Chapter 2 Concepts of Ecology and Natural Resources

2.1.Components of the Environment

The word ‘environment’ (which originates from the French word ‘environ’ meaning surrounding) is defined as the holistic view of the world as it functions at a given point of time, with a multitude of spatial, elemental and socio-economic systems distinguished by quality and attributes of space, and the mode of behavior of the various abiotic and biotic forms.

Types of Environment

The environment can be divided into three categories- physical, biological, and cultural. On the basis of structures, the environment may be divided into two fundamental types:

1. The abiotic or physical environment consisting of air, water and soil/sediment.
2. The biotic or biological environment consisting of flora, fauna, and micro-organisms.

On the basis of physical characteristics and state, the physical environment is further subdivided into three broad categories:

a. Lithosphere (sphere of rocks/soil/sediment)
b. Hydrosphere (sphere of water)
c. Atmosphere (sphere of gas)

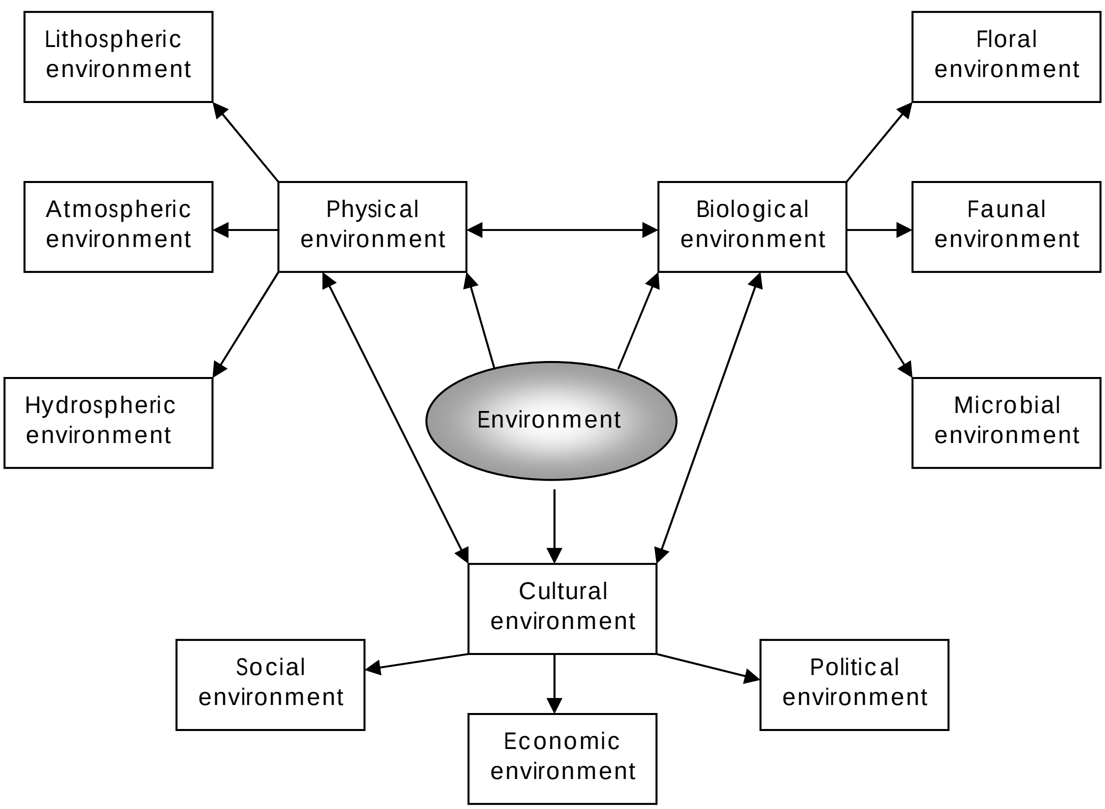

Figure 2-1: Interaction between various types of environment

2.2 Ecosystem

Ecology can be defined as the study of relationships between organisms and their environment. Examples of ecological studies are an investigation into the chemistry of solids to which a particular plant species is restricted, as study of the relationship between the number of eggs a bird lays and the amount of food available for its chicks to eat, and the changes occurring in a lake or river when untreated sewage is added to it.

The term **ecosystem** is an abbreviated for form of ‘ecological system’. An ecosystem is a group of plants and animals, along with the physical environment with which it interacts. The abiotic (non-living—organic/inorganic substances) and the biotic (living—plants, animals and microbes) components of an ecosystem form an interdependent ecological system. An ecosystem can be large or small, depending on the number of species present in it.

Ecology examines the life histories, distribution and behavior of individual species, as well as the structure and functions of a natural system in terms of populations, communities, ecosystems and landscapes.

Structure of an ecosystem

The structure of any ecosystem is composed of two chief components namely biotic and abiotic.

Biotic components

The biotic components of an ecosystem are of three types according to the specific roles they play in operating the system. They are producers, consumers and decomposers.

(a) Producers or Autotrophs

Producers are the autotrophic organisms which can manufacture their own food material. They capture solar energy to manufacture food from simple inorganic substances like water, carbon dioxide, salts, etc. A portion of the food thus synthesized is used by the producers for their growth and survival whereas the remaining is stored for future use. Producers are the following types:

i. Green plants, e.g. *Chlorella, Spirogyra (*algae*), Azadirachta indica* (neem tree)
ii. Photosynthetic bacteria, e.g. *Chromatium, Chlorobium*.
iii. Chemosynthetic bacteria. e.g. *Nitrosomonas, Nitrobacter, Beggiotoa*.

(b) Consumers or Heterotrophs

Consumers are heterotrophic organisms, (nourished by others) primarilt animals which consume the producers directly or indirectly.

Consumers are of various types depending on the nature of the food they consume:

(i) *Primary consumers/herbivores*: consume the producers directly.

(ii) *Secondary consumers/carnivores* (flesh eaters): They feed upon the primary consumers. Omnivores which feed on both flesh and plants are also included in this category.

(iii) *Secondary carnivores/tertiary consumers*: Carnivores which feed upon the secondary consumers, they are also called secondary carnivores, e.g. lions which feed upon cats and dogs, etc.

(c) Decomposers/Microconsumers/Reducers

The decomposers are also heterotrophic organisms which are saprotrophs. They consume the food by absorption but not by ingestion. They are mainly fungi, bacteria and certain protozoans. They secrete certain enzymes which can break down the complex organic substances into simple absorbable forms. This process is called *decomposition*. When the producers and consumers die, their bodies are acted upon by these enzymes and the resultant products are absorbed by the decomposers. Some of the absorbed products of decomposition are used for their own growth. The other products like inorganic nutrients, minerals and gases like ammonia are released back into the environment from where they are recycled i.e. they are again made available to the autotrophs for the synthesis of food. The continuous functioning of an ecosystem depends on the activity of decomposers in the recycling of matter.

Abiotic Components

The abiotic components of an ecosystem include the non-living constituents of the environment i.e. the habitat. A habitat is a specific set of physical and chemical conditions (space, substratum and climate) that surrounds a single species, a group of species or a large community.

Soil and water form the media as well as important abiotic factors in an ecosystem. In addition to this, there are other abiotic factors which can be broadly divided into two categories.

(a) Physical Factors

Some of the important physical factors include: *Light* (sun as the main energy source), *temperature* (controls the climate), *evaporation and precipitation* (control climate), *gravity* (controls rock material and hydrological cascade system, movement of matter, and orientation and distribution of animals), *pressure* (limits distribution of organisms), *humidity, and air and water currents.*

(b) Chemical Factors

Some of the important chemical factors include*: Oxygen, Carbon dioxide, minerals* (micro- and macro-nutrients), and *organic matter* (carbohydrates, proteins and lipids).

Energy flow in the Ecosystem

Ecosystems would not be possible were it not for the flow of energy into them. The sun us the primary source of this energy because all biological life is dependent on the green plants that use sunlight as a source of energy. As such, these sunlight-using organisms are called **primary producers**. Primary producers also obtain their carbon from inorganic sources such as carbon dioxide (CO_2) or bicarbonate (HCO_3^-). As such, they are referred to as *autotrophic*. These photosynthetic organisms that obtain their carbon from inorganic sources are called **photoautotrophic**. *Trophic* is the term used to describe the level of nourishment. Trophic levels are summarized in Table 2-1.

