouraging reuse of water in domestic and industrial sectors.
(f) By educating people to use less water and installing water saving devices.
(g) By reducing industrial consumption by means of efficient water saving technologies, reuse and recycling.
(h) By restoring traditional water conservation techniques particularly in villages.



DID YOU KNOW?
In the world, US is the largest energy consumer. For just 4.6% of world's population US consumes 24% of total commercial energy produced.

2. Energy Conservation

(a) By encouraging for more use of solar energy.
(b) By designing houses for optimum energy consumption through proper insulation against heat loss.
(c) By reducing the use of vehicles for individuals and encouraging people to use public transport system to save fuel.

(d) By educating public to develop habits switching electrical appliances like fans, tube lights and TV when not in use.
(e) By doing more plantation and greeneries near the houses.

3. Soil Conservation

(a) By encouraging people to use dust bins for throwing solid waste rather than anywhere on land.
(b) By segregating different solid waste generated like metals, garbage and refuse etc.
(c) By reducing over irrigation of agricultural fields.
(d) By educating public to develop habits of not throwing peelings of fruits and vegetables in the open.
(e) By doing more plantations to reduce erosion of soil.

3.4 MAIN NATURAL RESOURCES

Right from the evolution of human beings, use of natural resources had started by living beings to fulfill their needs related to food and shelter. Some of the main natural resources are given below.

3.4.1 Water Resources

Water is one of the essential elements for the survival of organisms on earth. That is why it is considered as one of the marvelous gift of nature to us. One can live for a month without food but can not survive for more than three to five days without water. About 70% of earth's surface is covered by water, out of that 97% is saline and rest 3% is fresh water. Out of 3% fresh water, around 2.3% is locked in icecaps at polar regions. Therefore, only 0.7% water is available for human consumption. Surface water through lakes, ponds, rivers and streams account for around 0.03% while 0.67% is by means of ground water.

Uses/Importance of Water as a Resource

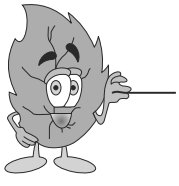
Water is very important natural resource which forms the basis of life on earth. It is so important that in the program of search of life on other planets, the presence of water is first tested. Human beings use the water in day to day life for different purposes as summarised below.

1. **Domestic purposes**: It basically consists of water used by human beings for daily house hold activities as shown below.

Table 3.6 Average water demand per capita per day in India

Purpose	*Water demand in liters per capita per day(lpcd)*
Drinking	5
Cooking	5
Bathing	55
Washing cloths	20
Washing utensils	10
Cleaning of houses	10
Flushing toilets	30
Total	135

2. **Agricultural purposes**: Traditionally, India is a agricultural based country in which most of the food production is through irrigated land and so very high amount (around 70%) is used for irrigation purposes. Lined and earthen canal networks are used for irrigating fields by different water sources like ponds, lakes, rivers, reservoirs and bore wells.



DID YOU KNOW?

Domestic water comsumption is only 8% of available water yet there is world wide scarcity of drinking water.

3. **Industrial purposes**: Plenty of water is used by different types of industries (around 15%) but major users are thermal power plants and oil and ores refineries and soft drink industries.
4. **Other purposes**: It includes water required for fire fighting system, public use like at bus stand, railway stations and airport etc., recreational use in cities, swimming pools, water parks and dilution of waste.

3.4.1.1 Sources of Water

There are two types of water sources available on earth. One is surface water sources and the other is ground water sources as shown below in flow chart.

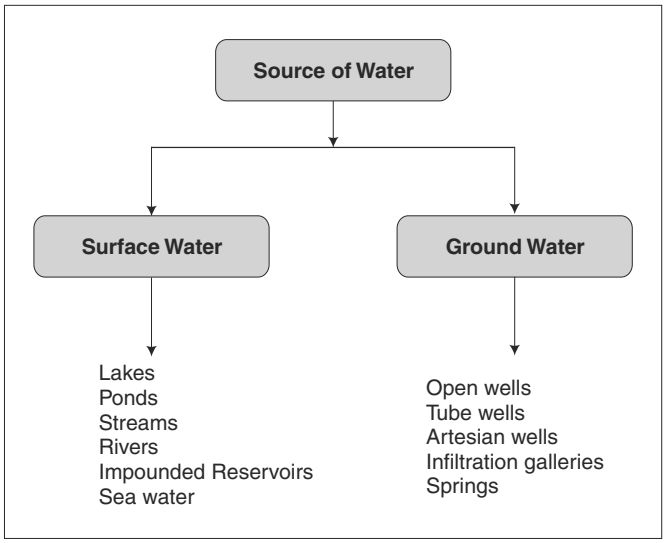
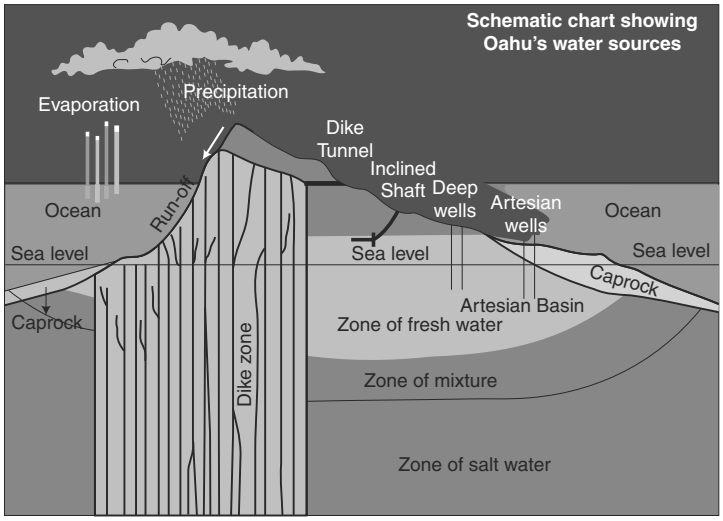


Fig. 3.12 Flowchart showing sources of water

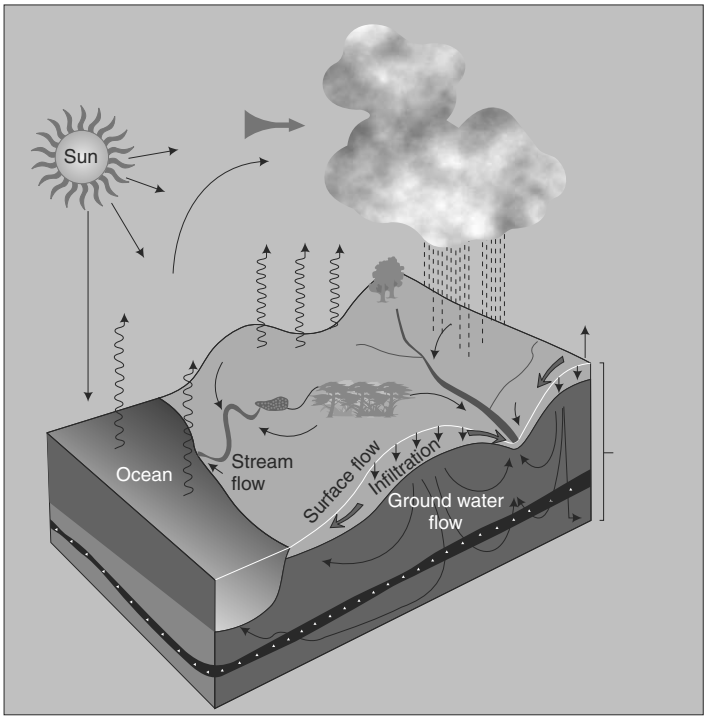
Surface Water Sources

1. **Lakes**: These are big natural inland depressions filled with rainwater which holds that water throughout the year. Quality of lake water is generally good which can be supplied to public with treatment of disinfection particularly in nonmonsoon seasons. In lakes, growth of algae and some water vegetables are generally common.

   India is famous for numerous lakes. Rajasthan, Himachal Pradesh, North-Western states and Northern states of India have more number of lakes than anywhere else in the country. Dhebar lake, Nakki lake, Pushkar lake, Dal Lake are some of the important lakes present in these regions. In South India also, there are numerous popular lakes like Husain Sagar, Vembanad lake, Chembarambakkam and Sashthamkotta. All these lakes lying in the different parts of the country attract large number of tourists, and have become hot picnic spots.
2. **Ponds**: They are also, natural inland depressions filled with rainwater but are small and shallow water bodies compared to lake. Quality of water in ponds is almost uniform.
3. **Streams**: Streams are formed by the small amount of water running down from the hills joining to rivers or lakes.
4. **Rivers**: They originate from hills and after running through their path finally reach ocean or sea. They are important sources of water for irrigation and public water



(a)



(b)

Fig. 3.13 Pictures (a) and (b) showing different water resources.
Source: Google.com

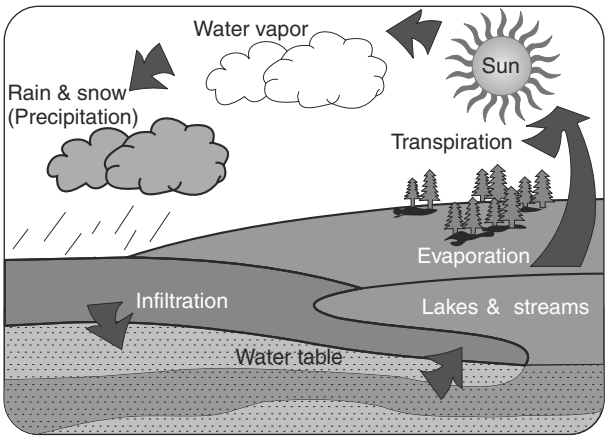


Fig. 3.14 Picture showing water resources with water cycle.
Source: Google.com

supply. The quality of this water is quite variable as in monsoon season, water is highly turbid compared to nonmonsoon season.

In India, people worship rivers particularly Ganga, Yamuna and Saraswati in the form of goddesses.

All major rivers of India originate from one of the three main regions: (i) Himalayas and Karakoram ranges, (ii) Vindhya and Satpura ranges, and (iii) Westurn Ghats. India has the following river basin systems:

(a) *Gangetic System* – It includes Ganga, Yamuna, Son, Gandak, Kosi and other tributeries. Ganga starts from Gangotri glaciers in the Himalayas and flows from Uttar Pradesh and Bihar, and then enters West Bengal and finally empties into the Bay of Bengal.

(b) *Indus River System* – It include Beas, Chenab, Ravi, Jhelum, Sutlaj and other tributeries.

(c) *Brahmaputra River System* – The river Brahmaputra originates from Mansarover and flows along Himalayas in China also.

(d) *Narmada River System* – Narmada originates from Amarkantak and this system include Narmada, the Tapti and the Mahi run from east to west..

(e) *Taapi River System* – It rises in the eastern Satpura Range of southern Madhya Pradesh state, before emptying into the Gulf of Cambay of the Arabian Sea, in the State of Gujarat.

(f) *Godavari River System* – It rises at Trimbakeshwar, near Nasik, and empties into the Bay of Bengal.

(g) *Krishna River System* – It originates at Mahabaleswar in Maharashtra and meets the sea in the Bay of Bengal at Hamasaladeevi in Andhra Pradesh. The Krishna River flows through the states of Maharashtra, Karnataka and Andhra Pradesh.

(h) *Kaveri River System* – Birth place of river kaveri is called *Dakshin Kashi*. It runs through Karnataka and Tamil Nadu and empties into the Bay of Bengal.

5. **Impounded reservoirs**: These are basically reservoirs formed on the upstream side of dams which are built across the river valley. The quality of this water is like the quality of lake water but its use is multipurpose i.e., water is used for public water supply, irrigation and power generation, etc.
6. **Sea water**: Though ocean and sea water account for 97% of total water in the world but due to its salinity it becomes uneconomical to convert it into fresh water.

Ground Water Sources

1. **Wells**: These are the water resources created by digging holes in the ground to extract water directly or by pumping.

These wells are of three types:

(a) Open wells- These are open holes of higher diameters (5-10 m) and lower depths (5-20 m).

(b) Tube wells- These are wells dug for higher depth to reach up to water bearing strata to get more discharge.

(c) Artesian wells- These are wells dug in such a way to have water from impervious layer of aquifer sandwiched between two impervious layers to have more water with pressure.

2. **Infiltration galleries**: These are the networks of smaller diameters horizontal tunnels constructed under the bed of rivers and/or near the shore of rivers. These galleries receive water through porous drains connected to them and send that water to sump well by gravity flow which can be utilised for different purposes.

3. **Springs**: Spring is a natural resource of water which can supply water due to the outflow of ground water. The discharge of these resources is generally temporal.

3.4.1.2 Water Needs

Need of water is one of the critical factors' in the country's economic growth, environmental safety, conservation of species, food security and public health care. We need fresh water for our daily water consumption which is circulated back for consumption through water cycle. We need water for the following uses:

1. **Domestic use**: Domestic uses comprise water used for household activities like drinking, bathing, cooking, washing and flushing. For domestic purposes, about 5% to 8% water is used worldwide. The amount of water required for domestic use in India is minimum 50 litres per capita per day to 200 litres per capita per day with average value of 135 litres per capita per day.

   The water which we use for drinking purposes is called *potable water* which is free from impurities but may contain some minerals to impart taste.
2. **Irrigational use**: This consists of use of water for irrigation purposes through canals, ponds, lakes, dams and bore wells. It accounts for 70% of total water required for different activities.

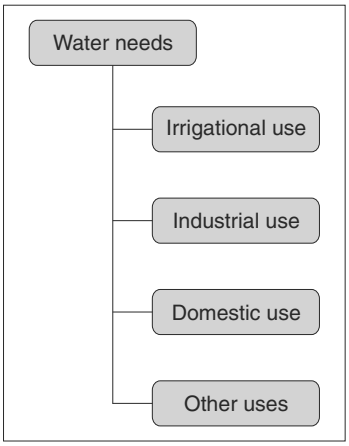
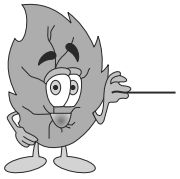


Fig. 3.15 Chart showing water needs



DID YOU KNOW?

One fourth of world's population do not get safe drinking water and about half of world's population lacks in sanitation facilities.

3. **Industrial use**: Every industry requires water as per their requirement of processing. Some industries require huge quantity of water but some requires little water, for example, soft drink industry and paper and pulp industry and dye industry require huge amounts of water compared to refineries and auto mobile industries. About 15 to 20% of freshwater is used world wide for industrial uses.
4. **Other uses**: Water is also used for fire fighting systems, recreational purposes and for diluting waste for disposal purposes. This includes water used for hydropower generation as well as water required at thermal power plants.

3.4.1.3 Water Scarcity

Though the quantity of water available on earth is so huge that if it is spread over the land, it can form around 3 km deep cushion of water on earth. But 97% of this available water is saline and can not be directly consumed by human beings so there is scarcity for getting remaining fresh water.

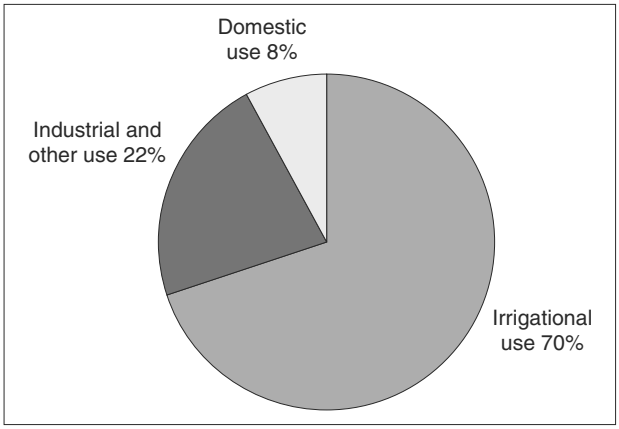


Fig. 3.16 Chart showing percentage water requirements for different uses.

Following are some factors which cause water scarcity:

1. High population and higher population growth rate.
2. Uneven distribution of water over the space and time.
3. Uneven rainfall causing floods and droughts.
4. Global warming, environmental pollution and climatic changes.
5. Inadequate extraction of ground water.
6. Improper water management.
7. Unscientific methodologies of irrigation.

3.4.1.4 Overuse of Water Resources

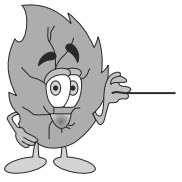
Rapid industrialisation and urbanisation leads to high demand of water which in turn results in overuse of natural water resources. Due to increase in population, direct human consumption as well as irrigational requirement has imposed high demand of fresh water and to fulfill these demands water resources are being over used.

Following are some effects of over use of water resources:

1. **Surface water**: Over use can cause reduction in flow of water in streams and rivers, drying of ponds and lakes particularly in summer, reduction in wet lands and green lands, and migration of public due to scarcity of water.
2. **Ground water**: Over use of ground water by high rate of pumping can cause lowering of water table and drying of wells, sinking of overlying soil due to depletion of aquifers, and salt water intrusion particularly in coastal areas.

3.4.1.5 Indian Scenario

India covers almost 2.4% of world's land area with population of around 15% of world's population. India receives annual precipitation of approximately 4000 km^3, out of which around 1100 km^3 is formed as usable water resource.



DID YOU KNOW?

In India, about 41% of total water is lost due to evaporation and 40% water is lost in runoff while 10% is retained in soil and 9% seeps down in soil to recharge ground water.

Average annual rainfall in India is about 200 cm. Water resources of our country are basically divided in two parts–surface water resources and ground water resources which are used for different purposes like domestic, agricultural, power generation, industrial, forestry, fisheries, navigation and recreational activities.

1. **Surface water resources**: Main surface water resources are ponds, lakes, streams and rivers. India has atleast 20 major rivers (perennial and seasonal) with their tributaries which are classified as per their origin as given below.

(a) ***Originated from Himalayas Mountains*** – Himalayan rivers ice melting in summer makes these rivers perennial. Some of these main rivers are Ganga, Brahamputra and Indus River.

(b) ***Peninsula Rivers*** – These are the rivers that originated from low hills of Western Ghats and receive water during monsoon are called as seasonal rivers. Some of these main rivers are Narmada, Mahanadi, Krishna, Cauvery, Godawari, and Tapti River.

2. Ground water resources: Main ground water resources are open wells, tube wells, infiltration galleries and aquifers used for satisfying different water demands. Around 80% of ground water is used for domestic purposes only.

Table 3.7 Use of water in different sectors

Use	*In India*	*At global level*
Use for Irrigation	80%	70%
Industrial and other use	15%	22%
Domestic use	5%	8%

3.4.1.6 Problems due to Overexploitation of Water Resources

Water is consumed by every living beings on earth but human beings are the maximum users of water. High population growth has created the problem of overexploitation of different water resources available on earth. Following are the main problems due to overexploitation of water resources:

1. **Surface water**: Over use of surface water creates the following problems:
   (a) Drying of lakes and ponds particularly in summer.
   (b) Drying and/or high reduction in flow of streams and rivers.
   (c) Decrease in the flow of perennial rivers.
   (d) Reduction in the surface area of wet lands.
   (e) Desertification of soil.
   (f) Migration of people from places of overexploited water resources.
   (g) Contamination of water bodies due to reduction in assimilating capacity of rivers.
2. **Ground water**: Over use of ground water creates the following problems:
   (a) Lowering down the water table of those areas which may cause subsidence problem of soil.
   (b) Drying of open wells, particularly in summer.
   (c) Depletion of water in aquifers due to heavy pumping.
   (d) Decreases in the production due to scarcity of irrigation water.
   (e) Intrusion of salt water and desertification of soil in coastal areas.
   (f) Migration of people from places of overexploited water resources.

3.4.2 Forest Resources

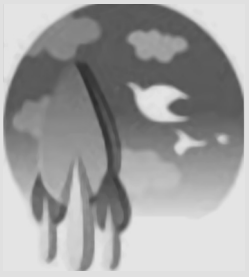
A forest is a self sustained biotic community of different natural species mainly consisting of living and nonliving components. Living components of forests include trees, shrubs, herbs, grass and different animals and birds while their corresponding nonliving parts include nutrients, water, sunlight, air and land. Forests vary in compositions and density and are very important to human beings.

There are basically three functions of forests as discussed below.

1. **Protection**: Forests protect living beings by conservation of soil, preventing erosion of soil and reducing runoff to store more ground water. Forests also protect us against pollution, radiation, weather effects, wind effects, etc.

An Interesting Note

In Kerala state (2000), with the permission of panchayat in the village Plachimada Hindustan Coca Cola set a bottling plant with the condition of employment to the villagers and some annual income to panchayat. But after some time in 2002 villagers found changes in the quality of water and lowering of ground water table which affect harvest of rice and coconut due to excess withdrawal of water by plant. Even after the agitation by people against the plant, the matter went to Kerala High Court. In 2003, court ordered the company not to draw water from the ground and said in judgment that **ground water was a national resource which belongs to society not to company even though company owned the land.** The plant has remained closed since then though the case is pending in court.



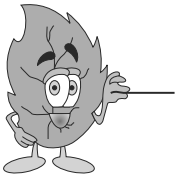
2. **Production**: Forests provide us with lots of products like food (which includes fruits, roots, leaves and plants for medicine), wood, timber, bamboos, different oils, resins, wax and number of pharmaceuticals.
3. **Regulation**: Forests regulate local temperature, balance of carbon dioxide and oxygen, water cycle and carbon cycle, radiant energy and mineral storage. Forests also control floods, draughts and soil erosion.

3.4.2.1 Indian Scenario

World's 30% of total land area is covered by forests which is around four billion hectares. As far as India is concerned, the forests cover 23% of total land area of our country. At the end of 20th century, the forest area in India was reduced from around 30% to 19.5%. Today, it is 0.06 hectares per capita which is far less than the 0.64 hectares per capita of the world's average. Most of the India's forests are broadly divided into five categories:

1. **Tropical moist deciduous forests**: These forests grow in regions where plenty of heat and moisture is present with minimal cold. In these forests, seasonal variations are less and precipitation is almost uniformly distributed throughout the year. Tropical moist deciduous forests are basically dense jungles having a wide variety and diversity of species.

2. **Tropical dry deciduous forests**: These forests grow in regions of warm summers, cold winters and average annual rainfall of around 1200 mm. In these forests, seasonal variations are high and most of the trees put off their leaves during summer and have thorns. Tropical dry deciduous forests are basically known for high productivity and richer nutrients in soil.
3. **Temperate evergreen forests**: These forests grow in the regions of relatively cool environment and average annual rainfall of around 1800 mm. These forests are mostly found at high altitude and have broad leaves. Temperate evergreen deciduous forests are basically known for remaining green throughout the year as very little leaf fall takes place in summer and therefore, the trees are never without leaves.
4. **Coniferous forests**: These forests occur in regions which have cold climate and snow fall around half of the year. These forests are found mostly at very high altitude and are usually tall trees with cone shaped canopy. Coniferous forests are basically known for having green needle leaves throughout the year in cone shaped like pine and deodar trees.
5. **Mangroves forests**: Mangroves are salt tolerant trees which grow in shallow marine sediments.



DID YOU KNOW?

Mangroves are found almost all along the Indian coast, which is around 7% of the world's total area of mangroves.

Mangroves are found in Indian coastal areas particularly in Andaman and Nicobar Island, West Bengal and Goa. In India, the largest area covering mangroves are found in Sunderban delta in West Bengal.

3.4.2.2 Importance of Forests

Forests are precious and invaluable natural renewable resource available on this earth. Economically and ecologically, forests are very important for human beings.

1. **Economical importance**: Forests are economically very important as they support the economy by several means as given below.

(a) Forests provide food by means of giving different types of fruits which support the fruit industry.

