ENVIRONMENT
AND ECOLOGY

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ISBN (13) : 978-81-224-2714-1

PUBLISHING FOR ONE WORLD

NEW AGE INTERNATIONAL (P) LIMITED,
PUBLISHERS 4835/24, Ansari Road, Daryaganj, New Delhi - 110002
Visit us at **www.newagepublishers.com**

Preface

The Hon'ble Supreme Court of India passed an order in 1991 for the introduction of a common course on Environment in colleges and universities at undergraduate levels for all disciplines. But the order was not properly implemented. Displeased with non-compliance of this order, the Supreme Court again ordered in 2003 for the introduction of Environment as a compulsory subject at higher secondary level in schools and undergraduate levels in colleges, and even issued warning of legal action, if necessary.

The introduction of the common course on environment and ecology under compulsion obviously brought confusion in the academic communities due to the lack of suitable textbooks in the subject and lack of orientation about the subject among the teachers and students of various disciplines. The authors, with their long experience in environmental teaching and research, took up the challenge and brought out a standard textbook.

The book is written as per UPTU syllabus and the various units associated with it have been presented in a simple and lucid style to suit the requirements of the course.

Glossary of key terms is given at the end for easy understanding of the subject while feedback exercises are intended to reinforce the knowledge of the students.

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Unit-I

A. Environment

1.1 DEFINITION

What is Environment and why do we now notice so much interest in Environmental Studies in recent years? *Environment is the sum total of all conditions and influences that affect the development and life of all* *organisms on earth.* The living organisms vary from the lowest micro-organisms such as bacteria, virus, fungus, etc. to the highest, including man. Each organism has its own environment (physical and biological).

The word "environment" originates from "environ" which means things that surround. As per definition of the Environment Protection Act, environment includes all the physical and biological surroundings and their interactions.

The study of environment or rather environmental studies is a multi-disciplinary subject which needs knowledge interest from physical sciences (physics, chemistry, mathematics), biological sciences (botany, zoology, microbiology, biochemistry), social sciences, economics, sociology, education, geography) etc. Obviously, environmental studies has a broad base, which requires integrated approach for dealing with the various aspects.

1.2 ECOLOGY ECOLOGY

The word "Ecology" was coined by a German biologist in 1869 and is derived from the Greek word, "Oikos" meaning "House". Ecology is the branch of science that deals with the study of interactions between living organisms and their physical environment. Both are closely inter-related and they have continuous interaction so that any change in the environment has an effect on the living organisms and vice-versa. Any unit of biosystem that includes all the organisms which function together (biotic community) in a given area where they interact with the physical environment is known as ecosystem.

The ecosystem is the functional unit in ecology as it consists of both the biotic community (living organisms) and the abiotic environment. The latter has close interaction essential for maintenance of life processes. The interaction is conducted by energy flow (solar energy) in the system and cycling of materials (natural cycles).

From the biological point of view, the ecosystem has the following constituents:

(i) Inorganic substances (carbon, nitrogen, carbon dioxide, water, etc.) involved in natural cycles. (ii) Organic compounds (proteins, carbohydrates, humic substances) etc.

(iii) Air, water and substrate environment including the climatic regime and other physical factors.

(iv) Producers, autotrophic (i.e., self-sustaining organisms) green plants that can manufacture food from simple inorganic substances.

(v) Heterotrophic (i.e., that depend on others for nourishment) organisms, mainly bacteria, fungi and animals which live on other organisms or particulate organic matter.

(vi) Micro-consumers, decomposers, mainly bacteria, fungi which obtain their energy by breaking down dead tissues or by absorbing dissolved organic matter, extracted from plants or other organisms. The decomposers release

inorganic nutrients that are utilised by producers. They also supply food for macro-consumers or heterotrophic organisms. Bacteria, fungi (and animals) often excrete hormone-like substances that inhibit or stimulate other biotic components of the ecosystem.

Typical profiles of a grassland ecosystem and of a pond ecosystem are shown in Fig. 1.1.

Sun

Autotrophic material Stratum

Sediment

Soil

Heterotrophic Stratum

Parent geological material

Parent geological

Water

Grassland Ecosystem Aquatic Ecosystem **Fig. 1.1:**

Grassland and pond ecosystems

The common features of all ecosystems—terrestrial, freshwater, marine and agricultural—are the interactions between the autotrophic and the heterotrophic components. The major autotrophic metabolism occurs in the upper “green belt” stratum where solar energy is available while the intense heterotrophic metabolism occurs in the lower “brown belt” where organic matter accumulates in soils and sediments.

1.2.1 Biomes

The Biome is a very large land community unit where the plant species are more or less uniform. It provides a basis for natural ecological classification. The main biomes of the world are the Tundra; Temperate, Coniferous and Deciduous forests, Temperate grassland; Tropical Savanna; Desert and Tropical Rain Forests.

The *Tundra Biome* is in the polar region (north of latitude 60° North)—it is characterised by absence of trees, dwarf plants and an upper ground surface which is wet, spongy and rough.

Temperate Coniferous Forest Biome Coniferous forests occur in cold regions with high rainfall, long winters and short summers.

Temperate Deciduous Forest Biome These are high altitude regions about 3000–4000 metres above sea level as in the Himalayas. Here pines, fir and juniper trees are found.

Temperate Grassland Biome This type of grassland occurs where there is about 25 to 75 cm of rainfall per year. Such grasslands are found as tall grass prairies, short grass prairies of North America and also in South America, steppes of Southern Russia and Asia.

Tropical Savanna Biome These are tropical grasslands with scattered drought-resistant trees. These are found in eastern Africa, Australia and South America.

Desert Biome These are found in very dry environment where temperature changes from very hot to very cold.
Tropical Rainforest Biome These occur near the equator and offer the most diverse communities on earth with fairly high temperature and humidity. The annual rainfall is more than 200–225 cm. Here one finds dense vegetation consisting of tall trees covered with creepers and orchids, numerous herbs and shrubs. Tropical rainforest is the habitat of numerous vertebrate and invertebrate animals.

1.3 SCOPE 1.3 SCOPE1.3 SCOPE

Environmental studies as a subject has a wide scope. It encompasses a large number of areas and aspects, which may be summarized as follows.

Natural resources — their conservation and management

Ecology and biodiversity

- Environmental pollution and control
- Social issues in relation to development and environment
- Human population and environment

These are the basic aspects of environmental studies which have a direct relevance to every section of the society. Environmental studies can also be highly specialized concentrating on more technical aspects like environmental science, environmental engineering or environmental management.

In the recent years, the scope of environmental studies has expanded dramatically the world over. Several career options have emerged in this field that are broadly categorized as:

(i) *Research & Development (R & D) in environment:* Skilled environmental scientists have an important role to play in examining various environmental problems in a scientific manner and carry out R& D activities for developing cleaner technologies and promoting sustainable development.

There is a need for trained manpower at every level to deal with environmental issues. Environmental management and environmental engineering are emerging as new career opportunities for environmental protection and management. With the pollution control laws becoming more stringent, industries are finding it difficult to dispose off the wastes produced. In order to avoid expensive litigation, companies are now trying to adopt green technologies, which would reduce pollution.

Investing in pollution control technologies will reduce pollution as well as cut on costs for effluent

treatment. Market for pollution control technology is increasing the world over. Cleaning up of the wastes produced is another potential market. It is estimated to be more than $100 billion per year for all American business. Germany and Japan having more stringent laws for many years have gained more experience in reducing effluents. Still there is a $ 200 billion market for cleaning up the former East Germany alone. In India also the Pollution Control Boards are seriously implementing pollution control laws and insisting on upgradation of effluents to meet the prescribed standards before they are discharged on land or into a water body. Many companies not complying with the orders have been closed or ordered to shift.

(ii) *Green advocacy:* With increasing emphasis on implementing various Acts and laws related to environment, need for environmental lawyers has emerged, who should be able to plead the cases related to water and air pollution forest, wildlife etc.

(iii) *Green marketing:* While ensuring the quality of products with ISO mark, now there is an increasing emphasis on marketing goods that are environment friendly. Such products have ecomark or ISO 14000 certification. Environmental auditors and environmental managers would be in great demand in the coming years.

(iv) *Green media:* Environmental awareness can be spread amongst masses through mass media like television, radio, newspaper, magazines, hoardings, advertisements etc. for which environmentally educated persons are required.

(v) *Environment consultancy:* Many non- government organizations (NGOs), industries and government bodies are engaging environmental consultants for systematically studying and tackling environment related problems.

1.4 IMPORTANCE OF ENVIRONMENT

Environment belongs to all and is important to all. Whatever be the occupation or age of a person, he will be affected by environment and also he will affect the environment by his deeds. That is why we find an internationally observed environment calender to mark some important aspect or issue of environment.

ENVIRONMENTAL CALENDER

World Wetland Day February 2 World Forest Day March 21 World Day for Water March 22 World Meteorological Day March 23 Earth Day April 22 International Biodiversity Day May 22 Anti-tobacco Day May 31 World Environment Day June 5 World Ocean Day June 8 World Population Day July 11 Ozone Week Sept. 16–23 World Car-free Day Sept. 22 Green Consumer Day Sept. 28 World farm Animal's Day Oct. 2 World Habitat Day Oct. 3 World Animal Welfare Day Oct. 4 Wildlife Week Oct. 1–7 World Conservation Day Oct. 24 International Day for Natural

Disaster Reduction Oct. 13 International Day for Biological Diversity Dec. 29

Global Vs. Local Nature of Environment

Environment is one subject that is actually global as well as local in nature.

Issues like global warming, depletion of ozone layer, dwindling forests and energy resources, loss of global biodiversity etc. which are going to affect the mankind as a whole are global in nature and for that we have to think and plan globally.

However, there are some environmental problems which are of localized importance. For dealing with local environmental issues, e.g impact of mining or hydro-electric project in an area, problems of disposal and management of solid waste, river or lake pollution, soil erosion, water logging and salinization of soil, fluorosis problem in local population, arsenic pollution of groundwater etc., we have to think and act locally.

In order to make people aware about those aspects of environment with which they are so intimately associated, it is very important to make every one environmentally educated.

Individualistic Nature of Environment

Environmental studies is very important since it deals with the most mundane problems of life where each individual matters, like dealing with safe and clean drinking water, hygienic living conditions, clean and fresh air, fertile land, healthy food and sustainable development. If we want to live in a clean, healthy, aesthetically beautiful, safe and secure environment for a long time and wish to hand over a clean and safe earth to our children, grandchildren and great grandchildren, it is most essential to understand the basics of environment.

1.5 NEED FOR PUBLIC AWARENESS ARENESS

International Efforts for Environment

Environmental issues received international attention about 36 years back in Stockholm Conference, held on 5th June, 1972. Since then we celebrate **World Environment**

Day on **5th June.** At the United Nations Conference on **Environment and Development** held at Rio de Janeiro, in 1992, known popularly as **Earth Summit,** and ten years later, the **World Summit on Sustainable Development,** held at Johannesberg in 2002, key issues of global environmental concern were highlighted. Attention of general public was drawn towards the deteriorating environmental conditions all over the world.