The process by which some organisms (namely chlorophyll-containing plants) are able to convert energy from sunlight into chemical energy (in the form of sugars) is called **photosynthesis** and can be represented by the simple equation.

$$6CO_2 + 6H_2O + 2800 \text{ kJ energy from sun} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

Table 2-1 Characteristics Terms for Biological Organisms Based on Energy and Carbon Sources

Type	Energy Source	Electron Donor*	Carbon Source
Phototrophs	Light		
Chemotrophs	Organic or inorganic compounds		
Lithotrophs (subgroups of chemotrophs)		Reduced inorganic compounds	
Organotrophs (subgroups of chemotrophs)		Organic compounds	
Autotrophs			Inorganic compounds (e.g., CO_2)
Heterotrophs			Organic carbon

*Electron donors (reducing agents) are the sources of electrons that come from reduced bonds (i.e., C—H bonds). The breaking of these reduced bonds may be coupled directly or indirectly to the production of adenosine triphosphate (ATP) within the cell.

The chemical compound represented by $C_6H_{12}O_6$ is the simple sugar glucose. The rate of carbon dioxide used and, therefore, glucose production is dependent on sunlight and the number and growth rate of the photoautotrophs, along with other environmental conditions such as temperature and pH. The rate of production of biomass glucose, cells, and other organic chemicals by the primary producers is referred to as **net primary productivity (NPP).**

Aerobic respiration is simply the breakdown of organic chemicals, such as sugars and starches, by molecular oxygen to form gaseous carbon dioxide.

Some organisms are able to obtain energy through photosynthesis but are not capable of reducing carbon dioxide. Thus, they obtain carbon from reduced carbon compounds generated by other organisms. These organisms are known as **photoheterotrophs:** heterotrophic referring to the fact that carbon for cell synthesis is derived from performed organic compounds usually produced by other organisms. This group of biota includes the purple nonsulfur bacteria; the green nonsulphur bacteria; some Chrysophytes; some Euglenophytes and some Cryptophytes.

These organisms all obtain their energy from light, and they acquire carbon from either inorganic or organic source. Similarly, the **chemotrophs** obtain their energy from organic or inorganic carbon rather than from light. Chemotrophs can be either autotrophic, that is they build cell mass from either inorganic forms of carbon, or heterotrophic, using organic forms of carbon to synthesis new cells and compounds. Chemotrophs can also be either lithotrophs, that is, they obtain energy by breaking inorganic chemicals, or organotrophs, which get energy by breaking organic chemical bonds.

Chemotrophs that are autotrophic obtain their energy from organic or inorganic compounds and used inorganic carbon compounds as a carbon source. And chemoautotrophs are prokaryotic, archaea, and bacteria.

Chemoheterotrophs use inorganic or organic compounds as energy sources; however, they use only preformed reduced organic chemicals as a source of carbon for cell synthesis. Examples include animals, protozoa, fungi, and bacteria.

The transfer of energy from one trophic level to another trophic level is called *energy flow*. In an ecosystem the flow of energy is unidirectional. The study of energy transfer between different trophic levels in an ecosystem is known as *bioenergetics*.

The energy in an ecosystem is controlled by two laws of thermodynamics.

i. Energy can neither be created nor destroyed.
ii. Every transfer of energy is accompanied by its dispersion.

The flow of energy in any ecosystem depends on the following factors:

i. Efficiency of producers to trap solar energy and convert it into chemical energy
ii. Use if chemical energy present in the producers by the consumers
iii. Amount of energy present in the producers by the consumers
iv. Loss of energy in the form of unused energy dead organism and heat during respiration.

The flow of energy through an ecosystem can be represented diagrammatically in a simplified manner.

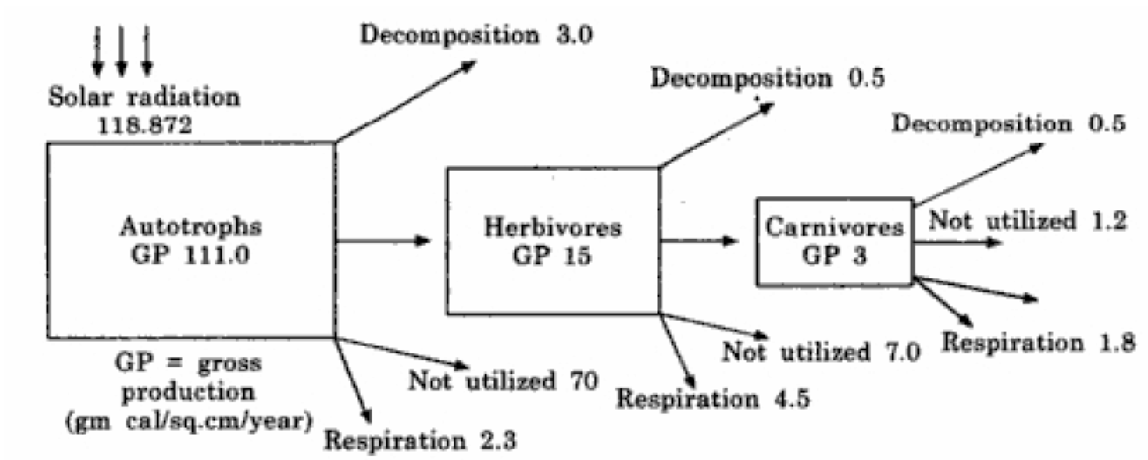

Figure 2-2 Energy flow model (lake) unidirectional.

Figure 2-1 indicates two aspects of energy flow in an ecosystem.

(i) The flow of energy in unidirectional.

(ii) There is a successive reduction in the energy flow at successive trophic levels.

Food Chain

The transfer of energy and nutrients from one feeding group of organisms to another in a series is called *food chain*. It is the sequence of eater being eaten, or who eats whom.

In each transfer some energy is lost. Therefore, the shorter the food chain, or the nearer the organism to the beginning of the chain, the greater the energy available to that population.

Each successive level of nourishment as represented by the links of the food chain is known as a *trophic level*. The producers of an ecosystem form the first trophic level, the herbivores form the second trophic level and the carnivores, the third trophic level. Energy is transferred from one trophic level to another. Figure 2-3 shows a simple food chain in a pond.

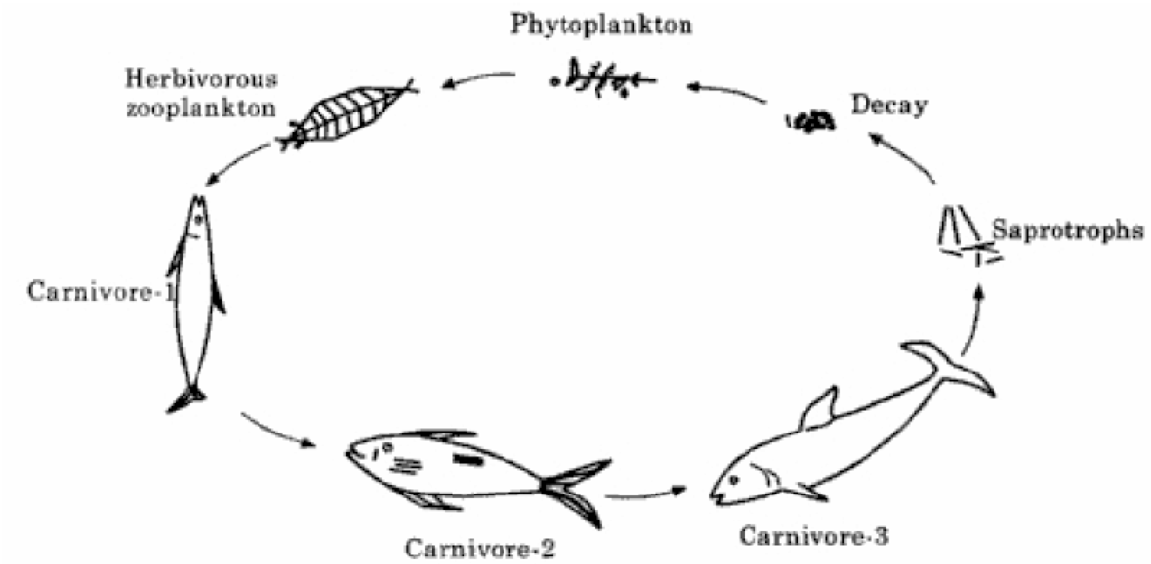

Figure 2-3 Simple food chain in a pond

In any ecosystem there are two major food chains, the grazing food chain and the detritus food chain.

(i) *Grazing food chain*: This food chain starts from living plants, goes through herbivores and ends in carnivores.

(ii) *Detritus food chain*: It starts from dead organic matter and ends in inorganic compounds.

Food Webs

The food chains in nature never operate as an isolated, simple, straight-line sequences. Instead, they are interconnected with each other to form a net work called food web.

Food webs are very important in maintaining the stability of an ecosystem. The complexity of any food web depends upon the diversity of species and their interconnectivity. Diversity of species is based upon their food habits which would determine the length of the chain. More interconnectivity patterns in food webs suggest alternatives at different points of consumers in the chain. Such complex food webs are more stable than simple one for the reason that if a species is removed, its position is taken by another species of similar trophic status so that the ecosystem is maintained.

