

**TEXT BOOK OF
ENVIRONMENTAL STUDIES
(With Experiments)**

**For IIInd Semester B.Tech. Students of
GGSIPU, Delhi**

**STRICTLY AS PER
NEW SYLLABUS 2013-14**

Common to All Branches

**GGSIPU
IGDTUW**

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SYLLABUS

ENVIRONMENTAL STUDIES

(GGSIPU)

ETEN-114

UNIT I: ENVIRONMENTAL STUDIES: ECOSYSTEMS, BIO-DIVERSITY AND ITS CONSERVATION

(i) The Multidisciplinary Nature of Environmental Studies Definition, scope and importance of Environmental Studies. Biotic and a biotic component of environment, need for environmental awareness.

(ii) **Ecosystems:** Concept of an ecosystem, structure and function of an ecosystem, producers, consumers and decomposers, energy flow in the ecosystem, ecological succession, food chains, food webs and ecological pyramids. Introduction, types, characteristic features, structures and function of the following ecosystem: (a) Forest ecosystem (b) Grassland ecosystem (c) Desert ecosystem (d) Aquatic ecosystem (ponds, streams, lakes, rivers, oceans, estuaries).

(iii) **Bio-diversity and its Conservation:** Introduction to biodiversity—definition: genetic, species and ecosystem diversity, Bio-geographical classification of India, Value of biodiversity: Consumptive use, productive use, social, ethical, aesthetic and option values, Biodiversity at global, national and local levels, India as a mega-diversity nation, Hot-spots of biodiversity, Threats to biodiversity : Habitat loss, Poaching of wildlife, man-wildlife conflicts, rare endangered and threatened species(RET) endemic species of India, method of biodiversity conservation: *In-situ* and *ex-situ* conservation.[T1], [R3]

UNITII: NATURAL RESOURCES: PROBLEMS AND PROSPECTS

(i) **Renewable and Non-renewable Natural Resources:** Concept and definition of Natural Resources and need for their management • **Forest resources:** Use and over-exploitation, deforestation, case studies, timber extraction, mining, dams and their effects on forests and tribal people. • **Water resources:** Use and over-utilization of surface and ground water, floods, drought, conflicts over water, dams-benefits and problems, Water conservation, rain water harvesting, watershed management. • **Mineral resources:** Uses are exploitation, environmental effects of extracting and using mineral resources, case studies. • **Food resources:** World food problems, changes causes by agriculture and over-grazing, effects of modern agriculture, fertilizer-pesticide problems, water logging, salinity, case studies. • **Energy resources:** Growing energy needs, renewable and non-renewable energy sources, use of alternate energy sources, Urban problems re-

lated to energy, case studies. • **Land resources:** Land as a resource, land degradation, man induced landslides, soil erosion and desertification. [T1], [R3]

UNIT III: ENVIRONMENTAL CHEMISTRY AND POLLUTION CONTROL

(i) **Chemistry of Environment** (a) **Green Technology:** Principles of Green technology, Zero Waste Technology, Green Chemistry & Its basic principles, Atom Economy, Green Methodologies, clean development mechanisms (CDM), concept of environmental impact assessment, (b) **Eco-Friendly polymers:** Environmental degradation of polymers, Biodegradable, Photo-biodegradable polymers, Hydrolysis & Hydrobiodegradable, Biopolymers & Bioplastics: polylactic acid, polyhydroxybutyrate, polycaprolactone., Concept of bioremediation.

(ii) **Environmental Pollution:** Definition, types, causes, effects and control measures of (a) Air pollution, (b) Water pollution, (c) Soil pollution, (d) Marine pollution, (e) Noise pollution, (f) Thermal pollution, (g) Nuclear hazards. Pollution case studies. Solid waste and its management: causes, effects and control measures of urban and industrial waste.

Chemical toxicology: Terms related to toxicity, impact of chemicals (Hg, As, Cd, Cr, Pb) on environment.

UNIT IV: DISASTER MANAGEMENT, SOCIAL ISSUES, HUMAN POPULATION AND THE ENVIRONMENT

(i) **Disaster Management:** Disaster management: floods, earthquake, cyclone and land-slides, nuclear accidents and holocaust, case studies.

(ii) **Social Issues, Human Population and the Environment:** Sustainable development, Climate change, global warming, acid rain, ozone layer depletion, Environmental ethics: Issues and possible solutions, Consumerism and waste products, , Wasteland reclamation. Population growth, problems of urbanisation. Environment Protection Act, 1986; Air (Prevention and Control of Pollution) Act, 1981; Water (Prevention and Control of Pollution) Act, 1974; Wildlife Protection Act, 1972; Forest Conservation Act, 1980; Environmental management system standards-ISO 14000 series.[T1]

ENVIRONMENTAL STUDIES

(IGDTUW)

BAS-106

UNIT 1:

Natural Resources, Conservation and Management: Forest resources: Use and over-exploitation, deforestation, Timber extraction, mining, dams and their effects on forest and tribal people. Water resources: Use and over-utilization of surface and ground water, floods, drought, conflicts over water, dams-benefits and problems. Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources. Food resources: World food problems, changes caused by agriculture and over-grazing, effects of modern agriculture, fertilizer-pesticide problems, water logging, salinity. Land resources: Land as a resource, land degradation, man induced landslides, soil erosion and desertification. Energy resources: Growing energy needs, renewable and non renewable energy sources. Biodiversity conservation and threats. Resource Management-Concept of Sustainable development, Environmental Acts and regulations, Environmental Management Systems, Environmental Impact Assessment

UNIT 2:

Environmental Pollution And Control: Air Pollution: Types of air pollutants: Source, effects, sink & control of common air pollutants (CO, oxides of nitrogen & sulphur, hydrocarbons and particulates). Photochemical smog, acid rain, green house effect, global warming, Carbon dioxide sequestration and the concept of Carbon Credits Water Pollution: Classification of pollutants and their sources, Waste water treatment (Primary, secondary and tertiary treatment), Impact of water pollution on hydrological ecosystems. Solid and Hazardous Waste Pollution: Classification, waste treatment and disposal methods: Sanitary landfill, thermal processes, chemical and biological processes, disposal methods for nuclear waste, nuclear disaster (case study), disposal methods for e-waste.

Green Technology And Green Chemistry: Introduction to concept of Green Technology and Zero Waste Technology, Green Chemistry & its basic principles, Atom Economy, evaluation of feedstock, reaction types, methods, reagents and solvents

UNIT 3:

Fuels and Alternate Energy Sources: Classification, Calorific value of fuels (gross and net), Dulong's formula, Determination of calorific value of fuels using bomb's calorimeter, Determination of calorific value of fuels using Boy's Gas Calorimeter, Proximate and ultimate analysis of Coal, High & Low temperature carbonization, Manufacture of coke (Otto – Hoffmann oven) Liquid fuels-petroleum chemical composition, fractional distillation, Cracking – Thermal & catalytic cracking, Octane & Cetane numbers with their significance. Analysis of flue gases (Orsat's Apparatus), Combustion of fuels. Use of alternate energy sources including solar energy harnessing (photovoltaics), wind energy, hydroenergy, geothermal energy, ocean energy, biodiesel, power alcohol, biomass energy.

