CHAPTER I

FUNDAMENTALS OF ENVIRONMENT

1.1. Life and the environment

The earth is our home. Here we have all the essential requirements of life for a happy and purposeful living through generations. In this beautiful planet we have got a unique, congenial environment that makes our existence possible. Here we have water to satisfy our thirst, air to breathe, fertile soils to produce food, enough natural resources, e.g. forests, wild-life, coal, oil, minerals, etc., to improve our standard of living. Moreover, here we have a congenial temperature and plenty of sunlight, source of all energies, to make our lives enjoyable.

The universe is vast and almost infinite; however, barring future possibilities, we are not so far aware of the presence of life anywhere in the universe except in our planet. Life, is the most unique and precious treasure of this planet. The creation, evolution and sustenance of life on this planet has been possible only because of its extraordinary environment. On the other hand, it is also an undeniable fact that this life will become extinct from the face of the earth if its constant, active and beneficial links with the environment are disrupted, or environment itself is fatally degraded.

1.1.1. Meaning of the term environment

Environment is a broad term. It encompasses all that surrounds us, both the natural world in which we live and all the things produced by people. Biologists use the term environment in a general way to describe the total living and non-living things which influence the lives of organisms present in a specific area. In present times, the man-made environment of ferro-concrete cities, huge industrial complexes, and the various wastes from these palces are playing an increasingly important role in changing the environment which affects the life of every individual species of plant and animal inhabiting the place.

1.1.2. Life is dependent on environment

The basic components of the environment are plants, animals, air, water, soil, temperature and light. Plants and animals are the biotic components, and air, water, soil (excluding organisms living in the soil), temperature and light are the abiotic components.

Life is totally dependent on the environment. If it is a green plant, it would require sunlight, water and carbon dioxide of the air to synthesize sugar in the green parts of the plant by a process called photosynthesis. It also requires oxygen of the air for respiration and minerals of the soil to synthesize proteins and other vital organic compounds. Many species of plants do require assistance from the insects and other animals for pollination of their flowers and dispersal of seeds.

If it is an animal, it would require obligatory assistance from the green plants. Directly or indirectly, all animals live at the expense of green plants. They could be regarded almost as parasites of plants. A community without green plants would not survive; a community without animals would. Animals also require oxygen from the air and plenty of water and minerals from the environment. Both plants and animals require congenial temperature to maintain their life-processes. They cannot tolerate too high or too low a temperature and the degree of tolerance varies from species to species. Hence, temperature is a very important component of the environment, which, to a great extent, determines the habitats of plants and animals.

The most crucial feature of these environmental components lies in the fact that their quality, quantity and relative proportion among themselves are not all constant and easily changeable by man-made as well as natural forces. And when such changes occur various insurmountable problems appear before the plants and animals including human beings. Many of them try to adapt themselves to those changes, some prefer to leave the place forever, some of them are simply destroyed and become extinct. The balance in nature is thereby disturbed.

1.1.3. Recognition of the importance of environment in ancient India

Since the birth of human civilization ancient people used to recognize and respect the beneficial roles of sun, soil, air, water, etc. They used to worship sun, water, air, soil and various species of plants and animals of their environment.

Ancient Indian philosophers used to hold that the entire universe including earth, plants, animals and human beings is composed of five essential elements, e.g., *Khiti*, *Op*, *Teja*, *Marut* and *Byom* (i.e., earth, water, energy (sun, fire), air and void (empty space of the universe). Bodies of plants, animals and human beings are created out of these five essential elements, and after death, their bodies are disintegrated and converted back to these elements.

The fundamentals of conservation ethics were brilliantly formulated in the *Isho-Upanishad* : "The whole universe together with its creatures belong to Nature. Let no one species encroach over the rights and privileges of other species. One can enjoy the bounties of nature by giving up greed." In other words, if nature is over-exploited because of our greed, we stand to lose all its benefits.

In the Buddhist era a mass awareness was created for conservation of nature and natural resources. Killing of animals was discouraged and all sorts of violence, animosity and warfare were condemned. Instead, love, respect and reasoning had been promoted in the search for eternal truth of nature.

The recognition of environment depicted in our ancient scriptures is in conformity with the outlook of the present-day world to save the nature and formulate an effective strategy for the conservation of nature and natural resources.

1.1.4. Philosophy in environmental study

Every discipline has its own philosophy that helps to understand its ultimate goal, and establish the link and relationship with other disciplines. We have divided our scientific knowledge into a number of disciplines and pursue them separately, this artificial classification has got its own merits and demerits, but in nature most of those disciplines are working together in an intricate network of interrelationship creating almost endless amazing products with which nature has been sustaining its existence. A holistic approach is therefore imperative to understand its significance and ultimate objective.

An apple falls from the tree : it is the action of law of gravity. Sir Isaac Newton discovered it and that was indeed a great discovery. At least fifty startling scientific discoveries from the same phenomenon unknown to the scientific world on that day could, however, be made from that apparently very simple observation. A few of them may be cited here, — formation of abscission cell-layer that causes the apple to drop (Plant Physiology); action of enzyme polygalacturonidases that makes the apple soft and edible (Biochemistry); synthesis of protiens in the apple during ripening (Biochemistry); production of esters emanating characteristic flavour of the apple (Organic Chemistry); dormancy of apple seed that checks its germination while confined inside the fruit (Plant Physiology); and the genetic code of the apple species which is hidden inside every cell (in the chromosomes) of the embryonic tissue, that on germination will produce only apple plant and not some other plant (Molecular Genetics).

Our purpose of telling the story of the fall of the apple is to show how numerous scientific principles of widely diverse nature, almost beyond our comprehension, work together in a closely coordinated manner for manifesting a single natural phenomenon. From the philosophical point of view one simple but crucial question may be asked : "for what prupose?"

If any one would spend some time under the apple tree he could observe that a number of birds and numerous insects attracted by the delicious flavour, colour and sumptuous food reserve of the fruit hurriedly show up there and devour it, but not the seeds, as the seed coat contains the deadly toxic hydrocyanic acid. These seeds, under favourable condition, would break their dormancy and initiate a new generation and the ultimate goal of the apple-fall would be accomplished.