Award of the Nobel Peace Prize (2004) to an environmentalist, for the first time, came as a landmark decision, showing increasing global concern towards environmental issues and recognition to efforts being made for environmental conservation and protection.

Public Awareness for Environment

The goals of sustainable development cannot be achieved by any government at its own level until the public has a participatory role in it. Public participation is possible only when the public is aware about the ecological and environmental issues.

The public has to be educated about the fact that if we are degrading our environment we are actually harming our own selves. This is because we are a part of the complex network of environment where every component is linked up. It is all the more important to educate the people that sometimes the adverse impact of environment are not experienced until a threshold is reached. So we may be caught unawares by a disaster.

A drive by the government to ban the littering of polythene cannot be successful until the public understands the environmental implications of the same. The public has to be made aware that by littering polythene, we are not only damaging the environment, but posing serious threat to our health.

There is a Chinese proverb "*If you plan for one year, plant rice, if you plan for 10 years, plant trees and if you plan for 100 years, educate people.*" If we want to protect and manage our planet earth on sustainable basis, we have no other option but to make all persons environmentally educated.

1.6 ECOSYSTEMS

Ecosystems of the world are studied on the basis of their principal habitats. Among the environmental segments, litho sphere and hydrosphere are the major habitats for a wide variety of flora and fauna.

Land-based Ecosystem

Land (terrestrial) ecosystems depend largely on the climate and soil. Higher plants and animals have evolved on land. For example, seed plants, insects, warm-blooded vertebrates and micro-organisms dominate on land now. The major terrestrial communities consist of herbaceous plants, shrubs, grass and also woody trees besides numerous insects, arthropods, birds, etc.

Marine Ecosystem

Oceans occupy 70 per cent of earth's surface, offering habitat to numerous plants (mainly algae), animals like zoo plankton, shrimps, oysters, fishes, reptiles, birds and mammals. They serve as the sink of a large quantity of run off and wastes from land.

Marine water has a high salt content (about 3.5% by weight) and poor fertility due to lack of nitrates and phosphates as compared to freshwater. Marine life is abundant near the shore and in the continental shelf. The species include commercial fishes, large sea mammals like whales and seals.

Freshwater Ecosystem

Freshwater bodies (ponds, lakes, rivers, springs) are rich in nutrients (nitrates, phosphates) and provide good habitat for phytoplankton, zooplankton, aquatic plants and fishes.

Wetland Ecosystems

Wetlands are transitional lands between terrestrial and eco-systems where water stands at 2.5 to 300 cm during most of the year. They include valuable natural ecosystem harbouring a wide variety of plants, animals, fishes and micro organisms. They are at present in danger due to increasing urbanization as in the case of eastern part of Kolkata.

Mangroves (Forest between Land and Sea) Mangroves are important forest communities in tidal zones or equatorial and tropical coasts. For example, the Sunderbans in the Gangetic estuarine delta touching the Bay of Bengal offer important mangroves, habitat of wild animals including Royal Bengal Tiger and of interesting plant species.

1.7 SUSTAINABLE ECOSYSTEM

The developing countries face today critical situation on economic and environmental fronts. For economic growth they have to give priority to agricultural industrial bases but at the cost of environment. The resource base, once depleted, sets in chain of environmental degradation which finally weakens the economy. Our population explosion remains the core issue. Our development policy should be such that the ecosystem is sustainable, i.e., it contains the element of renewability. This requires sound management strategy which ensures the continuation of socio-economic development in the long run.

The important components of sustainable development/ ecosystem are:

- Population stabilisation

- Integrated land use planning
- Conservation of biodiversity
- Air and water pollution control
- Renewable energy resources
- Recycling of wastes and residues
- Environmental education and awareness at all levels.

1.8 HUMAN ACTIVITIES AND ENVIRONMENT

Food: World grain production increased almost three times during the last 50 years. But at the same time population growth increased in the developing or Third World countries at such rate that it surpassed food production. Each year about 40 million people in the developing countries die of malnutrition and starvation. In other words, our food shortage in some areas is killing every year as many people as were killed by the dropping of atom bomb on Hiroshima during World War II.

India is the third largest producer of the staple crops—wheat, rice, maize but about 300 million people are still undernourished (receiving less than 90% of the minimum required calorie intake of 2500 calories/day). Our food crises are directly linked to population explosion (See also Unit-III).

Shelter, Economic and Social Security: India has the lowest man:land ratio—barely 0.48 ha. per capita. It has continuously declined since the 60s. Land is facing too much pressure on various fronts due to increasing population— housing (shelter), agriculture, industry, urbanisation etc. In order to satisfy his needs and greeds for better lifestyle, man has been exploiting the natural resources—forests, water bodies, minerals etc. excessively. This has led to environmental degradation and pollution which, in turn, have threatened his economic and social security and, as a matter of fact, his survival on earth.

B. HUMAN ACTIVITIES AND THEIR IMPACT ON ENVIRONMENT

For economic development and better living, man has sacrificed forest land for agriculture, industries, urbanization etc. This has brought in to trail environmental disaster and backfired on man himself endangering his existence on earth.

1.9 AGRICUL AGRICULTURE

The dawn of human civilization can be traced back to the discovery of agriculture almost 10,000 years ago. In the early period, man used the primitive practice of *slash and born cultivation or shifting cultivation*, which is still prevalent in many tribal areas, as in North East India in the hill regions.

The two modes of agriculture—traditional and modern —are described below along with their impacts. (i) ***Traditional Agriculture and its Impact:*** It involves small plots, simple tools, natural water, organic fertilizer and several crops. The yield is, however, low but it is still used by about 50% of the world population. The impacts of this type of agriculture are as follows:

(a) *Depletion of Nutrients:* During slash and burn of trees in forests, the organic matter in soil is destroyed and within a short period most of the nutrients are taken up by the crops. Thus the soil becomes deficient in nutrients and compels the cultivators to shift to another area.

(b) *Deforestation:* Forest land is cleared by slash and burn of trees in forest for cultivation purposes. Frequent shifting of cultivation plots leads to deforestation i.e., loss of forest cover.

(c) *Soil Erosion:* As a result of deforestation, soil gets exposed to the weathering forces i.e., rain, wind and storms and is subjected to erosion. The net result is loss of top fertile soil.

(ii) ***Modern Agriculture and its Impact:*** It is based on high input–high *output* technique using hybrid seeds of high-yielding variety and abundant irrigation water, fertilizers and pesticides. This is the basis of "*Green Revolution*" which boosted the production of wheat and India became self-sufficient in food. But

the fallout from Green Revolution has become evident since the 90s (1990) as shown below: (a) *Impacts from HYV (High-Yielding Varieties):* Application of seeds of HYV gave rise to monoculture i.e., the same species (genotype) grown over vast areas, such monoculture is vulnerable to attack by some pathogen, which spreads like wild fire, devastating crops over large areas.

(b) *Fertilizer Problems:* Essential micronutrients—nitrogen, phosphorus and potassium (NPK) are supplied by chemical fertilizers. Indiscriminate use of chemical fertilizers causes micronutrient imbalance in the soil which ultimately loses productivity.

(c) *Nitrate Pollution:* From agricultural fields nitrogenous fertilizers leach into the soil and finally contaminate groundwater. When the nitrate level of groundwater exceeds 25 mg/l, they can cause a serious health hazard known as *"Blue Baby Syndrome"*, which affects mostly infants even leading to their death.

(d) *Eutrophication:* Agricultural run-off water contains fertilizer components, particularly nitrogen and phosphorus, which reaches nearby waterbodies and causes their overnourishment. Excessive use of these fertilizers leads to overnourishment of the lakes/waterbodies and gives rise to the phenomenon of eutrophication (eu = more, trophication= nutrition).

As a result, there is excessive growth of algal species, which is known as *algal bloom*. The waterbody or lake soon gets filled up with algal species which quickly complete their life cycle and die thus adding a lot of organic matter. Dissolved oxygen in the lake is consumed and fish get killed

so that the lake becomes a dead pool of water devoid of plants and animals. Thus the lake ecosystem gets degraded due to eutrophication.

(e) ***Pesticide Side Effects:*** Several thousand pesticides are used in agriculture for destroying pests and boosting crop production. In the early period of human civilization arsenic, sulphur, lead and mer cury were used to kill pests. From 1940 synthetic organic pesticides have been used. Among these, DDT (dichlorodiphenyl trichloroethane), discov ered by Paul Mueller (1939), deserves special men tion. During 1940-1950, it saved 5 million lives from malaria, typhus etc. and also protected crops from huge losses. But DDT and other pesticides show a number of harmful side-effects on envi ronment.

(a) *Inducing Pest Resistance and Yielding New Pests:* In course of time new generations of pests de velop resistance to pesticides so that they sur vive even after pesticide spray. At present, about two dozen pest species are known to be immune to all types of pesticides.

(b) *Biological Magnification/Amplification:* Many pesticides including DDT are non-biodegradable so that they persist in the food chain. At each step of the food chain the pesticide level gets more and more concentrated. This is the pro cess of biological magnification or amplification. Thus, DDT builds up from 0.04 ppm in plank ton to 75 ppm in fish-eating birds. Man occu pies a high trophic level in the food chain and hence gets a high dose of pesticide, which is quite harmful.

(iv) ***Waterlogging:*** Excessive irrigation of croplands for good growth of crop leads to waterlogging. In the absence of adequate drainage, excess water is

accumulated which seeps into the underlying wa ter table. Pore spaces in the soil get fully drenched with water and soil-air becomes deficient. The water table rises and the roots of plants have in sufficient air for respiration. There is decline in crop yield with decrease in soil strength.

Punjab and Haryana have faced water-logging problems as a result of extensive irrigation by canal water or shallow tubewell water and consequently sharp decline in crop output.

(v) ***Salinity Problem:*** In addition to waterlogging, salinity also rises from excessive irrigation water. The latter contains dissolved salts which under dry conditions evaporates leaving behind salts in the upper soil profile. Saline soils are characterized by accumulation of soluble salts such as sodium chloride, sodium sulphate, calcium chloride, magnesium chloride etc. in the soil profile.

Salinity causes stunted plant growth and reduces crop yield. Thousands of hectares of land in Haryana and Punjab have been affected by soil salinity.

The best method for getting rid of salinity is to flush out by applying freshwater to such soils.

1.10 INDUSTRY INDUSTRYINDUSTRY

Industries produce environmental hazards everywhere. They consume 37 per cent of world's energy and emit 50 per cent of world's CO_2, 90 per cent of SO_x and almost all the chemicals now threatening O_3 layer with depletion.

Every year, they produce 2100 m illion tonnes of solid waste and 350 million tonnes of hazardous waste. In developing countries, small as well as big industries discharge untreated waste.

There is world-wide concern about the disposal of radioactive wastes from nuclear reactors. Nuclear reactor

accidents are expected to increase over the years. The stock of nuclear power stations is also ageing.