Table 3.8 Types of forest in India

Forest type	*Percentage of total*	*Annual rainfall (cm)*	*Mostly found trees*	*Areas mostly found*
Tropical moist deciduous forests	27–37	20–35	Orchids, lichens. Mosses and ferns, etc.	Western Ghats, Andamans, Karnatka, Kerala, Madhya Pradesh and Utter Pradesh
Tropical dry deciduous forests	20–28	10–15	Sal, teak, kair, shisam, sangwan, etc.	North west plain and low hilly area, Himalayas low area.
Temperate ever-green forests	5–15	10–25	Different types of Oak trees	Western Ghats, Andamans, Assam, Himalayas medium hills, etc.
Coniferous forests	5–12	5–18	Pine, deodar, cypress, silver fir, etc.	Himalayas
Mangroves forests	0.1–0.25	–	Mangroves trees	Andaman and Nicobar Island, West Bengal and Goa

Table 3.9 Total forest cover in different state/ Union territories of India

Sr. No.	*State/Union teritory*	*Total forest cover (sq km)*	*Sr. No.*	*State/Union teritory*	*Total forest cover (sq m)*
1	Madhya Pradesh	131830	17	Himachal Pradesh	13082
2	Arunachal Pradesh	68847	18	Gujarat	12956
3	Orisa	47033	19	Kerala	10323
4	Maharashtra	46672	20	West Bengal	8362
5	Andhra Pradesh	44229	21	Andman & Nicobar	7606
6	Utter Pradesh	34016	22	Tripura	5745
7	Karnatka	32467	23	Sikkim	3118
8	Bihar	26474	24	Punjab	1412
9	Assam	23688	25	Goa	1251
10	Jammu & Kashmir	20441	26	Haryana	964
11	Rajasthan	18871	27	Dadra & Nagar Haveli	202
12	Mizoram	18338	28	Delhi	88
13	Manipur	17384	29	Chandigarh	7
14	Tamil Nadu	17078	30	Daman & Diu	3
15	Meghalaya	15633	31	Pondichery	0
16	Nagaland	14164	32	Lakshdeep	0

(b) Forests stabilise the economy of different industries like paper and pulp industries, wood and timber industries, textile industries, oil industries, pharmaceutical industries by providing raw materials to these industries.

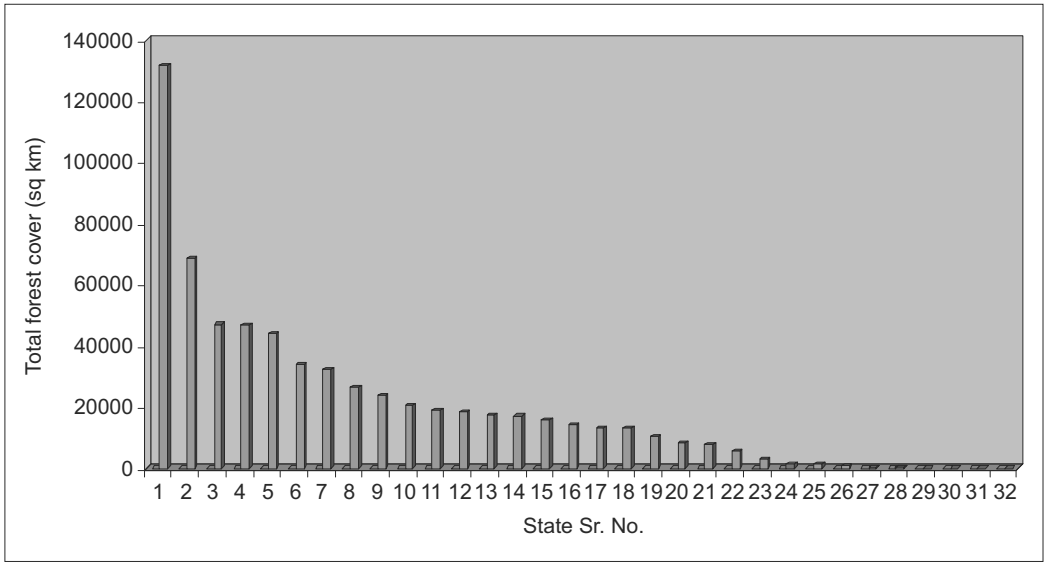


Fig. 3.17 Chart showing total forest cover in different state / Union territories of India uses

(c) Forests are important for wood and timber production.

(d) Forests also attract tourism industry and generate employment for youth.

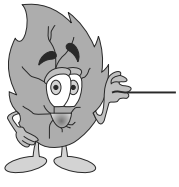
2. **Ecological importance**: Forests itself is an ecosystem in which different species interact with their physical environment. Forests are therefore ecologically very important as stated below.

(a) Forests help in temperature and pollution control by trapping pollutants (as forest acts as sink for carbon dioxide).

(b) Forests refresh air by releasing oxygen during photosynthesis.

(c) Forests prevent erosion of soil and improve its stability to prevent landslides.

(d) Forests also regulate water cycle and encourage water storage in ground by means of reducing runoff.



DID YOU KNOW?

Around 20% of atmospheric oxygen is contributed by Amazon forest in South America therefore it is called "Lungs of Planet".

3.4.2.3 Uses of Forest Products

Forest products are most invaluable and possess very high value for the life and prosperity of human beings. Uses of forest products can be summarised in the following two ways:

1. **Uses of forest products to get direct benefits**: This includes the different uses of forest products which gives direct benefits to human beings.

(a) ***To get food materials*** – Forests give numerous fruits, nuts, resins, leaves and different types of roots for having directly food for consumption. Human beings can also consume meat of forest animals for getting their food.

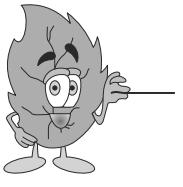
(b) ***To get shelter*** – Forests provide shelter to different animals, birds, reptiles, mammals, insects and microorganisms.

(c) ***To get wood*** – Forest provides wood for us which is used as a source of energy for poor people and to get timber for making furniture, wooden houses, tools, railway sleepers, small bridges, and boats etc. This is also used to make plywood, veneer, board, doors, windows, sports goods etc.

(d) ***To get bamboos*** – Forest provides bamboos which are used for making temporary structures (particularly by army), matting, flooring, ropes and baskets etc.

(e) ***To manufacture paper*** – The pulp of wood and bamboos are used to manufacture paper which is used widely for stationary, packing, printing etc.

(f) ***Other direct uses*** – There are several other products which are been provided to us by forests like gums, drugs, spices, tannins, insecticides, waxes, honey, musk, silk, etc. Oils obtained from plants are used for manufacturing different cosmetics and soaps.



DID YOU KNOW?

It is estimated that at least 17 trees can be saved by manufacturing one ton of paper by recycling.

2. Uses of forest products to get indirect benefits: This includes the different uses of forest products which gives indirect benefits to human beings.

(a) ***To have soil conservation*** – Forests bind the surrounding soil to their roots and thus prevent erosion of soil. Forests also reduce velocity of wind and intensity of rainfall which cause erosion.

(b) ***To reduce pollution*** – Forests purify the atmospheric air by releasing more oxygen and consuming more carbon dioxide by photosynthesis process.

(c) ***To cool the atmosphere*** – Forests increase humidity in atmosphere and prevent direct sunlight to reach on ground and thus cools the atmosphere.

(d) ***To regulate water cycle*** – Forests regulate water cycle by giving more moisture into the atmosphere by transpiration which after condensation pours down as rainfall.

(e) ***To control water flow*** – Forests consist of a thick layer of humus on surface ground which soaks rain water preventing its wastage through runoff and controls floods. Forests also prevent quick evaporation of water and thus encourages the rise of water tables of surroundings.

(f) ***To improve soil fertility*** – The fertility of forest soil increases due to deposition of humus which is formed by decay of forest litter.

3.4.2.4 Deforestation

Deforestation is the destruction of forests and woodlands. Deforestation causes deterioration of our environment and thus degradation in the quality of life and economy. There is sharp reduction in the world's forest cover especially in the developing countries in tropic areas. Tropical forests have lost around 40% of its area compared to 1% lost in the area of temperate forests.

Causes of Deforestation

As deforestation is severe in developing countries so the main problems of such countries like lack of food availability, poverty, over population, unplanned industrialisation, lack of political will, and poor education are also responsible for deforestation along with following main causes as given below.

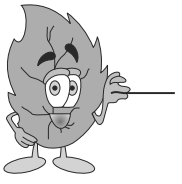
1. ***Population explosion***: High rate of growth in population leads clearing of wide forest area for human settlement for housing, roads, agriculture and industries. This also increases the demand of forest products which put stress on the forest resources.
2. ***Mining activities***: Large areas of forest become barren due to the mining activities of mica, coal and limestone etc. Coal mining in Jharkhand has caused extensive deforestation and mining of limestone in Uttrakhand has also resulted in the same.
3. ***Overgrazing***: Overgrazing of forests by animals has resulted in the loss of porosity of soil, soil erosion and desertification of soil and thus degrading forests.
4. ***Construction of Roads, Railways and Dams***: Construction of roads and railways in hilly areas and mountains resulted huge forest degradation. Dams also cause submergence of large forest area due to very large reservoir.

5. ***High demand of timber***: Timber is used for different construction activities and for manufacturing of furniture. High demand of timber cause more destruction of forest to fulfill high demand of wood by timber industries.
6. ***Forest fires***: Dried organic matter and leaves form thick layer on forest floor which is highly susceptible to get fire due to natural calamites (trees may catch fire due to rubbing action) or human activities (throwing burning cigarette stubbs).
7. ***Pest attack***: There are several kinds of pests and insects in forest which destroys trees by eating them and spreading different diseases.
8. ***Natural calamities***: Natural calamities like floods, storms, cyclones and tsunamis also cause destruction of forest.

Effects of Deforestation

Deforestation affects human beings directly and indirectly by degrading environment. The main effects of deforestation are given below.

1. **Erosion of soil**: As forest conserve the soil and prevent its erosion so deforestation causes to increase soil erosion.
2. **Reduction in fertility of soil**: Deforestation reduces the generation of biomass and humus and more leaching of nutrients and thus reduces its fertility.



DID YOU KNOW?

We have 16% of world's population, 2.3% world's land and only 1.7% world's forests. Nearly 1% of land is turning barren every year due to deforestation.

3. **Climatic changes**: Deforestation also causes warmer climate due to lack of humidity and more radiations and thus it induces regional and global climate change.
4. **Change in pattern of rainfall**: Deforestation causes decline in rainfall, thus changing the pattern of rainfall. It causes desertification in rain scared areas.
5. **Lowering of water table**: Deforestation also causes more runoff to take place and less recharging and is thus responsible for lowering the water table of that area.
6. **Loss of biodiversity**: Deforestation causes extinction of plants, animals and microbes leading to disturbance in ecological balance.
7. **Scarcity of food products**: Deforestation leads to scarcity of wood, fruits and other forest products.
8. **Degradation of environment**: Deforestation causes global worming due to high amount of carbon dioxide and other pollutants in atmosphere.

3.4.2.5 Forest Degradation in India

Deforestation and degradation of forest both are different concepts. *Deforestation* basically shows the decrease in the area covered by forest while *forest degradation* involves the reduction in the quality of forest condition by means of reduction in the balancing of forest ecosystem and reduction in interactions between different parts of forest ecosystem. India has around 64 hectare forest land which is 21% of total land. As far as per capital forest land is concerned, India's position is very poor as its value is around 0.1 ha compared to world's 1 ha. The growing population, heavy industrialisation and urbanisation, large scale construction activities, mining activities, dams and canal networking have caused forest degradation. Therefore, the present need is to plant and grow trees in every possible area which is called *aforestation* to minimise the effect of forest degradation and deforestation.

In India, most of the big projects have contributed somewhat towards deforestation. Among those Sardar Sarover dam constructed at Gujarat across the Narmada River has a big reservoir of 0.95 million hectare capacity which affected more than 4,200 villages of Madhya Pradesh, Gujarat and Maharastra and submerged huge areas of forest. Similarly, the largest dam in Asia, Bhakra Nagal dam across the river Sutlej at border of Punjab and Himachal Pradesh has large stretch of 518.25 km length and 304.84 km width with huge reservoir called Govind Sagar reservoir. Tehri dam in Uttrakhand, which has water reservoir of 42 square km has submerged very large areas of forest. Mining operations in Sariska (Rajasthan) in Tiger reserve forest has also put wild life under threat.

(a)

(b)

Fig. 3.18 Pictures showing (a) Deforestation caused by cutting of tree; (b) Deforestation caused by fires in forest

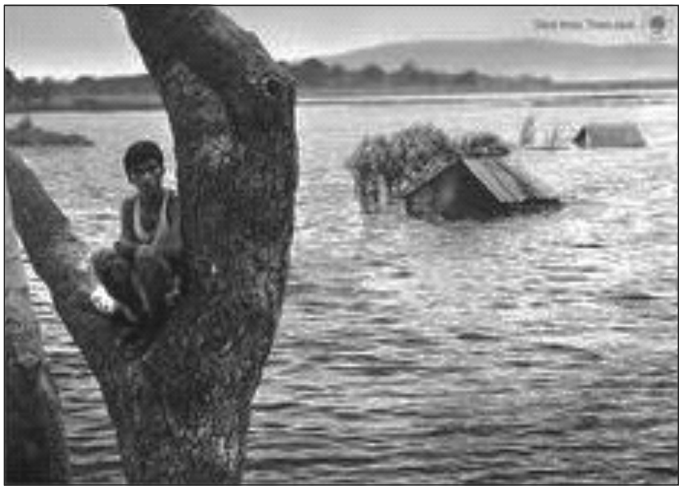
Sources: Google.com

3.4.3 Energy Resources

Energy is required to get work done and therefore it is important and almost essential for the development and economic growth of our country. Energy plays a crucial role for improvement in the quality of life and is used in different sectors like industrial sector, commerce, transport, telecom and IT, agricultural and domestic sectors. Demand of energy is increasing day by day due to the rapid increase in population but by the same time energy resources are becoming costlier and scarce.

Energy resources are mainly divided in two parts:

1. **Noncommercial energy resources**: This includes natural fuels like wood, crop and agricultural residues, animal dung and animal energy for farming and transportation.
2. **Commercial energy resources**: This includes conventional (nonrenewable) energy resources like oil, coal, and natural gas and nonconventional (renewable) energy resources like solar energy, wind energy, hydropower energy and biogas, etc. At global level, around 24% of total energy is used for transportation, 40% for industrial use, 30% for commercial and domestic use and remaining 6% for agricultural and others.



(a)

(b)

Fig. 3.19 Pictures showing (a) Deforestation caused by floods; (b) Deforestation caused by megma
Sources: Google.com

3.4.3.1 Conventional (Nonrenewable) Energy Resources

These types of energy resources include fossil fuels like coal, petroleum products, natural gas and nuclear energy.

1. **Fossil fuels**: Fossil fuels are basically found beneath the earth and formed by the compression and decomposition by heat of organic matter buried underneath the soil. Fossil fuels are mainly found in the following three states:

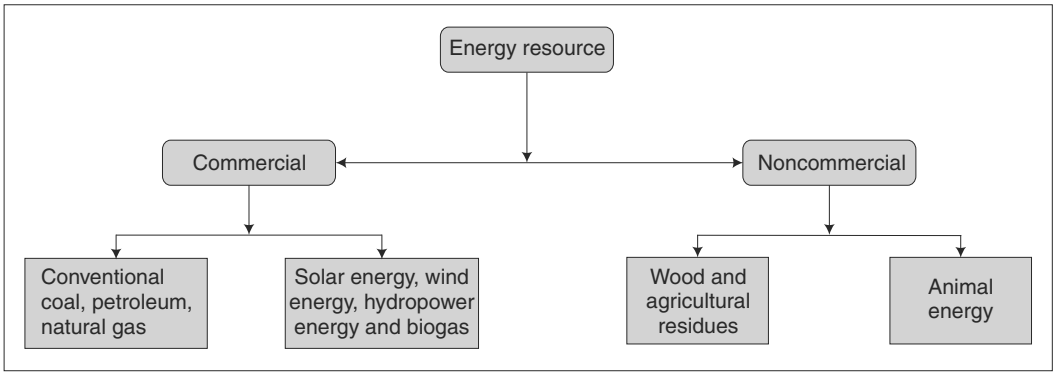


Fig. 3.20 Flow chart of energy resources

Table 3.9 Distribution of world wide total energy use

Energy Source	*Percentage of total energy*
Nonrenewable energy sources	
Oil	32
Coal	21
Natural gas	23
Nuclear	6
Renewable energy sources	
Biomass	11
Solar, hydropower, wind power, etc.	7

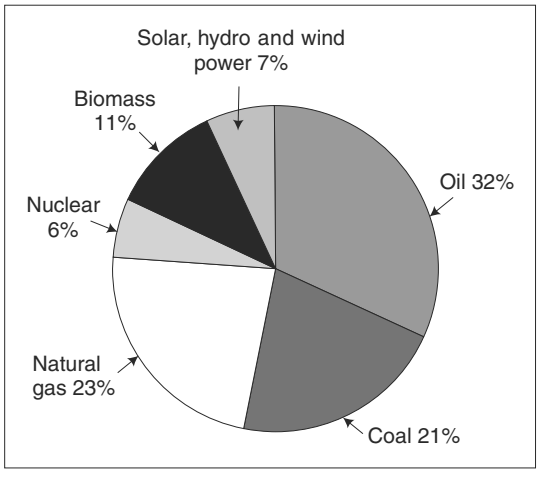
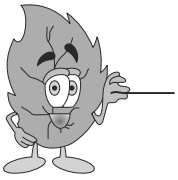


Fig. 3.21 Flowchart of world wide energy distribution



DID YOU KNOW?

OPEC countries reserves around 70% of world's crude oil reserve. Out of the total crude reserve Saudi Arabia alone has 25% accounts.

(a) ***Solid state*** – This includes coal and peat. Coal is the most abundant fossil fuel which contains carbon, water, sulfur and nitrogen. Coal is mainly of three varieties-high carbon (90%) called *anthracite* or hard coal, second with medium carbon content (80%) called *bituminous* or soft coal and third with low carbon (70%) called *lignite* or brown coal. Coal is used for cooking, heating and in thermal power plants for power generation.

(b) ***Liquid state*** – Main element in liquid state is petroleum which is highly inflammable and is used as fuel for transport, agricultural activities and industries. Consumption of petroleum products is given below in Table 3.10.

Table 3.10 Consumption of petroleum in India

Field of consumption	*Percentage (Approximate)*
Transport	40%
Industries	25%
Domestic	18%
Agriculture	9%
Others	8%

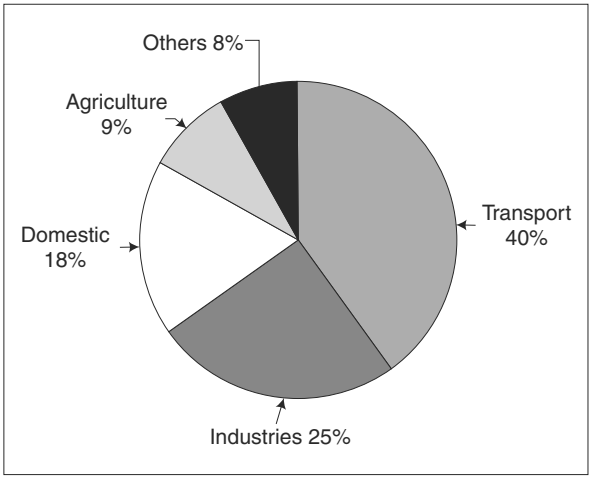


Fig. 3.22 Flowchart of petroleum consumption of different sectors in India

(c) ***Gaseous state*** – It is natural gas found mostly above the oil reserves. Natural gas is a mixer of methane, butane, ethane and propane but commercially used cooking gas (LPG) is a liquefied form of propane and butane. Methane can be used for heating, cooking and electric generation.

Problems Related to the Use of Fossil Fuels

1. Mining activities results in huge deforestation.
2. Mining activities (mining, loading, unloading) also creates dust and noise pollutions which disturb wildlife.
3. Mining activities, particularly under ground, cause mine firing and flooding which can create water pollution problems.
4. Combustion of fossil fuels release gases like CO_2, SO_2, CO and NO_x which are responsible for green house effect and acid rains.
5. Combustion of fossil fuels also release huge amounts of fly ash into the atmosphere which seriously effect health of human beings and animals.
6. Use of petroleum products in transport system cause air pollution.
7. Accidents like bursting of gas cylinders and burning of cars etc., sometimes take place.
8. Storage of CNG and LPG needs high pressure.

2. **Nuclear energy**: This energy is obtained by reactions like nuclear fission and fusion in the nuclear reactor. This high temperature heat energy is used for steam generation to run turbines. In nuclear fission process, radioactive isotopes like uranium 235 are split by neutrons bombarding to release huge amounts of energy while in nuclear fusion process two isotopes of light elements like deuterium are fused to form heavier nucleolus at high temperature releasing lot of energy. In India, nuclear power generation is in developing stage and there are four nuclear power stations situated at Tarapur (Maharastra), Kalpakkam (Tamilnadu), Narora (Utterpredesh) and Rana pratap sagar (Rajasthan). Nuclear power generation cost per unit of power is much less than thermal power and the area required for mining as well as water and air pollution problems are less.

Problems Related to Use of Nuclear Energy

1. Technology is to be imported as it is available with only few countries.
2. The wasted heat disposal creates thermal pollution and the effluents may contain radioactive waste which is very harmful to living beings.
3. Transport and safety of nuclear fuel is a challenging task.
4. Accident in nuclear power plant may create havoc and effect very large area.

Advantages of Conventional Sources of Energy

Following are the advantages of conventional energy resources:

1. These resources are generally found in highly concentrated form.
2. These resources are of multipurpose use as coal is used for cooking, heating, in industries and for power generation at thermal power plants. Petroleum is used for transport, agriculture and in industrial activities. Natural gas is also used for cooking and in industries.
3. These resources have reliable supply so demand and supply can be managed by storing these fuels.
4. The technologies used for getting these resources as well as technologies for using these resources are quite matured. Therefore, the cost is also reasonable per unit of energy.

Disadvantages/Limitation of Conventional Sources of Energy

Following are the disadvantages of conventional energy resources:

1. These resources are generally found in limited conditions because their natural formation process is very slow and it takes a long time for their formation.
2. These resources are of highly polluting in nature as coal burning emits large amounts of CO_2, SO_2, CO and NO_x gases in emissions from thermal power plants. Burning of coal also causes large amounts of fly ash generation which causes many health hazards. Consumption of petroleum and diesel in vehicles also releases hydrocarbons and carbon monoxide which adversely affects the human health.
3. Mining activities used for coal mining cause mine firing and flooding which can create water pollution problems as well as dust and noise problems.
4. Coal mining results huge deforestation and degradation of land.
5. Availability of these resources is at few places so it requires transportation, loading and unloading which increases its cost. India has to import more than 70% of its crude oil demand.

Environmental Impact of Coal Based Thermal Power Plant

Coal is a primary fuel used as a main source of energy in India. Mainly, coal is used to generate power at thermal power plants. Coal meets around 70% of total energy needs of the world and in India about 60% of commercial energy is obtained from the coal. Following are the impacts on environment of coal based thermal power plant:

1. Mining activities for getting coal results in high deforestation.
2. As a solid fuel, coal is less convenient to store, transport and use.

3. Coal dust combines with fog to form smog.
4. Under ground mining may cause mine firing and flooding.
5. Accident in nuclear power plant may create havoc and effect very large area.
6. Burning of coal also releases huge amount of fly ash into the atmosphere which seriously effects the health of human beings and animals.
7. Thermal power plants generate a lot of noise causing noise pollution.
8. The thermal power plants release huge quantities of hot water which causes thermal pollution in water bodies.

Environmental Impact of Nuclear Power Plants

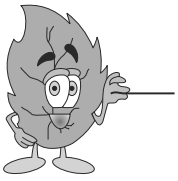
Nuclear energy has tremendous potential and is an interesting source of energy for developed and developing countries because of its lower cost of generation. The main problems associated with nuclear power plants are leakage and disposal of nuclear waste. Following are the impacts on environment of nuclear power plants:

1. Extraction of uranium used as a fuel in nuclear power plants is a dangerous process as radioactivity affects the body.
2. Long term exposure to these radiations may cause cancers, tumors and genetic problems.
3. Lots of heat generated due to fission process which generated huge quantity of hot water which can disturb the flora and fauna of water bodies.
4. Leakage and accident in nuclear power plant may create havoc and effect very large population and areas.
5. Inert gases and halogens which escape as vapours may affect environment directly or indirectly by joining water.
6. Waste generated by nuclear power plants is hazardous. It should, therefore, be disposed properly otherwise it can adversely effect the environment.