It is, therefore, quite apparent that the ultimate purpose of the series of extremely complex physical, chemical and biological reactions behind this simple natural event is to perpetuate the existence of the apple species on the earth. It may be the ultimate natural goal of all life-forms including human beings. In order to attain this goal a certainty of congenial environment is imperative which, however, is increasingly becoming uncertain with time.

1.1.5. The genesis of environmental problems

Life is not new in this world. The earliest traces of life on earth have been found in rocks about 3.5 billion (350 crore) years old. They are microscopic, laminated structures similar to

those of today's marine bacteria. It is generally accepted that the first forms of life were some kind of bacteria. Such earliest forms of life have been evolved into millions of species and varieties of plants and animals and they are now stabilized on the earth through the development of a strategy of survival

Fig. 1.1. A fossil of a marine bacterium. The earliest trace of life has been found in the rock about 3.5 billion years old.

The whole universe including life and environment of the earth is governed by numerous fundamental scientific laws. These physical, chemical and biological laws and principles have not been created by the scientists, they were already there. By following an explicit methodology scientists have just discovered a small fraction of those from the bosom of nature. Without paying any heed to their intricate role in nature, these discoveries are largely being used for earning immediate benefits with little consideration of their harmful side effects or long-term hazardous consequences which create numerous unresolved problems in the society. We are often using science without having a proper scientific temperament which may be the cause for most of the problems of our environment. Some times individuals act in ways that promote their own short-term interests which more often conflicts directly or indirectly with long-term environmental interests.

Most of the environmental problems are, therefore, exclusively man-made. The major

problems of the environment which have now been created can be divided into five main categories : (i) Overpopulation, (ii) Pollution, (iii) Global environmental changes, (iv) Depletion of natural resources, (v) War and insurgency.

It is of utmost interest to recall how these crucial problems have been tackled in nature since long. Controlling the population of a species is one of the foremost principles of the strategy of survival. Most species of plants and animals possess an infinite capacity to multiply, but their populations are not increasing by leaps and bounds, a very significant fact that was observed by Charles Darwin about one and a half century ago. In fact, the population growth rate of many species of plants and animals is much higher than that of man. Bacteria can double their population just within 20 minutes. There are numerous natural constraints for controlling population effectively, none of the species in nature can maintain their population growth steadily for a long time.

Experts consider that it is not the human population size but its steady growth rate maintained since the last two centuries that poses a serious threat to the economic growth through rapid depletion of natural resources of the world. At present, the annual growth rate of population in India is about 2.1% (doubling time of population is 35 years), in Europe it is only 0.3%, and the world average is 0.7%. Even 1% annual growth of population, if it is maintained steadily for a long time, should be considered as abnormally high and cannot be balanced with the carrying capacity of world. In an essay on food and world population written in 1969, S. Brody[1] has given an interesting example : "let us assume that Adam and Eve set up housekeeping 5300 years ago, and that the population increased at 1 percent per year. In 5300 years, the population P, would number $P = 2e^{0.01 \times 5300} = 2.0 \times 10^{23}$ individuals, weighing (at 100 lb per person) 2.0×10^{25} lb, equal to the weight of the entire earth itself." This is a good arithmetical proof that the present steady growth rate of human population is not sustainable i.e., cannot be maintained indefinitely, it has to be checked by all means, otherwise harsh natural methods would operate to reduce it through mass starvation, disease, violence and premature death.

Plants and animals not only control their own number but also maintain a definite ratio between themselves. Animals are dependent on green plants; therefore in a particular environment, the number of green plants must be much higher than that of animals. Of the total amount of solar energy actually trapped and used by the green plants about 80% is consumed by the plants themselves, a lot of energy is consumed by microbes. Of 100 parts of trapped solar energy utilized by plants only a meagre fraction is available to animals.

Man himself is very selective in food habit, he consumes only a few plant species for his food, and he seldom consumes the entire plant but only the grains or fruits. So, in comparison with other herbivores, much more green area would be needed for his survival. But the most paradoxical situation is that every day the number of people on earth is increasing by 0.3 million which requires a corresponding daily increase of green mass many times higher than the

1Brody, S. 1969, Facts and fallacies of feeding the world population. In the book : The Subversive Science, Essays toward an Ecology of Man. Ed. Paul Shepard & Daniel McKinley. Houghton Mifflin Co. Boston, USA.

[The mass of the earth is equal to 1.318×10^{25} lb (5.98×10^{24} kg)—Editor.]

newly incorporated human mass, but in reality, the green area of the world is decreasing every day. It reflects the scenario of a losing battle.

The five groups of environmental problems, mentioned earlier, are interrelated, for example, to feed the growing population, the agricultural lands have been extended at the expense of forest lands. Natural habitats of many wild species of plants and animals are thereby destroyed affecting the biodiversity of a country. When natural predators and parasites are eliminated outbreaks of harmful insects and diseases become more common. For controlling them various kinds of toxic pesticides have been introduced which pollute the land as well. Chlorine containing pesticide residues remain intact in the soils for a long time. The run-off water from the agricultural land also pollute the water bodies like ponds and canals, rivers and even the oceans.

In nature, the pollution problem is largely managed by recycling process. All the organic excretory products and dead bodies of plants and animals are disintegrated by microbes to simpler compounds and are utilized again by plants. But in modern times, these waste products are being accumulated in such a huge quantity that their natural recycling is almost impossible within a short period. More-over, a large amount of toxic heavy metals, like chromium, cadmium, lead, copper, mercury, arsenic, etc., along with many non-biodegradable compounds, like plastic and other synthetic compounds present in the industrial wastes, makes the situation more complex and difficult. There are at least 70,000 different synthetic compounds present in the environment, and about 2,000 new synthetic compounds have been entering the environment every year. They are present in drugs, fertilizers, pesticides, food additives, dyes, paints, detergents, clothes, plastics, cosmetics, refrigerants, aerosols, cleansing fluids, building materials, etc. Many of them pollute the environment and create serious problems through their bizarre chemical actions. Chlorofluorocarbons (CFCs) are largely used as a refrigerants as well as various other purposes. They deplete the stratospheric ozone layer by stealing an atom of oxygen from the ozone molecule with the help of this chlorine atom, allowing free entry of harmful infrared rays of the sun into the lower atmosphere.