Ecological Pyramids

Ecological pyramids are the graphic representation of the number, biomass and energy of the successive trophic levels of an ecosystem. The number, biomass and energy of organisms gradually decrease from the production level to the consumer level.

The loss of energy occurs in several ways.

(i) First, some consumed energy is not used efficiently: plants use a greater deal of energy in evaporating water, as well as in creating carbohydrates.

(ii) Second, a great deal of energy dissipates as kinetic energy and heat.

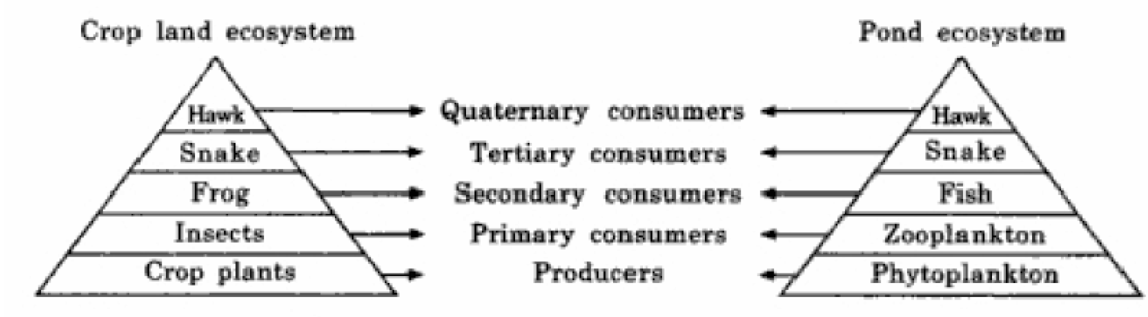

Figure 2-4 The ecological pyramid

2.3 Biogeochemical Cycles

Within an ecosystem there is a dynamic relationship between the various living forms and their physical environment, which includes rocks, air and soil. **Biogeochemical cycle** is the complete pathway that a chemical element follows through the Earth system—from the atmosphere, water, rocks, or soils, or to the living organisms and back to these components. It is a *chemical cycle* because chemical elements are the form that we consider. It is *bio*- because these are the cycles that involve life. It is *geo*- because these cycles include atmosphere, water, rocks, and soils. The natural cycles and ecosystems are functioning in a balanced manner which stabilises the biosphere and sustains life process in earth. We can consider a biogeochemical cycle at any special scale of interest to us, from a single ecosystem to the whole earth. It's apparent that human activities can influence global biogeochemical cycles.

The major global cycles include carbon, nitrogen, phosphate, and sulfur cycle.

The Carbon Cycle

The element carbon is the backbone of biological or organic chemistry, and the carbon cycle is an important chemical process. The atmosphere is a minor reservoir of carbon dioxide, while the oceans are a major reservoir, having as much as 50 times the concentration of CO_2 as compared to air, in the form of bicarbonate mineral deposits on the ocean floor and regulates the carbon dioxide level in the atmosphere. The cycle involves the exchange of carbon dioxide between the atmosphere, the biosphere and the oceans. The volumes of carbon dioxide absorbed and emitted by various processes annually are given below:

Table 2-2. The volumes of carbon dioxide absorbed and emitted by various processes annually

Absorption	Emission
Ocean – 5.5 billion tons	Burning of fossil fuels – 20 billion tons
Photosynthesis – 7.3 billion tons	Deforestation and others – 5.5 billion tons
Total = 12.8 billion tons	Total = 25.5 billion tons

The atmosphere contains about 2700 billion tons of carbon dioxide, the biosphere, vegetation and soil about 6600 billion tons and the oceans about 136,000 billion tons of carbon dioxide.

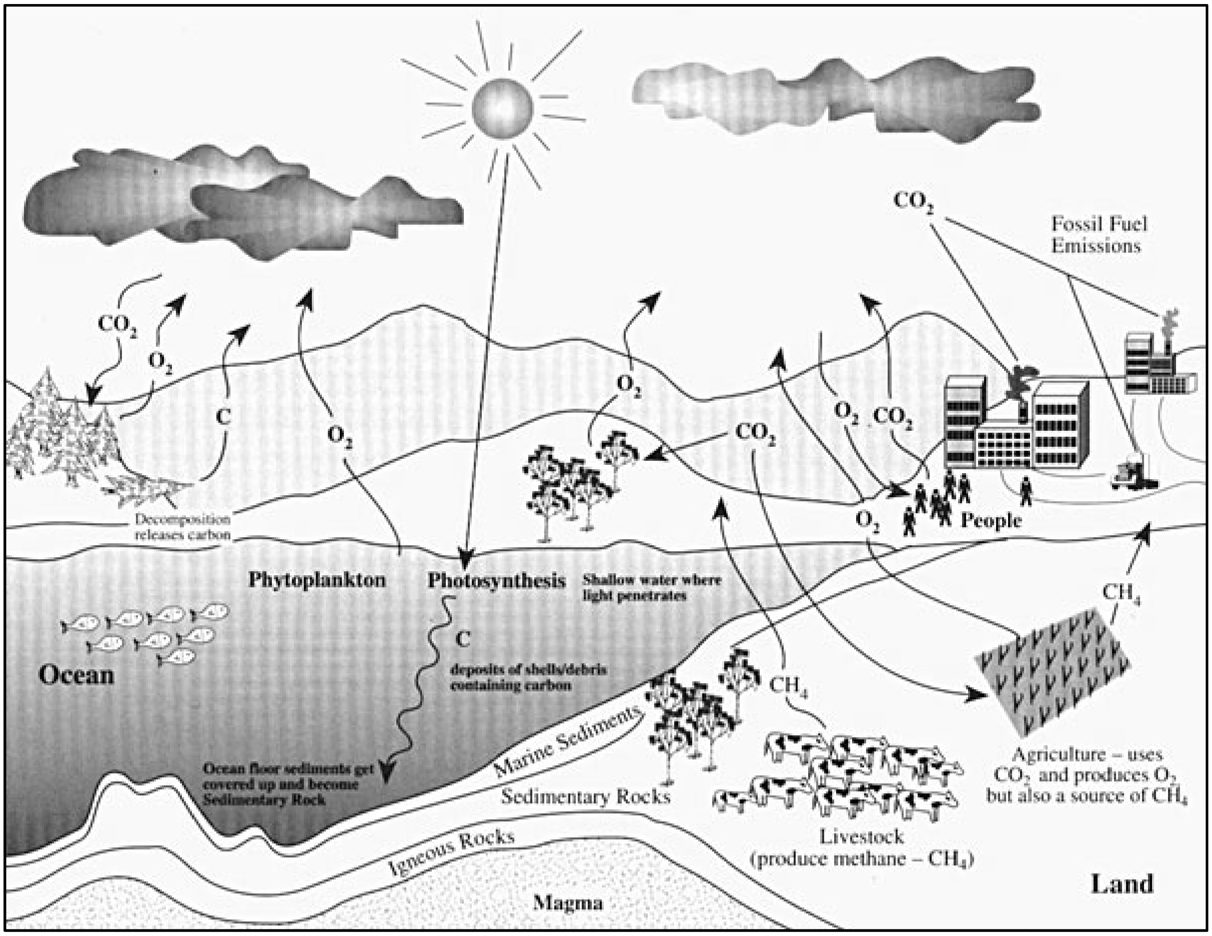

Figure 2-5: The Carbon Cycle

Fossil fuel burning releases roughly 5.5 gigatons of carbon (GtC [giga=1 billion]) per year into the atmosphere and that land-use changes such as deforestation contribute roughly 1.6 GtC per year. Measurements of atmospheric carbon dioxide levels (going on since 1957) suggest that of the approximate total amount of 7.1 GtC released per year by human activities, approximately 3.2 GtC remain in the atmosphere, resulting in an increase in atmospheric carbon dioxide. In addition, approximately 2 GtC diffuses into the world's oceans, thus leaving 1.9 GtC unaccounted for.

The Nitrogen Cycle

There is a continuous exchange of nitrogen within the ecosystem through the nitrogen cycle. Free nitrogen makes up approximately 80% of the Earth's atmosphere. However, organisms cannot take nitrogen directly. The process of converting inorganic, molecular nitrogen in the atmosphere to ammonia is called *nitrogen fixation*. Once in this form, it can be taken up on the land by plants and in the oceans by algae.

Proteins are organic compounds of nitrogen synthesized by plants and animals during metabolism. Most of the nitrogenous organic residue in the soil originates from decaying plants and the excreta of animals. These organic residues are utilized by various micro-organisms present in the soil for their metabolism, giving rise to products such as ammonia, nitrates and nitrites. Plants absorb these nitrates from the soil and another nitrogen cycle begins. Some organisms present in the soil breaks down soil nitrate into nitrogen by the *de-nitrification* process, while others transform nitrogen into soluble nitrogen compounds by nitrogen fixation, as shown in Fig 2.6.