UNIT 4:

Chemical Toxicology: Toxicology: terminology & toxic effects, chemical interactions, impact of toxic chemicals on enzymes, Biochemical effects of arsenic, mercury, lead, chromium, & cadmium, Biochemical effects of pesticides.

Eco-Friendly Polymers: Introduction: Functionality of monomer, polymerization, degree of polymerization, Number average and weight average molecular weight of polymers. Environmental degradation of polymers: Biodegradable, Photo-biodegradable polymers, Hydrolysis & Hydro-biodegradable polymers Biopolymers & Bioplastics, Thermal degradation of plastics during recycling

TEXT BOOK OF
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Published by:

S.K. Kataria & Sons®

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e-mail: katariabooks@yahoo.com

First Edition: January 2014

Price : ₹ 175/-

Laser Type Setting by:
SARAASSIGNMENTS, Delhi

Printed at:
A.S. OFFSET PRINTERS, Delhi

Preface

We are highly indebted to the faculty and students of various engineering colleges for their enthusiastic response to our previous work. Their tremendous appreciation has boosted our confidence and this book continues with the same spirit: presentation of the concepts in a clear, interesting and student friendly manner.

This book is intended to provide an in-depth coverage of wide range of topics, keeping in view all the important aspects of Environmental Sciences.

The text presented has been reviewed by the colleagues at other colleges and universities. We profoundly thank the reviewers for their valuable comments which have been used to polish the book in its present form.

While every effort has been made to eliminate errors in this book, inadvertently some will have crept through. We would appreciate notification by readers of any error or misprints.

We hope that readers will find the text interesting and informative at the same time.

Authors

Acknowledgements

We express our deep sense of gratitude and reverence to Prof. Nupur Prakash, Vice-Chancellor, Indira Gandhi Delhi Technical University for Women, Delhi and Dr. Ashok Kumar Chauhan, Founder President, RBFF whose inspiring words, stimulating encouragement and unflinching support have been a source of great strength in accomplishing this assignment.

We are highly indebted to Dr. D.C. Parashar, Scientist Emeritus (ex., CSIR) NPL, New Delhi; Prof. K. Gadgil, Centre for Energy Studies IIT, New Delhi and Prof. B.N. Mishra, Emeritus Fellow, H.P. University, Shimla. The principles of balanced scientific reporting learnt from them would go a long way in pursuit of future ventures.

One of the authors expresses her sincere gratitude to Sh. Atul Chauhan, Chancellor, Amity University, Uttar Pradesh for his continued encouragement and Dr. Balvinder Shukla, Acting Vice-Chancellor, Amity University for excellent professional guidance and encouragement.

We acknowledge our innumerable thanks and deep appreciation for our academician friends and colleagues for their support, significant inputs and constructive suggestions during the course of writing this book.

Our sincere thanks are due to Dr. Atanu Bhattacharya (BVCOE) for his special contribution for the chapter on Disaster Management.

No words can suffice to express our deep feelings for our family members (Dillip, Praneesh, Rajeev, Rachit, Ruchin, Sarthak, Samarth, Tanishq and Tanvi) for their moral support, understanding and unending patience without which the work was well nigh impossible.

Our special thanks are due to Mr. S.K. Kataria, Mr. Sharda Singh, Mr. Dinesh, Mr. Sachin Tyagi and the entire staff of S.K. Kataria & Sons Publications for their efforts in bringing out this book.

Authors

UNIT I

Multidisciplinary Nature of Environmental Studies

“Waste not the smallest thing created, for grains of sand make mountains, and atomies infinity”
— E. Knight

Objectives

- Introduction- Objectives and Importance of Environmental Studies
- Need for Public Awareness
- Introduction to the Concept of Green Technology

1.1 INTRODUCTION

Environment (from the French *environner*: to encircle or surround) can be defined as the circumstances or conditions that surround an organism or group of organisms. Alternatively it can be defined as the combination of

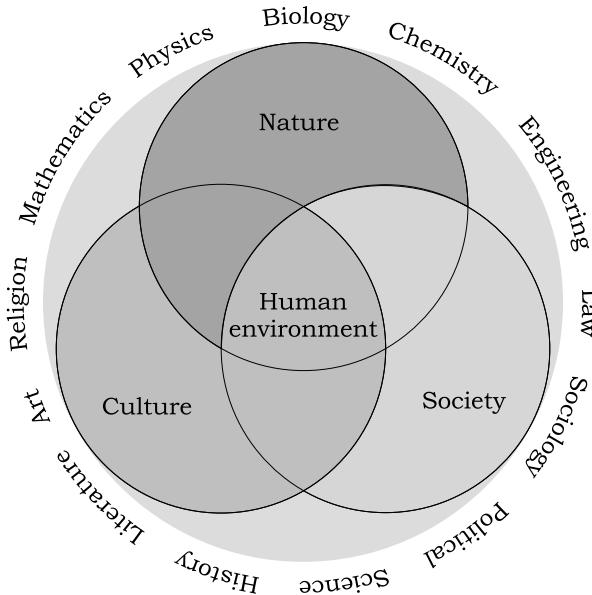


Fig. 1.1 The intersections of the natural world with the social and cultural worlds encompass our environment. Many disciplines contribute to environmental science and help us understand how our worlds intertwine as well as our proper role in them.

social or cultural conditions that affect an individual or community. Since humans inhabit the natural world alongwith technological, social and cultural world, together these constitute important parts of our environment (Fig 1.1).

Environmental Studies, is the systematic understanding of our environment and our existence in it. It includes many interconnected problems involving human population, Earth's natural resources and environmental issues or problems. It is highly interdisciplinary and integrates natural sciences, social sciences and humanities in a broad holistic study of the world around us.

1.1.1 Objectives of Environmental Studies

The objectives and guiding principles of environmental studies are as follows:
(UNESCO, 1971)

1. **Awareness:** To acquire an awareness and sensitivity to the total environment and its allied problems.
2. **Knowledge:** To gain experience and acquire basic understanding of the environment and its associated problems.
3. **Attitude:** To acquire set of values and develop feelings of concern for the environment and build motivation for active participation in environmental improvement and protection.
4. **Skill:** To develop skills in identifying and solving environmental problems.
5. **Participation:** To provide an opportunity to be activily involved at all levels in working towards resolving environmental problems.

1.1.2 Importance of Environmental Studies

The important social and economic benefits that would result from government's initiative towards the propagation of Environmental education are:

- Conservation of energy by introducing alternate sources, improved technologies and processes compatible with environment.
- Increase in economic productivity through improved health of people.
- Conservation of fast depleting natural resources and to find ways and means to maintain ecological balance.
- Imparting knowledge about waste management, treatment and disposal techniques to keep away from the hazards.
- Develop social responsibility towards control of environmental pollution and protection.
- Creating awareness in people to control population.
- Inculcating attitude and values towards understanding the interdependence of nature and man and work towards sustainable development.