The air is polluted by toxic hydrogen sulphide (H_2S) gas generated from the garbages creating characteristic bad smell in the locality. The air is also polluted by the smoke from burning of fossil fuels (coal, petroleum, diesel, kerosene) as well as fuel-woods. This smoke contains sulphur dioxide, nitrogen oxides, carbon monoxide and coal soots which are hazardous to health, it also contains carbon dioxide which is not toxic at the existing low concentration and utilized by the green plants for photosynthesis, but its concentration is on the rise in the atmosphere creating global warming or greenhouse effect.

These coal, petroleum, diesel, kerosene, minerals and metals of the mines are our natural resources. Their total reserves are rapidly depleting with ever increasing exploitation without replenishment, so they are called nonrenewable resources. On the other hand, renewable natural resources like water, air,soils, plants and animals are also suffering from rapid degradation, their wholesome qualities and natural distributions have been altered by man.

In the history of mankind, such changes never happened before. Hence, they pose a serious threat to the viability of the environment.

Intra-specific war is very rare among animals except in human. Other species struggle to protect their territories, their own lives, lives of their siblings but seldom engage in mass-killings of their own species. The meaning of the 'struggle' and 'war' is not the same. Wars and insurgencies lead to the depletion of all kinds of natural resources, including valuable lives and economic stability of the country, by far more extreme degrees than any other man-made environmental disruption. But even in the absence of actual war, the cost of maintaining standing army and armaments is enormous and it becomes the principal cause of resource depletion.

Experts indicate that war is not an inherited or inborn tendency in man but a product of his culture. All evolutionary changes take place because the changes are of advantage in promoting the survival of the species. A drive towards killing members of the same species cannot be a part of the normal process of evolution because it is so obviously a disadvantage to the species.

On the other hand, if we follow the history of evolutionary course of life extending through 3.5 billion (350 crore) years we would find that its basic format has been evolved and is still operating on interdependence, mutual coordination and active cooperation. A design of eternal harmony has been achieved through numerous complex chemical, physical and biological reactions using all the biotic and abiotic components of the environment. If we look at the working principle of a microscopic plant or animal cell, we would find that each and every tiny component of the cell is working jointly in an amazing coordination utilizing abiotic components of its surroundings to achieve certain results which keep the cell alive. The body parts or organs of a plant or an animal, e.g. stem, root, leaf, or heart, stomach, kidney, brain, etc., composed of those tiny cells are also working following the same format, — by mutual help and coordination they perform their respective jobs, so they remain alive and sustain the whole organism. In an ecosystem also, all organisms — plants and animals including human beings, are to follow the same strategy of mutual help and coordination to sustain their individual as well as collective existence on this earth. Perhaps this is the basic truth which deserves far more importance and appreciation for our own survival. Present man (*Homo sapiens*) evolved about 0.1 million (one lakh) years ago and he did follow the same principle for about 99% of the time of his existence. If they had been engaged in intra-specific wars since their origin, most probably, the human speices would have been extinct by this time.

1.1.6. Objective, utility and compulsion of environmental studies

The major objective of the environmental studies as reflected from the earlier discussion is to perpetuate a sustainable environment on an infinite time scale so that human population can continue to exist for an indefinite period of time keeping natural relationship with other life-forms and enjoying sound health and high standard of living.

Environmental studies impart adequate knowledge about philosophy, genesis and con-

sequences of local and global environmental problems with necessary know-how for their abatement and control. It also helps the people to identify their own role in the environment and provides them with adequate knowledge to adjust themselves with the limitation of natural resources and conditions avoiding long-term disasters. It also kindles the survival instinct of the people and inspires them to launch or participate in various environmental protection programmes at the state, national and global level.

Environmental studies encompass a large number of disciplines. It relies on botany, zoology, physiology as well as geography, geology, geophysics and meteorology to describe the biological and physical nature of the environment we live in. It is related to philosophy, ethics, psychology, anthropology, demography, archaeology, economics and political science to know how people function, separately and in a group. And finally, it tries to fit these information into a format of ecology offering a total holistic knowledge about the environment, for sustaining life on earth on an infinite time scale.

In our society environmental problems are comparatively of recent origin and these have been generated in such a quick succession that we have yet to acquire adequate knowledge and develop a proper ethical approach to counter these problems effectively. The problems are not possible to be dealt with by scientists alone. Every individual of the country has a role to keep the environment clean, viable and flourishing. The locus of generation of most of the environmental problems is not the machine but it is in the mind of the people. It is the mind that takes all kinds of decision before putting them into practice. Hence, proper education and articulation of mind is primarily necessary for abatement of the problems at the very roots. All these considerations indicate the compulsion of the environmental studies for the sake of our survival.

1.2. Non-anthropogenic and anthropogenic changes in environment: natural and man-made disasters

1.2.1 Natural changes

The earth's environment is not constant, it is ever changing. The environment of the earth has been fluctuating since its creation and, no doubt, it will continue that way in future for an indefinite period of time. When life evolved there was no oxygen in the atmosphere, it was full of carbon dioxide and other gases including water vapour. The earliest life-form was anaerobic, i.e., it used to survive imbibing oxygen not from the air but from other chemical compounds. Such primitive climate changed very slowly, it took over a couple of billions of years to accumulate enough oxygen in the atmosphere which helped the evolution of aerobic organisms. This oxygen was generated from splitting of water molecule by photosynthetic process of green plants, hydrogen of the water molecule was utilized for synthesis of glucose releasing the oxygen into the atmosphere. Virtually, most of the oxygen in the atmosphere today has come from water through the photosynthetic activities of green plants. Such change is non-anthropogenic, i.e., not man-made but it altered the chemical composition of the air radically which triggered a

series of other changes in the environment. From this atmospheric oxygen ozone gas was generated which made possible the formation of the protective umbrella of ozone layer at the upper atmosphere called stratosphere. This ozone layer prevents much of the sun's ultraviolet radiation from reaching the earth's surface. This ultraviolet radiation damages living things. The earliest living organisms lived in the ocean, the depth of the ocean-water protected their lives from the harmful effect of ultraviolet radiation.The formation of ozone layer permitted these organisms to thrive on the land as well as in the ocean. This change of environment directly influenced the organic evolutionary processes, a large number of terrestrial and aquatic plant and animal species were evolved which enriched the biodiversity of all primitive continents.