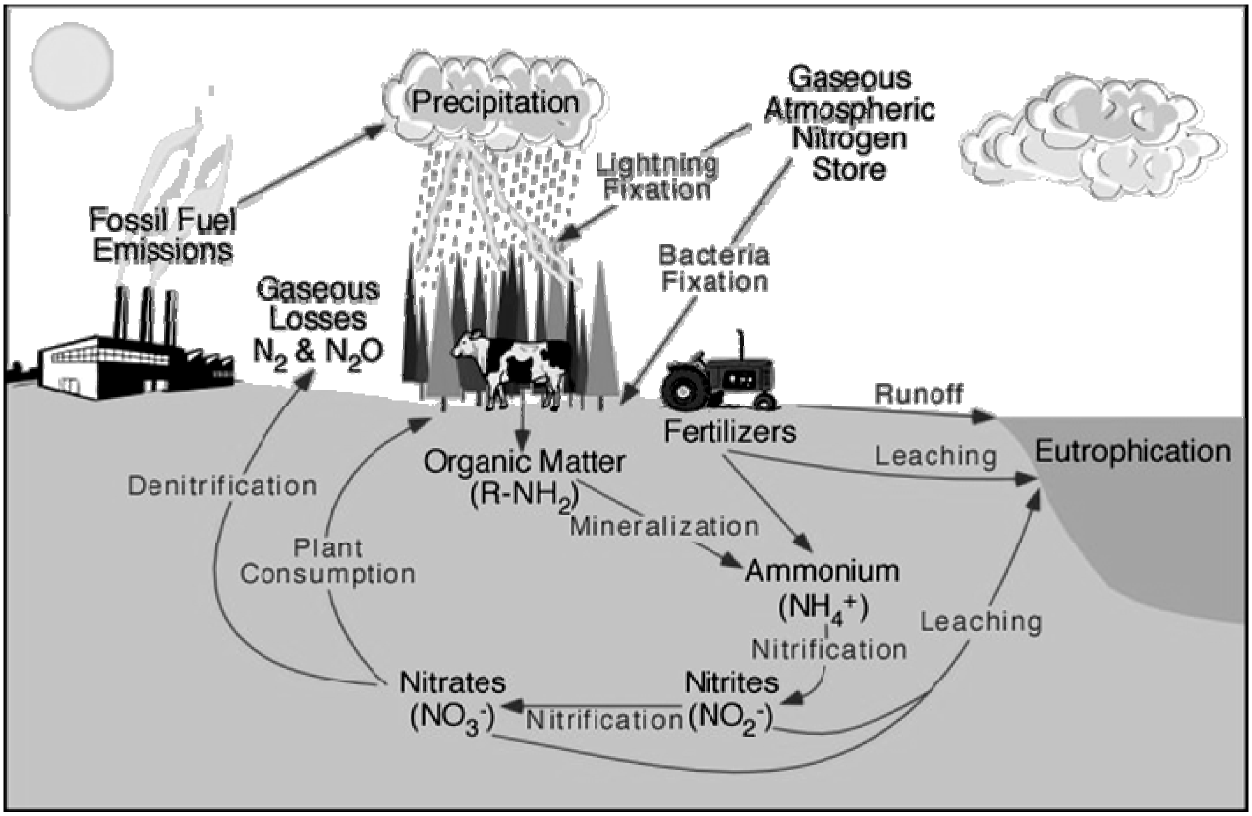

Figure 2-6: The Nitrogen Cycle

The Phosphate Cycle

Phosphates (PO_4) are necessary for the growth and maintenance of animal and human bones and teeth, while organo-phosphates are required for cell division involving the production of nuclear deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

Mineral phosphates both exist in soluble and insoluble compounds in rocks and soil. Plants absorb inorganic phosphates from the soil and change them into organic phosphates. Animals obtain their phosphates by eating the plants. Phosphates are returned to the soil by the decay of dead plants and animals. The bulk of the phosphate in soil is either fixed or absorbed by soil particles, where as part of it is leached out into water bodies.

The phosphate cycle differs from the other major biogeochemical cycles in that it does not include a gas phase; although small amounts of phosphoric acid (H_3PO_4) may make their way into the atmosphere, contributing – in some cases – to acid rain. The natural phosphate cycle is affected by pollution occurring mainly from agricultural run-off containing superphosphate and domestic sewage. Phosphate pollution of rivers and lakes causes algal bloom (*eutrophication*) which reduces the quantities of dissolved oxygen in water and disturbs the food chain. The phosphate cycles on land and in water is shown in Fig.

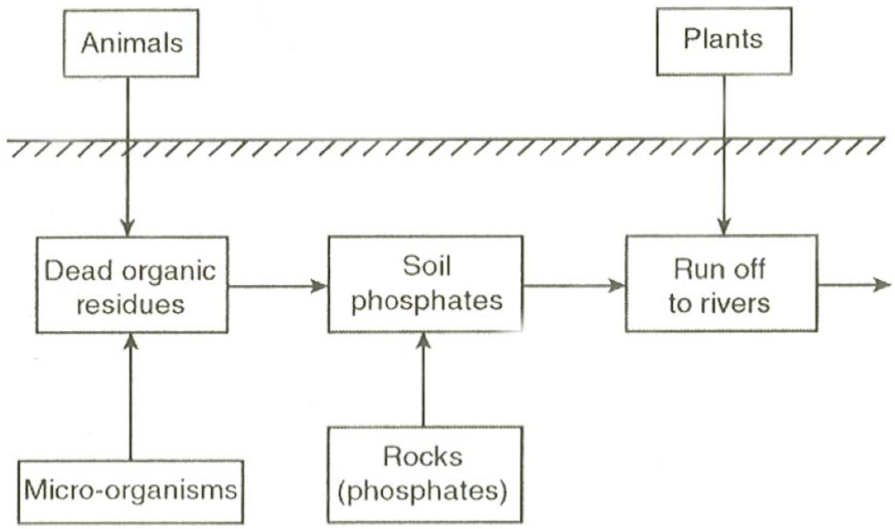

Figure 2-7: The phosphate cycle on land

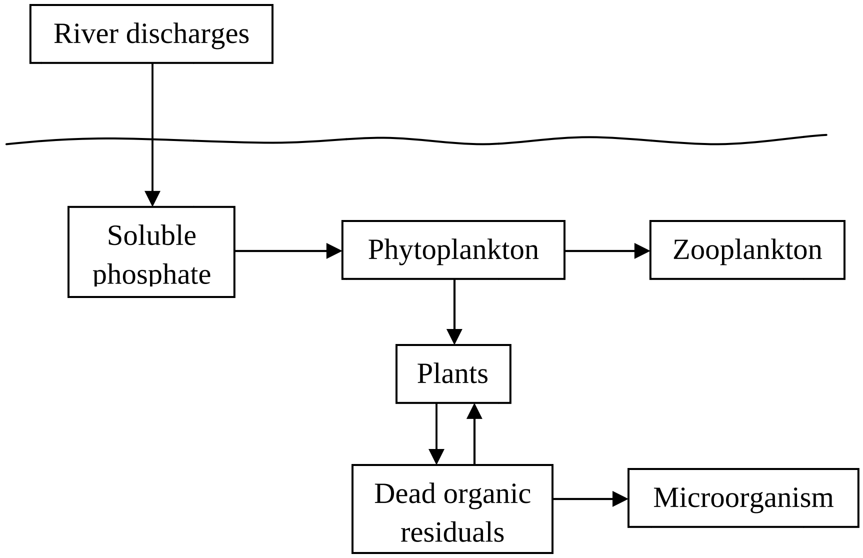

Figure 2-8: The phosphate cycle in water

The Sulfur Cycle

Sulfur (S), the tenth most abundant element in the universe. Sulfur and its compounds are required by plants and animals for the synthesis of certain amino acids and proteins. The sulfur cycle, shown in Fig is facilitated by some sulfur bacteria which act as the media for the exchange of sulfur and its compounds in the ecosystem.