In developed countries, industries have enforced economy during the last two decades in the use of resources and energy consumption. It is a common practice for these industries to recycle and reuse water. The average person in a developed country still consumes 15 times more energy than in a poor country. However, in a developed country energy is being used more efficiently and the expected rate of increase of energy consumption is only 1.3 per cent per year.

1.11 TRANSPORT

Transport is a great consumer of land and energy. The length of motor ways has almost doubled in developed countries over the past two decades, reaching 1,500,00 km. in 1990. Transport consumes 30 per cent of world's energy (of which 82 per cent is consumed on roads) and produces 60 per cent CO-emissions, 42 per cent of NO_x and 40 per cent of hydrocarbon emissions.

But there is a hope of new cleaner transport becoming popular in future. Almost one-third of Brazil's cars run on pure ethanol, obtained from specially grown crops and many cars run on ethanol/petrol mixture. Natural gas is being used as a fuel in several countries including Italy where 3 lakh cars run on compressed natural gas (CNG).

Major efforts have been made in developed countries in reducing petrol consumption by 50 per cent of the amount used two decades ago. Auto-emissions have also been cleaned up. Use of lead-free petrol has curtailed Lead (Pb) emission by 87 per cent during 1980-1990.

1.12 MINING

Minerals find extensive use in domestic, agricultural, industrial and commercial sectors and thus form a very important part of any nation's economy.

Minerals are broadly of two types:

(a) Non-metallic minerals e.g., graphite, diamond, quartz, feldspar etc.

(b) Metallic minerals e.g., bauxite, laterite, hematite etc. Since the early days of human civilization man has used metals extensively. That is why history labelled the eras as Bronze Age and Iron Age. The most abundantly used metals are Iron and Steel (Annual use 750 million tonnes) followed by Manganese, Copper, Chromium, Nickel and Aluminium. Mining and processing of minerals involve major environmental concerns including disturbance of land, air pollution from dust and smelter emissions and water pollution from disrupted aquifers.

India is the producer of 84 minerals at an estimated annual value of Rs. 50,000 crore. Six major mines are known to cause severe environmental problems.

(a) *Jadugoda Uranium Mine, Jharkhand:* Exposing local area and the population to radioactive hazards. (b) *Jharia Coal Mines, Jharkhand:* Underground fire causing land subsidence and displacement of people. (c) *Sukinder Chromite Mine, Orissa:* Seeping of hexavalent chromium into river posing serious health hazard. Chromium Cr^{+6} (hexavalent) is highly toxic. (d) *Kudremukh Iron Ore Mine, Karnataka:* Causing river pollution and threat to biodiversity.

(e) *East-Coast Bauxite Mine, Orissa:* Land encroachment and rehabilitation issue.

(f) *North-Eastern Coal Fields, Assam:* Very high sulphur contamination of groundwater.

Impacts of Mining: Mining involves extraction of minerals/fossil fuels from deep deposits in soil employing the techniques of sub-surface mining or surface mining. The former method is more dangerous and expensive including risks and accidents. The environmental damages are described as follows:

(a) *Devegetation and Defacing of Landscape:* Large-scale devegetation or deforestation leads to ecological imbalances besides disfiguring the landscape. The huge debris and tailings spoil the environment of the region and make it vulnerable to soil erosion.

(b) *Subsidence of Land:* Underground mining (e.g., coal) causes subsidence of the soil above resulting in tilting of buildings, cracks in soil/road, bending of rail tracks etc.

(c) *Groundwater Contamination:* Mining disturbs the hydrological processes and also pollutes the ground water. Sulphur impurity in many areas gets converted into sulfuric acid through microbial action, which makes the water acidic.

The acid mine drainage often contaminates the nearby streams and lakes and damages aquatic life (plants and fish).

(d) *Air Pollution:* Smelters in metal extraction processes in metallurgical industries emit huge volumes of air pollutants—sulphur oxides, soot, arsenic, lead, cadmium particles etc. These have public health hazards for local residents.

(e) *Occupational Health Hazards:* Most of the miners suffer from various respiratory and skin diseases due to constant exposure to the suspended particulate matter and toxic substances. Such diseases include asthma, bronchitis, black-lung disease, asbestosis, silicosis etc.

1.13 ENVIRONMENTAL IMPACT ASSESSMENT (EIA) CT ASSESSMENT (EIA)

The inherent conflict between development and environment can be solved to a great extent by a sound environmental management plan which is based on balancing development with environment. The necessary tool for this is *Environmental Impact Assessment* (EIA). Development should not be treated as an economic goal but as a multi-

dimensional concept covering economic as well as political, social and cultural aspects of life of common man. The basic objective of EIA is to identify, predict and evaluate the probable economic, environmental and social impacts of developmental activities and take necessary steps as remedial measures which will be a part of the overall environmental management plan (EMP).

It is the government's policy that any industrial project particularly major industry must obtain EIA clearance from the ministry of environment before approval by the planning commission. It may be mentioned that EIA is conducted by a team of experts in the field (environment), appointed by the Ministry of Environment, Government of India.

1.14 SUSTAINABLE DEVELOPMENT

As per the definition of the then director of World Health Organization (WHO), Prime Minister G.H. Bruntland (Norway), sustainable development means *"meeting the needs of the present without compromising the ability of future generations to meet their needs"*! Nowadays sustainable development is the keynote of many projects but only few of them achieve sustainable growth.

Overexploitation of natural resources, particularly by the developed countries, since 1970s is fast heading towards un sustainable growth and collapse of our life-support base. In 1992, the UN Conference on Environment and Development (UNCED) was held at Rio de Janeiro, Brazil. The Rio decla ration on Agenda-21 adopts a global programme of action on sustainable development in social, economic and political con texts for the 21st century.

The important components of sustainable development are:

• Population stabilization (growth below 0.5 per cent) • Integrated land-use planning
• Conservation of biodiversity

• Air and water pollution control
• Renewable energy resources
• Recycling of wastes and residues
• Environmental education and awareness at all levels

Questions

1. What is meant by
(a) Environment?
(b) Environmental studies?
2. What do you mean by ecosystem?
3. Illustrate land ecosystem and also aquatic ecosystem. 4. Classify the ecosystems on the basis of their habitats. Give examples.
5. What is sustainable ecosystem?
6. Give a short account of the impacts of agriculture on environment.
7. What is meant by
(a) Eutrophication?
(b) Waterlogging?
(c) Salinity of soil?
8. Enumerate the impacts of mining.
9. What is the significance of sustainable development? What are its main components?

Unit-II **RESOURCES**

A. NATURAL

Nature provides life support materials or resources for sustenance of life on earth for plants, animals and man. These resources are known as **Natural Resources**. Examples are water, air, soil, forests, minerals, crops etc.

There are two categories of natural resources: 1. *Renewable Resources:* These can be recycled and regenerated within a given span of time e.g., forests, wind energy, solar energy, biomass energy, hydropower etc.

2. *Non-renewable Resources:* These cannot be regenerated e.g., fossil fuels such as coal, petroleum, minerals etc. With increase in consumption, these will be exhausted in near future.

It must be noted that even renewable resources are endangered and liable to extinction if these are exploited recklessly e.g., forests.

The major natural resources are:

(i) Forest resources
(ii) Water resources
(iii) Mineral resources
(iv) Food resources
(v) Energy resources
(vi) Land resources.

2.1 FOREST RESOURCES

Forests are one of the most important natural resources on earth. Providing the earth with a green cover, the forests also offer several environmental services which are essential for sustenance of life.

About 33% of the world's land area is under forest cover. Former USSR (now CIS) accounts for about 20% of the world's forests, Brazil for about 15% and Canada and USA, 6-7%. But over the years the forest cover has been reduced due to reckless deforestation by man almost all over the world, particularly in tropical Asia.

Forest Resources/Wealth

Plants have been dominating the earth for about 3.0 billion years. They have the unique art of manufacturing their own food by photosynthesis from nature and the rest of the living world depends on them for their food and sustenance. Plants constitute 99 per cent of earth's living species and the rest 1 per cent include animals and man who depend on the plant world for their food. If this ratio (99:1) is disturbed by elimination of plants (i.e., deforestation), then the natural balance will be lost and the entire living world will suffer most. This dynamic balance is among plants (*producers*), bacteria and micro organisms (*decomposers* who decompose mineral salts in soil into elements which are cycled back into plants) and animals plus man (*consumers*). Once this dynamic balance is upset, there would be ecological crisis and the entire biosphere would be in danger.

Forests are renewable resources and have a key role in improving the quality of environment by exerting beneficial effect on the life support system. Moreover, forests also contribute much to the economic development of the country by providing goods and services to people and industry. They are the treasure house of valuable plant and animal genes

and medicinal plants, most of which are yet to be discovered. Hence tropical forests, in particular, are regarded as bioreserves. Our ancient civilisation flourished in forests, where Indian philosophy was built up by our "rishis" (seers).

It is well-known that forests play a vital role in the life and economy of all forest-dwelling tribes. They supply food (tuber, roots, leaves, fruits and meat from animals and birds), medicinal herbs and other forest products for commercial use which provides for forest-based subsistence.

Around 3000 BC, India had about 80 per cent forest cover. During the Maurya period of history emperor Chandra Gupta Maurya and later his grandson Ashoka adopted the policy of tree-plantation. Emperor Ashoka also ordered the establishment of the first *wildlife sanctuaries* (*abhayaranyas*). Carvings on stone pillars from this era show how wild animals were treated with medicine and care.[1]

But waves of migrants came to India from middle-east countries which were deserts and tree-less and they changed the whole landscape. During the Moghul period again the picture was reversed as the Moghuls came from tree-less countries—they converted forests into agricultural lands. During the British period, the rate of forest conversion into agricultural land continued. They also exploited forests for timber for laying communication system, particularly after 1867 (India's First War of Independence/Sepoy Mutiny). After our independence in 1947, the situation did not improve rather the trend continued to draw revenue from forests. The net result is that the forest cover has dwindled from 80 per cent to about 12 per cent in 5000 years. India has been losing 1.3 million hectares (1 ha = 2.5 acres) of forests each year.

[1] *Big hunting game by Hindu kings in the earlier periods had caused destruction of wildlife and forests.*

The main causes for forest destruction are human population and livestock (cattle, buffaloes, goats, sheep) population explosion. These enhance the demand for timber and fuel wood (for man) and grazing land (for livestock). At the global level wood consumption is 46 per cent for industrial and 54 per cent for firewood purposes. In developing countries like India the picture is reverse—82 per cent for firewood and 18 per cent for industrial purpose. The present requirements in India (in 2000) are—78 per cent for fuel wood, 16 per cent for timber and 6 per cent for pulpwood (for paper industry).

2.1.1 Forest Conservation

The Forest Policy of the Government of India (1952) laid down that one-third (33 per cent) of our land should be under forest cover. However, this has not been followed seriously with the result that the present forest cover has gone down to about 12 per cent. We have almost reached a critical state which must be remedied now before it is too late for our own survival. The remedial measures (conservation) have been suggested as follows:

(i) *Conservation of Reserve Forests*: These are areas where our major water resources are located, viz. the Himalayas, Western and Eastern Ghats and areas like reservoirs, National Parks, Sanctuaries, Biosphere Reserves, etc. These must be protected and no commercial exploitation be allowed in these areas. This is an important conservation strategy.