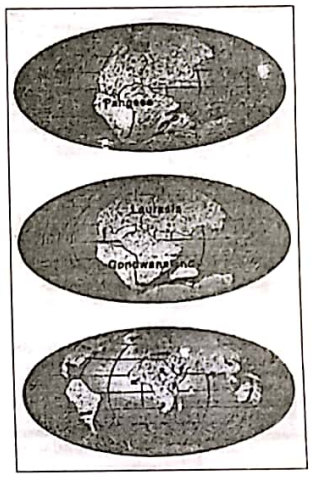


Fig. 1.2. Continental drifting. All the continents were once joined together forming a single mass called 'Pangaea' (top), at later period they drifted apart very slowly forming two major groups 'Laurasia' and 'Gondawanaland' (middle). Some 50 million years ago, the world's highest mountain the Himalayas were formed when the Indian plate collided with the Asian plate (bottom). Such changes will continue in future.

The most striking feature of those continents was that they were not stationary, they were slowly drifting apart. The entire outer shell of the earth is made up of a number of huge tectonic plates which float on the fluid core of the earth. German meteorologist Alfred Lothar

Wegener stated that all the continents were once joined together forming a single landmass, which he named 'Pangaea', the Greek word for 'all land', at later periods they drifted apart very slowly, the movement he called 'continental drift'. Further studies reveal that there are altogether seven major and twenty minor tectonic plates, their average thickness is about 100 km and the area of the largest one is about 100 million sq km.

The continents have drifted for at least 2500 million (250 crore) years, and continue to move at an annual rate of 20 to 75 mm. During the movement, part of a continent can split from the rest, in a process called rifting. Such a rift created the Atlantic Ocean, 175 million (17.5 crore) years ago. The Red Sea was formed in this way, as part of a rift that still goes on. Siberia, too, has an active rift system, which created Lake Baikal. When plates move away in one place, they converge in others. And when they collide, the impact can be catastrophic, crumpling mountain ranges, causing great earthquakes, opening up of volcanoes and ocean trenches. Some fifty million years ago, the world's highest mountain, our Himalayas, were formed when the Indian plate collided with the Asian. Once upon a time, the Sahara desert of Africa was situated near the South Pole, wherefrom it moved to the equatorial region. Certain rocks which are only found under the snow in polar region, have been discovered under the hot sand-bed of Sahara.

Such drifting of continents made profound changes both in abiotic and biotic components of the ancient environment. The process is still going on very slowly. Plants and animals had enough time to adapt themselves to such changed environment, those that could not, were simply replaced by newly evolved species suitable to thrive in the changed environment.

The earth's environment also witnessed drastic changes in average temperature of the earth surface creating the *Ice Ages*. The temperature appears to have fluctuated between two

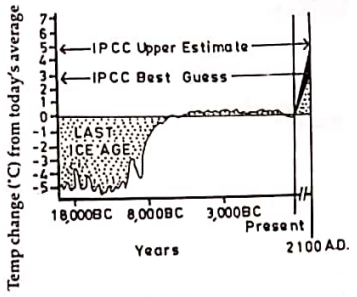


Fig. 1.3. Changes of global average temperature from 18,000 B.C. to 2100 A.D. A fall of only 4 to 5°C from today average brought about the ice age 20,000 years ago, hence one can imagine what drastic changes would occur when temperature will increase 3 to 5°C due to global warming. Note how temperature rose quickly around 8,000 B.C. as the world emerged from the last ice age. The average temperature rise predicted beyond 1990 by the IPCC (Intergovernmental Panel on Climatic Change) scientists is many times faster than theat past warming periods. The gray peak is the IPCC 'best guess' by 2100. The black peak is the upper range of the estimates from the IPCC models.

relatively stable states about 35 times during the earth's history, caused perhaps by the wobble (unequal rocking) of the earth on its axis and variations in the sun's activity. The peak of the last Ice Age was only about 20,000 years ago; human species observed it. A vast sheet of ice advanced south from North Pole, covering Canada, Greenland, Siberia, Scandinavia and most of Britain including the North Sea. When the ice retreated vast quantities of cold water flooded into the Atlantic, disrupting the ocean currents. Probably, we are still in the spell of the last Ice Age as the ice has not yet retreated from the polar regions. Gigantic woolly mammoth, sabre toothed tiger, certain species of sloth and some other species of plants and animals disappeared, but at the same time many new species evolved, so biodiversity was not permanently damaged.

1.2.1.1. Succession

Environment also may be changed by a natural process called ***succession***. It occurs when the land is initially lifeless, may be it is a new island rising from the sea, or a solid bed of rock created from the volcanic eruption. The environment may be hot and dry. But after some time, this area will be invaded successively by different communities of plants and animals. The area will be slowly transformed into a woodland and ultimately a dense climax forest may be developed full of microbes, insects, birds and wild animals. In course of time, a once hot, lifeless, dry environment may be changed into a moist, cool forested land. The formation of vegetation from initially lifeless substratum is called ***primary succession*** and those from denuded land with little or no vegetation left is called ***secondary succession***.

The first group of invaders that usually colonize on dry rocks are the lichens. Lichens are a special group of plants, their body is made up of fungi and algae living symbiotically, they do not require soil, they collect water and minerals from the atmosphere. The first layer of soil is built up with their colonies and air-borne dust particles deposited on them on which other groups of plants like mosses, ferns and grasses could grow. Woody plants and big trees come subsequently for developing long-lasting climax vegetation with a few dominant species.

Similarly, stagnant water bodies also slowly transform into dry lands and ultimately give rise to climax forests. Such natural transformation of aquatic environment into a forest-land is called ***hydrosere***, and that from a dry environment is ***xerosere***.

1.1.2. Natural disasters

Enormous changes of environment also have been caused by the natural disasters, e.g., ***cyclone, typhoon, hurricane, tornado, earthquake, volcanic eruption***, etc. within a very short time and more often without serving any notice, the environment is totally devastated, beyond any comprehension, inflicting huge damages on lives and properties.

Cyclone, typhoon and hurricane are synonyms for the same weather phenomenon. Storms that arise in the Indian Ocean and cause extensive flooding and damage in the Indian subcontinent including Sri Lanka and Myanmar are called cyclones. Those in the Pacific Ocean that threaten southeast Asia are typhoons, and those in the North Atlantic Ocean that batter the Caribbean and southeastern USA are hurricanes.