3.4.3.2 Nonconventional (Renewable) Energy Resources

Nonconventional energy resources are those which are regenerated by natural processes to be available for use every time. The main nonconventional energy resources are given below.

1. **Solar energy**: The sun gives us non polluted, inexhaustible and pure form of energy. This energy is generated in the sun due to thermonuclear fusion reaction constantly taking place inside it. It has an enormous potential that can meet our energy demands for ever.



DID YOU KNOW?

Sun is the prime source of energy on the earth. Without the Sun life on the earth would not exist as average temperature would go down to –240°C.

Roughly, the solar energy of one week radiation is equivalent to total coal reserve of the world. The main problem is that sun radiations are wide spread and available only during day time and so it is required to be stored after converting it into energy which increases its cost. The solar energy can be utilised by two ways as discussed below.

(a) **As solar heat** – In this system, heat of solar radiation is trapped to raise the temperature which can be used to boil water or other food items. The applications of solar heat are given below.
- For heating water by solar water heaters.
- For cooking food by solar cookers.
- For drying food products by solar dryers.
- For purifying water by solar distillation.
- For heating building by solar heating.
- For plantation in nurseries by having green houses.

(b) **As solar electricity** – The sun light can be converted directly into electricity by photovoltaic cell but the efficiency of this conversion is around 18% and this conversion is expensive also. These solar cells which convert sun rays into electricity are basically made of silicon, also known as silicon cells. The applications of solar electricity are as given below.
- For solar lanterns and solar street light.
- For solar pumps used for irrigation and water pumping.
- For solar furnaces.

The government is now giving subsidy for encouraging the use of solar energy particularly in villages to prevent extensive deforestation. In rural areas of West Bengal, solar lanterns and solar street light system is being used with government subsidy. The design of solar heated houses is recommended particularly in cool places and hilly areas. Solar powered small pumps are also been used in Delhi, Haryana and Himachal pradesh.

Advantages of Solar Energy

1. Solar energy is pollution free.
2. Solar energy is also noise free.

3. Its installation and maintenance is easy.
4. The solar photovoltaic cells have long life to fulfill electricity demand.
5. This system can be installed at remote places and connectivity can be obtained using electric cables.

Limitations of Solar Energy

1. Absence of solar radiations during night time.
2. Uncertainty regarding availability of solar radiations particularly in rainy season due to rain and clouds.
3. More surface area is required for collection of solar radiations.
4. Incoming radiation of sun depends upon location and topography of place.
5. Presently, the cost of solar energy is comparatively high.

2. **Biogas**: Biogas is a very important domestic energy source which can give solution to current energy crisis in villages. Roughly around 10 kg of wet dung is generated per animal per day which can be used for biogas generation. Biogas is obtained by decomposing animal dung anaerobically in biogas reactor by bacteria which can be used for cooking and lighting. Biogas slurries can also be used as organic manure to substitute chemical fertilisers.

Sources for biogas raw material are cattle waste, sewage, crop and vegetable residue, water hyacinth, algae, etc. In our country mainly two types of biogas plants are used as discussed below.

(a) ***Floating holder type biogas plant*** – In this type, the plant reactor or digester is under ground which has a partition wall to separate incoming dung water mixer from the spent slurry. It consists of an inlet pipe to feed dung water mixer to the reactor and a outlet pipe to discharge spent slurry. The reactor consist of an inverted steel floating drum to collect biogas which is supplied to household for consumption by pipes.

(b) ***Fixed dome type biogas plant*** – In this type, the plant reactor has a single unit with no partition but proper inlet and outlet chambers are constructed along with the dome shaped roof made of cement and bricks to hold biogas produced in the reactor.

Advantages of Biogas Energy

1. Best suited for rural areas as good availability of animal dung.
2. Biogas can be used for cooking and lighting puposes.
3. Plant installation and maintenance is easy.
4. It reduces use of kerosene and so reduces pollution also.
5. Biogas slurry can be used as good fertiliser.

Limitations of Biogas Energy

1. Biogas plant may have some operational troubles in rainy seasons.
2. It may have odour problem and insect problem.
3. Accidents due to manual mistake may lead to fire.

3. **Wind Energy**: Wind is basically moving air with some speed. At any point of time, the energy of wind is proportional to its speed at that time. Wind energy can be used for running turbines to generate electricity which can be used for different purposes. Wind energy is cheap and pollution free energy resource. Installation of wind power mills requires such locations where wind speed is more than 6.5 meters per second.

Advantages of Wind Energy

1. Completely nonpolluting source of energy.
2. No raw material is required.
3. Generation is cheaper.
4. Mostly used in costal and hilly areas.

Limitations of Wind Energy

1. Generation of energy is of low.
2. Locations must have high wind speed (> 6.5 m per second).
3. Wind mills can not be within the city.
4. Motion of wind is variable and unsteady.

4. **Tidal Energy**: The periodic rise and fall of sea water is called *tide*. Tides occur in seas and oceans due to the gravitational forces of sun and moon on the earth. During these tides, the sea experiences high water followed by low water twice daily. Tidal energy can be used to generate electricity by storing high tide water in the pond separated through partition wall for running turbine. During low tide same water can be sent back to the sea for running the two way turbines as shown in Fig. 3.24.

Advantages of Tidal Energy

1. Natural process.
2. No raw material is required.
3. Generation is cheaper.

Limitations of Tidal Energy

1. Generation of electricity is less.
2. Can be used only in coastal areas.
3. Operational problems and accidents may occur during cyclones and storms.
4. Transmission becomes costly.

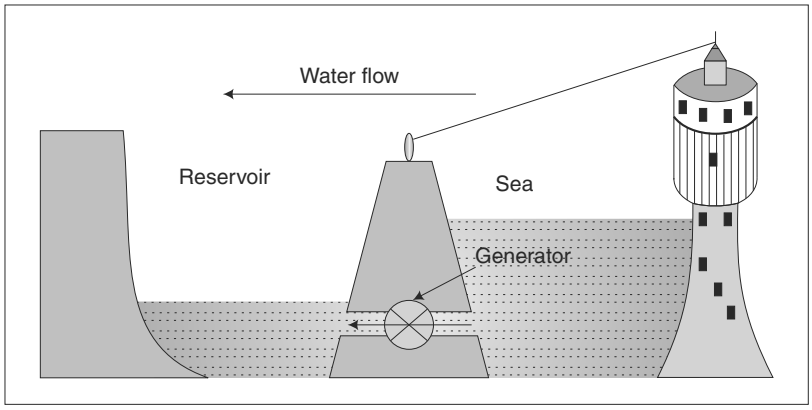


Fig. 3.23 High Tide

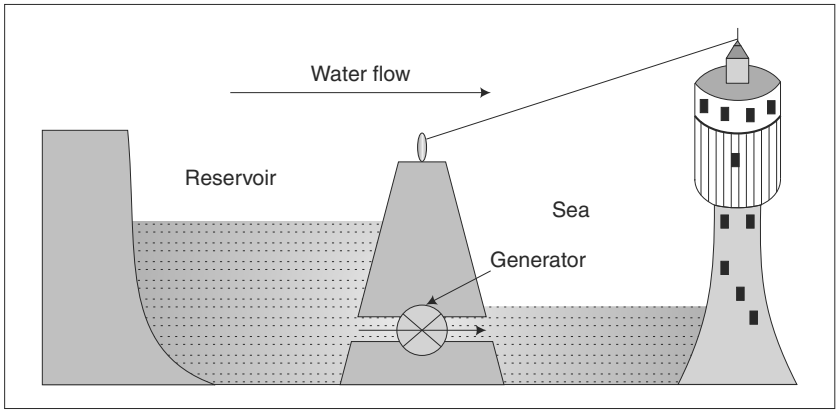


Fig. 3.24 Low Tide

5. **Hydropower energy**: Hydropower energy is produced by converting the potential energy to kinetic energy by water falling from a height to run the turbines for electricity generation. The hydropower generation requires construction of high dam on river with a large reservoir. Around 20% of world's electricity comes through hydropower projects.

Advantages of Hydropower Energy

1. Nonpolluting source of energy as no emissions are present.
2. Reservoir of dam can be of multipurpose. It can be used as reservoir, for fishing, recreational activities and water and can be supplied for drinking and irrigational purposes.
3. Cost of power generation is low.

4. Longer life of projects.
5. Recedes the flood problems.

Limitations and Problems of Hydropower Energy

1. Cost of dam construction is high and its construction requires a lot of time.
2. Reservoir submerges large area, creating problems of rehabilitation of humans and wild life.
3. Deforestation due to large area of submergence.
4. Reduction of silt flowing downstream of dam and due to accumulation of silt and clay usable capacity of dam storage reduces.
5. Projects suffer from lots of political and social hurdles.
6. Becomes a target of attack during war.

6. **Geothermal Energy**: Geothermal energy is the energy which lies inside the earth's crest. When ground water finds in its way molten magma (hot molten rock) then this ground water becomes hot water and comes out as hot springs above the ground. Therefore, geothermal energy is the energy generated from the heated water that comes out from the earth surfaces as hot springs. In India, around 350 hot water springs are present in different parts of the country with average temperatures of around 80°C at the point of occurrence. Some of the power plants ranging up to 5 KW are commissioned in Himachal Pradesh and Jammu and Kashmir.

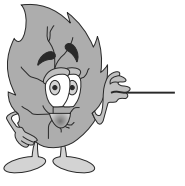
7. **Other Energies**: Hydrogen is the lightest fuel available in gaseous form which is considered as fuel for future. Mostly in nature, it is present in combined form in water, petrol, methanol natural gas, etc. Therefore, it is to be separated first for using as energy resource. It is highly explosive and also requires large tanks to store. Hydrogen burns and produces energy without creating any air pollution.

Another source of energy is called *fuel cell* which is an electrochemical unit like a battery. Hydrogen burns in fuel cell to produce electricity. A fuel cell runs as long as it gets input without creating pollution. It does not require recharging unlike battery.

3.4.3.3 Indian Scenario

As far as India is concerned, coal is still the main source of energy accounting for around 55% responsibility of energy. Energy obtained from oil and natural gas accounts for 31% and 8% followed by hydropower and nuclear power of 5% and 1% respectively. Following are the energy recourses commonly used in India:

1. **Coal**: In India, the main coal mines are concentrated in eastern part of the country like Assam, Jharkhand, Orissa and Chhatisgarh. Coal reserve in India is around 111,000 million metric tones. India is the third largest coal producing country in the world.
2. **Oil**: Oil reserves are found in India in coastal areas of Mumbai (Bombay high), Assam and Gujarat. Oil reserve (on-shore and off-shore) in India is around 0.3 million tonnes.
3. **Natural gas**: Natural gas reserve in India is around 240 million cubic meters.
4. **Solar energy**: In India, use of solar water heaters for heating water and solar cookers for cooking is already started domestically and industrially. In Gujarat (at Bhuj) solar pond is in operation to supply around 220 KWh of thermal power per annum and in Andhra Pradesh also, 22 KWh solar thermal power plant is in operation.
5. **Wind energy**: Out of total wind energy production in India which is around 25000 MW, 6000 MW is in Tamilnadu and 5000 MW in Gujarat.
6. **Tidal energy**: Total tidal power potential estimated in India is around 15000 MW but progress is too slow as 800-1000 MW capacity tidal power plant is proposed at Kandla in Gulf of Kutch.
7. **Biogas**: In India, cow dung is mostly used as raw material for bio gas generation through biogas plants particularly in villages for generation of power and as cooking gas.
8. **Hydro electric power**: In India, hydroelectric power generation is second most power generation source after thermal power generation.
9. **Nuclear power**: Nuclear power in India is at developed stage. At present India is in progress with nuclear treaty with US. There are four nuclear power stations at Maharastra, Rajasthan, Tamilnadu and Utterpradesh with an installation capacity of 2500 MW.



DID YOU KNOW?
One Kg of natural uranium (U^{238}) generates huge energy which is equal to energy generated by 35000 Kg of coal.

3.4.3.4 Problems due to Overexploitation of Energy Resources

Rapid industrialisation and urbanisation, high population growth, high living standards and advancement of technologies in each and every field have increased the utilisation rate of almost all types of energy resources. Thus, higher consumption of energy has put a lot of

pressure on energy resources and has created numerous problems which are summarised below.

1. **Environmental pollution**: Over exploitation of energy resources results in heavy emissions of green house gases, smoke and particulate matter. These emissions cause air pollution and problems like ozone depletion, acid rain and global warming.
2. **Deforestation**: Installation of thermal and hydropower plants require large area causing deforestation problems. Excessive mining activities and bombarding also affects the forest ecosystem adversely.
3. **Depletion of energy resources**: Over use of conventional resources may cause depletion of these resources as the rate of formation of these resources is very slow compared to its utilisation rate. If the world continues to use these resources in the same manner, coal reserves may last for another 200 years and oil reserves may not be able to fulfill the growing demands by next decade.
4. **Socio-economic effects**: The scarcity of conventional energy resources will increase the cost of fuels which will effect the economy of countries and will lead to monopoly of organisation of the petroleum exporting countries (OPEC) who account for world's 70% of crude oil reserve.

3.5 FOOD PRODUCTION

Human beings need air, water and food to survive but out of these, food is an important material for the growth and functioning of body. Main food resources are given below.

1. **Crops**: It includes mainly crops giving grains like rice, wheat, maize, etc.
2. **Vegetations and fruits**: It consists basically all vegetations and all types of fruits.
3. **Animals and Birds**: Animals like cow, goat, camel and hen are utilised for food production.
4. **Aqua animals**: This includes different types of fishes, ducks, crane and water birds.

The average rate of food production growth increased after 1980s compared to previous decades because of an increase in yields, rather than an increase in the area under crops. In India, there are three categories of agricultural growth, (i) With exceptionally high agricultural growth rate—states like Punjab, Haryana, and western Uttar Pradesh, (ii) With high growth rates—states like Andhra Pradesh, Maharashtra, and Jammu and Kashmir, and (iii) With lesser growth rate—states like Bihar, Gujarat, Karnataka, Orissa, Rajasthan, Tamil Nadu, eastern Uttar Pradesh, and West Bengal.

Around one sixth of the developing world's population suffers from hunger and fear of starvation in which one of the main problems is of distribution. To increase the food production, following points can be considered:

1. Training farmers for new techniques of agriculture, cultivation and crops rotation.
2. Improvement in the irrigation system and reservoirs functioning as well as canal networking.
3. Adopting water conservation and water harvesting techniques and soil remediation processes.

Around the world, basically two kinds of food problems are found:

1. Malnutrition, 2. Undernourishment

1. **Malnutrition**: Malnutrition arises due to the lack of minimum amount of proteins, carbohydrates, lipids, vitamins and other essential nutrients required for proper health and growth. It may cause productivity losses, educational losses, nutritional illnesses and problems of health and growth in children. This problem is common in poor countries and may include problems like iodine deficiency disorders and deficiency of iron and vitamins.
2. **Undernourishment**: The problem of undernourishment occurs when the body is not been given enough food or enough calories as required to support its need. Due to this, the body begins to break down its own stored proteins and fats which reduces mental and physical efficiency as well as affects adversely the body immune system. In the developing countries, this problem is common and has become a cause for diseases like anaemia and even death.

CASE STUDIES

Problem of Endosulfan in Kerala: Pesticide (Endosulfan) is highly effective against pests but highly toxic to human, birds and animals. In Kerala, aerial spraying of endosulfan was in practice over the cashew plantation but pesticide residues washed away to join water streams which contaminated that water. Presence of extremely high pesticide concentration in those resources was confirmed by IIT, Kanpur. Finally, after order of court and expert committee report state control board banned its use.

Jharia a town of fire: Jharia town in the state of Jharkhand has 100 years old history of coal fire. Presently, the condition is quite alarming as fire surrounded almost the whole town and these fire are visible on the earth surface. These fires are not only burning coal but also increasing temperature and releasing poisonous gases. These fires are estimated to

have consumed about 40 million tonnes of coal even after spending more than one billion to put out fires by Bharat Cooking Coal Ltd. State government is considering evacuation of 300,000 people out of Jharia.

Forest degradation: Mining operations in Sariska (Rajasthan) which is a tiger reserve forest has also put the wild life under threat. This region is rich in biodiversity and minerals like quartzite marble and granite. Even after the ban from the honorable Supreme Court, the government of Rajasthan has been unable to prevent illegal mining. Other mining operations in Karnatka, Jharkhand and Bihar have also degraded forest areas in India.

Chipko movement: In India, Chipko movement was started in Tehri Garhwal (UP now Uttarakhand) way back in 1972 by tribal women to oppose the cutting of trees by means of hugging the trees. This movement continued under the leadership of Shree Sunderlal Bahuguna, and was finally success full as the government abolished contractor system for falling trees and set forest development corporation department for welfare of hilly areas by preventing deforestation.

Cauvery water dispute: It is a dispute which has lasted for the past 100 years between Tamilnadu and Karnataka for sharing water of river Cauvery. Tamilnadu which is in downstream of the river wants more regulated water from Karnataka, the upstream state but Karnataka refuses to do. The matter is pending with court.

Satluj Yamuna link (SYL) canal dispute: This is an issue of sharing water between Punjab and Haryana states. Though Supreme Court has directed Punjab to complete SYL work within a year but the matter is still pending from construction and sharing point of view.

Important Terminology

1. *Demographic transition*: Zero population growth rates due to equal birth and death rates.
2. *Immigration*: Movement of people into country/city.
3. *Emigration*: Movement from the place to other country/city.
4. *Mortality*: Deaths per thousands.
5. *Aforestation*: Plantation and growth of trees.
6. *Photovoltaic cell*: Solar cell which convert solar energy into electricity.
7. *Desertification*: Transformation of fertile land into desert.

8. *Population explosion*: Very high increase in population within short time.
9. *Doubling time*: Time required for population to become double.

Review Questions

1. Describe the habitat pattern and discuss environmental factors governing human settlement.
2. What are the reasons for over population?
3. Define population growth and discuss the factors affecting population growth.
4. Describe the Malthusian and Marxian theory of population growth.
5. Explain the population structure of India.
6. Discuss the factors responsible to control the population growth.
7. Explain the demographic projection schematically.
8. Describe the renewable and nonrenewable natural resources.
9. Explain the importance and functions of forest.
10. Discuss the effects of deforestation.
11. Write short notes on
    (a) Tidal energy (b) Bio gas (c) Nuclear power
12. What are the different water resources? Discuss the problems due to overexploitation of water resources.
13. Discuss the different conventional and nonconventional energy resources.
14. What do you mean by population explosion? Explain its effects on the society.
15. Differentiate the exponential and logistic growth rates.
16. Enlist different methods of population forecasting and calculate population after three decades for the following data by (i) Geometrical increase method, and (ii) Incremental increase method.

Year	Population
1980	50000
1990	61000
2000	72900
2010	85100

17. Discuss the importance of natural resources and focus on the factors required for conservation of natural resources.

18. What are the main water sources available in India? Discuss the problem of water scarcity in India.
19. Describe the Indian scenario regarding energy availability and energy problems.
20. Differentiate malnutrition and undernourishment and discuss factors to improve the food production.

Objective Type Questions

1. Study of human population growth and projections is called
   (a) Demography (b) Geography
   (c) Seismography (d) Biography
2. Movement of people into country/city is called
   (a) Immigration (b) Emigration
   (c) Registration (d) None of these
3. Movement of people from their country to other country is called
   (a) Immigration (b) Emigration
   (c) Registration (d) None of these
4. When birth rate becomes equal to death rate i.e., zero growth, the region has
   (a) High growth (b) Low growth
   (c) Demographic transition (d) None of these
5. Capacity to support maximum population is called
   (a) Carrying capacity (b) Biotic capacity
   (c) Population potential (d) None of these
6. Main energy source in ancient time in villages was
   (a) Coal (b) Bio energy
   (c) Petrol (d) Wood and animal dung
7. Bio gas plants give
   (a) Bio energy (b) Only manure
   (c) Both power and manure (d) None of these
8. Fossil fuels are
   (a) Renewable resources (b) Nonrenewable resources
   (c) Both (a) and (b) (d) None of these

9. Forests are considered
   (a) Renewable resources (b) Nonrenewable resources
   (c) Both (a) and (b) (d) None of these
10. Planting of trees is called
   (a) Afforestation (b) Deforestation
   (c) Forestation (d) None of these
11. Renewable resources are
   (a) Coal and petroleum (b) Forest and plants
   (c) Natural gas (d) None of these
12. Nonrenewable resources are
   (a) Coal and petroleum (b) Forest and plants
   (c) Solar energy (d) None of these
13. Examples of conventional energy resources are
   (a) Coal, natural gas, wood and petroleum
   (b) Wind energy
   (c) Sun energy
   (d) None of these
14. Examples of Nonconventional energy resources are
   (a) Tidal energy (b) Wind energy
   (c) Solar energy (d) All above
15. The abundant energy resource is
   (a) Natural gas (b) CNG
   (c) Solar energy (d) None of these
16. Electricity is generated by sunlight using
   (a) Galvanic cell (b) Photovoltaic cell
   (c) Glassed cell (d) None of these
17. Common fuel used in nuclear reactor is
   (a) U^{232} (b) U^{235}
   (c) NP^{239} (d) None of these
18. Medha Patekar is related with
   (a) Narmada Bachao Andolan (b) Forest Bachao Andolan
   (c) Ganga Bachao Andolan (d) None of these

19. Chipko movement is related with
    (a) Soil conservation (b) Forest conservation
    (c) Ganga bachao andolan (d) None of these
20. Tundra Pradesh are regions with
    (a) Low temperature and low moisture
    (b) Low temperature and high moisture
    (c) Low rainfall and low moisture
    (d) None of these
21. Water dispute of cauvery river is between
    (a) Punjab and Haryana (b) Orissa and Bihar
    (c) Karnatka and Tamilnadu (d) None of these
22. SYL water dispute is between
    (a) Punjab and Haryana (b) Orissa and Bihar
    (c) Karnatka and Tamilnadu (d) None of these

ANSWERS

1. (a)	2. (a)	3. (b)	4. (c)	5. (a)	6. (d)	7. (c)
8. (b)	9. (a)	10. (a)	11. (b)	12. (a)	13. (a)	14. (d)
15. (c)	16. (b)	17. (b)	18. (a)	19. (b)	20. (a)	21. (c)
22. (a)						

List of questions asked in Gujarat Technical University Examinations from this chapter

Q.No.	Details	Marks
Q1.	Explain in detail conventional (nonrenewable) and non conventional (renewable) energy sources. **GTU, Jan 2009**	6
Q2.	What are the effects on environment due to the extraction of mineral resources? **GTU, Jan 2009**	8
Q3.	Describe the key benefits of forests. **GTU, Jan 2009**	7
Q4.	Enlist the different adverse effects of population explosion. **GTU, Jan 2009**	7

Q5.	How is habitation pattern developed? List all environmental factors governing human settlement. **GTU, Jun 2009**	5
Q6.	Why environmental education is provided to engineers? What is relationship between man and environment? **GTU, Jun 2009**	4
Q7.	Give reasons for validity-1. pollution increases with population. **GTU, Jun 2009**	1
Q8.	Give reasons for overpopulation and mention the problems created by overpopulation. **GTU, Jun 2009**	5
Q9.	Describe in detail uses and overuses of water resources in India. **GTU, Jun 2009**	4
Q10.	Give classification of natural resources. Why do we need to conserve natural resources? **GTU, Jun 2009**	4
Q11.	Give in detail different types of renewable resources available and used in India and the problems due to overexploitation of them. **GTU, Jun 2009**	5
Q12.	What is the importance of forest resources for economic and ecological wealth of a country? **GTU, Jun 2009**	5
Q13.	Describe conventional and nonconventional energy resources with environmental problems created by use of each of them. **GTU, Jun 2009**	5
Q14.	Describe in detail the types of forest resources and what are the problems created by deforestations in India? **GTU, Jun 2009**	5
Q15.	Describe the relationship of population and food production. **GTU, Jun 2009**	4
Q16.	Comment on urban energy problems and discuss the effects of overpopulation on energy problems in India. **GTU, Jan 2010**	7
Q17.	What is population growth? How is it calculated? Describe the factors effecting population growth. **GTU, Jan 2010**	7
Q18.	Give the classification of natural resources. Explain the conventional and nonconventional energy resources. **GTU, Jan 2010**	7
Q19.	Describe uses and overuses of land and forest. **GTU, Jan 2010**	7

Q20.	Comment on urban problems related to energy and discuss the effect of overpopulation on energy problems in India. **GTU, Jun 2010**	7
Q21.	Enlist different surface and ground water sources and explain how over exploitation of water resources exaggerate the problem of availability of safe drinking water. **GTU, Jun 2010**	7
Q22.	What are the various sources of energy? Explain in detail any one non conventional energy source. **GTU, Jun 2010**	7
Q23.	Describe the merits and demerits of nuclear power energy and discuss the major concerns regarding its use for electricity generation in India. **GTU, Jun 2010**	7
Q24.	What are the causes of deforestation? Describe in brief some major engineering projects which caused deforestations in India? **GTU, Jun 2010**	7

Chapter 4

ENVIRONMENTAL POLLUTION

Contents

"We won't have a society if we destroy the environment."
– Margaret Mead (1901 – 1978)
American cultural anthropologist

4.1 INTRODUCTION

Pollution is defined as the undesirable and unwanted element present in our environment i.e., air, water and land which may alter physical, chemical and biological characteristics of environment. Pollution may be natural pollution caused by natural disasters, like volcanic eruptions, earthquakes, storms and UV radiations etc., and/or man-made pollution caused by human activities. Pollutants are those agents which cause pollution due to production of end waste products or by-products produced by consumption of natural resources which may deteriorate quality of environment. All the pollutants are not always harmful if not present in excess amount, for example, phosphorus, nitrogen and sulfur increases the fertility and helps in growth if not present in excess amount than their requirement. This chapter describes all types of pollutions and detailed description of air pollution, water pollution, land pollution and the noise pollution. Finally, the chapter also describes the main global environmental problems, like global warming, green house effect, acid rain and depletion of ozone layer.