1.1.3 Role of Environmental Scientists

Environmental Scientists try to establish general principles about how the natural world functions. They use these principles to develop viable solutions to environmental problems based on scientific knowledge. The five elements or stages which contribute to addressing an environmental problem are (Fig 1.2):

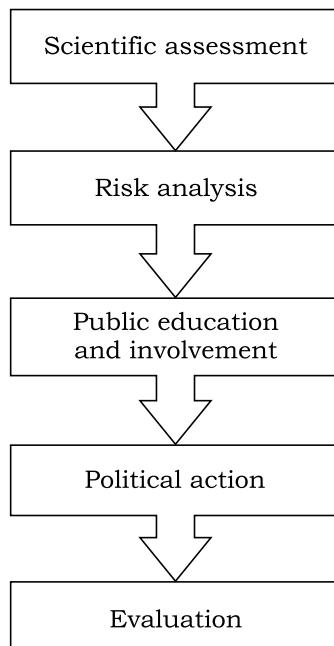


Fig. 1.2 Addressing environmental problems. These five steps provide a framework for addressing environmental problems

1. **Scientific assessment:** The first stage is the collection of information. The problem is defined and then the data are collected and experiments and simulations are performed to construct a model. This model then helps to understand how the problem arose and how to predict the future course of events.
2. **Risk analysis:** Using the results of the scientific investigation, the potential effects or the risk of one or more remediation options are calculated.
3. **Public education and involvement:** In a democratic country like India, public awareness and endorsement through media is an essential part of addressing environmental problems. When alternative courses of action exist, then the affected parties i.e., the public must be informed. This involves the explanation of the problem and the alternatives for action alongwith probable costs of each option.
4. **Political action:** The affected parties, through their elected officials, decide a course of action and implement it. Ideally the course of action

is based on the best evidence. But during a political process the action is based on economic, social and political considerations rather than scientific evidence.

5. **Evaluation:** The results of any action taken should be carefully monitored to see if the problem is really being addressed and also to improve the initial assessment and modeling of the problem.

However, in real life, addressing environmental problems is quite complex particularly when the problem is of regional or global level. Quite often the public becomes aware of the problem and starts discussing remediation measures before the problem is clearly identified.

1.1.4 Major Global Environmental Problems

Our planet, Earth is unique in the universe. Compared to the conditions on other planets in the solar system, temperatures on the earth are mild and relatively constant. Plentiful supplies of clean air, fresh water and fertile soil are regenerated endlessly and spontaneously by various geological and biological cycles like the carbon cycle, Nitrogen cycle, phosphorus cycle, sulfur cycle, etc. The most amazing feature of the Earth is the rich diversity of life that exists here. Millions of beautiful and intriguing species populate the earth and help sustain a habitable environment.

While there are many things about the Earth, which make it unique, there are many Environmental problems which need to be addressed:

Rapid population growth: Human populations have grown at alarming rates in this century, from 2.5 billion in 1950 to 7.8 billion in 2010. Unless birth rates are balanced with the death rates, it may reach 10–11 billion by 2050 and 14 billion by 2100. Most of the growth is in the developing and poorer countries where resources and services are already strained by present populations.

Food shortage and famines: These are too familiar in many places and may increase in frequency and severity if population growth, soil erosion, and nutrient depletion continue at the same rate in the future as they have in the past. *Food security* often is linked to *poverty, democracy* and *equitable distribution* than it does with the amount of food available.

Water shortage: Water deficits and contamination of existing water supplies are threatening environmental issues in the future for agricultural production as well as for domestic and industrial uses. Many countries already have serious water shortages and more than one billion people lack access to clean water and proper sanitation. This may lead to violent conflicts over control of natural resources if we do not learn to live within nature's budget.

Depletion of non-renewable fossil fuels: Fossil fuels are rapidly depleting due to their overutilisation by the growing population alongwith growth in industrialization all over the world. Their use is leading to air pollution

and damage to the environment. Cleaner renewable energy resources like solar, wind, thermal and biomass etc. together with conservation may replace environmentally destructive energy sources if appropriate technologies are applied.

Damage to the Environment: Burning of fossil fuels and biomass fuels release carbon dioxide and other heat absorbing species like black carbon, hydrocarbons etc. that cause *global warming* and may bring about sea-level rise and catastrophic climate change. Acids formed in the air due to Sulphur dioxide and Nitrogen oxide emissions from fossil fuel combustion cause extensive damage to the building materials and sensitive ecosystems in the form of *acid rain*.

Chlorinated compounds, such as chlorofluoro carbons used in refrigeration and air conditioning, also contribute to *global warming*, as well as *damage to the stratospheric ozone* that protects us from cancer-causing ultraviolet radiation in sunlight.

Deforestation and threat to biodiversity: Deforestation of tropical forests, coral reefs, wetlands and other biologically rich landscapes is causing an alarming loss of species and a reduction of biological variety and abundance that could severely limit our future options. Many rare and endangered species are threatened directly or indirectly by human activities like agriculture, building of dams, factories, highways, mining operations etc.

Disposal of solid and hazardous wastes: Mountains of solid and hazardous wastes are becoming an overwhelming problem throughout the world. We produce millions of tons of these hazardous materials annually and much of it is disposed off in dangerous and irresponsible ways.

The health effects of pollution, toxic wastes, stress and other environmental problems of this modern age have become a greater threat than infectious diseases for the whole world. The serious Global issues illustrate the importance of environmental science and environmental education for everyone.

“We have not inherited this beautiful earth from our ancestors, rather we have borrowed it from our children”

What we are doing to this world and what they may mean for our future and to our children is of paramount concern as we proceed through the twenty-first century.

1.1.5 Solutions Toward Global Issues (Ray of hope ...)

Increasing awareness towards the environmental issues have led the society to work towards finding solutions to these problems. Progress has been made by establishing laws, policies and treaties in controlling air and water pollution and reducing wasteful use of resources. Food production has improved the nutrition of millions in the developing world, and the

Note: **Biodiversity** is the number and variety of organisms found within a specified geographic region. It refers to the varieties of plants, animals and micro-organisms and the ecosystems they form.

percentage of individuals who are undernourished has declined from 35% to 20% over the past thirty years. Population has stabilized in most industrialized countries and even in some very poor countries where social security and democracy have been established. Over the last twenty years, the average number of children born per woman world wide has decreased from 6.1 to 3.4. This is still above the zero population growth rate of 2.1 children per couple, but still it is an encouraging improvement. If this rate of progress continues in the next twenty years as it has in the past, the world population could stabilize early in this century.

The incidence of life threatening infectious diseases has been reduced sharply in most countries during the past century, and the average life expectancy has nearly doubled. Many alternate resources have been discovered and more efficient ways of using existing supplies have been invented that allow us to enjoy luxuries and conveniences that would have seemed miraculous only a few generations ago.