Over very warm areas of ocean, warm, moist air starts rising so fast that it creates a

region of intense low pressure beneath it, pulling more warm air in from the surroundings. The phenomenon develops into a vast spiraling weather system — a cyclone. The spirals twist anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. They tend to drift at a very high speed, in case of super cyclone they can reach the speed of over 250 km/h, and the whole weather system may be 800 km across. Dense cumulonimbus clouds release torrential rain and the winds whip up high waves on the surface of the ocean beneath the cyclone. The intense low pressure can temporarily raise the sea-level by as high as 8m (25 ft) to what is known as storm surge, which can cause devastating floods along the coastal region. In the middle region of the cyclonic spiral known as the ***eye*** — the air can be clear and deceptively still. Cyclonic weather can continue for several days. Instead of low pressure, intense high pressure also can give rise to a cyclonic storm; it is called ***anti-cyclone***.

Dense afforestation on the coastal regions can reduce the impact of cyclone on the urban areas to a significant degree. The presence of ***mangroves of Sundarbans*** at the south of West Bengal thus lends some help in this way bearing the brunt of the impact themselves. Correct weather-forecast is also helpful for partial reduction of cyclonic damages.

Tornadoes are also caused by rising spiral of air but they are on a smaller scale affecting a smaller area with much shorter duration than those of cyclones. But they can be just as devastating as cyclones, up-rooting big trees, tearing off roofs, lifting cattle, cars, people and sucking up almost any thing on their path. Timely forecast can stop much of the damages they do, but the time interval between the alarm and their appearance is so short that often it becomes useless, more over, their exact path of movement is rather difficult to ascertain. Tornadoes are more common in certain parts of the world, e.g., Mexico, southern states of USA, etc.

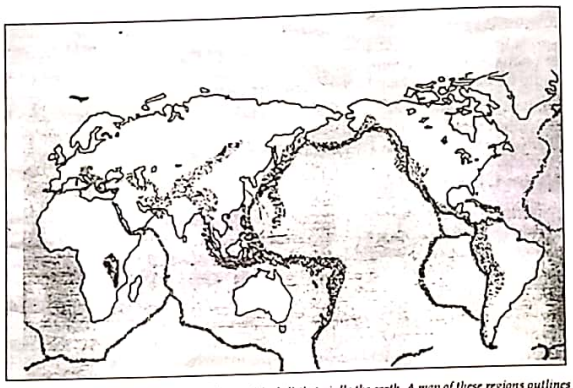


Fig. 1.4. Most earthquakes occur in clearly defined zones (shaded) that girdle the earth. A map of these regions outlines the major tectonic plates of the earth's crust which more and often collide.

Frequency of earthquake is very high, almost unbelievable, the figure is approximately one hundred per hour (100/h); every hour seismologists may record 100 earthquakes. But most of them are of low magnitudes and 90% of them are restricted to earthquake-prone regions that almost encircles the Pacific Ocean, and most of the others in a band stretching from Spain, Turkey and the Northern Mediterranean, through the Himalayas and Indonesia. The two zones meet near New Guinea. The earth's outer layer is broken into seven huge tectonic plates and squeezed among them are some twenty smaller ones. The plates move independently over the ***asthenosphere***, a partially molten mass of the upper mantle. The plates often converge and collide, frequently one plate slides beneath another releasing tremendous amount of energy in the form of ***seismic waves*** that run through the earth shaking the ground often with a tremendous destructive force.

American seismologist Charles Richter devised the ***Richter Scale*** for measuring the amplitude of seismic waves on a logarithmic scale, thus magnitude of 7 Richter is 10 times bigger than that of 6 Richter. The magnitude of earthquake of 1 Richter could be detected only by seismograph, magnitude 2 is about the smallest that humans can detect. In 1999, the earthquake of Izmit, Turkey that killed 15,000 people, was 6.7 on the Richter scale. The largest known earthquake that struck Quito, Ecuador in South America, was 8.9 on the Richter scale. It generated as much force as 125 million tonnes of TNT, which is equivalent to the explosive power of 10,000 Hiroshima type atomic bombs.

It is not possible to perdict earthquake, but various precautionary measures have usually been arranged in earthquake prone regions. In Japan wooden houses were constructed; at present, newer architectural designs are being used to resist the tremor of earthquakes.

Volcanoes sometimes explode with devastating power, erupting molten lava, silicate dust and sulphuric acid into the atmosphere. When Mt. Pinatubo, in the Philippines, erupted in 1991, it increased the dust content of the atmosphere to at least 60 times more than the usual amount and warmed the upper atmosphere by 3°C for several months. Today, there are more than 600 active volcanoes and numerous dormant and dead ones mostly located along the boundaries between tectonic plates that make up the earth's shell. Around the Pacific Ocean, volcanoes are situated forming a ring called the ***ring of fire***. In the past,great geological changes were induced by volcanic eruptions. Hawaiian islands came into existence from the molten lava. Sixty-five million years ago the landmass of western India was formed from the basalt flow of volcanic eruption. No one can prevent volcanic eruption, but some times prediction can be made from the sound of tremors and changes of quantity, chemical nature and temperature of the gases released from the dormant volcanoes, that helps mass migration.

1.2.3. Anthropogenic changes in environment

No species on earth has made such a radical and deleterious change of the environment

as that made by *Homo sapiens*. These changes even could be seen from the space : city lights and gas flares by night, and unearthly straight lines of irrigation canals, big dams like 'Three Gorges' in China, vast agricultural lands by day.

The basic components of the environment have been changed. The earth's atmosphere is now changing more rapidly than any time in the past. In the last 150 years there has been a 25 percent increase in carbon dioxide and 100 percent increase in methane in the atmosphere, largely due to burning of fuel woods, fossil fuels, expansion of agriculture and deforestation. Methane gas is generated by the methanogenic bacteria through decomposition of farm-manure. Expansion of farming increases the production of methane. Destruction of forest-lands destroys the sink for elimination of carbon dioxide, these two are greenhouse gases. Over the last 100 years, the world has warmed up by an average of 0.5°C, as these greenhouse gases trap the solar heat within the atmosphere. Scientists predict a continued warming of 0.2°C a decade. Quality of the air also has been changed by the presence of numerous newly synthesized toxic chemical compounds either in gaseous forms or as suspended particulate matters (SPM), e.g., chloroflurocarbons (CFCs), halone (these two gases are depleting the ozone layer in the stratosphere), DDT, PCB, aldrin, lindane, asbestos fibres and numerous other compounds containing toxic heavy metals. These are creating various insurmountable problems for all life-forms.