(ii) *Limited Production Forests*: These are less fertile areas at high altitude (more than 1000 metres) with hilly environment. Here the health of the forests should not be damaged and only limited harvesting with utmost care be allowed.

(iii) *Production Forests*: These are forests on the plains and their productivity can be enhanced by proper management. These should be maintained to make up for the losing of forest cover.

(iv) *Social/Commercial Forestry*: Such forestry is meant for supplying goods and services to meet the ever increasing demand for firewood, fodder, food, fertiliser, fibre, timber, medicine, etc. or for industrial purposes such as timber, plywood, matchwood, fibre board, paper and pulp, rayon, etc. The main idea is to remove pressure on natural forests for these requirements.

Social forestry is based on public and common land (private) to produce firewood, fodder, fruit and small timber for rural people.

The programme should be conducted by a co-operative system including farmers, tribals, panchayats and NGOs (non government organisations), etc. Degraded lands should be utilised for social forestry for firewood, whereby the quality of land improves in course of time.

Massive afforestation should be done involving multi purpose species of plants/shrubs so that every village/town/ city is able to meet its requirements for firewood, fodder and small timber. Production/Commercial Forestry is intended entirely for commercial purposes to meet the needs of the forest-based industry. Fallow lands, not used for agriculture, grazing lands, etc. can be used for raising such plantations.

2.1.2 Wood —A Major Renewable Resource

Wood is a major renewable natural resource. In USA, the production of wood and wood products is the fifth largest industry. Wood ranks first as a raw material for the manufacture of other products. Ideally, forests should cover one-third of the land area.

Rayan Ply
wood Cellophane
e
Methanol
Plastics
Paper
Particle board
Wood/turpentin

Fig. 2.1: *Many important products come from trees*

2.1.3 Biodiversity

There may be about 10 million species of plants, micro organisms and animals on earth while only about 1.5 million species are on record, i.e., identified so far. Among these the majority are insects (7,50,000), 41,000 are vertebrates (i.e., those having backbones or spinal columns), 2,50,000 are plants, 1,00,000 are fungi and the rest are invertebrates and micro-organisms.

Biological diversity or biodiversity involves genetic diversity among species as also between individuals and ecological diversity, i.e., number of species in a community of organisms. The existing species of plants and animals are the product of 3-billion years of evolution involving mutation, recombination and natural selection. Changes in environment, e.g., warm and cool periods exerted selection pressures and have been responsible for evolution of new species and extinction of others who could not survive in the struggle for survival. The dinosaur era is an example. These giant-sized animals dominated the earth for 130 million years and became extinct before the Ice Age.

Natural extinction, part of evolutionary process, has been accelerated by man-made extinction wave due to constant

greed and need of man. By this time, 1 out of 10 million species has become extinct and each day we are losing one plant and one animal species. At this rate of extinction, the survival of man himself is threatened. The *specide* (extinction of species) in which man is involved is more serious a crime than genocide (mass murder). In this context we may note our tradition. Charak, the well-known ancient physician, was asked by his teacher to get a plant that was useless. He returned after a few days and reported that there was no such plant. One cannot imagine a situation if *Penicillium* was extinct before man could make use of it as an antibiotic or if *Cinchona* became extinct before quinine was discovered as a cure for malaria. It is, therefore, in our own interest that we should conserve our plant as well as animal and micro organism (fungus and bacteria) wealth. There is a growing realisation all over the world about the urgent need to conserve the *biological diversity*.

The United Nations Earth Summit (Rio de Janeiro, 1992) adopted the Treaty on Biodiversity whereby countries agreed to conserve the Biodiversity—the living natural resources (plants, animals, microbes) for the welfare of mankind.

2.2 W A TER RESOURCES AND WATER USES TER USESTER USES

Man is using petroleum for more than a century extensively and coal for several centuries. Human civilisation spent 99.9 per cent of time without these fuels. The world's petroleum stock is likely to be exhausted in another hundred years and coal in a few centuries. This will pose a crisis before mankind. But when we realise that our usable water resources is also limited and will be out of stock in near future, then we indeed have cause for panic.

Water has no alternative—it is known as "*life*". It is essential for the sustenance of all living organisms including plants, animals and man. All plants, insects, animals and men have 60–95 per cent water in their bodies. This water is partly

released in the form of sweat, excreta, urine and vapour. So all these species require a lot of water daily. Besides, much water is also needed for body growth, nutrition, etc. So it is absurd to think of life without water. But our usable water resources like any other natural resource is finite and is likely to be exhausted within a century. Moreover, it is getting polluted by man-made activities and unfit for use sooner than expected. Water crisis is more serious than food or population crisis since food production or population problems are irrelevant without water supply. Use of polluted water itself takes toll of 25,000 people all over the world every day. In India, out of 6 lakh villages, one-third or about 2 lakh villages are without access to water. In these villages, women have to walk daily about

1–14 km to collect water for cooking and drinking. The United Nations Food and Agriculture Department estimates that if the present day practices of wasting and polluting water are not stopped, then within less than a century the world's biosphere including man will disappear.

> The world's total quantum of water is 1.4 billion cubic kilometre. If all the seabeds could be filled up and brought at the level of the earth's surface, then the entire water in the seas would cover the earth's surface and make it 2.5 km deep watermass. *About 97 per cent of earth's water supply is in the ocean which is unfit for human consumption and other uses due to high salt content. Of the remaining 3 per cent, 2.3 per cent is locked in the polar ice caps and hence out of bounds. The balance 0.7 per cent is available as freshwater but the bulk of it, 0.66 per cent, is groundwater and the rest 0.03 per cent is available to us as freshwater in rivers, lakes and streams.* The break-up of this 0.03 per cent freshwater is—lakes and ponds 0.01

> per cent, water vapour 0.001 per cent, rivers 0.0003 per cent and water confined in plants, animals and chemicals 0.0187 per cent.

[The United Nations Water Conference Report, Argentina (1977)]

Thus we see that we have a very limited stock of usable water, 0.03 per cent surface water (rivers, streams and ponds) and 0.66 per cent groundwater. The quantity of water vapour arising from evaporation of sea water and river water returns by the same volume to the earth's surface by rainfall and back to the water sources. The hydrological cycle in nature is more or less balanced in terms of charge (cloud formation) and discharge (rainfall). But we are drawing large quantities of groundwater for agriculture and industries while the waste water from these is much polluted and on mixing with rivers is polluting the rivers also.

The mass balance of annual rainfall shows that about 70 per cent is lost by evaporation and transpiration by plants, while the remaining 30 per cent goes into the stream flow. The approximate break-up of this stream flow, as consumed by man is—8 per cent for irrigation, 2 per cent for domestic use, 4 per cent for industries and 12 per cent for electrical utilities. Irrigation for agriculture and electric power plants are the major consumers of water.

These waste liquids (effluents) can be purified by filtration using activated charcoal or ion exchange resins. Activated charcoal has large surface area and is an effective filter medium for adsorption of organic molecules. Synthetic organic ion exchange resins are very useful for the removal of industrial waste metals (cations) and non-metals (anions).

Water Quality

It is essential to enforce water quality standards in the interest of public health. All developed countries strictly conform to water quality standards. Polluted water generates

water-borne diseases which kill millions of people every year all over the world, particularly in developing countries. The United States Public Health (USPH) has laid down standards for water quality parameters (indicators) for drinking water. These are the upper limits in parts per million (ppm) (1 ppm = 1 in 10^6 parts).

Table 2.1. *Water quality parameters (domestic water supplies) USPH standards (upper limits)*

Parameters (in ppm, except for pH)

pH 6.0–8.5 Dissolved oxygen (D.O.) 4.0–6.0 Total dissolved solid 500.0 Suspended solid 5.0 Chloride 250.0 Sulphate 250.0 Cyanide 0.05 Nitrate + Nitrite 10.0 Ammonia 0.5 Calcium 100.0 Magnesium 30.0 Iron 0.3 Lead 0.05 Mercury 0.002 Arsenic 0.05 Chromium (VI) 0.05 Zinc 5.5 Phenol 0.001 Chemical Oxygen Demand (COD) 4.0

All parameters except pH are in ppm.
1 ppm = 1 in 10^6 parts

The parameters for surface water (rivers, lakes, etc.) are 4–5 times higher than the above values for drinking water. Clean water is essential for healthy environment to support life systems on this planet. The task of delicately balancing the ratio of available and exploitable water

resources and sustaining their quality is most important for India as rainfall distribution is confined to 3–4 months in a year. Moreover, man-made global and local climatic distortions due to global warming (*see* Chapter 6), deforestation, loss of topsoil, etc. have adverse effect on the monsoon pattern in India.

India is blessed with good rainfall (average 200 cm in a year) but 70 per cent of it is wasted. The country faces recurring problems of floods, and droughts and highly polluted water resources. It is necessary to do rain harvesting, i.e., build large tanks and reservoirs all over the country to store rain water, flood water and excess water from the Ganga, Brahmaputra and other rivers. The rivers, the lifelines of our culture and economy, are dying because of severe pollution. This water pollution abatement and resource management should be at the top of our national agenda.

2.3 W A TER-BORNE DISEASES

The names of common water-borne diseases are given in Table 3.6: p. 90. The causative agents for water-borne diseases may be virus, bacteria, protozoa or helminths. The diseases like viral hepatitis (hepatitis A, hepatitis B), poliomyelitis and diarrhoea are caused by virus. The diseases like cholera, bacillary dysentery, typhoid and paratyphoid are caused by bacteria and the diseases like amoebiasis, giardiasis are caused by protozoa. Some common water-borne diseases are discussed in detail in the following section.

Cholera

This is a highly contagious disease (water-borne and food borne), caused by the bacteria, *Vibrio cholerae*. Typical symptoms are diarrhoea with rice water stool, vomitting, rapid dehydration, muscular cramps and anuria. In severe case, acute renal failure is possible. Epidemics of cholera had occurred in the past in India during Kumbha Mela or Ardha-

Kumbha Mela. Outbreaks of cholera were also reported in the past from Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Orissa and West Bengal.

The bacteriology of cholera is complicated. *Vibrio eltor* replaced the classical *V. cholrae* by the end of 1965. Most of the Eltor vibrios isolated were found to belong to the serotype Ogawa. *V. cholerae* are gram-negative, comma-shaped, actively motile organisms. The Eltor vibrios resemble the true cholera vibrios morphologically, serologically and also biochemically.

Factors for Spread of Cholera

Environmental Factors: Among environmental factors, water, food and flies play important role in spreading cholera in the community. Cholera vibrios do not multiply in water but they may survive up to two depending on temperature, pH, salt content, organic matter, sunlight and other factors. In our country there are a large number of uncontrolled water supplies (e.g., polluted river, ponds, canals, etc.) which are major sources of cholera infection. Cholera vibrios can multiply readily in certain foods and drinks like milk, milk products and some varieties of boiled rice. Fruits and vegetables get contaminated when washed or sprinkled with water from infected areas.