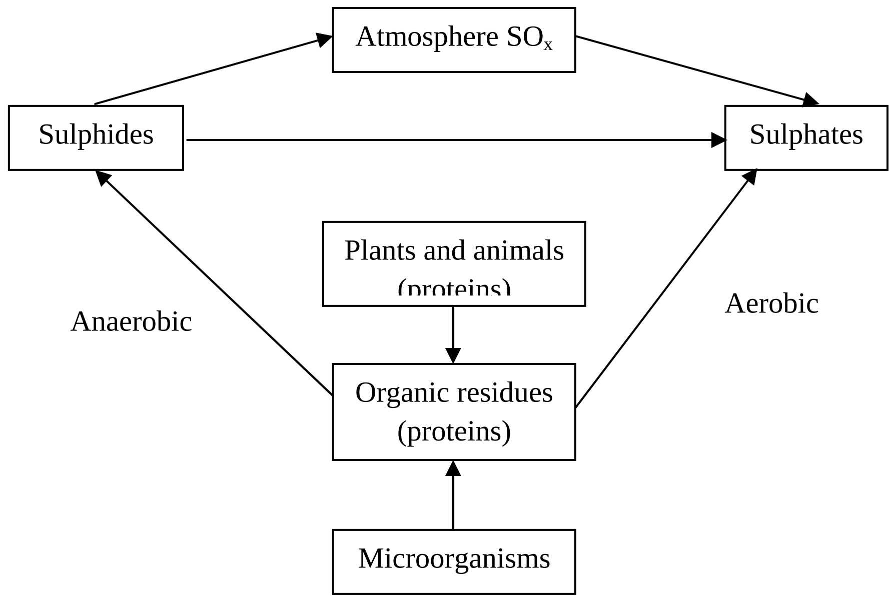

Figure 2-9: The sulfur cycle

The sulfur cycle contains both atmospheric and terrestrial processes. Within the terrestrial portion, the cycle begins with the weathering of rocks, releasing the stored sulfur. The sulfur then comes into contact with air where it is converted into sulfate (SO_4). The sulfate is taken up by plants and microorganisms and is converted into organic forms; animals then consume these organic forms through foods they eat, thereby moving the sulfur through the food chain. As organisms die and decompose, some of the sulfur is again released as a sulfate and some enters the tissues of microorganisms. There are also a variety of natural sources that emit sulfur directly into the atmosphere, including volcanic eruptions, the breakdown of organic matter in swamps and tidal flats, and the evaporation of water.

Sulfur eventually settles back into the Earth or comes down within rainfall. A continuous loss of sulfur from terrestrial ecosystem runoff occurs through drainage into lakes and streams, and eventually oceans. Sulfur also enters the ocean through fallout from the Earth's atmosphere. Within the ocean, some sulfur cycles through marine communities, moving through the food chain. A portion of this sulfur is emitted back into the atmosphere from sea spray. The remaining sulfur is lost to the ocean depths, combining with iron to form ferrous sulfide which is responsible for the black color of most marine sediments.

Since the Industrial Revolution, human activities have contributed to the amount of sulfur that enters the atmosphere, primarily through the burning of fossil fuels and the processing of metals. One-third of all sulfur that reaches the atmosphere – including 90% of sulfur dioxide – stems from human activities. Emissions from these activities, along with nitrogen emissions, react with other chemicals in the atmosphere to produce tiny particles of sulfate salts which fall as acid rain, causing a variety of damage to both the natural environment as well as to man-made environments, such as the chemical weathering of buildings. However, as particles and tiny airborne droplets, sulfur also acts as a regulator of global climate. Sulfur dioxide and sulfate aerosols absorb ultraviolet radiation, creating cloud cover that cools cities and may offset global warming caused by the greenhouse effect. The actual amount of this offset is a question that researchers are attempting to answer.

2.4 Impacts on the Environment

The Earth has limited resources to support populations of humans and other organisms. Our ever increasing human numbers is depleting many of our planet's resources and placing severe stress on the natural processes that renew many of our resources.

Ecosystem Processes

Natural ecosystems are involved in a wide variety of natural processes influencing humans and other organisms. The activities of humans in the environment are changing many of these natural processes in a harmful fashion. Some of these natural processes and a brief description of a human influence on these processes are indicated in Table 2.3.

Table 2-3: Human Influence on Some Ecosystem Processes

Ecosystem Process	Human Influence
Generation of Soils	Agricultural practices have exposed soil to the weather resulting in great loss of topsoil.
Control of the Water Cycle	The cutting of forests and other human activities have allowed increased uncontrolled runoff leading to increased erosion and flooding.
Removal of Wastes	Untreated sewage wastes and runoff from farms and feedlots have led to increased water pollution.
Energy Flow	Some industries and nuclear plants have added thermal pollution to the environment. The release of some gases from the burning of fossil fuels may be slowly increasing the Earth's temperature. (*Greenhouse Effect*).
Nutrient Recycling	The use of packaging material which does not break down, burning of refuse, and the placing of materials in landfills prevents the return of some useful materials to the environment.

Some Detrimental Human Activities

Humans are part of the Earth's ecosystem. Human activities can either deliberately or inadvertently alter the balance of an ecosystem. This destruction of habitat, whether accidental or intentional, is threatening the stability of the planet's ecosystems. If these human influences are not addressed, the stability of many ecosystems may be irreversibly affected. Some of the ways that humans damage and destroy ecosystems are indicated in Table 2.4.

Technological Developments

Human activities which have harmed ecosystems have resulted in a loss of diversity in both living things and the nonliving environment. Examples of these changes include land use, the cutting of vast areas of forest, and pollution of the soil, air, and water. Another way humans have changed ecosystems in a harmful way is by adding or removing specific organisms to these ecosystems. Our ever increasing demand for energy has impacted ecosystems negatively as well.

Table 2-4: Some Ways Humans Adversely Influence Ecosystems	
Human Influence	**Effect on Ecosystems**
Population growth	Our increasing numbers are using excessive amounts of the Earth's limited resources.
Overconsumption	Industrialized societies are using more resources per person from our planet than people from poor nations.
Advancing Technologies	Often we introduce technology without knowing how it will influence the environment
Direct Harvesting	This has resulted in a large loss of rainforest and the many products associated with its **biodiversity.**
Pollution	Land, air, water, and nuclear pollution have had many adverse influences on ecosystems.
Atmospheric Changes	These include the addition of Greenhouse gases mostly due to the burning of fossil fuels and depletion of our stratospheric ozone layer. Other pollutants also have negative effects on living things.

Many environmental risks are associated with our use of fossil and nuclear fuels. Many factors associated with human populations have influenced environmental quality. These include population growth and distribution on our planet, our use of resources, the ability of technology to solve environmental problems, as well as the role of economic, political, ethical, and cultural views in solving these problems.

Through a greater awareness of ecological principles and application of these principles to our natural environment, humans can help assure there will be suitable environments for succeeding generations of life on our planet.

Improvements

Individuals in our societies will always have to make decisions on proposals involving the introduction of new technologies.

Individuals in these societies need to make decisions which will assess the risks, benefits, trade-offs, and costs of these new technologies. The economic rewards of these technologies must be properly balanced with any adverse consequences these new technologies may have on the environment. It may be impossible to completely assess the consequences of introducing a new technology, but critical questions in reference to its introduction must be asked.

While the overall impact of humans on the planet's ecosystems have been negative, humans have done many things to improve the overall quality for living things in ecosystems we have damaged or destroyed. Ways in which humans have attempted to minimize negative impacts or improve the ecosystems are listed in Table 2-5.

.

Table 2-5: Some Positive Influences of Humans on the Ecosystem
• Sustaining endangered species by using habitat protection methods such as wildlife refuges and national parks. • Passing wildlife management laws, such as game laws and catch restrictions.. • Design new products which meet basic needs without generating pollution. • Inspection of all materials before entering a country to prevent pest introduction. • Increased use of **biodegradable** packaging materials which will recycle themselves quickly to the environment. • Use fuels which contain less pollutants, such as low sulfur coal and oil. • Remove pollutants by using such devices as afterburners or catalytic converters before they enter the air.

2.5 Major Global Environmental Hazards

The major environmental hazards are not easily linked with individual pollutants or sources only, but include a variety of conditions. These conditions are driven by a variety of factors that stress the environment and lead to imbalance and potential environmental degradation. They are sometimes global in scope which increases their importance but makes it even more difficult to define and address the causes. Some of these hazards include:

- Population growth
- Urbanization
- Industrialization
- Loss of biodiversity
- Global warming
- Inversion
- Acid rain
- Ozone depletion in the stratosphere

Population growth and standard of living

The rapid growth in human population in the past century has placed strains on the environment. Each member of the population has needs for food and shelter that can only be met at some expense to the environment. The environmental impact of human civilization depends on the needs and desires of the population (their standard of living) and the efficiency with which these needs can be met. The *ideal per capita resource usage* is the minimum amount of resources and environmental degradation required to achieve that standard of living.