In the past 500 years, especially the last 100 years, the destruction of forests for expansion of agriculture and roads, towns, factories has greatly increased. This development has destroyed the habitats that many plants and animals need to survive. Tropical rain forests cover only about 7 percent of the earth's surface, yet they house about three quarters of all species. Today, these forests are being destroyed at an alarming rate. The depletion rate of forested area of the world is now about 2 percent per year which indicates that after 50 years, perhaps there would be no forests left except reserve forests. India had forests cover of 80 percent around 3000 B.C. which is now reduced to about 21 percent. To maintain the ecological balance at healthy constant level at least 33 percent forest cover (one-third of the total land area) is essential.

Progressive deterioration of environment has led to the extinction of numerous species of plants and animals all over the world. Most of these species are becoming extinct without evolving their more adaptive forms. Fossil records indicate that in the past, the average rate of formation of new species through evolution has been slightly greater than the rate of extinction. Hence, the number of species on the earth has gradually increased over time. But today, the impact due to man-made changes of environment is so abrupt and intense that species are becoming extinct without any replacement, thus an irreversible damage is being inflicted to the living resources of the earth, its biodiversity is definitely on the decline.

Qualities of water and soils also have been altered due to human activities of varied nature. Farming practices result in the release of nitrates and phosphates from fertilizers and animal wastes into ponds, lakes and rivers, adding to sewage already released into rivers and seas causing blooms (excessive growth) of algae which subsequently deplete the oxygen of water (eutrophication) causing harmful effect on aquatic life with rising deterioration of their

environment. Millions of tonnes of top-soils are lost from crop fields each year eroded by wind and water. Irrigation is lowering the ground-water table and creating serious crisis in the net usable water reserve of the world.

Mining and industries release huge amount of synthetic products and waste matters that pollute the soils, water and air. Toxic as well as non-biodegradable compounds like insecticides, herbicides, drugs, plastics, nylons, chemicals containing mercury, lead, cadmium, chromium, copper, zinc, arsenic and radio-active nuclear wastes are the major culprits. They have reached everywhere including oceans and most of them get entry into the body of all organisms through the food chain seriously posing the problem of survival.

Man most probably evolved 100,000 years ago. He started farming about 10,000 years ago, the impact of which initiated the changes of his environment. But almost all the changes, described here, have been developed during the span of last 200 years, when man gained sufficient knowledge to control epidemics, premature death, infant mortality and acquired adequate technology to exploit natural resources. In the past the earth displayed a remarkable resilience, globally if not locally; today, an exploding population that demands ever increasing affluence may be pushing the man to dig out and spend up earth's resources to its last limit without considering ultimate consequences.

1.2.4. Man-made disasters

Man-made environmental catastrophies include wars, explosions, accidental release of poisonous chemicals or radioactive materials etc. At the same time, very slow and subtle man-made changes in the environment also bring about disasters in the long run. Burning of fossil fuels and deforestation result in global warming or greenhouse effect. Use of chloroflurocarbons and release of oxides of nitrogen gas by supersonic transport would cause ozone hole by depletion of ozone layer. Day-to-day activities of the people of the world perhaps are responsible for such long-term consequences. These are global problems which require international cooperation for abatement.

There are many examples of man-made disasters; only two examples, both of which became major environmental issues and drew world attention to the perils of environmental degradation are cited here.

1.2.4.1. Bhopal gas disaster

On December 3, 1984, in Bhopal, India, world's most disastrous single instance of gas pollution accident occurred when about 36 tonnes of toxic methyl isocyanate (MIC) escaped in a cloud of mist and vapour from a large storage tank belonging to the American multinational corporation, Union Carbide, which killed about 2,500 people, permanently disabled 17,000 and injured 200,000 people. The toxic gas is used to produce a common pesticide sevin. The need for sevin comes from increased agricultural production to feed the growing population.

The human errors, negligence and mechanical faults which are found related to the accident are as follows : (a) The plant was located too close to a major centre of population. (b) Union Carbide stored very large quantity of methyl isocyanate (MIC). (c) The accident started when a large amount of water was introduced in the MIC tank, how it was possible not yet known. (d) Safety mechanism did not work. The man on duty tried to turn on the scrubber to check the escape of poisonous gas but neglected to activate the circulation pump. The flare could not be used because it had been removed for maintenance work. (e) Medical aid was unavailable during the accident. (f) People had not the faintest idea what they should do during such a crisis.

Many such accidents, as well as the magnitude of disasters, can be controlled if proper precautionary measures are taken before hand.

1.2.4.2. Chernobyl nuclear plant disaster

World's most disastrous nuclear plant accident occurred on April 28, 1986 at Chernobyl in the erstwhile Soviet Union. Two subsequent gas explosions in a graphite-controlled, water-cooled reactor at the nuclear plant blew off the roof of the power house building and set the graphite on fire. The accident occurred when the engineers were performing an unauthorized safety experiment by turning off most of the reactor's automatic safety system. Fire broke out during the explosion, 31 people died due to direct exposure of radiation. About 100,000 people who lived near the nuclear plant had to migrate elsewhere. Radioactive particles carried down by the air current scattered over many hundred kilometres round the nuclear plant. Air, water and soils were highly polluted with nuclear wastes. These entered into the food chain. In the following year, a large number of cattle gave birth to deformed calves, such phenomenon continued for several years. Medical experts estimate that near about 100,000 people will die of cancer over the next 70 years caused by the radiation exposure from Chernobyl.

Further investigation revealed that the design of the nuclear plant was faulty. The accident was, however, caused largely by operator's errors. Plant design can be rectified, even it can be improved, but total elimination of human error is almost impossible to achieve.

1.2.5. Land use patterns : agriculture, housing, urbanization, environment *vis-a-vis* economic development : human concern about environment.