4.2 POLLUTANTS AND THEIR CLASSIFICATION

Pollutants are the substances present in the environment in such concentration that alter the quality of environment and affects the living things adversely. 'Environmental pollutant' means any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, injurious to environment (EPA, 1986).These are the waste end products or by-products which we throw away, for example, emission of chimneys and automobiles, chemicals discharged by industries, disposal of radioactive waste from nuclear power plant, wastewater from houses and other solid and liquid house hold waste, etc. Pollutants can be classified in the following different point of views as given below.

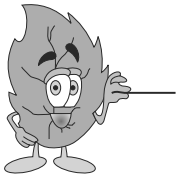
1. **On the basis of nature of material**
   (a) ***Biodegradable pollutants***: These are the pollutants which are degraded naturally by the bacterial action, for example, municipal wastewater and wastewater from houses.

(b) ***Nonbiodegradable pollutants***: These are the pollutants which can not be degraded naturally by the bacterial action or degrade very slowly, for example, pesticides like DDT, plastics, glass polythene bags, E-waste, etc.

2. **On the basis of concentration of pollutants**

(a) ***Quantitative pollutants***: It includes substances which are present in environment but becomes pollutants when their concentration increases the allowable limit, for example, carbon dioxide when released in excess amount in atmosphere can cause green house effect.

(b) ***Qualitative pollutants***: It includes substances which are added in to the environment by human beings for different purposes, for example, insecticides, pesticides and germicides.



DID YOU KNOW?

E-waste is a waste from discarded computers, mobiles and other electronic equipments. About 1.5 million PCs become absolute every year in India, which will increase year by year.

3. **On the basis of form of pollutants**

(a) ***Primary pollutants***: These are the substances which are direct pollutants and remain in the environment in the same form in which they are added, for example, ash, smoke, dust and hydrocarbon, etc.

(b) ***Secondary pollutants***: These are the substances which are formed by the interaction of primary pollutants and/or photochemical reactions of primary pollutants and considered more toxic than primary pollutants, for example, peroxyacyl nitrate (PAN), ozone, ketones and aldehydes, etc.

4. **On the basis of origin of pollutants**

(a) ***Natural pollutants***: This includes the pollutants released naturally due to volcanic eruptions, forest fires, storms, decay of organic matter and other natural disasters.

(b) ***Anthropogenic or man-made pollutants***: These are the pollutants generated by different human activities like industrialisation, urbanisation, deforestation, explosions in wars and in mining, over exploitation of different natural resources, use of fertilisers and pesticides.

4.3 TYPES OF ENVIRONMENTAL POLLUTION

The word environmental pollution is not new for our society but it was there after the origin of life on the earth. Environmental pollution is the pollution of environment with pollutants that adversely affect the human health, quality of environment and functioning of ecosystems. 'Environmental pollution' means the presence in the environment of any environmental pollutant (EPA, 1986). Environmental pollution came into picture since man started using natural resources. In the beginning, nature was able to absorb the pollution but after industrialisation, over population and urbanisation, nature was unable to process and neutralise harmful by products of human activities within reasonable time which led to environmental pollution. Following are the different types of environmental pollutions:

1. **Natural environmental pollution**: It is the pollution caused by –
   - Volcanic eruptions
   - Smoke from fires (grass and forest)
   - Dust storms
2. **Man-made environmental pollution**: It is the pollution caused by human activities which pollute the air, water and soil. Thus, it includes
   - Water pollution
   - Air pollution
   - Land pollution
   - Agricultural pollution
   - Industrial and thermal pollution
   - Transport pollution
   - Nuclear and radioactive pollution
3. **Other types of environmental pollution**: It includes the following types:
   - Noise pollution
   - Oil pollution
   - Light pollution
   - Marine pollution

4.4 WATER POLLUTION

We need fresh water for our daily water consumption which is used for different purposes like domestic, agricultural, power generation, industrial, forestry, fisheries, navigation and

recreational activities. The water used for direct human consumption should be free from unwanted and undesirable impurities. The potable water is the water which is used for drinking purposes and is free from impurities but essentially consists of some minerals in order to give it some taste.

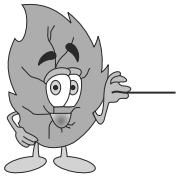
The potable water should have following qualities:

1. It should be odourless and colourless.
2. It should be free from suspended solids and turbidity.
3. It must not contain any pathogenic organisms.
4. It should be free from toxic substances.
5. It should be moderately soft.
6. It should be aesthetically pleasant i.e., cool and fresh.

Water after consumption becomes polluted and so water pollution is defined as presence of unwanted and undesirable impurities which may be organic, inorganic and biological in such a quantity so as to deteriorate the quality of water by alteration in physical, chemical and biological characteristics of water and making that unfit for use.

Some of the indications of water pollutions are:

1. Bad taste and presence of odour and colour due to presence of organic matter and algae cells.
2. Excessive growth of aquatic weeds due to high nutrients.
3. Presence of high chlorides due to contamination from sewer and /or brackish water.
4. Low clarity of water due to turbidity.
5. Sudden killing of fishes due to low dissolved oxygen or toxicity in water.



DID YOU KNOW?

Around 100 dead bodies are dumped every day into Ganga River as well as at least 260 million liters of chemical effluent join the river every day.

Ganga is the ninth largest river in the world with the length of around 2525 kms. It is a perennial river serving as a source of irrigation and water supply in the gangatic basin. But now the situation is alarming as water pollution has reached its peak in Ganga and therefore, government has launched Ganga action plan to improve the quality of Ganga water.

4.4.1 Water Quality Standards

In the beginning of the life on the earth, people could judge the quality of water only through physical senses i.e., by sense of sight, taste and smell but now with the advancement in science and technology as well as in medical science, highly developed methods are available for measuring the quality of water. Various quality parameters which are used to assess the physical, chemical and biological properties of water are listed below.

1. **Physical parameters**: These are the parameters which respond to sense of sight, taste and smell. These are:

(a) ***Suspended solids*** – These are inorganic particles (clay, silt and sand) and organic particles (plant residues, bacteria, algae, etc.) present in suspended form in water. Immiscible liquids like oils and greases also come in this category. Size of these particles varies from 100 μm to 1 μm.

- **Environmental significance of suspended solids** Presence of suspended solids in water is aesthetically not pleasing and these solids act as sites for adsorption of materials. Degradation of organics may impart objectionable smell. If they are present in higher amount than Indian standards, then they may be removed by detaining water in clarifiers and/or filtering water through sand beds.

(b) ***Turbidity*** – It indicates the dirtiness of water and thus measures the extent to which light absorbed or scattered by fine suspended and colloidal solids (these are microbial size inorganic or organic particles of size 1 μm to 10^{-3} μm). Turbidity is due to the presence of colloidal particles of clay, silt, metal oxides, soaps, detergents and kitchen waste.

- **Environmental significance of turbidity** Presence of turbidity in natural water body imparts colour and interfere with penetration of light and photosynthesis process. It varies seasonally and is higher in rainy seasons so to remove it, chemical treatment using coagulants like alum or ferrous sulfate is applied prior to clarifiers.

(c) ***Colour*** – Pure water has no colour but presence of suspended solids give apparent colour to the water while dissolved solids may impart true colour to water. This colour in water is basically due to organic material, humus and leaves, iron and manganese oxides as well as by industrial wastewater particularly dyeing wastewater, paper and pulp wastewater, etc.

- **Environmental significance of colour** Presence of colour in water is aesthetically not acceptable and highly coloured water is also not suitable for laundering, dyeing, beverage, dairy production, etc. If they are present in higher

amount than Indian standards, then they may be removed by aeration, adsorption and oxidation processes.

(d) ***Taste and odour*** – End products and by-products of biological processes, minerals, salts give taste and odour.

- **Environmental significance of taste and odour** Presence of taste and odour in water is aesthetically displeasing and sometimes may be carcinogenic. If it is in higher amount than Indian standards, then they may be removed by aeration, dilution and disinfection processes.

(e) ***Temperature*** – It can not be controlled in mass artificially so its effect is not evaluated directly but shallow water bodies are affected by ambient temperature while discharge of thermal power wastewater which is too hot may alter flora and fauna.

- **Environmental significance of temperature** Temperature is generally higher in summer so the rate of biological activities becomes fast, and solubility of gases in water becomes less. Density of water is maximum at 4°C temperature.

2. **Chemical parameters**: These are the parameters which are related to chemistry and solvent capabilities of water. These are:

(a) ***Dissolved solids*** – These are inorganic particles (minerals, metals and gases) and organic particles (decay products, organic chemicals and gases, etc.) present in dissolved form in water. Size of these particles varies from 10^{-3} μm to 10^{-5} μm.

- **Environmental significance of dissolved solids** Presence of dissolved solids in water is undesirable and it may impart colour, taste and toxicity to water. Degradation of organics may impart objectionable smell. If they present in higher amount than Indian standards, then they may be removed by tertiary treatment like reverse osmosis, electrodialysis, distillation, zeolite resins and ion exchange processes.

(b) ***pH*** – It is defined as the negative logarithm of hydrogen ion concentration present in water. It is measured on pH scale which varies from 0 to 14. At pH 7, water is neutral and below 7, it is acidic while above 7, it is basic or alkaline. Variations in pH may be due to the discharge of industrial wastewater into the water bodies.

- **Environmental significance of pH** For drinking purposes, water pH should be near to neutral i.e., 6.5 to 7.5. Very low and very high pH may also result in the shutdown of biological activities. Acidic or basic pH can be treated to achieve near to neutral by neutralisation and/or equalisation processes.

(c) ***Acidity*** – It is a measure of buffering capacity to neutralise basics. It is due to the presence of minerals and dissolution of carbon dioxide. Minerals like sulfur and

iron pyrites cause mineral acidity which may be in the pH range of 0–4.5 pH. CO_2 acidity is caused by dissolution of carbon dioxide in water from atmosphere which form carbonic acid and may be in the pH range of 4.5–8.2 pH. Acidity is measured in mg/l as $CaCO_3$.

- **Environmental significance of acidity** Presence of acidity causes the corrosion of metals and pipelines. As far as chemical streams are concerned, acidic and alkaline streams can be neutralised to get pH range of 6.5 to 7.5.

(d) ***Alkalinity*** – It is a measure of buffering capacity to neutralise acids. It is due to the presence of bicarbonates, carbonates and hydroxides. Alkalinity is measured in mg/l as $CaCO_3$.

- **Environmental significance of alkalinity** Presence of alkalinity give a bitter taste to water. It is also required for chemical reaction with coagulants like alum.

(e) ***Hardness*** – It is a property of water which alters the foam formation and accounts for higher consumption of soap. Hardness is mainly due to divalent cations of calcium and magnesium present in water. It may be temporary hardness due to presence of bicarbonates and carbonates (also called carbonate hardness) and permanent hardness due to presence of chlorides, sulphates and nitrates of calcium and magnesium (also called noncarbonate hardness). Hardness is measured in mg/l as $CaCO_3$.

- **Environmental significance of hardness** Presence of harness in water consumes more soap and in boiler, it may create problem of scale formation. Hard water can be treated to get soft water by tertiary treatment like lime soda method, reverse osmosis, zeolite resins, etc. Ground water is generally harder compared to surface water. As per the hardness, water can be classified as given below.

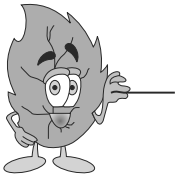
Range of hardness	Importance
0 to 75 ppm	Soft water
75 to 150 ppm	Hard water
150 to 300 ppm	Very hard water
> 300 ppm	Extremely hard water (Not fit for drinking)

(f) ***Chlorides*** – Chlorides are mainly due to the intrusion of sea water or municipal wastewater into the water supply source. They are mostly found as sodium chloride, calcium chloride and magnesium chloride.

- **Environmental significance of chlorides** Presence of chloride in water indicates fresh pollution or intrusion of fresh contamination in water source. It

imparts salty taste to the water. Chlorides above 250 ppm are not permissible in drinking water.

(g) ***Fluorides*** – Fluorides are mainly associated with some sedimentary or igneous rocks. It is toxic to living beings if present in large quantities.



DID YOU KNOW?

At least nineteen states with around 65 million peoples are affected by fluoride contamination in India in which around 60000 villages reported high fluoride levels.

- **Environmental significance of fluorides** Presence of fluoride in water less than 1.0 mg/l can cause dental cavities in children while more than 1.5 mg/l can concentration may cause discoloration or mottling of teeth.

(h) ***Metals*** – Almost all metals are soluble to some extent in water and they reach the water source by dissolution from natural deposits and discharges from industrial, domestic and agricultural wastewater. Metals are of two types, nontoxic metals which are sodium, iron, manganese, aluminum, copper and zinc and toxic metals like arsenic, barium, cadmium, chromium, lead mercury and silver.

- **Environmental significance of metals** Among nontoxic metals, sodium is corrosive, imparts bitter taste and may cause cardiac and kidney diseases while iron and manganese may cause colour problems. Copper and zinc both present in higher amount may be toxic to biological species. Toxic metals present even in minute amount may cause great threat to life of living beings as they are connected by the food chain.

(i) ***Organic matter*** – Almost all organic materials are soluble in water and come from natural sources (decay products) or from human activities (from industrial, domestic and agricultural wastewater). They are divided into two categories: (i) *Biodegradable organics* are used for food by microbes, for example, starch, fat, protein, alcohol, acid, aldehydes, and (ii) *Nonbiodegradable organics* are resistant to biological degradation for example, tannin, lignin, cellulose, pesticide and phenol, etc.

- **Environmental significance of organic matter** Presence of organic matter in water bodies create oxygen demand, as organic matter is consumed by aerobic bacteria which is called biochemical oxygen demand (BOD). This may decrease the dissolved oxygen (DO) level in water bodies.

(j) ***Nutrients*** – Nutrients are essential elements for growth and reproduction of animals and plants. Nitrogen and phosphorous are limiting factors for growth. Nitrogen and phosphorous come in aquatic system from animal wastes, wastewater discharges and chemical fertilisers.

- **Environmental significance of nutrients** Presence of nitrite may be poisonous so it should not be present in drinking water while excess amount of nitrate may cause blue baby diseases. Excess amount of nutrients may also cause rapid growth of aquatic plants in water bodies.

3. **Biological parameters**: Different organisms like bacteria, protozoa and viruses are found in water but pathogens (those organisms which cause diseases) are most important. These pathogens may cause: (i) *Bacterial infections* – It may cause diseases like cholera, diarrhea, typhoid, jaundice, etc. (ii) *Protozoal infections* – It may cause diseases like amebic dysentery and giardiasis, etc. while (iii) *Viral infections* – may cause disease like poliomyelitis, hepatitis, meningitis, etc.

Presence of pathogens is detected in water indirectly by *indicator organisms*. An indicator organism is one whose presence in water indicates the presence of pathogens and mostly its presence is detected by *E-coli test*. This test determines the MPN (Most Probable Number) of coliform bacteria in 100 ml water sample. Another fast way of detection of pathogens in water is membrane filter technique as described below.

1. **E-coli test for MPN (Most Probable Number)**: This test is conducted in the following three steps:
   (a) ***Presumtive test*** – In this test, a lactose broth is inoculated with water sample in different decimal fractions (0.1 ml, 1.0 ml, 10 ml etc) in a series of text tubes. These tubes are incubated for an appropriate time (generally 24 hrs, 48 hr and 72 hrs) at 35^{o}C temperature and inspected for gas formation. Number of tubes showing gas formations are considered positive tubes and rest of the tubes are negative.
   (b) ***Confimative test*** – In this test, the sample is inoculated from the positive tubes of preumtive test in to another set of tubes which contains BGB broth (Brilliant Green Broth) which suppresses the growth of other microbes than E-coli. As in presumptive test, in this also the number of tubes showing gas formations are considered positive tubes and are counted which indicates confirmation of the presence of pathogens.
   (c) ***Completed test*** – In this test, the ability of cultures grown in confirmed test is again tested with lactose broth like presumptive test to complete the test

$$\text{MPN per 100 ml} = \frac{\text{Number of positive tubes}}{\sqrt{(\text{ml of sample in negative tubes}) \times (\text{ml of sample in all tubes})}}$$

2. **Membrane filter technique**: It gives direct count of coliform bacteria and is a popular technique. In this method, water sample is filtered through 0.45 μm size filter and filtered bacteria are allowed to grow with selective media and inhibitors of other bacteria at appropriate temperature for 24 hrs. After incubation period, the visible colonies are counted by colony meter and the results are reported in numbers of bacteria in 100 ml of water.

Table 4.1 Indian Standards for Water quality (IS-10500)

Sr. No.	*Parameter*	*Desirable limit*	*Permissible limit*
1	Colour (Hazen units)	5	25
2	Odour	Unobjectionable	–
3	Taste	Agreeable	–
4	Turbidity (NTU)	5	10
5	pH value	6.5 to 8.5	No relaxation
6	Total hardness (as $CaCO_3$) Mg/l	300	600
7	Iron (as Fe mg/l)	0.3	1.0
8	Chlorides (as Cl mg/l)	250	1000
9	Residual free chlorine mg/l min	0.2	-
10	Fluoride (as F mg/l)	1.0	1.5
11	Dissolved solids Mg/l	500	2000
12	Calcium (as Ca mg/l)	75	200
13	Magnecium (as Mg mg/l)	30	100
14	Copper (as Cu mg/l)	0.05	1.5
15	Manganeses (as Mn mg/l)	0.1	0.3
16	Sulphate (as SO_4 mg/l)	200	400
17	Nitrate (as NO_3 mg/l)	45	100
18	Alkalinity (as $CaCO_3$) Mg/l	200	600
19	Phenolic compounds mg/l	0.001	0.002
20	Mercury (as Hg mg/l)	0.001	No relaxation
21	Cadmium (as Cd mg/l)	0.01	No relaxation
22	Selenium (as Se mg/l)	0.01	No relaxation
23	Arsenic (as As mg/l)	0.05	No relaxation
24	Cyanide (as Cn mg/l)	0.05	No relaxation
25	Lead (as Pb mg/l)	0.05	No relaxation
26	Zinc (as Zn mg/l)	5	15

Table Contd..

Table Contd..

27	Cromium (as Cn mg/l)	0.05	No relaxation
28	Aliminium (as Al mg/l)	0.03	0.2
29	Boron (as Bo mg/l)	1	5
30	Radioactive materials		
	Alpha- emitters pci/l	–	0.1
	Beta- emitters pci/l	–	1
31	E-Coli	No *E-Coli* in 100 ml	

Table 4.2 BIS (ISI) Standards for Discharge of wastewater

Characteristics of wastewater	*Tolerance limits for Domestic effluents discharged into inland surface water: IS4764-1973*	*Tolerance limits for Industrial effluents discharged into inland surface water: IS:2490-1974*	*Tolerance limits for Industrial effluents discharged into public sewer: IS:3306-1974*	*Tolerance limits for Inland surface water used public water supplies and bathing ghats: IS:2296-1974*
BOD (5 days at 20°C), mg/l	20	30	500	3
COD, mg/l	–	250	–	–
pH value	–	5.5 to 9.0	5.5 to 9.0	6.0 to 9.0
Total suspended solids Mg/l	30	100	600	–600
Temperature, °C	–	40°C	45°C	–
Oil and grease (mg/l)	–	10	100	0.1
Phenolic compounds mg/l	–	1	5	0.005
Fluoride (as F mg/l)	–	2.0	–	1.5
Chlorides (as Cl mg/l)	–	–	600	600
Sulphides (as S mg/l)	–	2	–	–
Total residual chlorine mg/l	–	1.0	–	–
Insecticides (mg/l)	–	0.1	–	0
Mercury (as Hg mg/l)	–	0.01	–	–
Cadmium (as Cd mg/l)	–	2	–	–
Selenium (as Se mg/l)	–	0.05	–	0.05
Arsenic (as As mg/l)	–	0.2	–	.2
Cyanide (as Cn mg/l)	–	.2	–	2

Table Contd..

Table Contd..

Lead (as Pb mg/l)	–	0.01	1	.1
Zinc (as Zn mg/l)	–	5	15	–
Cromium (as Cn mg/l)	–	0.01	2	.05
Nickel (mg/l)	–	3	2	–
Sulphates (mg/l)	–	–	–	1000
Radioactive materials				
Alpha- emitters mi/ml		10^{-7}		10^{-9}
Beta- emitters mi/ml		10^{-6}		10^{-8}
% sodium	–	–	60	–
Ammonical nitrogen, mg/l	–	50	50	–
Nitrate (as NO_3 mg/l)	–	–	–	50

Table 4.3 The WHO Standards for Water quality

Sr. No.	*Parameter*	*Permissible limit*
1	BOD (5 days at 20°C), mg/l	6
2	COD, mg/l	10
3	pH value	6.5 to 9.2
4	Total hardness (as $CaCO_3$) Mg/l	500
5	Iron (as Fe mg/l)	1.0
6	Chlorides (as Cl mg/l)	500
7	Dissolved solids Mg/l	500
8	Calcium (as Ca mg/l)	100
10	Magnecium (as Mg mg/l)	150
11	Copper (as Cu mg/l)	1.5
12	Manganeses (as Mn mg/l)	0.5
13	Nitrate and Nitrite (mg/l)	45
14	Mercury (as Hg mg/l)	0.001
15	Cadmium (as Cd mg/l)	0.01
16	Selenium (as Se mg/l)	0.01
17	Arsenic (as As mg/l)	0.05
18	Cyanide (as Cn mg/l)	0.05
19	Lead (as Pb mg/l)	0.01
20	PAH	0.2
21	Cromium (as Cn mg/l)	0.05
22	Ammonium (mg/l)	0.5
23	Boron (as Bo mg/l)	–
24	Pesticide	–
25	E-Coli	1-No *E-Coli* in 100 ml

4.4.2 Sources of Water Pollution

Sources of water pollution are basically divided into point sources and nonpoint or diffused sources as per the way by which they are discharged into water bodies.