The minimum ideal per capita resource usage can be defined as the actual per capita usage multiplied by an *environmental efficiency*. The environmental efficiency measures the effectiveness of translating environmental degradation and resource usage into the maximum possible standard of living. It simply measures the effectiveness of environmental control efforts and the environmental impact of the approaches and technologies employed to achieve the desired standard of living.

$$Environmental\ Impact\ \propto \frac{(Population)x\ (Ideal\ Per\ Capita\ Resource\ Usage)}{(Environmental\ Efficiency)} \qquad (2.1)$$

thus, reduction in the environmental impact of the Earth's population can be achieved by reducing population, decreasing their average standard of living (as measured by resource usage), or minimizing the impact of a given standard of living on the environmental controls and planning.

Note that the three factors of population, ideal resource usage, and environmental efficiency are not independent. In a developing country the lack of quality medical care (a component of standard living) can impact population, while the lack of access to appropriate environmental control technologies in the same population can decrease the environmental efficiency. Despite these limitations, the relationship does provide a means of conceptualizing the three most important factors in degradation of the environment as the result of human activities.

As environmental engineer we have to focus on improving the environmental efficiency; namely, minimizing the environmental impact per unit resource usage or standard of living. This can occur primarily through the use of practices and technologies that minimize the environmental impact or through technological advances in waste treatment.

Population

Population growth in less developed countries is about 2.1% per year, 2.4 % if the growth rate in china is not included in this total. In the more developed countries, the average population growth rate is only about 0.6% per year. In addition, the less developed countries, including China, contain about 80% of the world's population.

Growth that is proportional to the current population is referred to as exponential growth. Mathematically it can be written

$$\frac{dP}{dt} = kP \qquad (2.2)$$

where P is the population at any time, dP/dt is the rate of population growth with time, t, and k is a growth rate constant in fraction per unit time. The solution to this differential equation is

$$P(t) = P(0)e^{kt} \qquad (2.3)$$

The time required for the population to double is simply given by

$$\frac{ln2}{k} = \frac{70}{k(\%)} \qquad (2.4)$$

where k(%) is the growth rate constant in % per year. Thus, a 2.1% per year rate of growth results in a doubling in 33 years.

There is a finite capacity of the Earth to accommodate the needs of this growing population. Given a level of technological development and environmental efficiency there exists a corresponding human carrying capacity of the world. Of this carrying capacity is exceeded, either a reduction in numbers or a decrease in resource usage or standard of living must result. A system that is limited by a maximum carrying capacity is descried by logistic growth dynamics.

Mathematically, Equation 2.2 must be modified to indicate the slowing of growth near the carrying capacity

$$\frac{dP}{dt} = kP\left(1 - \frac{P}{C}\right) \qquad (2.5)$$

Here, C is the carrying capacity, the maximum allowable value of P. The factor P/C is resistance to continued population growth as the population nears the carrying capacity. For small values of the population the resistance factor is near 0 and the exponential growth of Equation 2.3 is followed. As the population nears the carrying capacity, however, the rate of growth slows as the environmental factors reduce the standard of living and force a steady-state population.

It is clear that population is a potentially significant factor in environmental degradation. Population must be stabilized prior to achieving the carrying capacity of the Earth or else natural forces will force stabilization of the population.

Urbanization

People increasingly want to live in cities and towns. This is mainly due to more employment opportunities, educational, medicare, and infrastructural facilities. Migration from rural areas to urban towns and cities is a regular and continuing phenomena. Agricultural land can decrease highly due to urbanization.

Problems associated with urbanization

There will be heavy demand for housing, water supply systems, waste treatment & disposal facilities, transportation, and other public facilities like: commerce, hospitals, hotels, educational facilities, etc; each of these highly affecting the environment.

- When more vehicles are on the road, traffic congestion and pollution from gaseous emissions are common.
- Consumers' life style is different in urban conglomerations. Solid wastes coming from each housing unit is more and varied. Most of the refuse quantities are either burnt out or disposed in low-lying areas, which leads to unhygienic and unsanitary conditions.
- As the built up land is going to be more, less open space is available for ventilation and vegetation. This results in an increase in temperature of the urban atmosphere. Ground water depletion and disappearance of surface water bodies add to the problem of drinking water supply.
- Quality of life in the urban environment appears to be more strenuous due to more work pressures and less comfort levels for an average citizen.

Remedies

A number of plans may appear on paper but policy implementation is difficult. Some remedial measures are suggested below:

- Effective method of reducing the migration trends to urban areas is to understand clearly the reasons for the migration. Education, unemployment, social services and commercial activities may be uniformly spread to other locations, rather than concentrating in major cities. Some of the headquarters of government departments may be shifted to different towns as communication facilities are possible and available in all respects from the capital city.

- Development of satellite townships around major urban center, with all infrastructural facilities should be encouraged, where planned growth is possible. This will reduce pressure on the heart of the city.
- City's master plan should clearly specify the various zones for residential and industrial activities without disturbing vegetation and water bodies.
- Slum areas also need the same basic facilities of living space, drinking water and drainage facilities as any other developed localities. An integrated development of slums in a society is a big asset for all.
- To reduce the demand on power supply, alternate energy can be obtained from the solid wastes (decomposition/burning) or from solar, wind and other sources. As urbanization appears to be inevitable to some extent, care should be taken to provide the necessary infrastructural facilities for the growing population. Care should be taken to prevent, stop and control all sorts of pollution from sources of emissions. Urban growth has its own limitations all checks.

Industrialization

Industrialization is driven by energy consumption from coal, petroleum, and natural gas. Solid, liquid and gaseous waste products are released into the atmosphere from various processing industries. Strength and volume of these wastes are known. They vary vastly from industry to industry depending upon the raw materials used and the manufacturing process. Domestic wastes have a neutral pH and exert an oxygen demand of 200 mg/L. But the liquid effluents from an industry may be extremely acidic or alkaline in nature. The oxygen requirement may also be 10 to 100 times even, in comparison with sewage. Hence and industry can do much damage if the effluents are not properly treated before disposal.

Characteristics of liquid wastes from selected industries are given below:

- Diary plant -- BOD = 1,000 mg/L, solids = 1,000 mg/L, oil and grease, odours, putrescibility
- Distillery unit -- Dark brown colour, solids = 50,000 mg/L, nitrogen, iron, sulphates, chlorides and phosphate. BOD = 40,000 mg/L
- Fertilizer plant -- Arsenic, fluorides, phosphates, chlorides, sulphates and nitrogen compounds
- Pharmaceutical unit -- BOD = 5,000 mg/L, extreme pH range, more solids, toxic organics, suphides, phosphates, strong odours
- Tanneries -- BOD = 3,000 mg/L, highly alkaline, solids - 10,000 mg/L strong odours, colour, organics, sulphides, chromium

Characteristics of gaseous impurities from selected industries are given below:

- Paper plant -- Mercaptons, dusts, SO_2, H_2S
- Tanneries -- Sulphides and mercaptons
- Metallurgical units -- Dusts, fumes and oxides
- Chemical industry -- Acid fumes
- Fertilizer unit -- NOx, HF, NH_3, Dusts of coal and sulphur

- Thermal power plant -- Flyash, NOx, SO_2, HC, CO
- Petrochemicals -- Particulates, dusts, hydrocarbons, NH_3, NO_2, CO

Inversion

Atmospheric temperature normally decreases with altitude. A certain mass of air rises and moves up vertically when it is warm until its own density equals with its surroundings. Then it becomes lighter and cooler. Warm air expands, and moves to adjacent regions of lower temperature. Cooler air mass gets compressed, becomes heavier and descends down. Changes in the internal, energy result in temperature variations. Vertical movements of air depend upon the environmental conditions. If a rising parcel of air arrives at an altitude in a cool or denser state than its surroundings then the displaced air will not move upwards. When there is no movement, harmful pollutants accumulate only at the ground level. Air near the surface of earth cools more than the layers above. This causes less dilution and little movement of air with pollutants in the ambient atmosphere.