Social Factors: Big fairs like Kumbha Mela or Ardha Kumbha Mela where lakhs of people assemble at the river ghats are one of the most important factors for the spread of cholera. The crowd bathe and drinking the same river water (Ganga) rapidly spread the disease. Cholera is a disease of the poor people who come from low income groups, live in slums under unhygienic and inhuman conditions. They participate in these melas and contaminate the river water.

Control of Cholera

The control of cholera can be achieved by early detection of the disease, isolation of the patients and their prompt treatment, improvement of sanitary facilities along with

adequate supply of safe drinking water to the community. Active immunisation and health awareness are also the important measures for cholera control.

For early detection, bacteriological examination of stools is required for confirmation of the disease. The disease should at once be notified to the local authority who will send the information to the State Health Authority and finally to the Central Health Authority.

The treatment of cholera consists of rehydration and antibiotics. Rehydration saves life. In case of kidney failure, *dialysis* is required. The rehydration should be accomplished either by injecting intravenous solutions of saline (consisting of sodium chloride: sodium bicarbonate: potassium chloride = 5:4:1) or by giving oral fluid containing a mixture of sodium chloride, sodium bicarbonate, potassium chloride and glucose in the ratio of 3.5:2.5::1.5:20 gm. dissolved in 1-litre water. Tetracycline and co-trimoxazole should be administered as antibiotic.

Improvement of sanitation for the entire community and their residential area is the most effective approach for the prevention and control of cholera. Provision for sanitary latrine for every household is essential for checking the incidence of cholera. Water to be used for domestic purposes, viz. drinking, washing, cooking, cleaning utensils, etc. from sources such as rivers, ponds, lakes, canals, etc. should be boiled. The provision of safe drinking water for all is the permanent solution as it will minimise the incidence of cholera. It is also necessary to observe the rules of hygiene rigorously—household pests, flies, cockroaches, etc. should be eliminated; cut fruits and vegetables which are exposed to dust and flies in open markets should be avoided.

Amoebiasis

This is a water-borne disease, defined by WHO as the condition of harbouring *Entamoeba histolytica* with or without

clinical manifestations. It has world-wide distribution. The disease is characterised by liquid stools with mucous and blood. *E. histolytica* are found as cysts or motile trophozoites. They can live outside the human body as *cysts*. Trophozoites cause ulcer in the large intestine. Some amoebas reach liver through portal vein any may cause hepatitis or abscess. Intestinal and hepatic amoebiasis are the main manifestations of the disease.

The cysts can live for several weeks outside the human body, if kept moist and cool. In a refrigerator, they can live in water for 6–7 weeks. They do not survive at moderate temperature, e.g., 50°C..

Man gets the infection through food chain (cut fruits, salads, vegetables, contaminated drinking water, cold drink, etc.). Uncooked food and vegetable can be disinfected by washing with iodine solution (200 ppm) or acetic acid (5–10 per cent) or vinegar. From water, cysts can be removed by *filtration* and *boiling*. The cysts in milk can be killed by pasteurisation. The diagnosis is usually based on the detection of *Entamoeba histolytica* in the stools.

The antibody of the parasite can be easily detected by Immuno-fluorescence method.

Prevention of Amoebiasis

The disease can be prevented by

(i) sanitary disposal of human excreta.

(ii) provision of safe drinking water to all (water should be boiled and filtered before drinking).

(iii) hygienic kitchen practice (uncooked fruits and vegetables must be thoroughly washed or disinfected as described before.

(iv) protection of foods against flies.

Treatment

The drugs usually prescribed by physicians are:

1. Metronidazole (400–800 mg) (Flagyl) to be taken

one tablet thrice a day for 5–7 days.

2. Entrozyme (250 mg)—one tablet thrice a day for 7 days

3. Trinidazole (1–2 gm)—one tablet for 3 days 4. Furamide (500 mg)—one tablet thrice a day for 10 days.

Fluorosis

Fluoride in diet or drinking water above 1.5 ppm causes fluorosis. The maximum tolerance level in human body is 1.5 ppm (WHO standard). The daily intake of F from food and drinking water is usually less than 1 ppm. Some parts of south India and South Africa have reported fluoride concentrations of 4 to 8 ppm. In India, some 25 million people spread over 100 districts in 15 states suffer from fluorosis. These affected states are Andhra Pradesh, Bihar, Delhi, Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, U.P., West Bengal and Kerala.

Fluoride does not concentrate in any tissue but only in the bones and teeth. Fluorosis affects bones, teeth, tissues and other organs of the body, leading to death after prolonged illness. It also leads to dental decoloration and deformation of bones causing knock knees, bow legs and stiffening of the joints, joint pains, back pain etc. In endemic areas, large percentage of people suffer from gastrointestinal complaints, diarrhoea etc. The expectant and lactating mothers are vulnerable groups—there is high incidence of stillbirths and abortions.

Provision of safe drinking water (1-ppm fluoride) and creating awareness among people of the dangers of fluorosis are the urgent needs of the hour for prevention of fluorosis.

2.4 MINERAL RESOURCES

Mining and processing of minerals/ores involve major environmental concerns, including disturbance of land, air

pollution from dust and smelter emission, and water pollution from disrupted aquifers.

The rate of depletion of resources is measured by two parameters—*per capita* mining and *per capita* consumption. Per capita mining is calculated by dividing the amount of resource mined by the population. Per capita consumption is obtained by dividing the amount of resource actually processed by the population. It is a better index of the standard of living of the population. Table 3.2 lists the world's mineral reserves along with the per capita mining and consumption figures on a global basis.

Table 2.2. *World's mineral reserves: per capita mining and consumption*

Resources Reserve Occurring as Per capita Per capita (tonnes) mining (kg) consumption(kg)

1 23 4 5

Al 1.1×10^9 Al_2O_3, nH_2O 15.1 2.8 Sb $3.6\times10_6$ Sb_2S_3 14.8 g 17.3 g Asbestos — — 1.0 0.9 Cr 4.4×10^9 Fe Cr_2O_4 0.7 0.5 Coal 4.7×10^{12} — 580 624 Co 2.2×10^6 $CuCO_2$ S_4, CaS_2 — 5.6g Cu 280×10^6 Cu FeS_2 Cu_2S 1.6 1.5 Au 11×10^3 Au 0.4 g 0.4 g Fe 88×10^9 Fe_2,O_3, Fe_3O_4 110 1.9 Pb 82×10^6 PbS, $PbCO_3$ 3.8 0.8 Mn 635×10^6 MnO_2, $Mn_2O_3{}^{\cdot}H_2O$ 2.0 2.2 Hg 115×10^3 HgS, Hg 2.6 g 2.2 g Mo 5.2×10^6 MoS_2 20.7 g 18.7 g Ni 68×10^6 (Fe, Ni) S 145 g 135 g Petroleum 54.1×10^9 — 582 471 Phosphate 19.8×10^9 $Ca_5(PO_4)_3$ (F, Cl, OH) 23 3.2 Potash 99.9×10^9 KCl, $KMgCl_2.6H_2O$ 4.6 3.6 Ag $171/10^3$ Ag, Ag_2S, Ag_3, AgS_3 — — Ti 310×10^6 SnO_2 50.6 g 70.5 W 3×10^6 $CaWO_4$, (Fe, Mn) WO_4 — — U 749×10^3 U_2O_8 — 4.8 g Zn 112×10^6 ZnS, ZnO 1.5 1.4

US Bureau of Mines "Mineral facts and problems", 1970; UN Statistical Yearbook, 1970.

Although quantitative in nature, the figures in the table show some interesting trends. The world per capita mining figures indicate that five minerals are mined to the maximum extent—coal, petroleum iron ore, aluminium and phosphate rock. However, the demand on resources is not equitably distributed over the entire population. This is reflected in the contrast between the per capita mining figures for the Asian and North American subcontinents. This disparity is further aggravated by the fact that USA, for example, imports substantial quantities of most of the resource so that its per capita consumption figure exceeds its per capita mining figure.

As far as metal resources are concerned, they may be grouped under two heads: non-ferrous (base and precious) metals and ferrous metals plus Aluminium.

Average reserve Av. per capita consumption

Group 1: Metals (non-ferrous) 0.05×10^9 tonnes 0.42 kg Group 2: Metals (ferrous+4) 11.8×10^9 tonnes 14.4 kg Ratio: Group 2/Group 1 210/1 34/1

The Group 1 metals are: Au, Hg, Sn, Ag, Zn, Pb, W, U, Cu, and Sb whereas the Group 2 metals are: Mo, Mn, Al, Co, Ni, Ti, Fe, Cr and K.

Non-metal Resources

The major non-metal resources include asbestos, carbonates, Cl_2, granite, O_2, phosphate, potash, sand and gravel, Na compounds and H_2O.

Asbestos (silicate minerals), the carbonates—principally those of Ca and Mg—sand and gravel, together with granite, constitue the common and most widely used building materials. As in the case of metals, the environmental aspects of many of these minerals are quite important.

2.5 NATURAL/BIOGEOCHEMICAL CYCLES

Within an ecosystem (*see* next Chapter) there are dynamic relations between the living forms and their physical

environment, i.e., rocks, air and soil of the earth (geo-). These relations are found as natural or biogeochemical cycles which involve continuous circulation of the essential elements and compounds required for life from environment to organisms and back to environment. The natural cycles and ecosystems function in a balanced manner which stabilises biosphere and sustains the life processes on earth.

2.5.1 The Hydrological Cycle

This cycle helps in the exchange of water among air, land, sea, living plants and animals. About one-third of the solar energy absorbed by the earth is used to drive the hydrological cycle—massive evaporation of water from the oceans, cloud formation and rainfall which supplies our reserves with freshwater.

Cloud
Lake Ground water
Precipitation Runoff
Cloud Sun
Ocean
Transpiration Evaporation Plant

Fig. 2.2: *The hydrological cycle*

At freezing temperature rainwater freezes into snow and forms hail in the presence of strong wind. Water as rain, snow and hail is precipitated on land and water surfaces. On land surfaces water seeps into the soil and is stored as groundwater. The natural water level or water table exists below the ground.

The water table is supported by the underlying clay and rock strata. Groundwater does not remain static but moves in various directions. It moves up and reaches soil surface where it is drawn by plant roots.

Another important groundwater resource is the aquifers. These exist above the impermeable rock strata—water percolates through porous rocks and forms these underground lakes or reservoirs. From the latter water can be pumped by digging tube wells and extracted by sinking wells.

When there is good rainfall, all the rainwater on land do not percolate into the soil. Surface water (run-off) flows into streams, rivers, seas, lakes and reservoirs. Normal evaporation from the oceans exceeds precipitation by 10 per cent. This excess 10 per cent moves as water vapour over land surface and balances the hydrological cycle. Plants absorb groundwater by root pressure and transpirational pull but give off excess water through leaves by the process of *transpiration*. Thus, water vapour level in the atmosphere is balanced and at the same time ensures conduction of water and dissolved mineral salts throughout the plants.