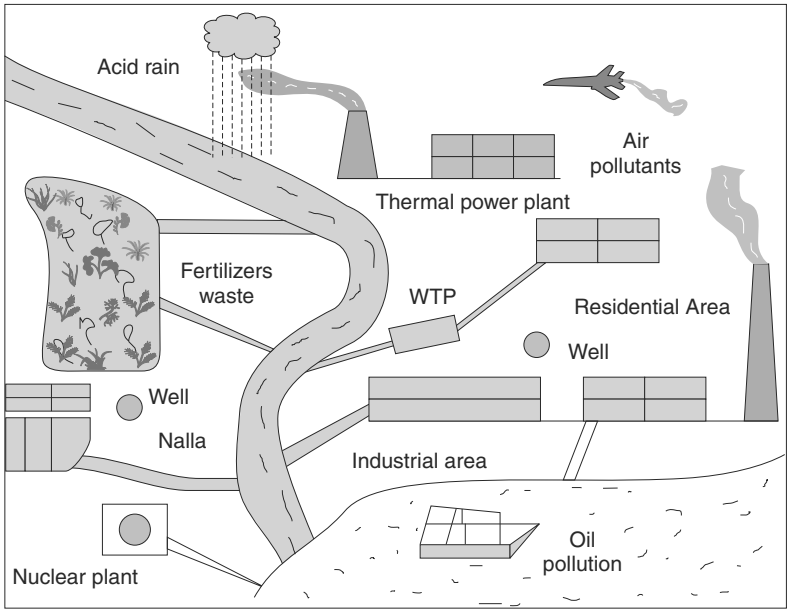
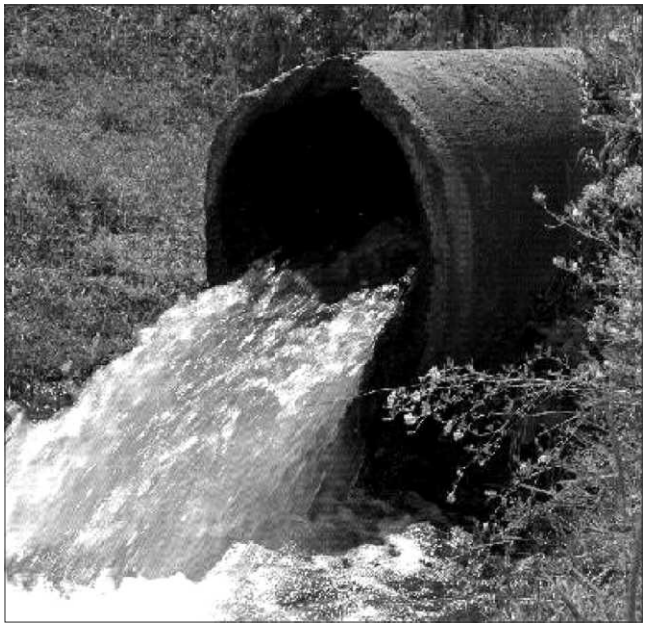


Fig. 4.1 Sketch showing sources of water pollution

1. **Point sources**: These are the sources of pollution from single identified location and this includes the following sources:

(a) ***Municipal wastewater outlet*** – This includes the discharges from houses, commercial centers and small industries discharging their wastewater into municipal sewer. This household wastewater contains human and animal urine and excreta, food residues, cleaning agents, etc., and thus very rich in organic matter. The wastewater from industries may have large amount of suspended solids, variable pH, presence of heavy metals and nutrients, etc.

(b) ***Industrial wastes*** – The waste water discharged from industries into water bodies are major sources of water pollution. Almost all types of industries (textile, dye, food processing, paper and pulp, metallurgical, oil, tanneries and plastic industries, etc.) generate lots of wastewater which contain inorganic pollutants like different metals, chlorides, sulphates, oxides of metals, acids and alkalies, etc., and organic



(a)

(b)

Fig. 4.2 Pictures showing (a) Water pollution by discharge of industrial effluent; (b) Water pollution in river by human activities

Source: Google.com

(a)

(b)

Fig. 4.3 Pictures showing (a)Water pollution in sea shore by human activities; (b)Water pollution by human activities in water bodies near to worship places.
Source: Google.com

pollutants like carbohydrates, proteins, oils, fates, aromatic compounds, cellulose and phenols, etc.

(c) ***Other point sources*** – Thermal and nuclear power plants use water as coolant and discharges it back to the water bodies. This causes sudden rise in temperature of water which imbalances the aquatic ecosystem. In coastal areas also, domestic and industrial wastewater is generally discharged directly into the sea which disturbs the

marine ecosystem. Oil spills due to accidents may also create problems in aquatic life.

2. **Diffused or Nonpoint sources**: These are those sources of pollution whose location can not be identified or fixed easily. Such sources are as given below.

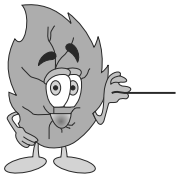
(a) ***Agricultural sources*** – To increase the production, chemical fertilisers are mostly used now a days which contain main plant nutrients like nitrogen, phosphorous and potassium. Farmers also use the pesticides to protect their crops which contain insecticides, herbicides, rodenticides, fumigants and DDT. All these chemical fertilisers, pesticides and soil nutrients leach down to ground water and also join the surface water bodies by runoff during rainy season. Pesticides are more persistent and are absorbed by producers and passed to consumers through food chain and at each trophic level, concentration of pesticides goes on increasing which is called bio-magnification or biological magnification.

(b) ***Atmospheric deposition by rain*** – Air pollutants get dissolved in rain water and contaminate the ground water as well as surface water sources.

4.4.3 Effects of Water Pollutants

Different types of pollutants present in water alter the physical, chemical and biological characteristics of water, thus, making water unfit for use. The main effects of water pollutants can be summarised as below.

1. **Effects on human beings**: Water contaminated by the domestic wastewater may contain pathogenic bacteria, viruses, protozoa, etc., and if such water is consumed by human beings they may get different water borne diseases like cholera, jaundice, typhoid, dysentery, etc.



DID YOU KNOW?

Methyl mercury poisoning caused by eating contaminated fish resulted Minamata disease in Japan which killed more than 100 people.

Water polluted by industrial effluents may contain lots of heavy metals which may be responsible for different health hazards if found in the concentration more than the permissible level as given below.

Table 4.4 Effects of heavy metals on human beings

Name of the heavy metal	*Effect on human health*
Cadmium	Kidney damage, disorder of liver and brain, intestinal disorder
Mercury	Kidney damage, blurred vision, Deafness and mental disorder
Lead	Liver and kidney damage, mental disorder
Arsenic	Damages bone marrow and cellular elements of blood, skin cancer

2. **Effects on Aquatic system**: If the polluted water from the houses, reaches directly into the water bodies, then it may impart high oxygen demand as such wastewater contains mostly biodegradable organic matter which has high BOD. BOD is called *biochemical oxygen demand* which is defined as oxygen demand created by the aerobic bacteria to decompose the biodegradable organic matter aerobically. Industrial wastewater may contain biodegradable organic matter and nonbiodegradable organic matter. Therefore, its strength is determined by COD rather than by BOD. COD is called *chemical oxygen demand* which is defined as requirement of equivalent oxygen to degrade biodegradable and nonbiodegradable organic matter by oxidising agents like potassium dichromate under controlled conditions. The valve of COD is mostly more than the BOD. Thus, polluted water from the houses and industries may effect aquatic system in the following manner:

(a) Discharge of such wastewaters in water bodies reduces dissolved oxygen of those water bodies. If the dissolved oxygen (DO) reduces below to 4.0 mg/l, then it may kill the fishes and pose danger to other aquatic life. Therefore, the strength of wastewater discharged into the water bodies should be such that DO should not go down below 4.0 mg/l.

(b) If the industrial wastewater is discharged into the water bodies then the presence of organic acids may alter pH value which may disturb the aquatic ecosystem.

(c) Discharge of heavy metals may impart toxicity to the aquatic life and even eliminate some species.

(d) Discharge of hot waters from thermal power plants and nuclear plants may reduce the DO and alter the flora and fauna.

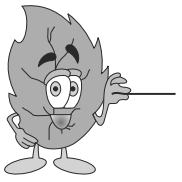
(e) High turbidity in rainy season results in interference in the process of photosynthesis.

3. **Biological magnification**: The process by which some pollutants get accumulated in organisms in increasing concentration as per the food chain is called *biological magnification*. Some of the pesticides are nondegradable and remain for a long time as DDT are most persistent pesticides. DDT stands for dichloro, diphenyl trichloroethane. It is a chlorinated hydrocarbon, which has a half-life of 15 years, which means if you use

100 kg of DDT, it will break down to 50 kg after 15 years. This means DDT will require around 200 years becoming negligible in its concentration. These pesticides can not be metabolised or excreted to reach from one organism to another organism through food chain as small organisms are eaten by big ones in food chain. Thus, towards top trophic levels consumption of more and more biomass cause more and more accumulation of toxic materials. The biological magnification of pollutants can be estimated by 'Biological Concentration Factor' (BCF) as given below.

$$BCF = \frac{\text{Concentration of toxic material in organism}}{\text{Concentration of toxic material in environment}}$$

The best example of biological magnification is accumulation of DDT in tissues of organisms of aquatic system in USA where the DDT was sprayed to control the growth of mosquitoes for long time which resulted in declination in fish eating birds. It was found that this was due to the increase in DDT concentration in the birds due to biological magnification of DDT through food chain.



DID YOU KNOW?

As per the report from WHO, more than 25 millions farm workers in developing countries are suffering with pesticide poisoning.

In a food chain, the concentration of DDT was found more in zooplanktons who eat phytoplankton and still higher concentration in different small fishes as they consume zooplanktons. The fish eating birds accumulated highest DDT concentration as they consumed different fishes which caused the killing of these birds.

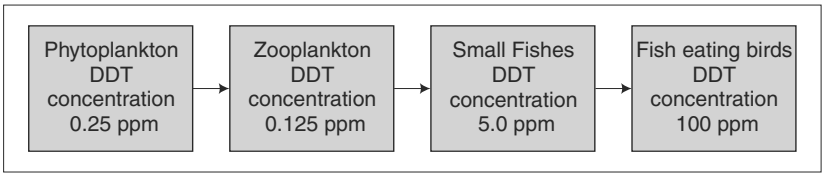


Fig. 4.4 Food chain showing biological magnification in aquatic system

4. **Effects on ground water**: Seepage from industrial wastewater, domestic wastewater and agricultural runoff may contaminate groundwater. Excess amount of nitrate in drinking

water taken from tube wells may cause blue baby disease and excess fluoride may cause fluorosis (decolorisation of teeth). Over exploitation of groundwater may leach arsenic from soil to contaminate water whose chronic exposure may cause black foot disease.

5. **Eutrophication**: Eutrophication is the phenomena which causes enrichment of water bodies by nutrients like phosphorous and nitrogen. Presence of nutrients is must for growth and reproduction of organisms but if these nutrients are present in excessive amount then they act as pollutants because they allow excessive growth of aquatic plants like algae. On the basis of presence of nutrients, aquatic system may be classified as given below.

(a) ***Oligotrophic aquatic system*** – In this system, water contains low nutrients so it shows low productivity of aquatic plants.

(b) ***Mesotrophic aquatic system*** – In this system, the water contains moderate concentration of nutrients so it shows average productivity of aquatic plants.

(c) ***Eutrophic aquatic system*** – In this system, water contains very high concentration of nutrients so it shows high productivity of aquatic plants.

Eutrophication is a natural process and takes several years to become enriched with nutrients but is also enhanced through human activities. Discharge from municipal sewers, industrial wastewater and runoff from agricultural land may provide lots of phosphates and nitrates along with some minerals required for algal growth.

After some time, due to excessive growth of algae, the entire water body becomes green. After that dyeing of algal cells starts. This decay of algae causes depletion of dissolved oxygen in water body, bad taste and bad odour, high turbidity which lead to dying of fishes and other aquatic life. Slowly, after some time such a water body becomes useless. Generally, it is observed that concentration of nitrogen higher than 0.3 mg/l and phosphorous more than 0.15 mg/l causes eutrophication.

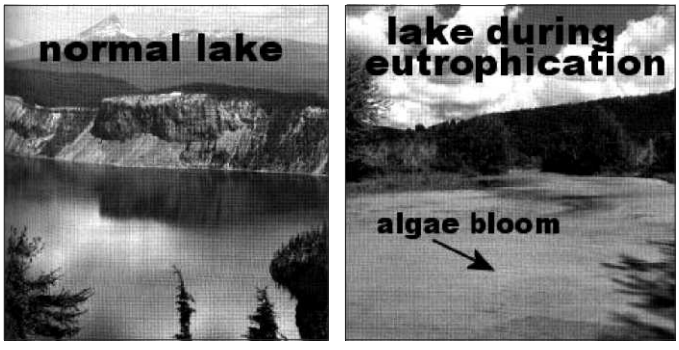


Fig. 4.5 Pictures showing normal lakeand lake during eutrophication
Source: Thinkquest Team "Fish," March 2005

As far as control of eutrophication is concerned, concentration of phosphorous, act as a limiting factor because it is somewhat difficult to control nitrogen as it is fixed from atmosphere.

Different Steps Required to be Taken for Control of Eutrophication are given below.

1. Restrictions on discharges of nutrients to reduce the growth of algae.
2. Reduction in the discharge of agricultural runoff and intrusion of domestic wastewater in the pond or lake.
3. Restrictions on direct discharge of the detergents in water bodies and limiting the use of phosphorus in the detergents.
4. Removal of algal blooms by dredging the excessive algal blooms.
5. Application of algaecides (copper sulphate) on water surface.
6. Using lime treatment for precipitation of phosphorus.

4.4.4 Control of Water Pollution

The water which is used by human for various activities, becomes wastewater after its consumption. This wastewater can not be discharged directly into water bodies if sufficient dilution is not available. Therefore, wastewater is to be treated at wastewater treatment plant and after that it can be discharged into water bodies where further purification takes place by natural processes if strength of wastewater discharged does not exceed its assimilating capacity.

Every natural source of water whether it is running water body like river or stagnant water body like lake, has its self purification capacity by which it purifies itself with time and space. This process of self purification of natural water sources is due to the following process:

1. **Dilution and Dispersion**: When polluted water of less quantity is discharged into the water body containing large volume of water, then it is rapidly dispersed and diluted in it. Thus, due to dilution process, the net concentration of pollutants in water reduces as given below.

$$C = (Cw\ Qw + Cr\ Qr)/(Qw + Qr)$$

Here, C is the net concentration of pollutant in a mixer of river water and wastewater,
Cw is a concentration of pollutant in wastewater,

Qw is a flow rate of wastewater,

Cr is a concentration of pollutant in water body,

Qr is a flow rate of water body.

2. **Sedimentation**: It is the process in which the particles present in polluted water settle due to gravitational forces and reduction in velocity when wastewater joins water body and thus helps in self purification process.

3. **Sunlight**: It helps in bleaching the colour and acts as compulsory source for photosynthesis process.

4. **Oxidation and Reduction**: Oxidation of organic matter starts as soon as wastewater is discharged into water body as it contains dissolved oxygen. The deficiency thus created, is filled up by re-oxygenation through atmospheric oxygen. Therefore, it is a strong process which self purifies the water body. Reduction process is a process of hydrolysis of organic matter due to microbes or chemicals which converts complex organic matter into simple organic matter.

Now if the concentration of pollution is very high and is beyond the self purification capacity then effective control measures are required as discussed below.

1. By treating wastewater at wastewater treatment plant before discharging it into water bodies. This involves (i) Primary treatment like screening: removes floating particles, grit removal; removes grit materials and sedimentation processes: removes settable suspended particles, (ii) Secondary treatment like activated sludge process (ASP): reduces organic matter (BOD and COD) by aerobic biological oxidation through suspended growth and trickling filter process (TFP): reduces BOD by aerobic biological oxidation through fixed growth, and (iii) Tertiary treatment like chemical oxidation: removes dissolved organic matters, nutrients and microbes by chlorine gas or ozone, etc.
2. Industries should be forced to set up their own effluent treatment plant (ETP) to treat their wastewater before discharging it into water bodies.
3. By prohibiting direct washing of cloths and animals in water bodies used for drinking water supply.
4. By making public aware about the adverse effects of water pollution and educating those to prevent direct pollution in water bodies by human activities.
5. By having water purifiers in households, in order to have safe drinking water.
6. By reducing the oil spills and discharge of pesticides in water bodies.
7. By preventing the discharge of hot water from thermal power plants directly into the water bodies.
8. By promoting the growth of water hyacinth and other aquatic weeds in water bodies like lake and ponds which reduces effects of toxicity and heavy metals.

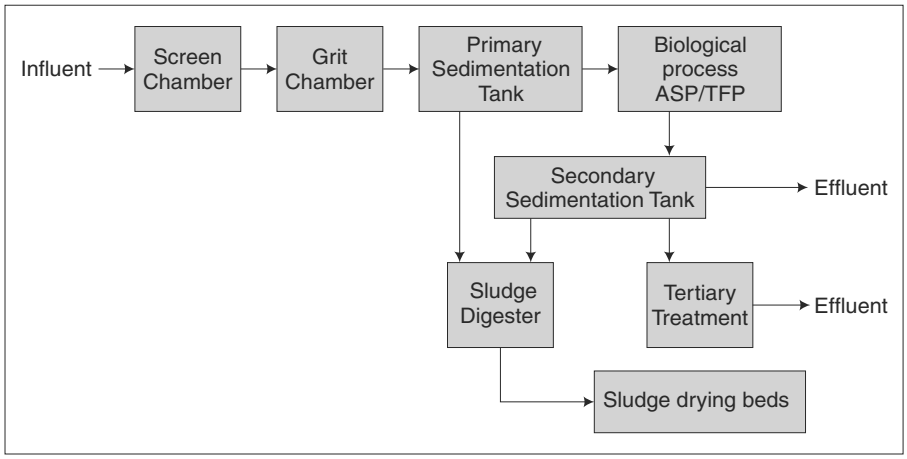


Fig. 4.6 Flow diagram of wastewater treatment plant

4.5 AIR POLLUTION

Air pollution is defined as presence of unwanted and undesirable foreign particles and gases in the air which may have adverse effects on human beings, animals, plants, vegetations, and important structures. Every living being require oxygen for survival which is available from the air present in atmosphere. At present, due to rapid industrialisation, urbanisation and overpopulation, this air has become polluted.

4.5.1 Compositions of Atmospheric Air

Atmospheric air is a mixer of various gases, water vapour, and fine particulate matters. The major gases present in atmospheric air are nitrogen, oxygen, argon and water vapours and important minor gases are carbon dioxide, neon, helium and methane. The detailed compositions of atmospheric air and as shown in Table 4.5.

Table 4.5 Composition of Atmosphere Air

Sr. No.	*Names of gases*	*Concentration by % Volume*	*Category in atmospheric gases*
1	Nitrogen (N_2)	78.09	
2	Oxygen (O_2)	20.95	Major gases
3	Argon (Ar)	0.93	

Table Contd..

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4	Water vapours	0.1	
5	Carbon dioxide (CO_2)	0.032	
6	Neon (Ne)	0.0018	Minor gases
7	Methane (CH_4)	0.0002	
8	Helium (He)	0.0005	
9	Krypton	0.0001	
10	Hydrogen	0.00005	
11	Nitrous oxide	0.000025	
12	Carbon monoxide	0.00001	
13	Xenon	0.000008	Trace gases
14	Ozone	0.000002	
15	Ammonia	0.000001	
16	Nitrogen dioxide	0.0000001	
17	Sulphur dioxide	0.00000002	

4.5.2 Structure of Atmosphere

On the basis of altitude and temperature change, the atmosphere can be divided into five regions as given below.

1. **Troposphere**: It is the first layer over the ground in which the living organisms exist. In this layer, temperature decreases with altitude (Negative lapse rate-6.5°C/km). This layer is known for pollution, presence of water vapours, dust, air movement and clouds. This layer is very important as all climatic changes takes place in this layer itself. It extends from ground up to about 8 – 16 km towards polar and equator region.
2. **Stratosphere**: It is the next vertical layer after troposphere from the ground. In this layer temperature increases with altitude (Positive lapse rate). Stratosphere is known for the presence of ozone which is found at around 20 km from ground. This layer of ozone formed by photochemical reactions is called *ozonosphere*.

   $$O_2 + \text{heat radiation} \rightarrow O_3$$

   This layer acts as a protective shield against the harmful effects of ultra violet radiations (wavelength-190-380 nm) on living organism.
3. **Mesosphere**: It exists over stratosphere and in this layer, temperature decreases with altitude (Negative lapse rate) because of low concentration of ozone and low

absorption of radiations. This layer is very special as all sound waves as well as short radio waves coming from earth are reflected from this layer.

4. **Thermosphere**: After mesosphere, thermosphere starts and extends up to 500 km above earth's surface. Temperature rises in this zone with altitude and this trend continues further. Ionisation of elements like oxygen and nitric oxide take place in the top portion of layer therefore the upper layer of thermosphere is also called *ionosphere*.
5. **Exosphere**: The upper most layer of atmosphere which extends up to 1600 km and gives way to space is called *exosphere*. In this layer, very high temperature (> 1200°C) is found.

Table 4.6 Structure of Atmosphere

Sr. No.	*Name of Layer*	*Altitude from earth's surface in km*	*Temperature Range (°C)*	*Remarks*
1	Troposphere	0-12	20 to –56	Presence of O_2, CO_2, N_2, NOx, SOx, and water vapors
2	Stratosphere	12-50	–56 to –2	Presence of ozone and oxygen
3	Mesosphere	50-85	–2 to –90	Presence of ozone and nitrogen
4	Thermosphere	85-500	–90 to 1200	Presence of ozone, oxygen, NO and charged gases
5	Exosphere	500-1600	> 1200	Air less and contains hydrogen gas in ionized state

4.5.3 Ambient Air Quality Standards

Ambient air quality standards in India for the different air pollutants like sulphur dioxide (SO_2), oxides of nitrogen (NO_2), suspended particulate matter, respirable particulate matter and carbon monoxide (CO), etc., are given in Table 4.7 as given below.

Table 4.7 Indian Ambient Air Quality Standards

Pollutant	*Time Weighted Average*	*Concentration in Ambient Air*		
		Industrial Area	*Residential, Rural and other*	*Sensitive Area*
Sulphur Dioxide (SO_2)	Annual 24 hours	80 µg/m^3 120 µg/m^3	60 µg/m^3 80 µg/m^3	15 µg/m^3 30 µg/m^3
Oxides of Nitrogen (NO_2)	Annual 24 hours	80 µg/m^3 120 µg/m^3	60 µg/m^3 80 µg/m^3	15 µg/m^3 30 µg/m^3

Table Contd.

Table Contd.