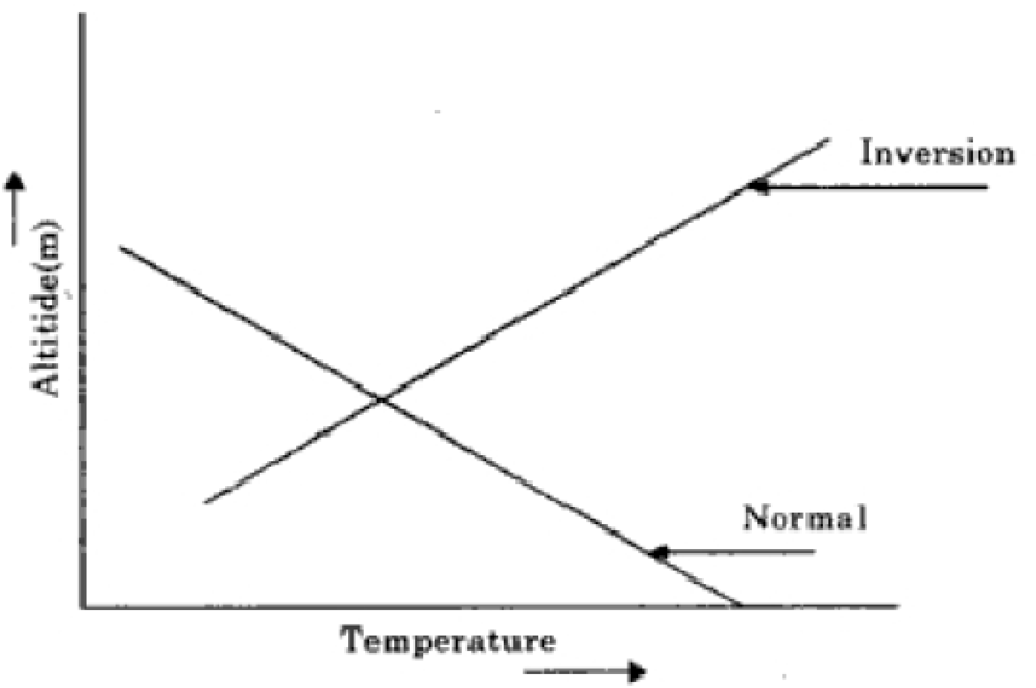

Figure 2-10. Inversion

Increase in temperature with altitude is known as an inverse condition (Figure 2-10), which is unfavorable for the dispersion of pollutants. Valleys, low lying areas and coastal areas are affected as dense and cooler air stays below the warm air. Early morning fog traps gaseous and particulate pollutants. Unequal cooling rates of surface of earth and air layers in contact (before sunrise), air moving down to replace air which has flown out from high pressure regions and hill ranges near sea experience inverse conditions. In Belgium (1930), Los Angeles (1941) and Thames Valley (1962), many people died in a few days due to exposure to the adverse inverse atmospheric conditions

Affects due to inverse conditions may be reduce if

(i) gaseous pollutants are minimized at source;
(ii) the stack height is adequately increased; and
(iii)care is taken at the time of locating the industries

Acid Rain

Industrial activities (combustion or chemical process) release SO_2, NO_2 and other gases into the atmosphere. Fine particulates, aerosols and various slats of acidic origin accumulate in the polluted atmosphere, water vapour condenses on these aerosols and increase in their size. These large size droplets acidic in nature get mixed with rain water. Oxidation takes place in the presence of OH, O_3 or H_2O_2, SO_2 is oxidized to SO_3 and forms sulphuric acid under humid conditions. NO_2 is oxidized to NO_3 or N_2O_5 and forms nitric acid in the presence of moisture. HCL gas may also result into forms nitric acid. Dry in or droplet deposition on plant leaves or building materials in the atmosphere mixes with precipitation and decreases the pH value of water and soil or so. Reduction of pH releases harmful chemicals dangerous to human beings.

Adverse Impacts

Adverse effects of acid rain are as follows:

- It causes damage (erosion, corrosion, fading, and cracking) to materials like steel, paints, fibrous material, and fabrics.
- It reduces soil fertility (lack of sufficient nutrients) and crops yield.
- It affects aquatic organisms, plant life and biodiversity. Some species may be eliminated.
- It results irritation to skin and respiratory tract.
- It adds toxic chemicals to food products, water bodies and soil.
- Ancient monuments like Tajmahal get corroded.

The only available remedy is to prevent or reduce the release of sulphur and nitrogen oxides, into the atmosphere from various industries. Use of cleaner coal (without sulphure) or alternate energy sources may be preferred. Industries may use electrostatic precipitators or catalytic converters to reduce gaseous emissions.

Global Warming

Carbon dioxide and other gases warm the surface of the planet naturally by trapping solar heat in the atmosphere. This is a good thing because it keeps our planet habitable. However, by burning fossil fuels such as coal, gas and oil and clearing forests we have dramatically increased the amount of carbon dioxide in the Earth’s atmosphere and temperatures are rising (Figure 2-11).

The first large-scale environmental change that seemed to be linked to human activities is the rapid increase in atmospheric carbon dioxide levels that has been observed since the beginning of the industrial revolution. Examination of air bubbles trapped in ice Antarctica has suggested that carbon dioxide levels fluctuated between 180 and 300 ppm over the past 150,000 years. While carbon dioxide levels were 280 ppm as recently as the year 1750, they had increased to more than 360 ppm in the southern hemisphere and to more than 370 ppm in the northern hemisphere by 1990. This is illustrated in Figure 2.12.