Thus, the hydrologic cycle consists of a balanced continuous process of evaporation, transpiration, precipitation, surface run-off and groundwater movements.

2.5.2 Nitrogen Cycle

Nitrogen and its compounds are essential for life processes in the biosphere. There is continuous exchange of nitrogen within the ecosystems operating the nitrogen cycle. Proteins produced by plants and animals in their metabolic processes are organic compounds of nitrogen. The major load of nitrogenous organic residue in soil originates from death and decay of plants and excreta of animals. These organic residues in soil are taken up by various soil micro-organisms for their metabolism which give products such as ammonia, nitrates

and nitrites. Plants absorb nitrates from soil which re-enter the nitrogen cycle. Some soil micro-organisms break down soil nitrate into nitrogen by denitrification process while others transform nitrogen into soluble nitrogen compounds (*see* Fig. 2.3).

micro-organisms

Chemical and atmospheric synthesis

Atmospheric Nitrogen
Nitrogen fixation by

Chemica l

Denitrificator

fixation

Nitrogen oxide

Nitrosomonas bacteria

Nitrate

Nitrate

Microbial decay

Nitrobacter

Ammonia

Fig. 2.3: *The nitrogen cycle*

2.5.3 Carbon Cycle

As carbon is the backbone of biological chemistry, the carbon cycle is a very important chemical cycle. The atmosphere is the minor reservoir of carbon dioxide while the oceans are the major reservoir, containing as much as 50 times more as that of air where it is stored as bicarbonate mineral deposit on the ocean floor. The latter regulates the carbon dioxide level in the atmosphere. The cycle operates in the form of carbon dioxide exchanging among the atmosphere, biosphere and the oceans (Fig. 2.4). The Carbon dioxide balance sheet per year is given:

(i) emissions by fossil fuel 20 billion tonnes, (ii) emissions by deforestation and changes in land use 5.5 billion tonnes,

(iii) uptake in the oceans 5.5 billion tonnes, (iv) uptake by carbon dioxide fertilization, i.e., photo-syn thesis, 7.3 billion tonnes.

Thus there is a net increase of carbon dioxide in the atmosphere of 11 billion tonnes per year. This can be reduced by 50 per cent if we can stop deforestation (Fig. 2.5).

The atmosphere contains 2700 billion tonnes of carbon dioxide; biosphere, vegetation and soil about 6600 billion tonnes and the oceans about 1,36,000 billion tonnes of carbon dioxide.

CO_2

CO_2 = Carbon dioxide

HCO_3^- = Bicarbonate

CO_3^{2-} = Carbonate

CO_2

HCO_3^- CO_3^{2-}

CO_2

CO_2

CO_2

Uptake by Photosynthesis

Atmosphere

CO_2

CO_2

CO_2

CO_2

CO_2

Ocean
uptake

Plants

Ocean

HCO_3^-

Auto
Factories
exhaust

Plants

Organic

CO_2 CO_2

HCO_3^-

CO_3^{2-}

CO_3^{2-}

(Biomass)

Carbon Mineral deposit

Fig. 2.4: *Sources and sinks of carbon dioxide*

Atmosphere
2700

Fertilization
3.7–11.1

3.7–7.4

Fuel 20

Photosynthesis
Deforestation

Ocean 3.7–7.4

Fig. 2.5: *Important fluxes of carbon dioxide (in billion tonnes)*

2.5.4 Phosphate Cycle

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

Phosphate minerals exist in soluble and insoluble forms in rocks and soil. Plants absorb inorganic phosphate salts from soil and change them into organic phosphate. Animals obtain their phosphate by eating plants. After death and decay, plants and animals return phosphates to the soil. Bulk of the phosphate in soil is fixed or absorbed on soil particles but part of it is leached out into waterbodies.

The natural phosphate cycle is affected by pollution, mainly from agricultural run-off containing superphosphate and also from domestic sewage. Phosphate pollution of rivers and lakes is the cause of algal bloom (eutrophication) which reduces dissolved oxygen in water and disrupts the food chain. The phosphate cycles on land and in water are shown in Figs. 2.6 and 2.7.

Animals

Plants

Dead organic
residues

Soil
phosphates

Run-off to rivers

Micro-organisms

Rocks
(Phosphates)

Fig. 2.6: *The phosphate cycle on land*

Ecology River

discharges

Phyto plankton

Zoo
plankton

Soluble
phosphates

Plants Animals

in water

Dead organic

residues

2.5.5 Sulphur Cycle

Micro
organism

Fig. 2.7: *The phosphate cycle*

Sulphur and its compounds are required by plants and animals for synthesis of some amino acids and proteins. Some sulphur bacteria act as the media for exchanges of sulphur within the ecosystems. The sulphur cycle (Fig. 2.8) illustrates the circulation of sulphur and its compounds in the environment.

The sulphur oxidation process is shown in the upper half of the cycle. The lower section shows the conversion of sulphate into plant and cellular proteins and the decay of dead plant and animal material by bacterial action. In polluted waters under anaerobic conditions hydrogen sulphide is produced by bacteria giving deposits of iron sulphide. In unpolluted waters under aerobic conditions the sulphur bacteria transform sulphides into sulphates for further production of proteins.

Atmosphere
SO_x

Sulphides Sulphates

Plants and
animals (proteins)

Anaerobic Aerobic

Organic residues
(proteins)

Micro-organisms

Fig. 2.8: *The sulphur cycle*

B. ENERGY

2.6 CONVENTIONAL ENERGY RESOURCES

The invention of steam engine in 1780 brought about Industrial Revolution in Britain. In 1799, Volta invented the *battery,* the first source of electric current. In 1820, Michael Faraday demonstrated a device—dynamo, for production of electricity using “dynamo” (electro-magnetic induction). Electricity generation using heat of steam marked the begin ning of thermal power production in the middle of 19th cen tury.

The demands on energy are increasing with progress in human civilization. The quality of life or standard of living is linked with the quantum of energy consumption. In USA,

per capita energy consumption is 200 million British Thermal Units, BTU (1 BTU = energy required to raise the temperature of 1 lb. of water by 1°F), 125 million BTU in UK, 50 million BTU in Japan and only 5 million BTU in India. But generally much of the energy (about 60 per cent) is wasted. Maximum wastage is observed in power plants and vehicles.

The conventional energy resources are fossil fuel (coal, petroleum and diesel), wood, natural gas, hydroelectricity and nuclear energy. The energy, as consumed by man, is: 33 per cent from petroleum and diesel, 27 per cent from coal and 5 per cent from nuclear fuels.

2.6.1 Coal

Coal is substantially more abundant than oil or gas, the total reservoir being 7×10^{12} metric tonnes, which is equivalent to 5×10^{22} calories. This is 1000 times more than the total global energy consumption from all fuels. The stock of coal is likely to last several centuries.

The natural defect of coal is that it is a dirty fuel to burn. On combustion, it emits sulphur dioxide which is an offensive gas, forms sulphuric acid in air and causes acid rain in far away places. Thus, it poses environmental hazards (*see* acid rain in previous chapter). Excavation of coal from mines is followed by soil subsidence (depression) which endangers the residential areas above the coal mines. Moreover, flyash arising from combustion of coal is a nuisance as solid waste which brings about environmental problems. Also being a solid, coal is less convenient to handle than petroleum or natural gas.

In order to overcome these problems, the developed countries use less polluting forms of coal by transforming it into gaseous, liquid or low sulphur, low-ash solid fuel. In a typical case, high-grade ash-free coal is produced as solvent refined coal (SRC) by suspending pulverized coal in a solvent and treating with 2 per cent of its weight of hydrogen at a pressure of 1000 pounds per sq. inch and 450°C.

The product is a semi-solid, m.p. 170°C having a calorific value of 16,000 BTU per pound. This compares well with the best-grade anthracite coal.

2.6.2 Thermal Power

Electricity is generated by combustion of coal in a furnace. This heat is utilised to produce steam at high temperature and pressure. The latter is then used to run a steam turbine which is linked with the generator producing electricity.

Thermal power stations are operated on the above principle by combustion of coal in a furnace.

Electricity

Coal
Furnace

Mechanical
Rotation

Generator

Steam

Heat

Steam turbine

Thermal power contributes about 65,000 megawatts (MW) of electricity i.e., 70 per cent of India's power supply. Some of the major thermal power stations of the National Thermal Power Corporation (NTPC) of India are at Singrauli and Rihand in U.P., Talchar in Orissa, and Farakka in West Bengal. They are the sources of severe air pollution.

2.6.3 Methanol, CH_3OH

It is a convenient liquid fuel which can be produced from coal. On a commercial scale, it is produced by the reaction of carbon monoxide (CO) and hydrogen (H_2) at 50 atmosphere pressure and 250°C in the presence of copper-based catalyst. The reactants (CO and H_2) are obtained from coal, oxygen and steam:

$$CO + 2H_2 \; CH_3OH$$
(methanol)

15 per cent methanol makes an excellent additive to gasoline which improves fuel economy and also cuts down the emission of practically all automobile pollutants.

2.6.4 Petroleum or Mineral Oil

The consumption of petroleum and natural gas is maximum in the developed countries and has become the status symbol of a country. USA is the largest consumer of petroleum in the world (about 80 per cent of total energy consumption in USA).

The Industrial Revolution (1780) was initially fuelled by coal but later on preference was given to oil and gas which provide cleaner fuels and easy transportation. The world reserve of petroleum is about 800 billion barrels (1 barrel = 31.5 gallons = 120 litres) which will last for less than 100 years.

80 Fuel

60 40 20

Coal
wood
Petroleum and
Natural gas

0
1860
1900 1940 1980

Fig. 2.9: *Energy consumption patterns in USA*

2.6.5 Hydroelectricity

The output from hydroelectricity (electricity from water) accounts for 21 per cent of total electricity generation, which is less than that from thermal power but greater than that from nuclear power. In Venezuela, South America, 10,000 mega-watts of hydroelectricity is produced which is equivalent to the production of electricity from 10 thermal power plants. In India, if water resources are properly utilised, it may be possible to generate more than 10,000 megawatts

of electricity. But at present, only 16 per cent or 6,500 megawatts of hydroelectricity is generated.

For generation of electricity from hydel project, it is nec essary to utilise energy produced from the descent of water from higher to lower level. In practice, a water reservoir is constructed by means of dam in a river for storage of water. Subsequently the stored water is released from upper level into a water-driven turbine placed at a lower level (Fig. 2.10) whereby electricity is generated. The hydel projects of Maithon, Panchyet and Jaldhaka are typical examples.