Suspended Particulate Matter (SPM)	Annual	360 μg/m^3	140 μg/m^3	70 μg/m^3
	24 hours	500 μg/m^3	200 μg/m^3	100 μg/m^3
Respirable Particulate Matter (< 10 um) (RPM)	Annual	120 μg/m^3	60 μg/m^3	50 μg/m^3
	24 hours	150 μg/m^3	100 μg/m^3	75 μg/m^3
Lead (pb)	Annual	1.0 μg/m^3	0.75 μg/m^3	0.50 μg/m^3
	24 hours	1.5 μg/m^3	1.00 μg/m^3	0.75 μg/m^3
Carbon Monoxide (CO)	8 hours	5.0 μg/m^3	2.0 μg/m^3	1.0 μg/m^3
	1 hour	10.0 μg/m^3	4.0 μg/m^3	2.0 μg/m^3

Source: Ministry of Environment and Forests, Government of India notification, 1994

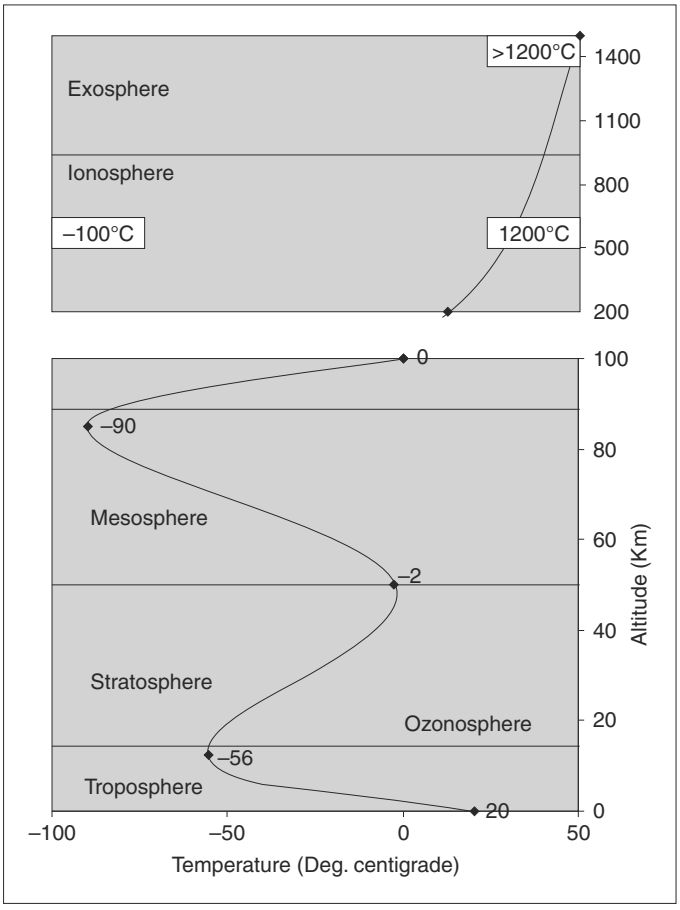


Fig. 4.7 Temperature profile of atmosphere

Table 4.8 New National Ambient Air Quality Standards (NAAQS)

Pollutant	*Time Weighted Average*	*Concentration in Ambient Air*	
		Industrial Area	*Residential, Rural and other*
Sulphur Dioxide (SO_2)	Annual	50 $\mu g/m^3$	20 $\mu g/m^3$
	24 hours	80 $\mu g/m^3$	80 $\mu g/m^3$
Oxides of Nitrogen (NO_2)	Annual	40 $\mu g/m^3$	30 $\mu g/m^3$
	24 hours	80 $\mu g/m^3$	80 $\mu g/m^3$
Suspended Particulate	Annual	60 $\mu g/m^3$	60 $\mu g/m^3$
Matter (PM_{10})	24 hours	100 $\mu g/m^3$	100 $\mu g/m^3$
Respirable Particulate	Annual	40 $\mu g/m^3$	40 $\mu g/m^3$
Matter (< 2.5um) (RPM)	24 hours	60 $\mu g/m^3$	60 $\mu g/m^3$
Lead (pb)	Annual	0.5 $\mu g/m^3$	0.5 $\mu g/m^3$
	24 hours	1.0 $\mu g/m^3$	1.0 $\mu g/m^3$
Carbon Monoxide (CO)	8 hours	2.0 $\mu g/m^3$	2.0 $\mu g/m^3$
	1 hour	4.0 $\mu g/m^3$	4.0 $\mu g/m^3$
Ozone (O_3)	8 hours	100 $\mu g/m^3$	100 $\mu g/m^3$
	1 hour	180 $\mu g/m^3$	180 $\mu g/m^3$
Ammonia(NH_3)	Annual	100 $\mu g/m^3$	100 $\mu g/m^3$
	24 hours	400 $\mu g/m^3$	400 $\mu g/m^3$
Benzene (C_6H_6)	Annual	5 $\mu g/m^3$	5 $\mu g/m^3$
Benzopyrene (BaP)	Annual	1 $\mu g/m^3$	1 $\mu g/m^3$
Arsenic (As)	Annual	6 $\mu g/m^3$	6 $\mu g/m^3$
Nickel (Ni)	Annual	20$\mu g/m^3$	20 $\mu g/m^3$

Source: Central pollution control board data

4.5.4 Classification of Air Pollutants

Air pollutant means any solid, liquid or gaseous substance present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment (EPA, 1981). The air pollutants can be classified in three ways as per the origin, as per the state of matter and as per the presence.

1. **As per the origin of pollutants**: According to the origin of pollutants, the air pollutants are basically classified into two types:

(a) ***Primary air pollutants*** – Primary air pollutants are those types of air pollutants which are directly emitted from the source into the atmosphere and remains in the same form in the atmosphere. Some of the examples of these pollutants are oxides of carbon, nitrogen and sulphur, hydrocarbons and particulate matter which include ash, smoke, dust, fumes, mist and sprays, etc.

(b) ***Secondary air pollutants*** – Secondary air pollutants are those air pollutants which are formed by chemical reactions among primary pollutants and atmospheric chemical species. Some of the examples of secondary air pollutants are aldehydes, ketones peroxyacyl nitrate (PAN), ozone and sulphur trioxide, etc.

2. **As per the state of matter**: According to the state in which air pollutants are found in atmosphere, their classification is of two types:

(a) ***Gaseous air pollutants*** – Gaseous air pollutants are those air pollutants which are found in the gaseous state at normal temperature and pressure in the atmosphere. Most common examples of these pollutants are oxides of carbon dioxide, carbon monoxide, nitrogen oxides, sulphur dioxides, hydrocarbons and photochemical oxidants.

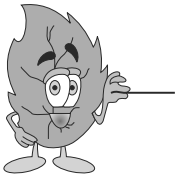
(b) ***Particulate air pollutants*** – Particulate is a term used to describe dispersed air borne solid and liquid particles larger than single molecules which remain for very long time in suspension. These pollutants are further classified as per the mode of formation and their size as given below.

- **Dust** These are small solid particles of size 1 to 200 μm and are generated by material crushing, grinding or blasting. They remain in suspension but finally settle under influence of gravity.
- **Mist** They are liquid droplets of size around 0.1 to 10 μm and formed by the condensation of vapours in the atmosphere of chemicals.
- **Fumes** They are fine solid particles of size around 0.1 to 1 μm and formed by the condensation of vapours of solid matter.
- **Smoke** They are also fine sold particles of size around 0.1 to 1 μm and formed by the incomplete combustion of organic matter like coal and wood.
- **Aerosols** These are air borne suspensions of solid or liquid particles smaller than 1 μm. Larger class fumes, smoke, mist and dust are called aerosols.
- **Fog** If the mist is made up of water droplets at high concentration so as to obscure vision then mist is called fog.
- **Flyash** These are inorganic substances released after the burning of organic part from coal or wood. Thus, these are finely divided noncombustible light particles.
- **Soot** These are the carbon particles impregnated with tar and released by the incomplete combustion of carbonaceous materials.
- **Photochemical smog** Atmospheric pollution formed by chemical reactions among hydrocarbons, ozone, and other pollutants in the presence of sunlight.

3. **As per the presence in environment**: According to the presence in the environment, the air pollutants are also classified into two ways:

(a) ***Indoor air pollutants*** – Indoor air pollutants are those types of air pollutants which are generated from the households, for example, mosquito repellents, cleaning agents, pesticides, paints, glues and varnishes. They also include cigarette smoke, gases from stoves and microbes like viruses, bacteria, fungi and pollens.

(b) ***Outdoor air pollutants*** – Outdoor air pollutants are those air pollutants which are found or formed outside the buildings, for example, automobile pollutants, industrial pollutants, mining pollutants and natural emissions from decaying organic matter and animals, etc.



DID YOU KNOW?

A cigarette smoking causes premature death of 5 million people every year. In India around 8 lacs lives are lost every year due to tobacco smoking.

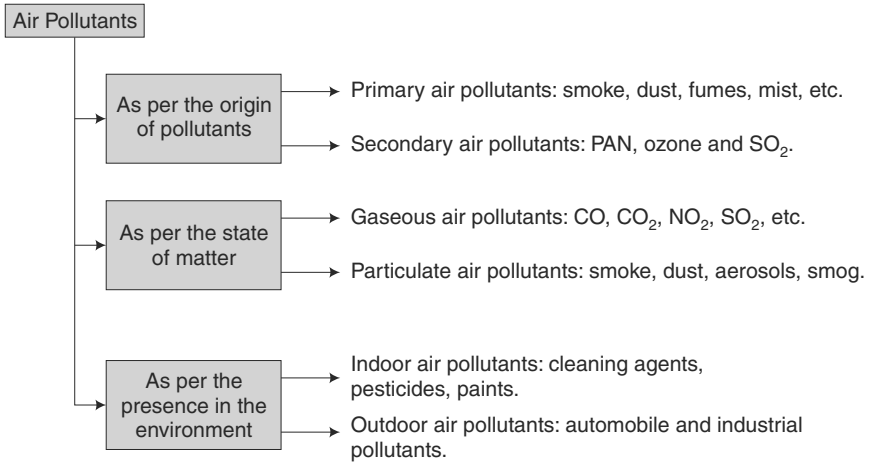


Fig. 4.8 Flow chart showing classification of air pollutants

4.5.5 Sources of Air Pollution

Release of poisonous gases from the industries and automobiles pollute the air and affects both the living as well as nonliving components of environment. There are two main sources or causes of air pollution:

1. **Natural Sources of Air Pollution**: These are the sources of air pollution which occurs naturally as given below.

(a) Marsh gases due to decay of vegetable matter in marshy places.
(b) Many gases and ash released by volcanic eruptions.
(c) Smoke and green house gases released by forest fires.
(d) Harmful gases, particulate and chemicals from dust storms, electric storms, solar flares, etc.
(e) Presence of bacteria, viruses, fungi and pollen.

2. **Man Made or Anthropogenic Sources of Air Pollution**: Rapid industrialisation, automobile revolution, over population, advanced agricultural techniques and deforestation are mainly responsible for man made air pollution which also includes the following sources:

(a) Point sources like chimneys of different industries releasing emissions in air which affects only restricted areas.
(b) Mobile sources like vehicles, trains, aeroplanes which emit exhaust into air over long distances.
(c) Area sources like release of air pollutants from industrial area of town or city which affects particular area.

4.5.6 Common Air Pollutants-Sources and Effects

There are several types of air pollutants present in either gaseous form or as particulate material in the atmosphere. Some of these common and important air pollutants are discussed below with their sources and effects on human, animals and materials.

1. **Carbon dioxide (CO_2)**: Carbon dioxide is ideally not considered as an air pollutant if its presence does not exceed the concentration ideally present in atmosphere. Rapid industrialisation and discharge of high combustion gases in the atmosphere has increased its concentration, thus making it a pollutant.

Main sources of CO_2 are combustion of fossil fuel, emissions from jet planes, respiration processes, decay of organic materials, forest fires, etc.

Effects: It is the main greenhouse gas responsible for rise in average temperature of atmosphere. It disturbs atmospheric stability and thus plays an important role in climatic changes in atmosphere.

2. **Carbon Monoxide (CO)**: Carbon monoxide is also a pollutant if its concentration exceeds more than 0.1 ppm in atmosphere. It is colourless, tasteless and odourless gas.

Main sources of CO are incompletes combustion of fossil fuel, emissions from vehicles, stoves and gas heaters, decay of organic materials, forest fires, etc.

Effects:

(a) CO has extremely high affinity with hemoglobin (approximately 210 times its affinity to oxygen) and thus it combines with blood hemoglobin immediately after inhalation to form carboxyhemoglobin (COHb) which reduces the oxygen carrying capacity of blood.

(b) It affects the nervous system and imparts laziness.

(c) It causes cardiovascular disorders.

(d) It reduces the vision also.

3. **Oxides of Nitrogen (NOx)**: Among the six different oxides of nitrogen (NO, NO_2, N_2O, N_2O_3, N_2O_4, N_2O_5), nitric oxide (NO) and nitrogen dioxide (NO_2) are very important pollutants. Though N_2O also present in lower atmosphere but it is not considered as air pollutant.

Main sources of oxides of nitrogen are combustion of fossil fuel, emissions from vehicles and industries, natural photochemical reactions, decay of organic materials, lightning and forest fires.

Effects:

(a) NO can also combine with hemoglobin and thus reduces the oxygen carrying capacity of blood.

(b) NO_2 can react with moisture in atmosphere to form nitric acid which causes acid rain and affects vegetables and metals.

(c) NO_2 is more toxic then NO and may affect lungs and cause bronchitis.

(d) NO_2 absorbs light and thus reduces the visibility.

4. **Oxides of Sulphur (SOx)**: Oxides of sulphur (SOx) are most widespread and important air pollutants. Among the six different oxides of sulphur (SO, SO_2, SO_3, SO_4, S_2O_3, S_2O_7), sulphur dioxide (SO_2) and sulphur trioxide (SO_3) are very important pollutants. Sulphur dioxide (SO_2) is a colourless, nonflammable and nonexplosive gas which may impart suffocation. SO_2 can photo chemically oxidised to SO_3.

Main sources of oxides of sulphur are burning of fossil fuels, emissions from vehicles and industries, solid waste disposal, etc.

Effects:

(a) Oxides of sulphur also attacks building materials especially marbles and lime stone. This effect was observed on the Taj Mahal at Agra which became the reason of shutting down lots of industries neat to Taj Mahal.

(b) SO_2 react with moisture in atmosphere to form sulphuric acid which causes acid rain and affects vegetables and metals.

(c) SO_2 may affect mucous membranes of respiratory tracts and cause bronchitis.

(d) Oxides of sulphur may affect cloths, leather, paper and plants.

5. **Hydrocarbons**: Some of the main hydrocarbons which may be gaseous and/or volatile air pollutants are methane, acetylene and ethylene.

Main sources of hydrocarbons are incomplete combustion of fossil fuels, emissions from vehicles, refineries and industries, agricultural burning, forest fires, etc.

Effects:

(a) Unburned hydrocarbons with oxides of nitrogen in the presence of sunlight form photochemical smog which can have adverse effects on humans and plants.

(b) Some aromatic hydrocarbons may cause cancer.

(c) Hydrocarbons like ethylene may inhibit the growth of plants.

6. **Particulates**: As described before in classification of air pollutants, particulates are basically suspended droplets, solid particle or mixer of the two present in atmosphere.

Main sources of particulates are volcanic eruptions, dust storms, spraying of salts and paints, fly ash from combustion of fossil fuels, smoke from vehicles and mining and metallurgical activities, etc.

Effects:

(a) Flyash and soot discharged by burning of coal causes respiratory diseases.

(b) Metal dust containing heavy metals and cotton dust may also cause respiratory diseases.

(c) Smog and dust impart adverse effect on man, animals and may inhibit the growth of plants.

(d) Vehicular particulates containing lead affects hemoglobin formation.

(e) Aerosols released from aeroplanes may affect ozone layer.

7. **Photochemical Oxidants**: These are the substances which can oxidise the iodine ion of potassium iodide, for example, ozone (O_3), peroxyacyl nitrate (PAN), peroxybenzoyal nitrate (PBN). These are secondary pollutants and damaging effect of photochemical smog is related to these pollutants.

Main sources of photochemical oxidants are photochemical reaction among hydrocarbons, exhaust of automobiles and oxides of nitrogen in the presence of sunlight.

Effects:

(a) Ozone**,** PAN and PBN oxidants cause eye irritation nose and throat irritation, coughing and inability to concentrate.

(a)

(b)

Fig. 4.9 Pictures showing (a) Air pollution by thermal power plant; (b) Air pollution by oil burning in ocean

Source: Google.com

(b) Ozone attacks synthetic rubber, tires and insulation of wires.
(c) These oxidants reduce strength of fibers, and cause fading of fabrics.
(d) Aerosols formed from chemical reactions create smog which reduses visibility.

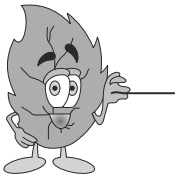
4.5.7 Effects of Air Pollution

Revolution in automobile industry and rapid urbanisation and industrialisation can cause high concentration of air pollutants which can exceed the self cleansing capacity of

environment. The air pollutants which may adversely affect the humans, animals, plants and building materials are given below.

1. **Effects of Air Pollution on Human beings**: Air pollutants may have following effects on human being which may be acute (effect of higher concentration on short term exposure) and/or chronic (effect of low concentration after continuous exposure). The effects of air pollutants on human beings are summarised below:

(a) Most of the hydrocarbons like methane, acetylene and ethylene may cause acute respiratory diseases and cancer.



DID YOU KNOW?

As per WHO estimates, 10-15% of Indian children in the 5-11 years age groups suffer from asthma. A decade before, in Delhi itself, 40% hike in asthma cases was due to polluted air.

(b) Exposure to dust, smog, smoke and soot may induce several respiratory troubles like asthma, bronchitis and lung cancer.

(c) Oxides of nitrogen and sulphur may cause irritation to throat, eye and nose as well as diseases like asthma, bronchitis, etc.

(d) Carbon mono oxide and nitrogen oxide may combine with blood hemoglobin immediately after inhalation to form carboxyhemoglobin (COHb) which reduces the oxygen carrying capacity of blood. Thus, it leads to nervous and cardiovascular disorder which ultimately may cause death.

(e) Ozone formed by photochemical reactions in the troposphere may cause coughing and eye irritation.

(f) Excess amount of heavy metals may cause poisoning effects on nervous system, damage of kidney and vision problems.

Table 4.9 Effects of Air Pollutants on Human beings

Sr.No.	*Name of pollutant*	*Effect on human being*
1	Hydrocarbons	Effects respiratory system and can cause cancer
2	Dust	Respiratory disease like silicosis, asbestosis, cough, sneezing and allergy, etc.
3	Sulphur dioxide	Respiratory disease, eye and throat irritation and suffocation.
4	Nitrogen dioxide	Irritation to eye and nose, bronchitis and effects on lungs.
5	Carbon monoxide	Reduction in oxygen carrying capacity of blood, weakens lungs and bones.
6	Photochemical Oxidants	Asthma, bronchitis and effects on lungs.

Table Contd.

Table Contd.

7	Hydrogen sulphide	Irritation to eye and nose, nausea and causes bed smell.
8	Hydrogen fluoride	Diseases of bone, mottling of teeth, cavity in teeth and respiratory diseases.
9	Heavy metals	Poisoning, effects on nervous system, damage of kidney and vision problems.
10	Aldehydes, ketones and ammonia	Irritation in respiratory tract and nasal, long term exposure may cause leukemia.

2. **Effects of Air Pollution on plants and vegetations**: Use of pesticides and excess chemical fertilisers have exposed plants and vegetables with air pollutants which can adversely affect their growth and metabolism. Following are some of the effects of air pollutants on plants and vegetables:

Table 4.10 Effects of Air Pollutants on plants and vegetables

Sr.No.	*Name of pollutant*	*Effect on human being*
1	Sulphur dioxide (SO_2)	Loss of chlorophyll, bleached spots and injuries to leafy vegetables.
2	Nitrogen dioxide (NO_2)	Premature leaf fall (Abscission), and reduction in productivity.
3	Ozone	Damages and bleaching of leaves, destruction of vegetation.
4	PAN	Bronzing of leafs, damage to small plants and young leaves.
5	Ethylene	Leaf abscission, flower dropping.

3. **Effects of Air Pollution on animals**: As animals feed on plants, grass and fodder which may be effected by air pollutants especially by heavy metals, it may cause poisoning and diarrhea in animals. Inhalation of fluorine compounds may cause fluorosis i.e., decolorisation and excess calcification of teeth. Lead poisoning causes bronchitis and loss of appetite in pet animals.

4. **Effects of Air Pollution on materials and buildings**: Exposure with air pollutants of materials and monuments cause the following damage to them:

(a) Acid rain caused by SO_2 and NO_2 have corrosive effects on buildings and materials.

(b) Ozone, SO_2 and NO_2 decolorise and deteriorate the paints, metals, textiles and marble. Famous monument Taj mahal is also under danger of this effect.

(c) Hydrogen sulphide decolorises silver and paints.

(d) Ozone oxidises rubber items like tires, insulation wires and other rubber products.

5. **Effects of Air Pollution on climate**: Deforestation, industrialisation and automobiles have increased concentration of CO_2 and other green house gases in atmosphere which resulted in the increase in temperature of earth. This increase in temperature has also

(a)

(b)

Fig. 4.10 Pictures showing (a) Air pollution by dust and smoke (b) Air pollution by vehicles
Source: Google.com

caused the melting of polar ice leading to rise in the sea water level and change in rainfall pattern.

4.5.8 Control of Air Pollution

To control air pollution is difficult because once the air is polluted, it effects the people at large as every one inhales air. Therefore, it is desirable to control the source of air pollution

rather than after its emission. Air pollution can be controlled by taking the following measures:

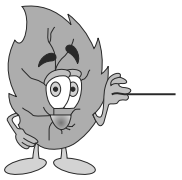
1. **Preventive measures**: To control air pollution, it is most important to control the source or the point of generation as preventive measure. These preventive measures are listed below.

(a) Burning of coal, wood agricultural and plastic wastes should be restricted to minimum.

(b) Selection of suitable fuel and modifications in processes to minimise pollution.

(c) Installation of chimneys of high height to release the emissions away from residential areas.

(d) To encourage the use of low sulphur fuels and natural gas for the reduction in the hydrocarbons and auto mobile emissions. For example, CNG (compressed natural gas) is being used now a days in metros and big cities instead of petroleum and diesel.



DID YOU KNOW?

More than 60% of carbon monoxide (CO) is contributed into atmosphere by vehicular emissions caused by the transportation services.

(e) Periodic checking of vehicles for lead pollution and vehicular emissions. Lead free petrol should be encouraged to control the lead pollution.

(f) Industries should be asked to adopt effluent gas treatment facilities before releasing those gases in atmosphere. For example, catalytic carbon removal can be adopted to reduce the particulate concentration in smoke.

(g) Replacement of CFCs and more and more use of solar energy.

(h) Educating and making public more aware about the adverse effects of air pollution.

2. **Using equipments and catalytic as control measures**: As discussed above, the important way to control air pollution is to prevent the formation of it or to control air pollution at source itself. But once air pollutants are emitted in the atmosphere then the equipments like cyclone separators, gravity settlers, bag filters, scrubbers and electrostatic precipitators are used which remove particulate matter as well as gaseous pollutants from polluted air.

(a) ***Cyclone separator*** – This equipment is used to remove the particles of higher size range of 5 to 20 μm. In this equipment, centrifugal force causes dust particles to

collide with inner wall of cyclone separator and gravity force causes then, these dust particles to fall in collector.

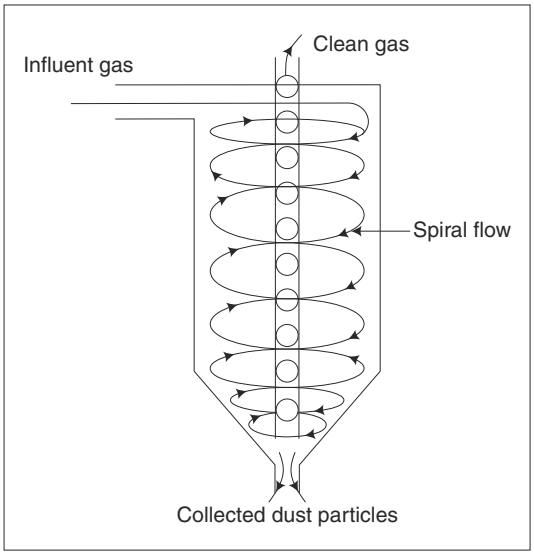


Fig. 4.11 Cyclone separator

(b) ***Gravity settler*** – These types of equipments are used to remove the dust particles from the influent air. Influent air is passed from the gravity settler of higher length so that dust particles are settled at the bottom of the tank by the force of gravity and clean air passes out from the other end of the tank.