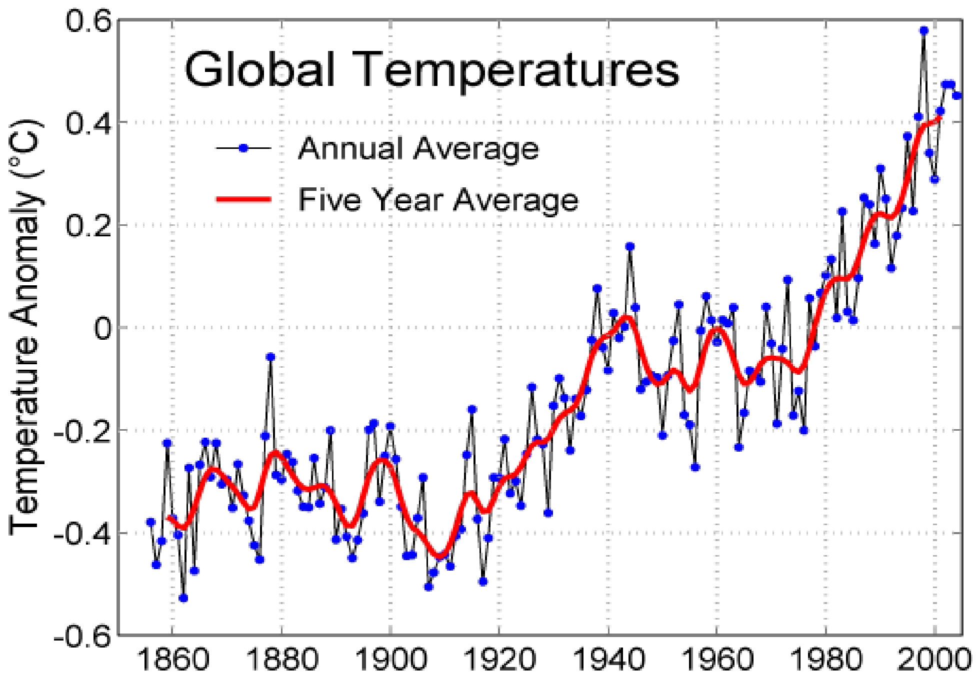

Figure 2-11. Global Temperature

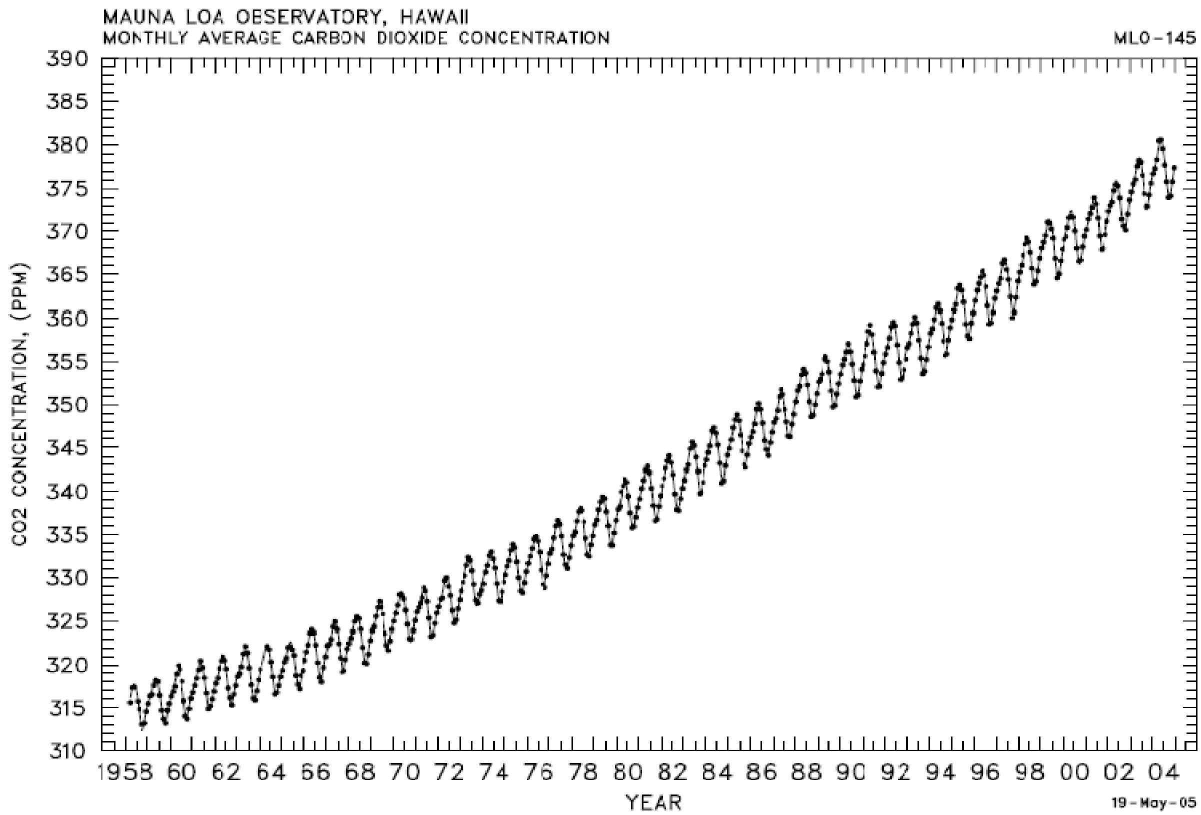

Figure 2-12: Atmospheric concentration of carbon dioxide

The importance of the increased emissions of carbon dioxide is the result of greenhouse effect. The greenhouse effect is the ability of atmospheric gases to absorb the energy radiating from the Earth, reducing energy losses to space and ultimately increasing the Earth's temperature. Figure 2.13 depicts the resulting greenhouse effect.

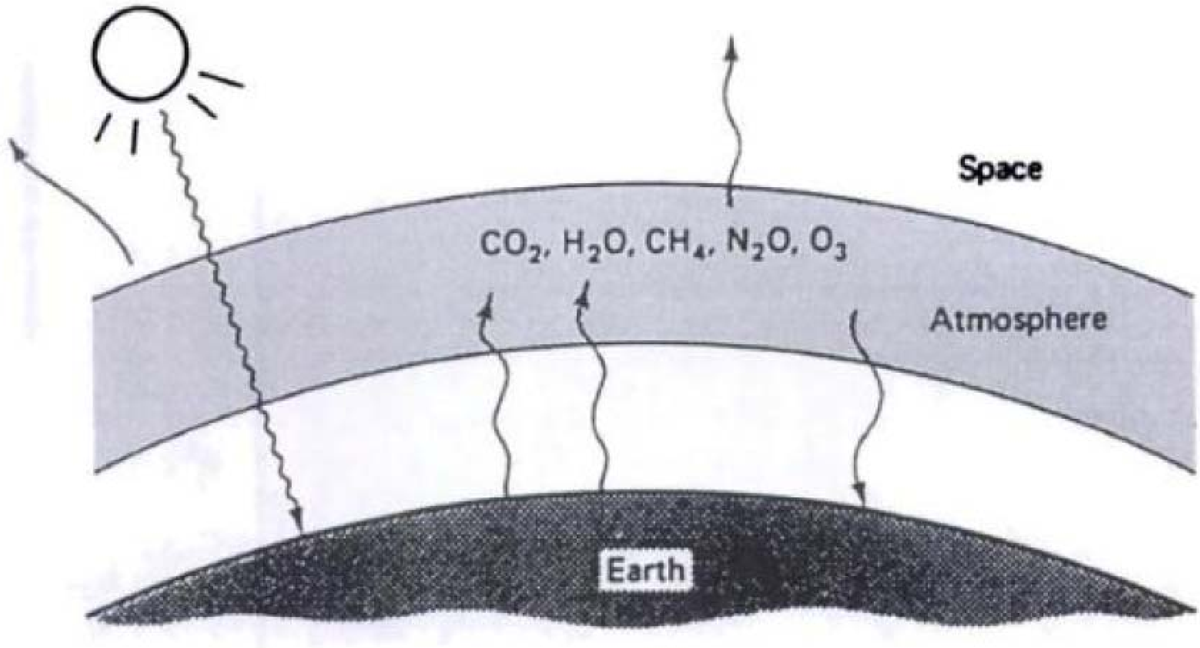

Figure 2-13: Greenhouse gases trap long-wavelength energy from the Earth's surface, heating the atmosphere, which, in turn, heats the Earth.

Adverse effects

- a rise in sea level between 3.5 and 34.6 in. (9-88cm) leading to more coastal erosion, flooding during storms and permanent inundation
- severe stress on many forests, wetlands, alpine regions, and other natural ecosystems
- greater threats to human health as mosquitoes and other disease-carrying insects and rodents spread diseases over larger geographical regions
- disruption of agriculture in some parts of the world due to increased temperature, water stress and sea-level rise in low-lying areas such as Bangladesh or the Mississippi River delta.
- The number of Category 4 and 5 hurricanes has almost doubled in the last 30 years.
- Heat waves will be more frequent and more intense.
- Droughts and wildfires will occur more often.
- The Arctic Ocean could be ice free in summer by 2050.
- More than a million species worldwide could be driven to extinction by 2050.

Loss of biological diversity

Human development and population growth has resulted in rapid extinction of a number of plant and animal species. This has led to concern about the ability of the Earth to sustain the biological diversity upon which all life depends. Biodiversity refers to the wide variations seen in plant and animal life on the planet. At least three types of diversity exist.

Genetic diversity - Variation between individuals of the same species

Genetic diversity - Variation between individuals of the same species

Species diversity - Variation within an ecosystem by the presence of different species

Ecosystem diversity - Variations within and among species in different ecological environments.

Many reasons exist to protect biological diversity. Moral, ethical, and aesthetic reasons are commonly cited to protect and preserve the beauty of the natural environment for present and future generations. There are a number of practical reasons to work to maintain biodiversity. These include:

- Genepool preservation - A broad genepool provides a source of plant and animal traits that may be introduced into valuable agricultural products
- Genepool diverstiy - Biodiversity preserves traits that may be needed to adapt to a changing environment or conditions
- Important products - Many important medicines are extracted from natural plants and , in addition, many plants have never been evaluated for commercial or medical benefits; retention of biodiversity ensures that these products will be available when found
- Ecosystem stability - Ecosystems depend on a variety of interdependent organisms to survive and thrive, and elimination of any one organism could threaten the survival of the entire ecosystem.

The most important cause of loss of biodiversity, though, is the physical alteration of the environment. These alterations can be placed into one of three categories.

1. Conversion of the natural environment to other uses (e.g., residential development).
2. Fragmentation of the ecosystem resulting in smaller ecosystems that are not themselves sustainable.
3. Simplification of an ecosystem by selective harvesting or creating conditions leading to dominance by a single species.

The goal of maintaining biodiversity is central to minimizing the impact of human activities and the concept of sustainable development. Achieving the goal requires knowledge of the processes operative in an ecosystem and recognition of the role that individual plant and animal species play in those processes. The importance of biodiversity to an environmental engineer is the need to recognize the interdependence of organisms within an ecosystem and the attempt to understand the broad, long-term impact of an engineering development. An environmental engineer may not lead or control the effort to maintain biodiversity, but he needs to ensure that he does not become overly focused on the goals of the particular project and not the broader environmental implication.

Disaster Management

Earthquakes, landslides, cyclones, floods, explosions, epidemics, nuclear accidents may be identified as disasters causing instantaneous damage on a large scale in the environment. They cannot be sometimes predicted but areas prone to each type of disaster can be identified on the basis of earlier records. A devastation causes the following:

(i) Human, animal and plant life or the entire ecosystem is lost.
(ii) Buildings and infrastructural facilities are severely damaged
(iii) Road, railway and other communication systems collapse completely.
(iv) Water supply and power systems fail.
(v) Crops and cattle feed get spoilt beyond use.
(vi) Cholera, plague and other epidemics spread.
(vii) Economic and social disturbance increases.

Rehabilitation is a very difficult task and requires a lot of money, effort and time to restore normalcy.

Preventive Measures

(i) Landslides can be reduced along the mountain slopes by providing suitable drainage measures and preventing deforestation.
(ii) Floods can be prevented by constructing suitable bunds and developing vegetation along the banks.
(iii) Special design procedures and construction practices can be care of impacts from cyclones or earthquakes.

Community shelters provide safe accommodation during disasters. Things to be ready in the event of disaster are as follows:

(i) Home guards for distribution of food and medicines
(ii) Fire, medical and ambulance services
(iii) Information centers to create public awareness

Measures needed are as follows:

(i) Rescue and relief operations
(ii) Restoration of power, water and communication systems
(iii) Supply of food, medicine and other basic needs
(iv) Maintenance of sanitation
(v) Safeguarding agricultural products, livestock and public properties