We, individually and collectively can do much more to protect and restore our environment. Being, aware of the problems we face is the first step towards finding their solutions. We are in a position to address these issues because we have resources, motivation and knowledge to do something about our environmental problems.

"If we don't act now, we may not have another chance to do so".

1.2 NEED FOR PUBLIC AWARENESS

Environmental Studies/Education is a process of recognising values and clarifying concepts in order to develop skills and added tools necessary to understand and appreciate the inter-relationship among man, his culture and his bio-physical surrounding. It creates an overall perspective, which acknowledges the fact that natural environment and man-made environment are interdependent. The protection and preservation of environment in totality is thus a foremost issue. Every person, organisation and institution has an obligation and duty to protect it. Environmental consciousness deserves to be propagated at all levels. Environmental conservation can be achieved if we all share a single thought, the thought of creating a better world to live in, the thought to give a better deal to everyone, human or otherwise, to the present as well as to the future generation who all have to share the Almighty's great gifts of clean environment and abundant natural resources on this planet earth.

Environmental protection encompasses not only pollution but also sustainable development and conservation of natural resources and the eco-system. Environmental degradation can be either localised such as the depletion of a nation's forest resources, or global, such as destruction of the ozone layer. Environmental studies/Education is thus a continuous lifelong process beginning at the pre-school level and continuing through all stages. It is of inter-disciplinary nature and examines major environmental issues from local, national and international point of view. It should utilize various educational approaches to teach and learn about

and from the environment with stress on practical activities and first-hand experience. It is through this process of education that people can be sensitized about the environmental issues.

The major goals of imparting Environmental Education and training are:

- Development of educational/teaching materials and aids in the formal education sector;
- To encourage non-governmental organisations, mass media and other concerned organisations for promoting awareness among the people at all levels;
- To promote environment education through existing educational/scientific/research institutions;
- To ensure training and manpower development in environment education; and.
- To mobilise people's awareness for the preservation and conservation of environment.

To achieve the above goals, the Ministry of Environment and Forests has been implementing several schemes and programmes. Some of the major schemes implemented for imparting environmental education and for creation of environmental awareness among the general public are as follows:

1.2.1 Formal Environmental Education

Though formal education is the mandate of the Ministry of Human Resource Development (MHRD), the Ministry of Environment & Forests has been interacting with the MHRD, NCERT, State Departments of Education etc. to ensure that environmental components are adequately covered at the school levels by infusion into the school curricula at various levels. The major initiatives taken by the Ministry in this direction are mentioned below:

(i) Environmental Education in School System

Under this project, which was initiated in 1999, an exercise to strengthen environmental education in the formal school curriculum has been undertaken. During the first phase of this project, a comprehensive study was conducted to assess the status of infusion of environment content in the school curriculum in the country and to assess the effectiveness of classroom teaching. The study was conducted in all the States and Union territories of the country and textbooks of all the classes from standards I to XII were analysed. Based on the findings of the study, the textbooks in Science, Social Science and Languages of middle school level have been modified to strengthen the infusion of environmental concepts. The modified textbooks are being used since 2002 in the schools around the country. The concerned teachers of the selected schools have also been trained to effectively teach the modified textbooks.

(ii) Environmental Education at College & University level

There are nearly two hundred departments of Environmental Studies in the universities and colleges all over India. They offer degree or diploma programmes covering all aspects of environmental science and engineering. There are also diplomas, bachelor's degree, M.Sc, M.Phil and Ph.D programmes in Environmental Sciences or Environmental Studies. Besides these, M.E., M.Tech and Ph.D programmes in Environmental Engineering are offered by Civil Engineering and Chemical Engineering departments.

Post graduate degree programmes in Environmental Management and courses, which lead to M.Sc in Environmental Chemistry/ biology/Geology or environmental toxicology are also available. Environmental education at doctoral level is also available in a large number of autonomous Research and Development (R and D) institutions founded by central government, state governments and agencies such as CSIR, ICAR and ICMR i.e. formal education in environmental science or engineering is available in India upto the highest possible level.

(iii) Environmental Appreciation Course

Though there are several courses on environmental sciences at present in the formal system, there were no structured courses available outside the formal system for people who desire to learn about environmental issues. IGNOU alongwith Ministry of Environment and Forests (MOEF) have developed a non-credit awareness course of three months duration. The main objectives of the course are to create environmental consciousness and facilitate development of environmental leadership among individuals who may organize/participate in environmental upgradation programmes.

(iv) Environmental Concepts in Management & Business Studies

Realising that the industry Managers and leaders need to be sensitized towards environmental issues and concepts of Environmental Management so that they can play an important role in introducing environmentally sound practices in their operations, the Ministry has taken an initiative to introduce/enhance environmental concepts in the Business/ Management Education. A committee comprising representatives from Management Institutions, Industries, All India Council of Technical Education (AICTE), University Grants Commission (UGC), and Ministry of Environment and Forest (MOEF) is already looking into various aspects like course content and syllabi of the existing courses so that gaps could be identified and suggestion could be given for enhancing/introducing the environmental content where necessary.

1.2.2 Non-formal Environment Education and Awareness

Environmental Education, Awareness and Training plays a significant role in encouraging and enhancing people's participation in activities aimed at conservation, protection and management of the environment, essential for achieving sustainable development. The Ministry, therefore, accords priority for the promotion of non-formal environment education and creation

of awareness among all sections of the society through diverse activities using traditional and modern media of communication. Some of the major activities undertaken in this regard are as follows:

(i) *National Environment Awareness Campaign (NEAC)*

The NEAC was launched in mid-1986 with the objective of creating environmental awareness at the national level. It is a multi-media campaign which utilises conventional and non-conventional methods of communication for disseminating environmental messages to a wide range of target groups. Under this campaign, nominal financial assistance is provided to registered NGOs, schools, colleges, universities, research institutions, women and youth organisations, army units, State Government Departments etc. from all over the country for organising/conducting awareness raising activities. These activities which include seminars, workshops, training programmes, camps, padyatras, rallies, public meetings, exhibitions, essay/debate/painting/poster competitions, folk dances and songs, street theatre, puppet shows, preparation and distribution of environmental education resource materials etc., are followed by action like plantation of trees, management of household waste, cleaning of water bodies etc. Diverse target groups encompassing students, youth, teachers, tribals, farmers, other rural population, professionals and the general public are covered under NEAC. The programme is being implemented through Regional Resource Agencies (RRAs) for specific states/regions of the country.

(ii) *Eco Clubs (National Green Corps)*

The main objectives of this programme are to educate children about their immediate environment and impart knowledge about the eco-systems, their inter-dependence and their need for survival, through visits and demonstrations and to mobilise youngsters by instilling in them the spirit of scientific inquiry into environmental problems and involving them in the efforts of environmental preservation.

Since the modification of the scheme in 1993, large number of Eco-clubs have been provided grants in various parts of the country. Keeping in view the potential of this programme in sensitizing the school students, this programme is being intensely covered in each and every district of the country.