Electricity

Dam

Water
Reservoir

Turbine

Water

River

Fig. 2.10: *Hydroelectricity from hydel project*

The merits of hydroelectricity are: (1) clean source of energy; (2) no emission of greenhouse gases; (3) no consumption of fuel; (4) no need of high technology. But there are several environmental issues—flora and fauna in the region are disturbed due to construction of dam; local people become refugees as they are uprooted from their houses; the capacity of the reservoir gets reduced due to siltation; occurrence of floods in the area when surplus water has to be discharged in monsoon season. Hydroelectric dams are costly and take a long time for construction. In order to make hydroelectricity generation viable, it is necessary to adopt a long-term programme of afforestation, environmental

conservation, housing, public health and transport and ensure close co-ordination among these departments.

2.6.6 Nuclear Power

It contributes only 5 per cent of total electricity generation. Nuclear power plants do not emit polluting gases such as carbon dioxide, sulphur dioxide, like thermal power plants. But they have some severe drawbacks, viz. they are costly and release large quantities of radioactive fission products.

The radioactive wastes remain lethal (deadly) for thousands of years and for this no foolproof disposal method has been devised. That is why big nuclear power projects have not succeeded in the long run.

In India, the production target was fixed at 10,000 megawatts by 2000 AD, but the actual production is much less in the nuclear power stations at Tarapur, Rajasthan and Chennai. Nuclear power plants cannot match thermal power plants at present but in future, its unlimited resources will allow it to dominate the energy scenario when other energy resources are exhausted.

Zirconium–94

Neutron

Caesium–140

Uranium–235

Neutron

Neutron

Energy

Fig. 2.11: *Nuclear fission*

At present, nuclear fission is used to produce nuclear power. Heavy large atoms like Uranium and Plutonium split up into smaller atoms when bombarded by neutrons (nuclear particles with mass 1 and charge 0). This splitting or fission liberates vast amounts of energy, which through conventional techniques is converted into electricity. Thus nuclear power is generated.

It has been calculated that 1 kg of Uranium-235 on a complete fission by slow neutrons releases energy equal to 1.7×10^{13} calories. This means energy-wise, 1 lb. of Uranium 235 ≡ 5 million lbs. of coal ≡ 20 million lbs. of T.N.T. (highly explosive chemical).

This is the secret of nuclear energy/power.

2.6.7 Wood

Wood is a major renewable natural resource. The major important products are wood, paper, cellophane, rayon, plywood, plastic, particle board, turpentine, methanol, etc. In USA, the production of wood and wood products is the fifth largest industry. Ideally, as in USA forests cover 38 per cent. of the total land area; in India it has come down to about l5 per cent at present from 80 per cent, 2000 years ago.

It is interesting to compare between India and USA in respect of deforestation. In USA, the Sunday issue of the leading newspaper, **New York Times** *consisting of 500 pages requires 25 hectares (1 hectare = 2.5 acres = 7.5 bighas) of forest.* According to an estimate, an American destroys as much forest for his needs for paper as an Indian for his domestic fuel. The value of a 50-year-old tree has been estimated as about more than Rs 20 lakhs—the various functions of a 50-year-old tree are roughly evaluated as follows:

(i) Oxygen production (for 50 years) Rs. 2,50,000 (ii) Transformation into protein Rs. 20,000 (iii) Control of soil erosion Rs. 2,50,000 and soil fertility

(iv) Recycling of water and control Rs. 2,50,000 of humidity and atmospheric temperature

(v) Habitat for birds and other animals Rs. 2,50,000 and insects, etc.

(vi) Control of air and heat pollution Rs. 5,00,000 Total Rs. 15,20,000

This estimate excludes the value of timber/wood for furniture, fuels, medicines, etc. which will be an extra Rs. 3–4 lakhs.

Rayon

Wood/
turpentine

Cellophane

Particle board

Paper

Methanol

Plywood Plastics

Fig. 2.12: *Trees—sources of many important products*

Thus the tree, with its 50-year services as above, costs about Rs. 20 lakhs (1980 estimate) which at present market prices will be around Rs. 40 lakhs. The public should be made aware of the value of a tree and its services to man and environment during its life time.

In India, 76 per cent of population lives in villages—almost all of them use wood as fuel for cooking. This is the main reason for extensive deforestation in rural areas: each

year we are losing about 1.3 million hectares forests. Deforestation helps increase in greenhouse gas, carbon dioxide concentration. Hence for the welfare of the country as a whole, it is essential to minimise deforestation by adopting alternative resources of afforestation on a large scale to meet the needs of domestic fuel.

2.6.8 Natural Gas

It is a better fossil fuel than coal and petroleum since on burning, it produces less carbon dioxide. For production of one unit of energy, mineral oil, coal and wood, on burning, produces respectively 35 per cent, 75 per cent and 80–90 per cent more carbon dioxide than natural gas. Hence, natural gas is the obvious choice as a cleaner fuel. Its reserves, however, are limited and can continue to feed only for the next 70–80 years. At present, in India the exploitable reserve of natural gas is about 700 billion cubic metres.

2.7 NON-CONVENTIONAL ENERGY RESOURCES

2.7.1 Solar Energy

India, being a tropical country, is blessed with abundant sunshine, 2,000 kilowatt hour/sq. metre (kWh/m^2) per year for about 200–300 days in a year. The daily sunshine is between 5–7 kWh/m^2. This is an enormous and model energy resource, which is clean, pollution-free and inexpensive. It requires to be converted into other forms of energy by suitable techniques—it can meet our energy demands forever. The solar energy, incident on earth in one week, is equivalent to the energy from the entire coal reserve of the world. Again the solar energy available on earth for 45 minutes is enough to meet our energy demand for one year.

However, the major problem is that sunlight is diffused (widespread) in nature and difficult to be stored and utilized. But with advanced technology, the present high costs may be cut down so that solar energy can be utilized on a large

scale in future. At present, solar energy is ten times more expensive than thermal power. But with advanced technology, it will be cheaper and will hold the key to meet our energy demands in future.

Sunlight may be directly converted into electricity through photovoltaic cell. The latter is a device for conversion of light energy into electrical energy. The efficiency of conversion of light into electricity is only 18 per cent and it is expensive at current prices. We can use solar energy in two ways: (1) use of solar heat and (2) use of solar electricity. Use of the former permits one to boil water or dry foodgrains. Accordingly, several gadgets have been produced such as solar cooker (for cooking), solar dryer (for drying grains), solar water heater (for heating water), solar distillation (for water purification), etc. Recently there have been extensive use of these solar equipments in rural and semi-urban areas. By using the second method, i.e., solar cell, sun rays are converted into electricity. Since these solar cells are made of silicon, these are called *silicon cells*.

The advantages of solar photovoltaics are that they can replace systems which use diesel and they are free from chemical and noise pollutions. They could be installed in remote areas in forests and deserts where installation of electric cables are cost-prohibitive.

Solar power, with government subsidy (Department of Non-conventional Energy Source (DNES), Government of India) is being used in remote rural areas in West Bengal in the forms of solar lanterns, solar streetlights and solar pumps (for irrigation). Solar powered small pumps are being used in Delhi, Haryana and Himachal Pradesh. It is desirable to use solar cookers in villages on a large scale so that extensive deforestation can be prevented. About 1 tonne of wood per head per year can be saved by this process.

Figure 4.5 illustrates a detailed design for a solar heated house during winter in developed countries like USA. In these countries, 20–25 per cent of fuel is consumed for providing hot water to houses and buildings. Sunlight is collected on

plates in the roof and the heat is transferred to a circulating water system. An average house with roof area about 1300 sq. ft. in central USA can get its energy supply for heating and hot water supply in December by this method. This may well apply to hill station houses in India in Jammu & Kashmir, Nainital, Mussoorie, Darjeeling, etc. in December–January.

Sunlight

Solar
heated water

Hot water tap

Heated floor slab

Hot water storage tank

Details of heating system

120 m collector 2

Cold water
at 25°C

Pump on when

Solar heated water at
65°C
Hot water

supply at 65°C

heating
system
Pump on

To hot water
heating system

5000 gallon
water tank

From

main

sun shines
From water for heat

Fig. 2.13: *Solar heated house*

Figure 4.6 illustrates the function of a solar cell. Light is absorbed in a plate, with the generation of positive and negative charges, which are collected at the electrodes on either side. The silicon solar cell, developed for space programmes, consists of a sandwich of *n*-type and *p*-type silicon semi conductors (e.g., silicon, germanium is a crystalline substance which is intermediate between a metallic conductor on the one hand and non-conducting insulator on the other)—the charge separation is developed across the junction between them. *p*-type silicon conducts positive charge while *n*-type silicon conducts negative charge. The silicon cell produces electricity but is quite expensive since very high-grade crystalline silicon is required for the cell.

(Sunlight)
hv

p–n junction

p-type silicon
+ + n-type

=

silicon

+-+

Load

flow
–
Electron

Fig. 2.14: *Solar cell for electricity generation*

2.7.2 Biogas

This offers an important solution to the present energy crisis in rural areas. Besides being an important domestic energy source, it offers an environmentally-clean technology. There is a vast reserve of biogas in Indian villages. It is estimated that 1000 million tonnes of animal dung per year is available from 250 million cattle population. On an average 10 kg of wet dung is available per animal per day, which at 66 per cent collection efficiency, can yield 22,500 million cubic meters of biogas through biogas plants. This can replace kerosene oil whereby 14,000 million litres of kerosene per year

can be saved in villages. Besides, biogas slurries can produce 200 million tonnes of organic manure per year which can be a good substitute for chemical fertilisers for agriculture.

The composition of the biogas is: methane, carbon dioxide, hydrogen and nitrogen. The proportion of methane and carbon dioxide varies considerably as does the calorific value. At 40 per cent methane content, the calorific value is 3200 kcal/cubic metre, while at 50 per cent, it is 4500 kcal/cubic metre.

2.7.3 Wind Energy

This is a cheap and clean energy resource. India, with its climatic diversity, has areas which are quite windy. According to the Indian Meteorological Department, average annual wind velocity is 6.5 metres per second at a number of places in peninsular India as also along the coastlines of Gujarat, Western Ghats and parts of central India. Such velocities are available for 6–7 months in a year.

There are some limitations for setting up wind power mills or windmills. They require locations where the wind velocity is at least 6.5 metres per second. In Denmark and Holland, there are rows of windmills in extensive areas and these generate 50 megawatts of electricity. A standard windmill produces 55 kilowatts of electricity daily. Windmills spread over extensive areas on seashore or very high site present a beautiful scenery. Windmills prevent earthquakes where continuous wind flow causes soil erosion. In Scotland, Wales, Sweden, Germany and USA many windmills have been constructed for cheap generation of electricity.

The technology for harnessing wind energy has become commercial in some developed countries but in India it is still in the preliminary stage. The Department of Non conventional Energy Sources, Government of India has installed several wind pumps with pumping capacity of 20 litres. A windmill with a capacity to pump 400 litres of water per hour at a pumping head of 19 metres has been installed. Prospective sites are in Gujarat and Orissa on the seacoast. A 100-km stretch of coastline in areas having wind speed of

In France and Hungary, hot water from hot springs has been utilised for heating houses and agricultural farms.