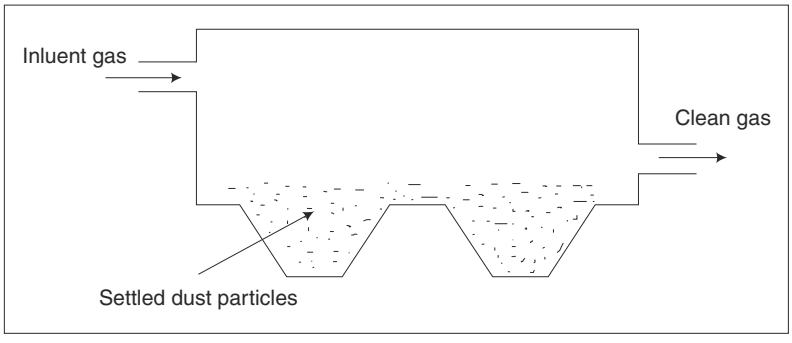


Fig. 4.12 Gravity settler

(c) ***Scrubber*** – These types of equipments are used to remove the dust particles as well as gases from the influent air contaminated by both. Influent air is passed from the bottom side of scrubber and water or liquid is sprinkled from the nozzles attached at higher height so that dust particles and gases are dissolved or make slurry with liquid and removed from the bottom of tank. The clean air comes out from the top of scrubber as shown below.

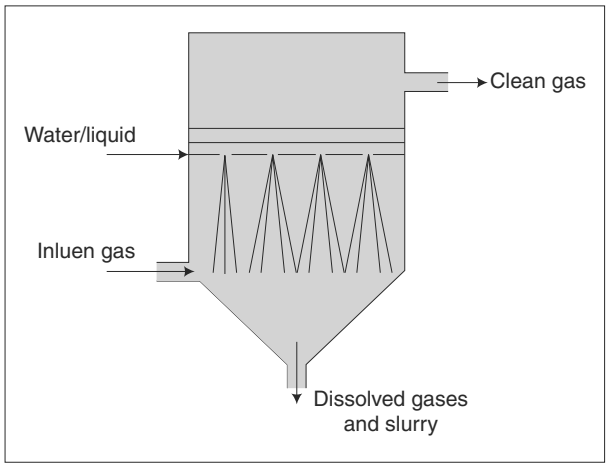


Fig. 4.13 Scrubber

(d) ***Electrostatic Precipitator*** – Electrostatic precipitators are used to remove the particulate matters of size 1-10 μm and gas molecules by ionising them at high voltage (high voltage-100 KV) and are mostly used in the thermal power plants. In these equipments, polluted air is passed through the charged plates as shown below

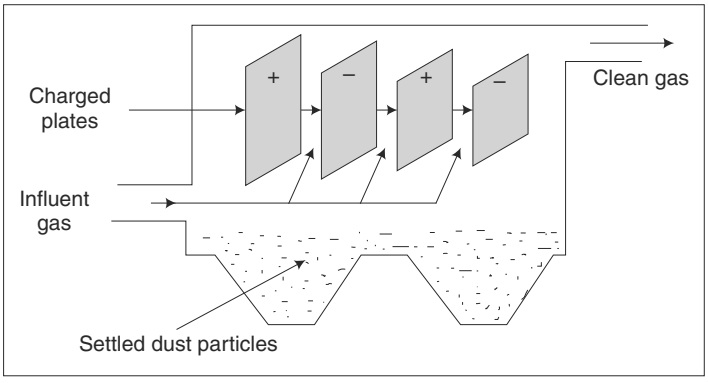


Fig. 4.14 Electrostatic Precipitator

which act as collecting surfaces for the charged particulates and gas molecules of opposite charges.

(e) ***Bag house*** – Bag houses are used to remove the very small particles of around 1 μm size and above by means of fabric filtration. Influent gases containing dust are passed through the fabric filter bags and after some certain time, these filters are screened to remove filtered dust. These bag houses generally provide very good efficiency near to 100%.

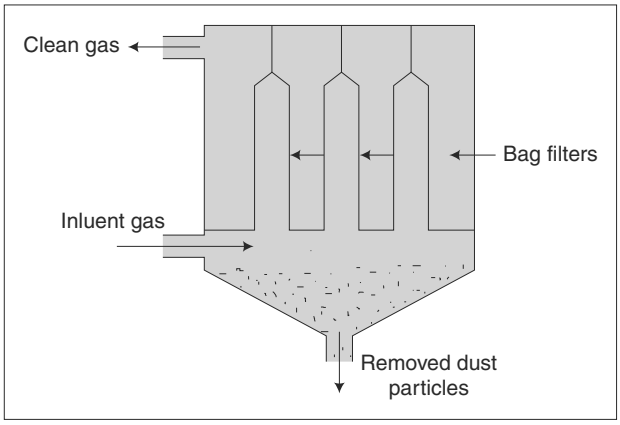


Fig. 4.15 Bag house

To reduce the hydrocarbons and auto mobile emissions catalytic converter and efficient engines are used.

(f) ***Catalytic converter*** – Catalytic converters are used mostly to control the pollutants from the automobile emissions. These equipments are fitted in the vehicles and can convert the CO and hydrocarbons into CO_2 and NOx into N_2. The efficiency of these is reduced by leaded petrol. Therefore, it is advised to use unleaded petrol to have good efficiency.

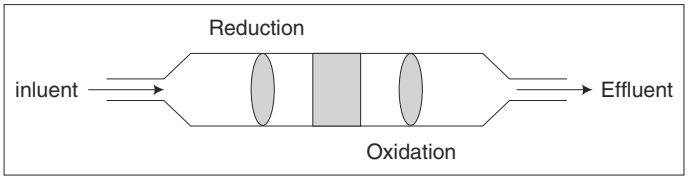


Fig. 4.16 Catalytic converter

4.6 LAND POLLUTION

Land is a very important part of lithosphere which comes under the category of limited natural resource. Land supports the life on earth as it provides us with water, shelter and all necessary nutrients along with the food and fruits for us and animals. At present, this natural gift is under threat from human activities which have polluted the land. Following are the different sources of land pollution:

1. **Domestic and Industrial wastes**: Both solid and liquid wastes from house as well as industries are dumped on to the land which contains organic and inorganic substances, solid wastes, plastic begs, acids, alkalies, heavy metals and toxic chemicals.
2. **Fertilisers and Pesticides**: Now a days different types of chemical fertilisers are used to increase the productivity of crops which degrades the quality of soil. Number of chemicals like pesticides, germicides, insecticides and rodenticides are also used to protect the crops against the attacks of pests and insects. These pesticides also reduce the fertility of soil and adversely affects the microbes. Some of the pesticides like DDT absorbed by the plants remain for a long time and may travel through food chains and food webs.
3. **Unused Solid Materials**: Large amount of discarded materials used in day to day life of human activities are disposed on land which includes concrete, asphalt, paper and rags, leather, plastics, cans, glass and other packing materials.
4. **Special wastes**: Radioactive wastes and nuclear wastes from reactor accidents and nuclear explosions also reaches finally into the land. Many water pollutants and air pollutants falling through acid rains also become a part of land.

4.6.1 Lithosphere

It is basically that portion of the earth which is made up of soil, minerals, rocks and other organic as well as inorganic matter. Lithosphere has mainly three layers whose compositions are as given below.

1. **Crest**: It is the top layer of earth which extends up to approximately 17 km in depth. It is composed of different rocks, minerals and soils. Earth's crest also acts as shelter for biotic communities.
2. **Mantle**: It is the next layer after crest which comprises around 68% of total mass of earth. The upper layer up to around 500 km of mantle predominantly contains silicate materials while lower portion up to 2900 km consists basically mixer of oxides.

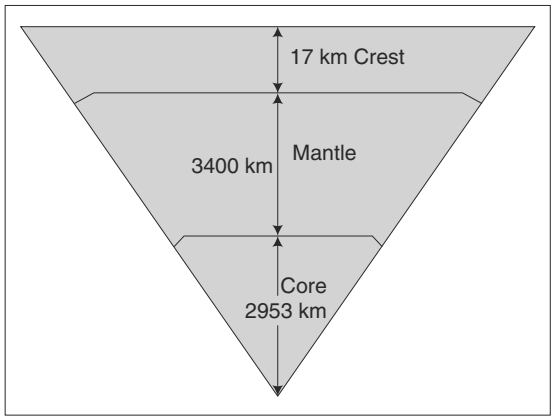


Fig. 4.17 Lithosphere

3. **Core**: It is the main layer of earth over which two other layers are supported. This extends from 2900 km to the centre of earth (up to 6370 km). The outer core which is in liquid form contains iron and nickel alloys while inner core basically consists of pure iron. Temperature in the core of the earth is around 5000 – 5500°C.

4.6.2 Land Uses

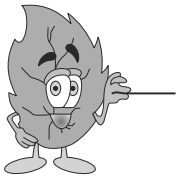
Almost all human activities and natural activities requires space which is provided as land surface. Various uses of land are summarised as given below.

1. Providing shelter for living beings.
2. Getting food production by carrying out different agricultural activities on it.
3. Residential purposes to build different types of domestic building and commercial purposes for building commercial centers.
4. To install different types of industries for the progress and development of country.
5. Forestation purposes which provide shelter and food for animals, birds and other living beings.
6. Developing transport means i.e., for construction of roads, railway lines, airport, etc.
7. Construction of irrigation structures and generation of power by constructing thermal power stations and hydro power stations.
8. Disposal of solid and liquid wastes.

4.6.3 Land Degradation

The deterioration in the quality of land and reduction in its fertility is called *land degradation*. The different factors causing land degradation are as given below.

1. **Soil pollution**: Top layer of soil is responsible for productivity of land and therefore discharge of different types of pollutants on land alters the physical, chemical and biological characteristics of soil which is called *soil pollution*.



DID YOU KNOW?

Every year an additional six million hectares of productive land turns into desert and more than 11 hectares of forests are destroyed.

(a) ***Causes of soil pollution*** – Disposal of domestic and industrial wastes, agricultural wastes and other special wastes on to the soil are responsible for soil pollution. Intrusion of salty water and discharge of pesticides and chemical fertilisers may also cause soil pollution.

(b) ***Sources of soil pollution*** – The main sources of soil pollution are domestic and industrial wastes, agricultural wastes, use of pesticides for protecting crops, use of chemical and biological fertilisers, disposal of solid waste and discarded materials, oil leakage and disposal of radioactive and nuclear wastes.

(c) **Effects** – Soil pollution leads to reduction in productivity of crops and has adverse effects on physical, chemical and biological properties of soil.

2. **Soil erosion**: The quality of soil is also affected by its erosion through floods, landslides, illegal soil transport, heavy vehicles, and deforestation.

(a) ***Causes of soil erosion*** – Very high rainfall in short duration and intensive rainfall are responsible for soil erosion. The ground with steep slopes and lesser plantation are also susceptible for more soil erosion.

(b) ***Sources of soil erosion*** – The main sources of soil erosion are floods, storms and very large flow in rivers. In desert areas, storms and heavy wind flow also causes soil erosion.

(c) ***Effects*** – Soil erosion leads to widening of rivers which affects the dwelling of river banks. It sometimes also causes the change in the flow of directions of rivers. It reduces the soil fertility and thus effects production.

3. **Desertification and Salination**: Desertification is the process in which the productive land converts into desert. Dust and sand storms, grazing of livestock, erosion of top fertile soil, deforestation and excessive lowering of water table may cause desertification of soil. In the salination process, the productive land is converted into the salty soil by the presence of excess amount of salts like sodium and chlorides. Water logging, intrusion of sea water, leaching of minerals and poor drainage of irrigational and flood water may cause the salination of land.

4. **Shifting Cultivation**: It is defined as shifting of growing crops from the current cultivated areas because of reduction in fertility and production. In this method, new cultivated sites are searched and are used till they become less fertile.

5. **Urbanisation**: Due to urbanisation people are moving from the villages to cities and town areas and therefore the productive areas in such places are continuously reducing because of different developmental activities.

4.6.4 Control of Land Pollution

Following are the measures required to be taken to control the land pollution:

1. Solid waste disposal should be managed properly and dumping should not be done in open spaces. Sanitary land filling and methods like composting must be used for disposal of solid waste.
2. Excessive use of chemical fertilisers and pesticides should be avoided and use of bio fertilisers and bio-pesticides should be promoted.
3. In order to avoid the depletion of nutrients in soil, crop rotations should be practiced.
4. Proper sanitation system should be used to discharge the contaminated liquid waste. Industries should be forced to develop their own effluent treatment plants (ETP) to minimise soil contamination due to toxic chemicals from industries.
5. Aforestation and bioremediation can reduce the soil erosion and maintains nutrient circulation.

4.7 NOISE POLLUTION

An unwanted and unpleasant sound which may cause discomfort is called noise and presence of such sound in the atmosphere is called *noise pollution*.

Following are the different sources of noise pollution:

1. **Constructional and Industrial machinery**: It includes different types of equipments used in industries, generators, boring and drilling machineries, pile drivers, simple and pneumatic road rollers and other such machinery.
2. **Means of Transport**: This contains the sound created by means of different transport like aircraft, trains, tractors, trucks and other vehicles.
3. **Other sources**: It includes the sound generated from the use of loud speakers during marriages, festivals, political meetings, etc. Use of crackers during festivals and celebrations also creates high volume sound.

4.7.1 Measurement of Sound

Sound is measured in *decibel* (dB) which measures how much intense is the sound compared to reference intensity. The intensity of sound is expressed in watts per square meter i.e., amount of sound energy through unit area of medium in unit time and value of reference intensity is 10^{-12} watts per square meter. Decibel is expressed in logarithm scale as given below.

$$1 \text{ decibel (dB)} = 10 \log_{10} (\text{measured intensity/reference intensity})$$

Not only the loudness determines the harmfulness of sound but the frequency or the pitch of the noise is also responsible for this. To take the pitch into the account, a modified scale is used now a days that is decibel-A, expressed as dBA.

Table 4.11 Noise levels for different source

Sources of noise	*Noise level (dBA)*
Whisperings	30
Normal conversation	60
Shouting	75
Motorcycle	88
Truck	100
Food blender	90
Rock music	120
Jet plane	130

4.7.2 Effects of Noise Pollution

Noise is harmful to us as it imparts lots of health hazards. Effects of noise pollution on humans can be classified in three ways – physical, physiological and psychological.

1. **Physical effects**: Long time exposure of loud sound (80-90 dBA for more than eight hours a day) may cause loss in hearing and in chronic cases, the it may result in total deafness. Sudden loudness particularly from crackers and explosions may affect the ear drum and sensitive ear membranes.
2. **Physiological effects**: Among different physiological effects some are headache, nausea, dizziness, gastric ulcers, high rate of heart beat, fluctuations in blood pressure and sugar.
3. **Psychological effects**: Among different psychological effects some are depression and fatigue, insomnia, mental stress, behavioral effects and loss of ability to reproduce.

4.7.3 Control of Noise Pollution

Noise is not a simple pollution but it is a serious environmental pollution problem so like other pollution it is required to be controlled by different measures as given below.

1. **Control by protective devices**: People can use ear protection aids like ear plugs, noise helmets, headphones, etc. to reduce occupational exposure of noise.
2. **Control noise at source**: It includes proper design and fabrication to replace noisy machines, lubrication and time to time servicing of machines, using sound absorbing materials and sound proof cabins, using silencers to control noise from automobiles and ducts, etc.
3. **Sound insulation**: Sound insulation can be done in building and offices by using acoustical tiles, perforated plywood, wooden ceiling and floors, sound absorbing materials in doors and windows.
4. **Plantation**: Planting green trees along the roads and in and around buildings also reduces noise.
5. **Regulations**: Strict rules and regulations like minimum use of loud speakers, restricting the use of loud horns, etc., may reduce the noise level drastically.

4.8 CURRENT ENVIRONMENTAL GLOBAL ISSUES

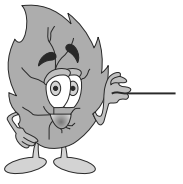
Presently, the world is facing lots of environmental problems. Among those the main problems which have disrupted the global ecosystem are, (i) Population explosion: which

has created an imbalance in demand and supply by creating huge demands for shelter, food and various natural and man made resources, (ii) Industrialisation and Urbanisation: rapid industrial growth has resulted in more consumption of natural resources and more degradation of environment due to pollution. Present urbanisation has resulted in an imbalance in villages and cities and has caused migration of people towards metro cities which has altered the quality of air, water and land of urban areas. All these factors are responsible for following global environmental problems which are being discussed at international level:

1. Global warming and green house effect
2. Acid rain
3. Ozone deplition

4.8.1 Global Warming and Green House Effect

The abnormal increase in the atmospheric concentration of greenhouse gases has caused the increase in the average temperature around the world by around 1°C in the last century. About the two third of this rise in temperature has occurred in the last three decades itself. This increase in the average temperature of global atmosphere is called *Global warming*.



DID YOU KNOW?

Accurate predictions of global warming are difficult, but almost all computer models show an average rise of 3°C temperature by 2100.

4.8.1.1 Green House Effect

Green house is a house made of glass to have higher temperature inside compared to outside and is used particularly in cold countries. Higher growth of plants inside the house is maintained by controlling the temperature, humidity and carbon dioxide.

Glass walls of house allow the short wave radiations from the sun but prevent the long wave infrared radiations coming out after reflection by earth inside the house. This causes an increase in temperature inside the house compared to outside.

Almost similar phenomena takes place in the atmosphere where green house gases like water vapours, carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and ozone act like a glass in green house and allow the short wave radiations from the sun but absorb long wave radiations and reflect heat back to earth. Most of the incoming short wave solar

radiations are of 0.2 to 4 μm range which becomes long wave radiations (range 4 to 100 μm) after getting reflected by earth. It is found that between the wavelengths of around 7 to 12 μm, absorption of reflected radiations is almost nil which is called *atmospheric window*. Thus a maximum of radiations absorbed by green house gases heat the atmosphere and very little is passed to escape into space. Therefore, if the atmosphere had been free from green house gases then the earth would have been very cold because of complete radiation lost from atmosphere to space. Rapid industrialisation, increased standard of people and increase in automobile and vehicles has increased the concentration of green house gases which is responsible for the increase in the average temperature of earth. Following are the different green house gases:

1. **Carbon dioxide (CO_2)**: It is the most abundant gas produced by burning of fuels, respiration processes of animals and plants, and deforestation. The level of CO_2 has increased from 280 ppm to 370 ppm in the last five decades. Contribution of this gas towards global warming is around 50%.
2. **Methane (CH_4)**: Methane gas is formed by the anaerobic decomposition of organic wastewater and sludge by anaerobic bacteria called *methanogens*. It is produced by dumped garbage, wetlands, biomass burning and anaerobic decomposition. The level of CH_4 has increased from 700 ppb to 1750 ppb in last the five decades. Contribution of this gas towards global warming is around 19%.
3. **Chlorofluorocarbons (CFCs)**: CFCs are highly stable and nonflammable compounds of carbon and halogens and were used mostly as refrigerants, propellants, insulators and fire extinguishers. They are emitted in the atmosphere from leakage by air conditioners and refrigerators, emissions from plastic and solvent industries and spraying paints, etc. The level of chlorofluorocarbons is around 280 ppt.
4. **Ozone (O_3)**: In the troposphere, ozone is a secondary pollutant and is formed by the reaction of atomic oxygen with oxygen gas in the presence of nitrogen. Atomic oxygen is formed by the photo dissociation of NO_2 into NO as given below.

$$NO_2 + h\nu \rightarrow NO + O$$
$$O + O_2 + N_2 \rightarrow N_2 + O_3$$

   Ozone has strong absorption band at 9 μm and is quite unstable in troposphere. Contribution of this gas towards global warming is around 8%.
5. **Nitrous oxide (N_2O)**: Its main sources are agricultural resources, industrial processes and burning of biomass. It is produced by breakdown of fertilisers in soil and ground water, combustion of nitrogenous fuel, nitrogen rich biomass burning and industrial emission from textile industries. The level of CH_4 has increased from 270 ppb to

320 ppb in last the five decades. Contribution of this gas towards global warming is around 4%.

6. **Water vapours (H_2O)**: As more than 70% earth's surface is covered by the water so huge amount of water vapours present in atmosphere is due to evaporation of water. Water vapours absorb radiation at less than 8 μm and more than 18 μm. Contribution of this gas towards global warming is around 2%

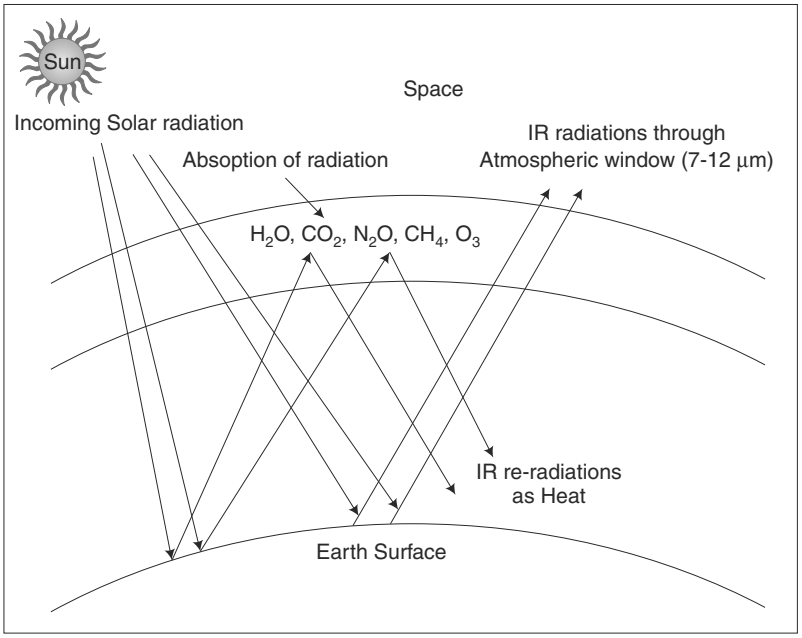


Fig. 4.18 Green house effect

Table 4.12 Relative contribution of green house gases

Sr No.	*Name of Greenhouse gas*	*Percentage contribution in green house effect*
1	Carbon dioxide (CO_2)	50
2	Methane (CH_4)	19
3	Chlorofluorocarbons (CFCs)	17
4	Ozone (O_3)	8
5	Nitrous oxide (N_2O)	4
6	Water vapours (H_2O)	2

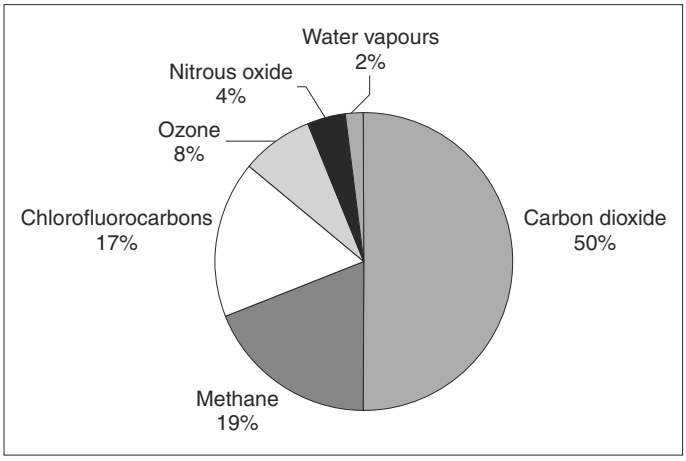


Fig. 4.19 Contribution of different gases to Green house effect

4.8.1.2 Effects of Global Warming

The abnormal increase in the atmospheric concentration of greenhouse gases in the last few decades has caused the increase in the global average temperature around the world which has adversely affected the human beings and the climate. Some of the effects of global warming are described below.