A programme of raising 'National Green Corps' (NGC) through the Eco clubs was, launched during 2001-2002. Under this programme, Eco-clubs are being set up in more than 100 schools of each District of the country. Almost 50,000 Eco-clubs have been set up so far in the country. This programme is being implemented in each State/Union Territory through the Nodal agency appointed by the State/Union Territory Govt.

The Government of India provides financial assistance for establishment of Eco clubs, training of Master Trainers, teacher training and distribution of resource materials.

(iii) Global Learning and Observations to Benefit the Environment (GLOBE)

The GLOBE is an international Science and Education Programme, which stresses upon hands-on participatory approach. India joined this programme during August, 2000. This programme, which unites students, teachers and scientists all over the world, is aimed at school children. The students of GLOBE schools are required to collect data about various basic environmental parameters under the supervision of a GLOBE trained teacher and use it for explaining hypothesis as well as to enhance their scientific understanding of the earth. This data is also used by the scientists in their research work. The GLOBE also provides an opportunity to the students to interact not only with the GLOBE scientists but also with the students from GLOBE schools in other parts of the world. Many schools spread over different parts of the country have already joined this programme. The teachers of these schools have also been trained in various GLOBE protocols. International training workshops for trainers are held from time to time and the participants at these workshops are trained in Basic and Advanced GLOBE Protocols by a training team from GLOBE Headquarters in USA.

(iv) Mass Awareness

Despite great efforts to spread environmental awareness by the Ministry through several schemes, it is felt that a large population especially in rural areas is still left out. The best way to reach out to them and make them aware of the environmental problems is through media, particularly the electronic media. "Mass Awareness" has therefore been identified as one of the thrust areas of the Ministry, not only to intensify the efforts already being made in this direction but also to launch new initiatives. The Doordarshan and few other television channels are extensively used for telecasting environment based programmes and commercials. Professional Media agencies which are hired to assist the Ministry in carrying out the campaign also play a major role. To encourage individual efforts in producing films/documentaries on environment/wildlife related themes in the country, the Ministry sponsors organisation of film festivals.

(v) Other Awareness Program

The Ministry also sponsors various programs which do not fit into programs like NEAC, NGC, etc., and are aimed at creating environmental awareness among children. These include environment quiz (both written as well as televised), organization of activities for observation of special occasions such as earth day, special programs for children, etc. These proposals which are received throughout the year from various NGOs and other agencies, are considered on merit as and when received and are supported. Few examples of such programs are:

- An international written Environment Quiz program known as Green Olympiad conducted by TERI. It is conducted in more than 200 centers across the country. Every year the quiz is conducted in both Hindi and English and more than 80,000 school students from India, Russia and UAE and other countries participate in this competition.

- Awareness activities/events by NGOs, academic institutions etc. on the occasion of special Environment days like Earth Day etc.
- Written environmental quiz programs in different regional languages is also being done. The winners of written quiz participate in a televised quiz program.
- Organization of an annual Vacation Program on Environmental Resources for high school level students namely “Vacation program on Natural resources- building a broader constituency of support for conservation” by Ashoka Trust for Research in Ecology and the Environmental (ATREE) an NGO.

(vi) Centres of Excellence

This scheme was started in 1983 to strengthen awareness, research and training in priority areas of environmental science and management.

The Centres of Excellence have been established by the Ministry for providing financial assistance.

The proposals on the priority areas on environment received by the Ministry are referred to experts for comments and considered by an Internal Committee constituted under the scheme.

1.3 INTRODUCTION TO THE CONCEPT OF GREEN TECHNOLOGY

Technology in the 20th century was a boon for mankind. It brought prosperity and modernization in the society by the utilization of natural environmental resources. The advancement in science & technology threatened the ecological security of the earth due to over utilization and indiscriminate exploitation of scarce and exhaustible resources. The use of natural resources in such unsustainable manner led to the generation of huge amounts of chemical and synthetic wastes and pollutants as by-products of the development. These synthetic materials generated as a by-product or as waste after their use cannot be decomposed in nature and hence their safe disposal is creating extraordinary technical, health, environmental, economic, political and social problems. Another serious concern is that all living organisms including human beings have been exposed to such synthetic and toxic materials on the road to technological development for which there has been no evolutionary adoption and experience.

Thus today, the social pressure is working towards evolving environment friendly technologies for the sustainable development. Thus development is redefined as the “Development to meet the needs of the present without compromising with the abilities of the future generations to meet their own needs and a system of stable economic development that should improve the total quality of life on earth now and in the future too, while maintaining the social and ecological integrity of the earth upon which all life depends”.

Thus “green technology” abbreviated as Clean Tech (Clean Technology) is the application of Environmental Sciences to conserve the natural

environment and resources and by curbing the negative impacts of human involvement. It is a continuous process of development of materials and methods for generating energy to give non-toxic products. It is believed that the changes which this technology will bring, will be of similar magnitude to that of Information Technology.

Expected Goals from this Technology

Sustainability: It will help to meet the present needs of the society without compromising the needs of future generation.

Cradle to Cradle Design

The products obtained by this technology should not have any toxic effects on the environment. On the contrary, if any by-products are obtained, they should be used in other processes.

Source Reduction

Emphasis is laid here on ‘atom economy’ so that the waste generated (by products or the unreacted reactants) is minimum in the reaction technology. The concept of atom economy is discussed in detail in chapter 8.

Innovation

This technology will look into the alternatives to the existing technologies which are harmful to human health and environment. For instance, these days a lot of research is being done on biofuels which can be used instead of the existing fossil fuels causing global warming.

Viability

The technology used should not only be environmentally benign but also at the same time be economical to enhance its implementation.

1.3.1 Areas Covered Under Green Technology

Energy

This is one of the most important areas of green technology which lays emphasis on the opportunities for development of the future alternative fuels for generating energy.

Green Buildings

This includes the substances used as building materials and the location of the building.

Environmentally Preferred Purchasing

This is targeted mainly on the ‘governmental purchasing’ where care should be taken to avoid buying of toxic substances.

Green Nanotechnology

Nanotechnology means when the materials used are reduced to the nano scale i.e. one billionth of a meter. The application of Green technology to hand scale will bring a lot of development changes.

Green Chemistry

Chemists are addressing complicated environmental issues in safe and profitable manner under various names like clean chemistry, environmentally benign or favourable chemistry, sustainable chemistry and more popularly green chemistry, which means the judicious use of chemistry for prevention of pollution. It involves modified engineering practices, bioremediation, ecofriendly reaction media and concepts of atom economy leading to almost zero waste.

All green environmental technologies for sustainable development have to be cost-effective, economically viable, ecologically sustainable and socially acceptable. Acceptance of a technology by the society plays a very crucial role in its implementation and promotion. Cheaper and cost effective technology and technological products are easily acceptable by society. Sometimes the technology and its product appears costly, but is environmental friendly, it will be beneficial for the society. Thus it is the responsibility of the mankind to decide their future. For example, we should understand that use of fossil fuels and non-biodegradable plastic bags, which are apparently cheaper than the alternatives available, are proving very expensive in terms of degrading the environment and affecting human health.