The time of origin of our own species *Homo sapiens* cannot be pinpointed very precisely. Most possibly humans appeared about 100,000 years ago evolved from *Homo erectus*. In the beginning they were hunter-gatherers, people who obtained food by collecting plants and killing animals including fishes and oysters. But their main source of food was plant materials, e.g., fruits, nuts, roots, seeds, berries, leaves, young buds, inflorescence, etc. Most early hunter-gatherers were nomadic moving from place to place in groups according to availability of food. For about 90,000 years they did follow the same lifestyle, i.e., 90% of the time of human history man was that of the hunter-gatherer.

Most probably, 10 to 12 thousand years ago humans slowly learnt how to grow plants and domesticate animals and also discovered herbal medicines and other natural resources for betterment of health and housekeeping. Primitive type of cultivation perhaps originated simultaneously at several places in the world. As compared to hunter-gatherers, ancient farmers had to lend much longer time and harder labour for procuring food, they also had to face drought, flood, insect-pests and other natural calamities, yet agriculture gained popularity in primitive societies because it was possible to obtain much more food by farming than by hunting and gathering. Manual labour of every one was not compulsory, a small number of people could produce sufficient food for a large group, others were freed to become potters, painters, builders, teachers, etc. and a division of labour grew up within the group. Value of land and properties gained recognition. People used to settle in villages and largely became dependent on farming and landed properties.

Development of agriculture has been considered as a great revolution in human history. However, the genesis of most of the environmental problems can be traced back to agricultural practices, for examples : depletion of virgin forests with destruction of species habitats, extinction of large number of plants and animals, reduction of soil fertility due to increased soil erosion, pollution of air, water and soils, acceleration of human population, etc. Our objective, however, is not to discredit agriculture but to find out a sustainable system for maintaining the sound and healthy growth of human society.

Demographers have concluded that the primitive cultures experienced very low growth rate. Population of hunters and gatherers was stable over a long period of time. As agriculture became increasingly efficient, people used to get more food, more leisure and women began to bear more children, and human populaton started to increase. The population in between 10,000 BC and 100 AD was less than a billion and it was largely a result of the increasing birth rate that coincided with the progress in agriculture. But even during this period the human population did not increase steadily. Periodic decline of population occurred due to the recurrence of famine, epidemic disease, natural disaster, human warfare, etc. Hence, in the ancient period, the human population did follow a wavy pattern of growth curve comparable to that of wild plants and animals in nature.

With the growth of population and advancement of human culture and lifestyle, towns and cities came into existence. These human settlements were mostly built up along the bank of rivers for easy access to water and transport facilities. Along the bank of the rivers, Tigris and Euphrates, the first cities arose about 6000 years ago. In India along the bank of Ganga ancient cities Varanasi, Haridwar, Pataliputra (Patna), Nabadwip (Nadia), etc., were developed. But urban population was thin, most people lived in villages. Even in Europe, in 1800 AD only 2.2% of population lived in cities and no European city had 1 million inhabitants.

The basic difference in environment between the city and outside lies in the fact that the urban environment is not viable or in other words not self-sustainable. Urban people are totally dependent on outside natural environment for their food, clothing, building material, coal, oil, etc. If the demand for those life-supporting materials becomes too high and exceeds the bearing

capacity (production potential) of the surrounding natural environment the crisis for survival appears in both the places.

During the span of last two hundred years a spectacular change in the urban environment occurred. With the discovery of scientific principles through proper observation and experimentation, with the development of newer technologies, the exploitations of natural resources, e.g., fossil fuels such as coal, petroleum, and natural gas and various metals from the mines increased thousand-folds. Mass collection of raw materials were made from different areas even from remote parts of the world. Cities became the nerve centres for manufacturing and trading of numerous finished products. A large number of people moved to the cities to find good wages, better lifestyle, better medical and educational facilities and urban regions became centres for art, culture and social activities of all kinds. In 1900, only 12 cities of the world had populations of more than 1 million, but in 1985, a total of 230 cities were there with a million or more inhabitants. About 40% of inhabitants of the world are now living in urban areas. These changes have been brought about by the Industrial Revolution which was initiated in Europe, more precisely in England in the 18th century.

1.2.5.1. Industrial revolution

The name was first given by Friedrich Engels in 1844, to describe the radical changes that took place in England during 1760-1840 to transform an agricultural country into a predominantly industrial one. It started with the introduction of mechanization in textile industry with subsequent major advancement in mining, transport and ship-building and industrial organization. It was based on Britain's rich mineral resources, particularly coal and iron ore. James Watt, a Scottish engineer in 1785 made important improvements to Newcomen's steam-engine by inventing a separate condenser with the application of Black's discoveries on latent heat. With the use of steam-engine as power, industries proliferated and the great industrial (as well as highly polluted) cities of Manchester, Newcastle, Birmingham and Glasgow developed. Britain became supreme in constructional ironwork. All over the world railways, canals, bridges and ships were built and great advances were made on practical application of scientific principles. Aided by colonial exploitation Britain became the most prosperous country in the world. The new industrial capitalists began to replace the country's old land-lords as the ruling class. However, the massive accumulation of wealth at one pole of the society was matched at the other by poverty and misery, — child labour, long working hours, low wages, and slums with highly polluted environment, which were the salient negative features of the industrial revolution. It, however, produced related changes in all fields of social life — in politics, science, religion, art, literature and ethics.

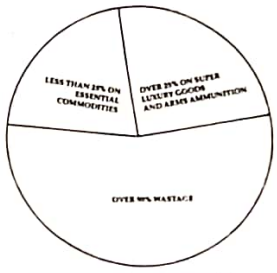
1.2.5.2. Environment *vis-a-vis* economic development

Economic development describes changes aimed at improving standard of living of general people of the country, increasing wealth, eradication of poverty, hunger, famine, and

spreading of culture and education and augmenting peace and stability of the country which is imperative to all countries and obligatory to a developing country like India. On the other hand, sustainable development, essential for a viable environment, describes changes that do not deplete natural resources and such condition is imperative if the above mentioned developmental activities are to continue for an indefinite period of time. Physical laws indicate that we cannot go on depleting natural resources forever. It is basically a self-destroying process reducing the carrying capacity of the earth towards a catastrophe.

The industrial revolution initiated in 18th century was extended to all other countries in Europe, USA, Canada and Japan, which are now called developed countries. In fact, intense industrialization of those countries was largely responsible for their economic prosperity. During the peirod of rapid economic progress they paid little attention to the environment and numerous problems related to environment were allowed to grow up.