1. **Effects on climate**: In the twentieth century, the global average temperature has increased by about 0.6°C and is expected to increase by more than 1.5°C by the twenty-first century. This increase in temperature causes to increase moisture carrying capacity of atmosphere which also effects the rainfall pattern and is responsible for extreme drought or flood conditions.

Some of the major effects experienced due to the climatic change or strange weather.

- About 10 cm rain fall recorded in Mumbai for 18 hrs on July 26, 2005.
- Hurricane Katrina hit US and thousands of people lost their homes.
- Cloud bursting in Leh, Jammu & Kashmir destroyed every thing there in 2010.
- Excessive ice fall experienced in the beginning of New Year 2011 in UK, US and Europe.

2. **Rise in ocean water**: Global warming causes melting of ice caps and glaciers which may cause the rise in the sea water level. In the twentieth century, rise in sea water was around 1 to 2 mm per year and if the rate of rise continues at least in then same way then in the next 100 years rise may be more than 20 cm. This rise of sea water may cause the submergence of coastal areas. The effect of rising sea has already started in the small country Tuvalu which is halfway between Australia and Hawaii as waves started washing of main roads there and people are now forced to evacuate the islands within three to four decades. Like in Tuvalu, this problem has also alarmed other Pacific islands like Cook Islands and Marshall islands.
3. **Effects on human health**: Global warming has led to occurrence of different new diseases which are basically caused by the climate changes and rise in average temperature of atmosphere. It also discrupts the rainfall pattern which generates drinking water problems at global level.
4. **Effects on productivity**: Increase in temperature will have detrimental effect on productivity as this effect will sharpen the water scarcity effect. Increase in temperature also increases plants diseases and pests which may retard the production.

4.8.1.3 Control of Global Warming and Green House Effect

Some of the measures required to control the global warming and green house effect experienced globally are:

1. Reduction in the use of fossil fuel for energy generation and promoting other sources like solar energy, wind energy and nuclear energy.
2. Minimising the use of nitrogenous chemical fertilisers for agriculture.
3. By reducing deforestation in planting more and more trees as they trap air pollutants and utilise CO_2.
4. By using the substitutes like HCFCs in place of CFCs.
5. By using the energy of methane as fuel or power instead of its emission.

At international level lots of steps are being taken to control and minimise the global warming. Some of those are briefly discussed in case studies.

4.8.2 Acid Rain

The rain water is the pure water but as it falls down different air pollutants get dissolved in that and it no more remains pure. This natural rain water has pH slightly acidic (around 5.6 pH) because dissolution of CO_2 forms carbonic acid as given below.

(a)

(b)

Fig. 4.20 Pictures showing (a) Melting of ice in Himalayas due to global warming; (b) Melting of ice in Polar Regions

Source: Google.com

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad \text{(carbonic acid)}$$

But when the pH of the rain water becomes less than 5.6, then it is called *acid rain*. This reduction of pH is basically due to the dissolution of oxides of nitrogen and sulphur present in the atmosphere which forms nitric and sulphuric acids as shown below.

$$2SO_2 + O_2 \rightarrow 2SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4 \quad \text{(Sulphuric acid)}$$
$$2NO + O_2 \rightarrow 2NO_2$$
$$2NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3 \quad \text{(Nitric acid)}$$

Photochemical reaction also leads to acid formation as given below.

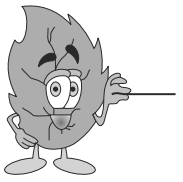
$$NO + O_3 + h\nu \rightarrow NO_2 + O_2$$
$$NO_2 + O_3 + h\nu \rightarrow NO_3 + O_2$$
$$NO_2 + NO_3 \rightarrow N_2O_5$$
$$N_2O_5 + H_2O \rightarrow 2HNO_3 \quad \text{(Nitric acid)}$$

Contribution in the acid rain of H_2SO_4 is more compared to HNO_3.

4.8.2.1 Causes of Acid Rain

The main causes of acid rain are given below.

1. Dissolution of oxides of nitrogen and sulphur formed by the burning of fossil fuels along with the rainfall.
2. Dissolution of oxides of nitrogen and sulphur released from the chimneys of smelting industries and other industries manufacturing sulphuric acid, nitric acid and hydrochloric acid humidity and carbon dioxide.
3. Dissolution of oxides of nitrogen and sulphur emitted from automobile exhaust.



DID YOU KNOW?

In acid rain contribution of H_2SO_4 is 60-70% and that of HNO_3 is 30-40%.

4.8.2.2 Effects of Acid Rain and its Control

Acid rain may have the adverse effects on human beings, aquatic life, building materials and soil as stated below.

1. **Effects on Human beings and Animals**: Due to lower pH of acid rain water it may dissolve in different types of heavy metals which may be consumed by human beings and animals via food chain or drinking water. Direct contact of acid rain water may cause respiratory diseases and skin diseases.
2. **Effects on Aquatic life and Plants**: Acidification of lakes due to acid rain may cause disappearance of aquatic species and killing of bacteria, algae and small fishes. Acid rain may decolourise the leaves of plants and reduces chlorophyll content.
3. **Effects on Building**: Acid rain can damage the structural materials like marble and lime stone. It may corrode and decolourise the walls of monuments and thus deteriorate their beauty.

Control of Acid Rain

It may be reduced by reducing the emission of SO_2 and NO_2 gases in the atmosphere. This can be done by using pollution controlling devices in the industries, changing processes and recovering acids using these gases. Acidification of ponds and lakes can be controlled by addition of lime in the water.

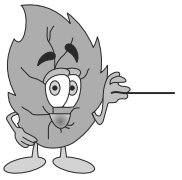
4.8.3 Ozone Depletion

Around 90% of the total atmospheric ozone is generally present in the stratosphere as ozone layer while the remaining 10% is found in the troposphere. This ozone is beneficial when found in the stratosphere because there it protects us from the harmful effects of ultraviolet rays coming from the sun while the same is harmful when present in troposphere as it forms photochemical smog with other air pollutants.

Ozone absorbs all the solar UV radiations below 290 nm. The formation of ozone in the stratosphere is cyclic as it is continuously formed as well as destroyed as given below.

$O_2 + hv \rightarrow O + O$	(Atomic oxygen)
$O_2 + O + N_2 \rightarrow O_3 + N_2$	(Formation of ozone)
$O_3 + hv \rightarrow O_2 + O$	(Atomic oxygen)
$O + O_3 \rightarrow 2O_2$	(Destruction of ozone)

The above reactions are continuously performed in the stratosphere which are not responsible for destruction of ozone contents but if atomic Cl is present in stratosphere it destroys the ozone layer. Stratospheric ozone layer over Antarctica is severely damaged as found in satellite pictures as a big hole. The main chemical responsible for this is



DID YOU KNOW?
Generally CFCs trap at least 1500 times more heat per molecule than CO_2.

chlorofluorocarbons (CFCs) and chlorofluoro bromines (CF_3Br). Among the CFCs, the main chemicals causing ozone destruction are $CFCl_2$, CF_2Cl_2, $C_2F_3Cl_3$, Freon-11 (CCl_2F), and Freon-12 (CCl_2F_2).

These CFCS are inert, stable and remain for a long time (more than 100 years) in the atmosphere. CFCS are destroyed by UV radiations in the stratosphere and releases atomic Cl which destroys the ozone layer as below.

$$CF_2Cl_2 + h\nu \rightarrow CF_2Cl + Cl \quad \text{(Atomic chlorine)}$$
$$Cl + O_3 \rightarrow ClO + O_2 \quad \text{(Destruction of ozone)}$$
$$ClO + O \rightarrow Cl + O_2$$
$$\overline{O_3 + O \rightarrow 2O_2}$$

As shown above, the Cl reappears again and again and it is estimated that one Cl atom can destroy 10^5 ozone molecules in one to two years.

High concentration of NO_2 if present in stratosphere (by the emissions of Jet planes) may also destroy ozone as given below.

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$

Unit of measurement of ozone in atmosphere is *Dobson unit (DU).* One Dobson unit (DU) is defined as 0.01 mm thick ozone layer at STP (i.e., 0°C and 1 atm). Under normal conditions, earth atmosphere contains about 300 DU i.e., 3 mm thick slab of ozone layer which is reduced to 100 DU i.e., 1 mm thick ozone slab at 'ozone holes'.

4.8.3.1 Causes of Ozone Depletion

The main cause of ozone destruction is the release of CFCs in the atmosphere. These CFCs are released by the leakage through air conditioners, propellants and refrigerators, emissions from plastic and solvent industries and spraying paints, etc.

4.8.3.2 Effects of Ozone Depletion and its Control

Ozone depletion may have adverse effects on human beings, aquatic life and materials as stated below.

1. **Effects on Human beings and Animals**: Ozone depletion cause more UV-B radiations to reach on to the earth which affects DNA and causes skin cancer as well as affects the lens and cornea of the eye.
2. **Effects on Aquatic life and Plants**: Ozone depletion may cause low productivity and reduction in photosynthesis. It may reduce the growth of phytoplankton, zooplanktons and small fishes by disturbing the aquatic ecosystem.
3. **Effects on Materials**: More UV radiations due to ozone depletion can also cause degradation of paints, plastics and polymers, etc.

As far as control of ozone depletion is concerned, it may be controlled by using the substitutes like HCFCs in place of CFCs. Due to the presence of hydrogen bond, HCFC is less stable and reactive compared to CFC.

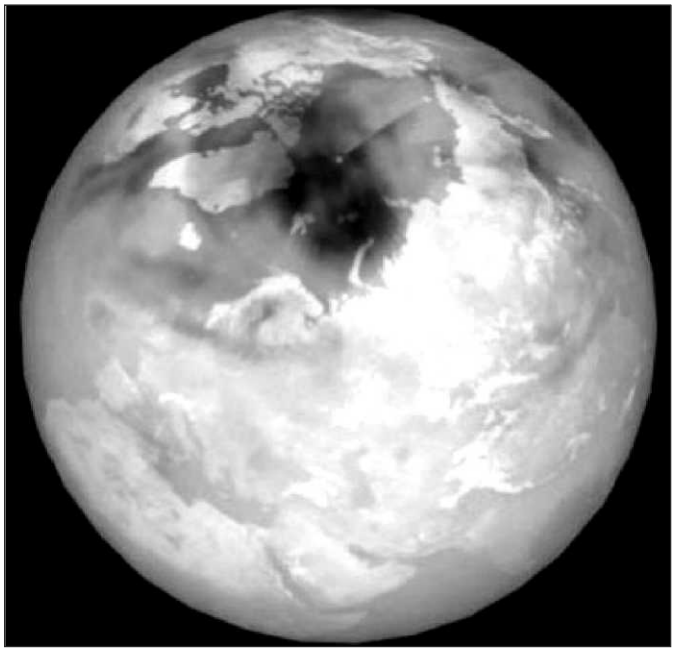


Fig. 4.21 Picture showing the Arctic ozone depletion

Some Local and International Disasters

Bhopal Gas Tragedy: On december 2, 1984, methyl isocyanate (MIC) leaked from Union Carbide's pesticide factory in the mid night at Bhopal. The effect of the gas was felt near about 100 sq km area from the factory and more than 8000 people died in the disaster. Even today more than 150,000 people are still suffering from the effects of this gas.

Mumbai and Surat Plague: Plague is one of the deadly infectious diseases caused by the enterobacteria Yersinia pestis and is primarily carried by rodents (most notably rats) and spread to humans via fleas. The symptoms of plague depend on the concentrated areas of infection in each person: such as bubonic plague in lymph nodes, septicemic plague in blood vessels, pneumonic plague in lungs, etc. In September 1896, the first case of bubonic plague was detected in Mandvi, Bombay. The death toll was estimated at 1900 people per week through the rest of the year. Many people fled from Bombay during that time, and in the census of 1901, the population had drastically fallen. In 1994, there was a pneumonic plague epidemic in Surat, Gujarat that resulted in 52 deaths and in a large internal migration of about 300,000 residents. A combination of heavy monsoon rain and clogged sewers led to massive flooding which resulted in unhygienic conditions which had caused this epidemic.

London Smog: In December 1952, at London, a high pressure air mass created temperature inversion which formed dense smog with smoke and fumes from the heavy coal combustion. During the smog and for two weeks following, approximately 4,000 people were killed. The deaths were primarily attributed to pneumonia, bronchitis, tuberculosis, and heart failure. Total number of people who were killed was approximately 12,000.

The Great Fire of London: The Great fire started at the bakery of Thomas Farriner after midnight on Sunday, September 2, 1666, and it spread rapidly west across the City of London. The use of the creation of firebreaks by means of demolition was critically delayed due to the indecisiveness of the Lord Mayor of London which turned fire into a firestorm. Finally it was decided to blow up houses in the path of the fire. The Navy was used to using gunpowder and so they carried this out to stop the fire. It is estimated that it destroyed the homes of 70,000 of the city's inhabitants. After this incident, the black plague which had killed many people was eliminated and the city was rebuilt using stone over the following 30 years.

CASE STUDIES

Vienna Conference: It was the first international conference on ozone depletion. It was held in Vienna, Austria in 1985 when a hole in the stratospheric ozone layer was observed in the South Pole marked by increased UV-B infiltration over Antarctica. It was agreed to protect the ozone layer, at the conference and it entered into force in 1987.

Montreal Protocol in 1987 proposed the phasing out of 96 chemicals including CFCs which were causing depletion of ozone layer. Due to this Protocol, ozone layer is likely to return to normal level by 2050.

Earth Summit in 1992 at Rio deJanerio, Brazil, the first Earth summit was held and counties have established principles to reduce green house gases. Objectives of the summit were: to secure renewed political commitment to sustainable development; to assess progress towards internationally agreed goals on sustainable development, and to address new and emerging challenges. The summit focused on two specific themes: a green economy in the context of poverty eradication and sustainable development, and an institutional framework for sustainable development. In this summit, developed countries demanded environmental sustainability while developing countries urged that they should be given a chance to catch up the developed world socially and economically. Next summit is scheduled in 2012 on sustainable development at Rio deJanerio.

Kyoto Protocol: In December 1997, an international conference was held at Kyoto, Japan, to discuss climate change which was attended by 37 industrialised countries and the European community for reducing greenhouse gases. It was decided that the countries will reduce the green house emission by 5 % compared to 1990 level up to 2012.

Copenhagen International Conference: During 7-19 December 2009, an international conference was held at Copenhagen (Denmark) after United Nations Climate Change Conferences took place in December 2007 at Bali to prevent climate changes and carbon emissions. Governmental representatives from 192 countries, NGO's, journalists and others representatives attended the conference. United Nations Framework Convention on Climate Change (UNFCCC) has received submissions of national pledges to cut or limit missions of greenhouse gases by 2020 from 75 parties, which together account for more than 80% of global emissions from energy use after the closing of this conference.

Important Terminology

1. *Decibel*: A unit of sound measurement.
2. *Bioremediation*: Process of using bacteria to treat the polluted soil.
3. *Photochemical smog*: Atmospheric pollution formed by chemical reactions among hydrocarbons, ozone, and other pollutants in the presence of sunlight.
4. *Eutrophication*: Enrichment of water bodies by nutrients like phosphorus and nitogen.
5. *DDT*: Dichloro diphenol trichloroethane is a insecticide that protects crops and humans from insects.

6. *Volcanic eruptions*: It is molten magma coming out from hills at a high temperature.
7. *Global warming*: Rise in the temperature of globe due to green house gases and pollution.
8. *CFC's*: Chlorofluorocarbons (combination of carbon, hydrogen, fluorine and chlorine).
9. *PAN*: Peroxyacyl Nitrate, produced by photochemical reaction between hydrocarbons and NO.
10. *Flora and Fauna*: Flora includes all plant species while fauna includes all animal species present in a given region.

Review Questions

1. Define environmental pollution and describe the different types of pollutions.
2. What are the sources of water pollution? Discuss the effects of water pollution.
3. Enlist different water quality parameters and discuss their environmental significance.
4. Describe at least three common air pollutants stating their sources and effects.
5. Explain the effects of air pollution on human beings and animals.
6. What is air pollution? Give the classification of air pollutants.
7. State the Indian ambient air quality standards.
8. What is dBA? Give its values for different sources of noise.
9. What is noise pollution? Describe the effects of noise pollution.
10. What are the global environmental problems? Discuss the green house effect schematically.
11. Write short notes on
    (a) Acid rain
    (b) Ozone depletion
    (c) Land pollution
    (d) Control of noise pollution
    (e) Eutrophication
12. What do you understand by pollutants? Give classification of pollutants.
13. What is potable water? State the qualities of potable water.
14. What are indicator organisms? Discuss the MPN test.
15. Differentiate the point and nonpoint sources of water pollution.

16. Define biological magnification of pollutants and discuss the importance of Biological Concentration Factor (BCF) used to estimate it.
17. Discuss the different processes of self-purification of natural water bodies.
18. Define (a) mist, (b) aerosol, (c) fog, (d) smog, (e) smoke, (f) soot, (g) fume.
19. Differentiate (a) primary air pollutants and secondary air pollutants, (b) indoor and outdoor air pollutants.
20. Enumerate different air pollution control devices and describe with sketches, the scrubber and electrostatic precipitator.
21. What do you mean by land degradation? Discuss the different factors to control land pollution.
22. What is global warming? Discuss the different green house gases indicating their contribution to green house effect.
23. What is Dobson Unit (DU)? How is ozone formed in stratosphere?
24. What are the main causes of acid rain? Discuss its control measures.
25. What do you mean by 'Ozone whole'? Describe the factors caused this problem.

Objective Type Questions

1. The BOD is a measurement of
   (a) Pathogens
   (b) Inorganic matter
   (c) Organic matter from domestic wastewaters
   (d) None of these
2. The COD is a measurement of
   (a) Pathogens
   (b) Only biodegradable organic matter
   (c) Only nonbiodegradable organic matter
   (d) Both (b) and (c)
3. Affect of fluoride pollution is on
   (a) Skin (b) Eyes
   (c) Teeth (d) None of these
4. Nitrate pollution causes
   (a) Skin diseases (b) Typhoid
   (c) Blue baby disease (d) None of these

5. Hardness in water is due to
   (a) Divalent ions (b) Monovalent ion
   (c) Both (a) and (b) (d) None of these
6. Turbidity is mainly responsible for
   (a) Increase in salt concentration (b) Reduction in light penetration in water
   (c) Reduction in solids (d) None of these
7. Water is acidic if its pH is
   (a) Greater than 7 (b) Less than 7
   (c) 7 (d) None of these
8. Fishes may start dying if DO in water body is
   (a) Less than 4 mg/l (b) More than 4 mg/l
   (c) 9 mg/l (d) None of these
9. Acid rain is due to high concentration of
   (a) CO_2 and CO (b) SO_2 and NO_2
   (c) N_2 and O_2 (d) None of these
10. Reactivity of which gas is more than the oxygen with hemoglobin
   (a) SO_2 (b) CO_2
   (c) CO (d) N_2
11. Ozone layer destruction is basically due to
   (a) CFCs (b) SO_2
   (c) CO (d) None of these
12. Damaging effect on Taj Mahal is due to
   (a) CFCs (b) Hydrogen
   (c) CO (d) SO_2
13. Chemical reaction of nitrogen oxides and hydrocarbons in the presence of sun light form
   (a) SO_2 (b) Benzene
   (c) CO (d) PAN
14. Type of radiations absorbed by CO_2 are
   (a) IR radiations (b) UV radiations
   (c) Visible radiations (d) None of these
15. Atmospheric window is between the wavelengths
   (a) 2 – 20 μm (b) 7 – 12 μm
   (c) 20 – 30 μm (d) None of these

16. Lakes which are poor in nutrient are called
    (a) Oligotrophic (b) Mesotrophic
    (c) Eutrophic (d) All of these
17. Coal is the main contributor of
    (a) SO_2 (b) CO_2
    (c) CO (d) N_2
18. Potable water is
    (a) Polluted water (b) Safe drinking water
    (c) Wastewater (d) River water
19. Lakes which are rich in nutrient are called
    (a) Oligotrophic (b) Mesotrophic
    (c) Eutrophic (d) All of these
20. HCFC is less stable and less dangerous compared to CFC because of
    (a) Covalent bond (b) Hydrogen bond
    (c) Electro bond (d) All of these
21. Bhopal gas tragedy was due to leakage of
    (a) Methyl isocyanate (b) Chloro benzene
    (c) Carbon monoxide (d) None of these
22. The biggest pollutant receptor or sink on the earth is
    (a) Biosphere (b) Atmosphere
    (c) Lithosphere (d) Hydrosphere
23. Noise levels in residential areas should not exceed
    (a) 30 dBA (b) 80 dBA
    (c) 120 dBA (d) None of these
24. Asthma, bronchitis and silicosis disease are
    (a) Air borne (b) Water borne
    (c) Both (a) and (b) (d) None of these
25. Soot particles come in air by
    (a) Photochemical reactions (b) Fuel combustion
    (c) Volcanic eruptions (d) None of these

ANSWERS

1. (c)	2. (d)	3. (c)	4. (c)	5. (a)	6. (b)	7. (b)
8. (a)	9. (b)	10. (c)	11. (a)	12. (d)	13. (d)	14. (a)
15. (b)	16. (a)	17. (b)	18. (b)	19. (c)	20. (b)	21. (a)
22. (d)	23. (b)	24. (a)	25. (b)			

List of questions asked in Gujarat Technical University Examinations from this chapter

Q. No.	Details	Marks
Q1.	Describe the different air pollutants. **GTU, Jan 2009**	8
Q2.	Explain the effect of air pollution on human beings and animals. **GTU, Jan 2009**	7
Q3.	Give the water quality standards as per ISI. **GTU, Jan 2009**	7
Q4.	Describe the sources of water pollution. **GTU, Jan 2009**	7
Q5.	How is acid rain formed? What are its effects on atmosphere? **GTU, Jan 2009**	6
Q6.	Explain by drawing a sketch of green house effect. **GTU, Jan 2009**	8
Q7.	Give reasons for validity-1. Sabarmati river is one of the polluted rivers' of Gujarat. 2. Salinity and water logging is a problem in south Gujarat. 3. Dilution is not a solution of water pollution 4. Well waters near sea are contaminated. 5. Water harvesting is made compulsory in metro cities. **GTU, Jun 2009**	5
Q8.	Enlist the parameters of water quality standards for drinking water in India. **GTU, Jun 2009**	4
Q9.	Describe the uses and overuses of land. What are the causes and effects of land pollution? **GTU, Jun 2009**	6
Q10.	Define noise pollution. Describe all effects of noise pollution. **GTU, Jun 2009**	5
Q11.	Enlist all global environmental problems. Describe global warming and green house effects in detail. **GTU, Jun 2009**	5

Q12.	Describe the effects of air pollution on humans. **GTU, Jun 2009**	4
Q13.	Enlist the parameters of water quality standards for drinking water in India and state their significances. **GTU, Jan 2010**	7
Q14.	Enumerate the different air pollutants and explain its effect on human beings. **GTU, Jan 2010**	7
Q15.	Enlist the global environmental problems and discuss any one. **GTU, Jan 2010**	7
Q16.	Write short notes on (i) Acid rain, (ii) Environmental degradation **GTU, Jan 2010**	7
Q17.	Discuss about the effects of noise pollution and its control. **GTU, Jan 2010**	7
Q18.	What is potable water? Describe the different water pollutants which make water unfit for drinking. **GTU, Jun 2010**	7
Q19.	Enlist common air pollutants stating their permissible limits as per ambient air quality standards. Discuss the effects of high carbon monoxide's presence in atmosphere upon human beings. **GTU, Jun 2010**	7
Q20.	Explain the green house effect with schematic diagram and compare the effect of different green house gases in global warming. **GTU, Jun 2010**	7
Q21.	What is an ozone? How is it formed? Describe the main causes of depletion of ozone layer and briefly comment over control measures taken to prevent further ozone depletion at international level. **GTU, Jun 2010**	7

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