Some green technologies developed in the past decades which have proved to be environment friendly are:

- A significant reduction in the air-borne lead and sulphur by developing un-leaded petrol and sulphur free clean coal technology. More fuel efficient and less polluting automobiles driven on Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), biofuels, and hybrid vehicles driven on rapidly chargeable electric batteries have further reduced the emissions of CO, HC and NO_X from transport sectors.
- The development of “genetically engineered crops” have brought significant reduction in the use of chemical pesticides due to their high genetic resistance against pests and diseases. Use of biodegradable pesticides and fertilizers have further reduced the degradation of the environment from agriculture sectors.
- More efficient air pollution control equipments and devices for industries such as electrostatic precipitators, flue-gas desulphurization units etc. to reduce particulates and SO₂ emissions. Use of alternate renewable sources of energy such as solar energy, hydro energy, geothermal energy, Ocean energy etc. have further reduced the pollution in the Environment from industrial sectors.

- Recycling of community wastes such as paper, metal, glass and some hazardous industrial wastes like flyash, slag, phospho-gypsum and red mud for developing construction materials and useful consumer products.

Green technology promises mankind to

- Deliver clean, non polluting and renewable sources of energy.
- Work towards food security by developing safe and nutritive crops, which have short harvest cycles, are pest and disease resistant, without harming the natural ecosystems.
- Optimise the use of natural resources and improve the efficiency of resource use, specially of water and electricity.
- Manage all the wastes generated by their reduction, re-use and recycling and through cleaner production technologies which focus on zero-waste production.

EXERCISES

Short Answer Questions

1. Define the term 'Environment'.
2. Elaborate the term 'Environmental Science'.
3. What are the objectives of Environmental Studies?
4. What are the objectives and guiding principles of environmental Studies?
5. Explain in brief the measures taken by mankind to find solutions towards Global Environmental Problems.
6. What are the major goals of Environmental Education & training?
7. Explain the difference between formal and informal system of Environmental Education in India.
8. Define the term 'Green Technology'.
9. What are the goals of Green Technology?

Long Answer Questions

1. Explain the various stages which contribute to understand an environmental problem.
2. Explain the term 'Environment'. Explain the importance of environmental studies in the present context.
3. What is 'Environmental Science'. Discuss the multidisciplinary nature of environmental science and its importance.
4. Discuss the importance of environmental studies. What is meant by Environmental Pollution? Discuss the requirement of a non-polluted environment.
5. Unawareness or ignorance with protection of environment will lead to detrimental consequences—comment.
6. Explain the major Global Environmental issues which need to be addressed.
7. What could be the feasible solutions towards the Global issues?

- 8.** Explain the need for public awareness to understand the different environmental problems.
- 9.** What is Green Technology. How can sustainable development be achieved by this technology.
- 10.** Explain briefly some technological developments towards sustainable future.
- 11.** What are the advantages of Green Technology?
- 12.** What is Green Technology? How has this technology proved to be environmental friendly in the agriculture and transport sectors?



UNIT 2

Ecosystems

“Everytime we lose a species we break a life chain which has evolved over 3.5 billion years”.

–Jeffrey McNeely, IU CN Chief Scientist

Objectives

- Introduction
- Structure and function of an ecosystem
- Energy Flow through the Ecosystem
- Ecological succession
- Food chains, food webs and ecological pyramids
- Types, Characteristic Features, Structures and Function of the Ecosystem

2.1 INTRODUCTION

An **ecosystem** is a community of living organisms (plants, animals and microbes) that occurs in some locale, in conjunction with physical and chemical factors (air, water and soil ,climate etc.). These features create conducive conditions to make the plants and animals live. The biotic and abiotic components are linked together through nutrient cycles and energy flows. Ecosystems are generally fragile and can be disturbed by human activities like mountains are disturbed by constructions of roads; buildings and rivers are disturbed by dams and so on. Ecosystems can be classified as natural ecosystem which includes the forests, grasslands, deserts, ponds, rivers, lakes, and the sea and man -modified ecosystems which include agricultural land and urban or industrial land use patterns.

2.1.1 Components of Ecosystems:

The classification of ecosystem into biotic and abiotic component is given in Table 2.1.

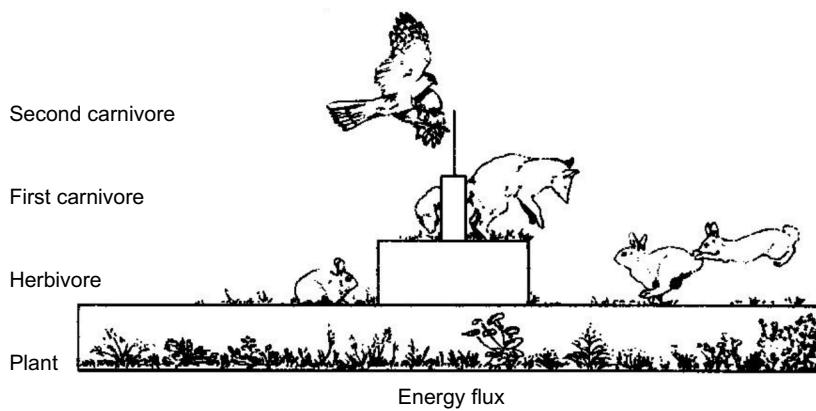
Table 2.1 Biotic and Abiotic Components

Abiotic Components	Biotic Components
Sunlight	Primary producers
Temperature	Herbivores
Precipitation	Carnivores
Water or moisture	Omnivores
Soil or water chemistry (e.g., P, NH ₄ ⁺) etc.	Detritivores etc.

2.2 STRUCTURE AND FUNCTION OF AN ECOSYSTEM

The two main structural features of any ecosystem are its 'species composition' and 'stratification'. This is also called the 'Trophic structure' of an ecosystem, where each animal population is present in different trophic level Plants or the producers are in the first trophic level ,Herbivores are in the second trophic level because they feed on producers followed by secondary consumers, tertiary consumers and so on.

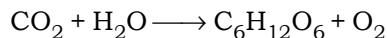
Ecosystem processes are broad generalizations that actually take place through the actions of individual organisms.. The nature of the organisms, functional groups and trophic levels to which they belong decide the efficiency of the activities of these individuals. A **functional group** is a biological category composed of organisms that perform mostly the same kind of function in the system. Plants are the producers in the ecosystem as they manufacture their food by using energy from the sun. Hence all the photosynthetic plants are in the same functional group. Members of the same functional group do not depend on the identity of the individual members but only on the function they perform in the ecosystem.