Italy is the pioneer in this field. Later on USA, Philippines, Japan and New Zealand have been working on the exploration of geothermal energy as an energy resource.

During the oil crisis period in 1973, England developed the technology for harnessing geothermal energy. If in many areas wells are dug about 5-km. deep, then geothermal energy may be exploited. With advanced technology, it may be possible to generate electricity from geothermal energy in India and other developed countries.

2.7.6 Energy Plantation

Energy Production from Wastes

Energy can be produced from wastes—agricultural, industrial and municipal wastes.

Agricultural wastes are mainly crop residues. They are dried and used as fuel. Straw, jute sticks and other crop residues are burnt by villagers for cooking and partial boiling of paddy.

In certain industries, the waste materials can be utilised as a source of energy. Food processing, jute, sugar, paper and textile industries are the major industries where the waste materials can be utilised for the production of heat and electricity. Various processes have been developed for effective use of bagasse, jute, cotton and paper industries for energy production.

Petro-crops: Some latex-containing plants like *Euphorbias* and oil palms are rich in hydrocarbons and can yield an oil like substance under high temperature and pressure. This oily material can be burnt in diesel engines directly or may be refined to form gasoline.

2.7.7 Hydrogen Fuel

An attractive energy storage scheme is chemical storage in the form of H_2. This gas is generated directly by electrolysis of water (H_2O), as shown in Fig. 2.15. Electricity is passed between electrodes immersed in a conducting aqueous solution. H_2 is generated at the cathode and O_2 at the anode.

The energy stored in H_2 can then be reconverted into electricity using the reverse of the electrolytic cell called the *fuel cell*, as shown in Fig. 2.15. Here H_2 is oxidised at the cathodes, where electrons are produced, and passed through the circuit to the anode, where O_2 is reduced. The overall efficiency of this conversion and reconversion is quite lower to various energy barriers connected with the electrode processes. A lot of current electrochemical researches are centered on lowering these energy barriers.

Production of hydrogen Electron

Electron
flow

O_2 H_2 Pt wire

KOH
solution
OH OH

Anode reaction: $2O^-H \rightarrow H_2O \rightarrow H_2O + \frac{1}{2}O_2 + 2^-e$

Cathode reaction: $2H_2O + 2^-e \rightarrow H_2 + 2O^-H$

Production of electricity from hydrogen

O_2-deficient
air

flow H_2 for recycling
H_2

Air
or
O_2

KOH
solution
O^-H

Porous carbon
electrode
Electric motor Electron

Anode reaction: $\frac{1}{2}O_2 + H_2O + 2^-e \rightarrow 2O^-H$

Cathode reaction: $H_3 + 2O^-H \rightarrow 2H_2O + 2^-e$

Fig. 2.15: *Storage and production of electricity with hydrogen*

The problem of energy transport would be solved to a large extent by the ability to store energy in the form of H_2. H_2 transport by pipeline is more efficient and less expensive than electrical transmission over large urban centres. These considerations have given rise to the concept of the hydrogen economy (Fig. 2.16 in which H_2 will be the main energy currency). It can be consumed directly for electrical generation and heating, and can be used to synthesize liquid fuels by chemistry similar to that described for coal gasification.

Local power stations

Industrial fuels and
reducing gas
Synthetic

transport pipeline
chemicals and liquid fuel

Large electric power
and water
electrolysis plant Underground H_2

Domestic fuel

Fig. 2.16: *The Hydrogen economy*

2.7.8 Gasohol

Gasohol blended with up to 20% methanol or ethanol is known as gasohol. This can be used as a fuel in existing internal combustion engine, with little or no adjustment. Individually, methanol or ethanol itself can be used as fuel (instead of gasoline) in a suitable designed internally combustion engine. Methanol is produced by the destructive distillation of wood, or from synthesised gas manufactured from coal or natural gas (Sec. 2.6.3).

Because of its photosynthetic origin, alcohol is a renewable resource.

The manufacture of alcohol can be carried out by fermentation of sugar resulting from the hydrolysis of cellulose in wood wastes and crop wastes. Fermentation of these waste products provides an excellent opportunity for recycling.

Brazil is the leading country in the manufacture of ethanol for fuel. This country possesses few fossil-fuel resources, but it provides optimum conditions for the growth of large quantities of biomass from the fermentation of sugarcane. In Brazil, a new abundant source of fermentable biomass is *Cassava* or *manioc*, a root crop growing in large quantities throughout the country.

Questions

1. Name the major natural resources.
2. Give examples of (a) renewable and (b) non renewable resources.
3. What is the significance of forest resources? 4. Explain the imortance of biodiversity and its conser vation.
5. What are the sources of water? Name also the sources of freshwater. Express their quantities in term of percentage of water resources.
6. Name the important water quality perameters. Mention their tolerance limits as per USPH standards.
7. What are water-borne diseases?
8. Give an account of environmental factors for the outbreak of cholera. How can it be prevented? 9. Write a note on fluorosis.
10. What are the major minerals mined to the maximum extent?
11. How do you classify metals? Name some base metals and also precious metals.

12. Write notes on:

(a) Nitrogen cycle

(b) Carbon cycle

(c) Phosphate cycle

(d) Sulphur cycle

(e) Hydrologic cycle

13. Name conventional and non-conventional sources of energy. Compare their effects on environment. 14. What are the products of combustion of coal? Discuss their damaging effect on environment.

15. Starting from coal, how would you manufacture material?

16. Write notes on:

(a) Biogas

(b) Hydroelectricity

(c) Geothermal energy

(d) Hydrogen fuel

17. "Solar energy is the energy for future in India." Elucidate.

18. Comment on: "Wood is a major renewable energy resource — it offers multiple benefits to man, but it is vanishing fast."

Unit-III

A. ENVIRONMENTAL POLLUTION

Man-made activities have caused environmental degradation. We have degraded lands, destroyed forests at suicidal rates, thrown tonnes of toxic waste into rivers indiscriminately and poured toxic chemicals into the seas. Furthermore, we discharged green-house gases into the atmosphere leading to climatic changes. The net result is: we are surrounded by pollution in our daily lives—we breathe, we drink, we eat pollution.

We shall discuss water pollution, land pollution, noise pollution and air pollution in this and the next chapters.

3.1 WATER POLLUTION

The normal uses of water for public supply are—recreation (swimming, boating, etc.), fish, other aquatic life, and wildlife, agriculture (irrigation), industry, navigation, etc. Any change in the dynamic equilibrium in aquatic ecosystem (waterbody/biosphere/atmosphere) disturbs the normal function and properties of pure water and gives rise to the phenomenon of water pollution. The symptoms of water pollution of any water body/groundwater are:

- Bad taste of drinking water
- Offensive smells from lakes, rivers and ocean beaches
- Unchecked growth of aquatic weeds in waterbodies (eutrophication)

- Dead fish floating on water surface in river, lake, etc.
- Oil and grease floating on water surface

The quality of water is of vital concern for mankind since it is directly linked with human welfare. It is a historical fact that faecal (human excreta or stool) pollution of drinking water caused water-borne diseases, which wiped out entire populations of cities. In the developing countries like India, everyday some 25,000 people die of water-borne diseases, e.g., jaundice, hepatitis, cholera, dysentery, etc. In India about 2 lakhs out of 6 lakh villages have no access to safe drinking water—women have to walk 1–14 km daily for collecting water for drinking and cooking. In urban areas, 40 per cent people are without access to safe water. The major sources of water pollution are domestic sewage from urban and rural areas, agricultural run-off (wash water) and industrial waste which are directly or indirectly discharged into waterbodies.

3.1.1 Water Pollutants

The large number of water pollutants are broadly classified under the categories:

1. Organic pollutants
2. Inorganic pollutants
3. Sediments
4. Radioactive materials
5. Thermal pollutants

Organic Pollutants

These include domestic sewage, pesticides, synthetic organic compounds, plant nutrients (from agricultural run off), oil, wastes from food-processing plants, paper mills and tanneries, etc. These reduce dissolved oxygen (D.O.) in water. Dissolved oxygen (D.O.) is essential for aquatic life, the optimum level being 4–6 ppm (parts per million). Decrease in D.O. value is an indicator of water pollution. The organic

pollutants consume D.O. through the action of bacteria present in water.

Sewage and agricultural run-off provide plant nutrients in water giving rise to the biological process known as *eutrophication*. Large input of fertiliser and nutrients from these sources leads to enormous growth of aquatic weeds which gradually cover the entire waterbody (*algal bloom*). This disturbs the normal uses of water as the waterbody loses its D.O. and ends up in a deep pool of water where fish cannot survive.

The production of synthetic organic chemicals (more than 60 million tonnes each year since 1980) multiplied more than 10 times since 1950. These include fuels, plastic fibres, solvents, detergents, paints, food additive, pharmaceuticals, etc. Their presence in water gives objectionable and offensive tastes, odour and colours to fish and aquatic plants.

Oil pollution of the seas has increased over the years, due to increased traffic of oil tankers in the seas causing oil spill and also due to oil losses during off-shore drilling. Oil pollution reduces light transmission through surface water and hence reduces photosynthesis by marine plants, decreases D.O. in water causing damage to marine life (plants, fish, etc.) and also contaminates sea food which enters the human food chain.

Pesticides have been largely used for killing pests and insects harmful for crops and thereby boosting the crop production. At present, there are more than 10,000 different pesticides in use. They include insecticides (for killing insects), e.g., DDT (dichloro diphenyl trichloroethane), herbicides (for killing weeds and undesirable vegetation) and fungicides (for killing fungi and checking plant disease).

It has been found that pesticide residues contaminate crops and then enter the food chain of birds, mammals and human beings. The persistent pesticide, viz., DDT (which is

not degraded in the environment) accumulates in food chain, getting magnified in each step from seaweed to fish and then to man by about ten thousand times (10^4). Thus, the average level of DDT in human tissues is found to be

5–10 ppm, maximum being among the Indians (25 ppm) compared to the Americans (8 ppm).

Inorganic Pollutants

This group consists of inorganic salts, mineral acids, metals, trace elements, detergents, etc.

Acid mine drainage: Coal mines, particularly those which have been abandoned, discharge acid (sulphuric acid) and also ferric hydroxide into local streams through seepage. The acid on entering the waterbody destroys its aquatic life (plants, fish, etc.).

Sediments

Soil erosion, as a matter of natural process, generates sediments in water. Solid loadings in natural water are about 700 times as large as the solid loading from sewage discharge. Soil erosion is enhanced 5–10 times due to agricultural and 100 times due to construction activities. Bottom sediments in aquatic bodies (streams, lakes, estuaries, oceans) are important reservoirs of inorganic and organic matter, particularly trace metals, e.g., chromium, copper, nickel, manganese and molybdenum.

Radioactive Materials

Radioactive pollution is caused by mining and processing of radioactive ores to produce radioactive substances, use of radioactive materials in nuclear power plants, use of radioactive isotopes in medical, industrial and research institutes and nuclear tests. The discharge of radioactive wastes into water and sewer systems is likely to create problems in future.