As early as 16th century, during the period of ***Renaissance***, when exploitation of natural resources was initiated, our knowledge in ecological science was almost nil and we took it for granted that the earth's resources were unlimited and could be consumed for ever. In the later period, contrary facts were placed before the policy makers, but they did not pay any heed to it. Only during the latter half of the last century, more precisely, after the United Nations Stockholm Conference on Environment in 1972, people who matters just started talking on ***'sustainable development'***. But meanwhile, irreversible damages had been inflicted on plants, animals, soils, air and water — all life-supporting resources of this planet.



CONSUMPTION OF NATURAL RESOURCES

Fig. 1.5. The total amount of natural resources we use (e.g., water, fuel, minerals, etc.), only less than one fourth of them is utilized on essential commodities, e.g., food, clothing, housing, medicine, transport, education, sports and cultural activities. Over half of them is simply wasted due to basically inadequate and faulty processes of utilization. Over quarter of them is spent on commodities which are not essential and some of them are even against public health, these are superluxury goods, arms and ammunition, drugs and narcotics etc.

In a true sense, the term 'development' means, wholesome, perpetual development without entailing future complications. But at the same time, we have to realize that if we are going to have sustainable development, we cannot leave the environment totally pristine, there will be some obvious change, some significant impact will be made on the environment. But there is an ample scope to make those changes bearable, even favourable to the life-supporting system of the environment. Now-a-days, ***Environmental Impact Assesment*** has been made compulsory for starting a developmental project. If environmental laws and regulations are properly enforced developmental work can go on with minimum injury to the environment. Lack of ethics and knowledge would also stand against the developmental work. A huge wastage of natural resources can be saved with a sizable dividend if we take some precautions regarding their misuse and abuse. It is a very significant fact that of the total amount of natural resources (like water, energy, minerals, metals, etc.) we use per year only less than one-fourth is being utilized on essential commodities, e.g., food, clothing, housing, medicine, health, transport, education, sports and culutral activities. Over half of the valuable resources are simply wasted due to basically inadequate and faulty methods of utilization producing serious environmental problems. The most efficient diesel engine can convert only 40 percent of the diesel into energy, remaining 60 percent is just wasted creating air pollution. Only 20 percent of irrigation water is utilized by the crop plants, the rest is wasted during transport creating serious water crisis and incurring huge expenditure on construction of more dams. Only 10-15 percent of costly fertilizers is used by crops, the rest is wasted generating algal bloom in water bodies. Less than one percent of solar energy is used jointly by man and green plants, problems of food and fuel would have been solved if only one percent more could be used.

Nearly one-fourth of natural resources is spent on commodities which are not essential and some of them are even against the public health, these are super luxury goods, arms and ammunition, drugs and narcotics, etc. Military spending in the past 25 years absorbed more than the total increase of global productivity. Between 1960 and 1985, the world-wide economic output per person grew by 62%, but military outlay grew by 146% (more than double and amounted to nearly $ 14 trillion). The money obviously comes from depleting natural resources, a cut in our standard of living and from enormous increase in national debts. During formulation of development plan priority should therefore be given to save natural resources from wastage, misuse and over-exploitation.

1.3. Environmental hazards and risks

The earth's environment touches every one. Every human activity, small or large, lighting a match stick or igniting a blast furnace, creates some kind of distrubance of change in the surrounding environment. If such change is of a very high magnitude some time disastrous result may ensue. The lighting of a match stick in the vicinity of an inflammable object may bring about a fire accident, hence there is 'risk factor' when any one deals with inflammable objects, but such a risk factor is almost negligible when one lights a lamp in the house. On the other hand, dealing with blast furnace which contains molten iron at 1000°C is of course a very

risky and hazardous job, a slight fault may cause irreversible damage, hence its risk factor is enormous. In the commercial field lists of hazardous chemicals, hazardous machineries, hazardous occupations are available, similarly, lists of eco-friendly chemicals, eco-friendly chemical processes, which apparently do not produce any problem in the long run, can be obtained. Earlier, we have discussed the Bhopal gas disaster and Chernobyl nuclear plant disaster, in both the cases the machineries and occupations were very risky and hazardous. But it was revealed, after the accidents, that in every turning point some gross mistake, negligence and wrong decisions (not befitting the inherent risk factor) were taken. Prior calcualtion of the risk factor of an environment-related operation is very essential, it can avert many a disaster of far-reaching consequences. In 1955, at Minamata Bay in Japan a plastic paint factory started releasing mercury containing effluents into the water of Minamata Bay, the whole food-chain of the aquatic ecosystem of the region was polluted, quite a large number of local fishermen died due to Minamata disease, a special name given to mercury poisoning. After losing a long legal battle, the factory owner had to pay a huge sum as a compensation. Such loss of lives and wealth could easily be averted if prior risk assessments were performed and implementation of recommendations ensured.

Economists often point out that it is worth spending vast sums to prevent environmental degradation. Cost-benefit analysis shows that a huge loss is incurred on such degradation. If we assess the cost of air pollution damages, we have to count the costs to human health, to plants and animals, to damages to properties. In West Germany as in many other countries, a large number of trees die of air pollution, the value of trees killed worldwide must be enormous. Value of a tree should be calculated not only on the basis of dead weight and quality of the timber but also on the other benefits derived from a tree, i.e., amount of organic matters it contributes, elimination of carbon dioxide and enrichment of air with oxygen, recycling of water, etc. As we discover more and more indirect costs of pollution, we find that pollution costs us enormous sums. Economists are convinced that much greater investment in the control of environmental pollution would pay larger dividends.

Recurrence of very slow and subtle changes in environment caused by us also initiate profound changes and may produce global problems, — burning of fossil fuels and use of CFCs are the best examples. In these cases mistakes are committed not by a few people but by a large mass and the whole world has to suffer. Sometimes, such mistakes committed by a few countries create an unresolved problem for all. Each and every inhabitant of the world, therefore, has to think of the risk factors when he deals with the environment. He has to play a precise role in keeping his own environment clean and viable, he is to act locally while thinking globally. A full scale operation of the international action programme with active participation of all the nations is essential for achieving a tangible result, there is no easy and quick solution in this matter.