**Fig. 2.1** Structure of an ecosystem

2.2.1 Producers, Consumers and Decomposers

The biotic community can be divided into producers, consumers and decomposers. Producers are the green plants or algae which can synthesize glucose (organic compound) from carbon dioxide and water (inorganic

substance) in the presence of sunlight. The glucose so produced can be used both as a direct energy source or can combine with other molecules to produce biomass that provides the total theoretical energy available to all non photosynthesising organisms in the ecosystem. The primary function of an ecosystem is a systematic transfer of energy from one organism to another. This energy flow drives the movement of vital nutrients throughout the ecosystem



Producers transform light energy (from the sun) into chemical energy

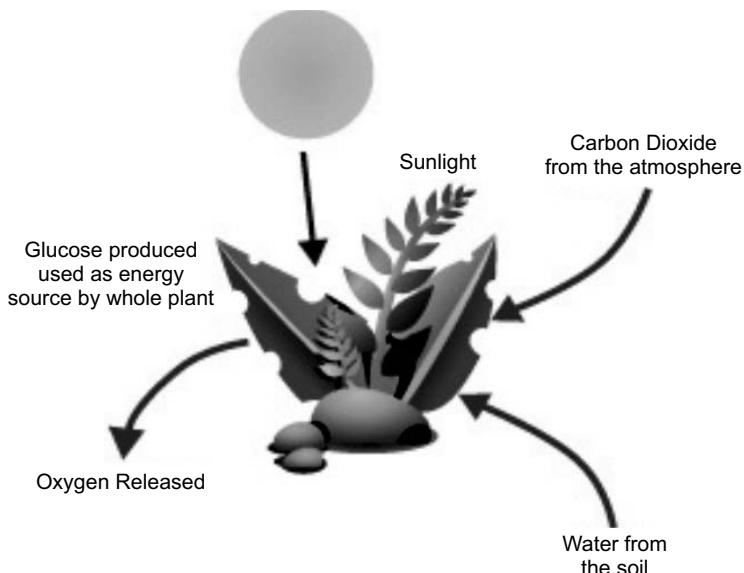


Fig. 2.2 Process of photosynthesis

- **Consumers** or *heterotrophs* are organisms that obtain organic molecules by eating or digesting other organisms. These organisms eat other organisms to obtain energy. For example, herbivores eat the plants, which are then eaten by carnivores or omnivores. Thus herbivores and carnivores are the consumers of the ecosystem. By eating other organisms they obtain energy supply and nutrient molecules from within the biomass ingested. For instance to build new protein consumers have to eat protein containing amino acids.
- **Decomposers** are the final link in a food web breaking down dead organic matter (DOM) from producers and consumers to produce energy which is returned to the atmosphere. Decomposers in the forest come in many different shapes and sizes. Shelf fungus is a typical fungus that grows on the sides of trees. It grows into the tree and decomposes it slowly.

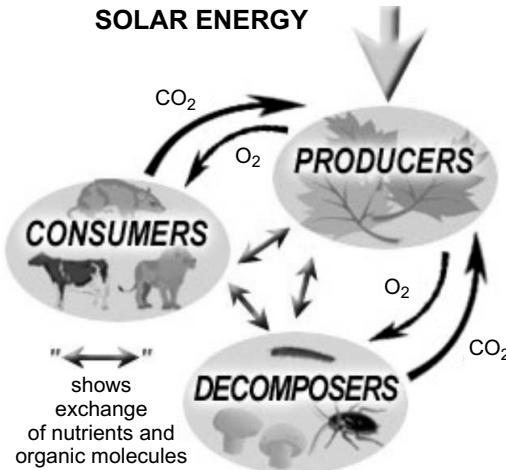


Fig. 2.3 Producers, Consumers and Decomposers in a ecosystem

2.3 ENERGY FLOW THROUGH THE ECOSYSTEM

In the ecosystem sun is the largest source of energy. In the food chain energy flows from one organism to the other when one organism eats another organism. Any energy remaining in a dead organism is consumed by decomposers. Nutrients can be cycled through an ecosystem but energy is simply lost over time. In ecology, **energy flow**, also called the **calorific flow**, refers to the flow of energy through a food chain. In an ecosystem, ecologists seek to quantify the relative importance of different component species and feeding relationships.

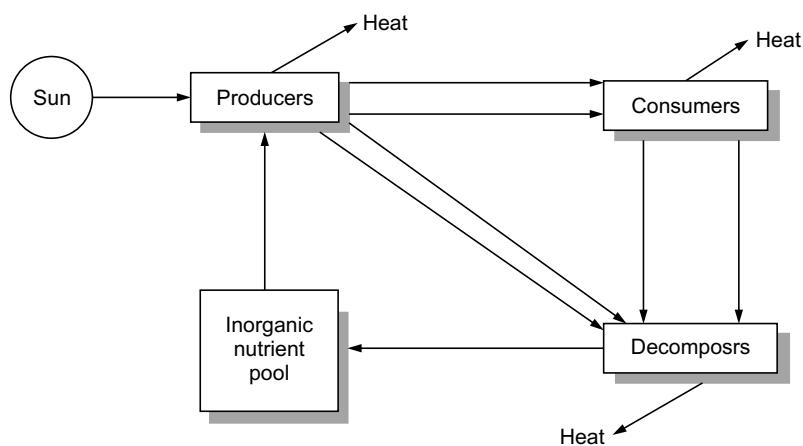


Fig. 2.4 Energy Flow Diagram

The diagram above shows the flow of both energy and inorganic nutrients through the ecosystem. When respiration occurs, the carbon-carbon bonds are broken and the carbon oxygen bonds are formed to produce carbon dioxide. During plant respiration, a carbohydrate combines with oxygen and is reduced to carbon dioxide, water, and heat.



This process releases the energy, which is either used by the organism (to move its muscles, digest food, excrete wastes, think, etc.) or the energy may be lost as heat. The dark arrows represent the movement of this energy Solar Energy that is not used in an ecosystem is eventually lost as heat. The other component shown in the diagram is the inorganic nutrients (which do not contain carbon-carbon bonds. The movement of the inorganic nutrients is represented by the open arrows. The autotrophs obtain these inorganic nutrients from the inorganic nutrient pool, which is usually the soil or water surrounding the plants or algae. . In the food chain energy flows from one organism to the other , when one organism eats another organism. Any energy remaining in a dead organism is consumed by decomposers. Nutrients can be cycled through an ecosystem but energy is simply lost over time. The inorganic nutrients are recycled, the energy is not.

2.4 ECOLOGICAL SUCCESSION

Ecological succession is the observed process of change in the species structure of an ecological community over time. The community begins with relatively few living organisms (plants and animals) and becomes complex over a period of time and becomes stable. Sometimes, within a community some species may become less and eventually vanish due to some reason. Ecological succession occurs because within a ecosystem an organism can have optimum growth and produce the most viable offspring till set of environmental conditions remains constant. If there is any change in the environment, the previously dominant species may fail and another species may become ascendant thus giving rise to economic succession.

Ecological Succession

	Year	
	Crab-grass	0–1
Tall grass-herba/ceous plants		1–3
Pines come in		3–10
Pine forest		10–30
Hard-woods come in		30–70
Hard-wood forest climax		70+

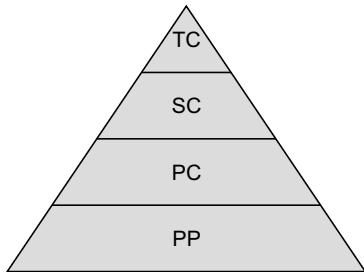
Fig. 2.5 Ecological succession

The most often quoted examples of succession deal with plant succession. It is worth remembering that as plant communities' change, so will the associated microorganism, fungus and animal species. Succession involves the **whole** community, not just the plants. Change in the plant species present in an area is one of the driving forces behind changes in animal species. This is because each plant species will have associated animal species which feed on it. The presence of these herbivore species will then dictate which particular carnivores are present.

2.5 FOOD CHAINS, FOOD WEBS AND ECOLOGICAL PYRAMIDS

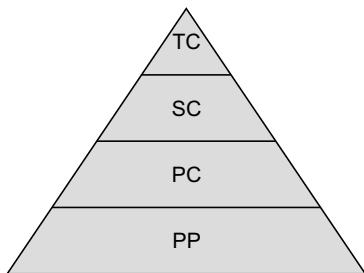
- **The food chains:** In nature energy must flow from one living organism to another. Energy is transferred from plants to animals when herbivores feed on plants and subsequently from one animal to the other in case of carnivores. In an ecosystem, some of the animals feed on other living organisms, while some feed on dead organic matter. The latter form the 'detritus' food chain. At each linkage in the chain, a major part of the energy from the food is lost for daily activities. Each chain usually has only four to five such links. However a single species can be linked with a large number of species.
- **The food webs:** In the ecosystem, a large number of interlinked chains constitute a web. If due to any human activity any link in the web is broken, then the species linked with the web may become extinct.
- An **ecological pyramid** (also **trophic pyramid** or **energy pyramid**) is a graphical representation designed to show the biomass (organic matter present in an organism) or biomass productivity (production of biomass) at each trophic level in a given ecosystem.

Ecological pyramids begin with producers at the bottom (such as plants) and proceed through the various trophic levels (such as herbivores that eat plants, then carnivores that eat herbivores, then carnivores that eat other carnivores, and so on). The highest level is the top of the food chain. This pyramid actually refers to the amount of biomass present in unit area (expressed in grams per meter² or calories per meter²). One gets a similar shape, whether the food or energy relationship between organisms at different trophic level is expressed. Thus, relationship is expressed in terms of number, biomass or energy. The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer. The three ecological pyramids that are usually studied are (a) pyramid of number; (b) pyramid of biomass and (c) pyramid of energy. To show the total biomass of individuals in each trophic level. Pyramid of biomass is better than pyramid of number in showing the relationships between organisms. Pyramid of biomass is upright in case of grassland and forest ecosystem whereas inverted in case of pond



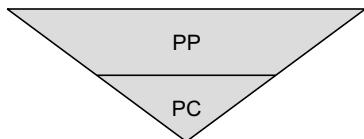
Trophic Level	No. of Individuals
TC (Tertiary Consumer)	3
SC (Secondary Consumer)	3,54,000
PC (Primary Consumer)	7,08,000
PP (Primary Producer)	5,842,000

Fig. 2.6 Pyramid of numbers in a grassland ecosystem. Only three top carnivores are supported in an ecosystem based on production of nearly 6 millions plants (Source: ncert.nic.in)



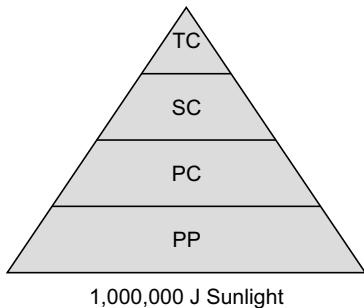
Trophic Level	Dry Weight (Kg/m ³)
TC (Tertiary Consumer)	1.5
SC (Secondary Consumer)	11
PC (Primary Consumer)	37
PP (Primary Producer)	809

Fig. 2.7 Pyramid of biomass shows a sharp decrease in biomass at higher trophic levels. (Source: ncert.nic.in)



Trophic Level	Dry Weight (Kg/m ³)
PP (Primary Producer)	21
PC (Primary Consumer)	4

Fig. 2.8 Inverted pyramid of biomass small standing crop of phytoplankton supports large standing crop of zooplankton (Source: ncert.nic.in)



Trophic Level	Energy (J)
TC (Tertiary Consumer)	10
SC (Secondary Consumer)	100
PC (Primary Consumer)	1000
PP (Primary Producer)	10,000

Fig. 2.9 An ideal pyramid of energy. Observe that primary producers convert only 1% of the energy in the sunlight available to them into NPP (Source: ncert.nic.in)

2.6 TYPES, CHARACTERISTIC FEATURES, STRUCTURES AND FUNCTION OF THE ECOSYSTEM:

The ecosystem can be divided into two major groups:

2.6.1 Terrestrial Ecosystems

This category of ecosystem includes, Grassland, Semi arid areas, Deserts, Mountains and Islands.

2.6.2 Aquatic Ecosystems

This category of ecosystem includes ponds, streams, lakes, rivers, oceans, estuaries

Terrestrial ecosystems in this type of ecosystem since land is an integral part, it has been modified into agricultural, pastoral or forest area. In the recent times the land has been rapidly converted into irrigated agricultural ecosystems or urban and industrial centers. The conversion has led to the overuse or misuse of land thereby degrading the environment.

(i) Forest ecosystem: A forest is an ecosystem that supports innumerable plant and animal species as well as ground cover, water, and air subsystems. The subsystems which are also the by products of the forest, provide the essence of life. Each forest type forms a habitat for a specific community of animals that are adapted to live in it. The forest has a vertical structure ,horizontal structure and environmental structure.

- **Vertical structure:** The forest is divided into distinct layers, each adapted to increasingly filtered sunlight if going top down. The layers are: canopy, understory, ground layer, and the forest floor. Not all forests have each layer. Generally; extreme environments such as deeply shaded woodlands, boreal forests, and frequently flooded woodlands have fewer layers.
- **Horizontal Structure:** The composition and distribution of species can vary widely from one place to the other depending on the environmental gradients, such as moisture, drainage, slope, slope aspect, soil type, and light intensity
- **Environmental structure:** The forest is influenced by environmental factors like soil type, temperature, moisture, precipitation pattern etc.

The classification of forest is given in the following Table 2.2.

(ii) Grassland ecosystem

Grasslands are areas where the vegetation is dominated by grasses. The vegetation is shrubs, plants , woody trees etc. Grasslands are predominantly found in areas where the temperature varies between -5°C to 20°C and the rainfall is between 600-1500 mm. The vegetation present in the grassland can be both natural and cultivated. The most predominant grassland of India is found in the floodplains of rivers coming out of the Himalayas onto the Indo-Gangetic Plain — mainly composed of alluvial

Table 2.2 Classification of Forests

Forest type	Plants Examples	Common Animal Examples
Himalayan Coniferous	Pine, Deodar	Wild goats and sheep, Himalayan black bear
Himalayan Broadleaved	Maple, Oak	Himalayan Tahr, Asiatic Black Bear, common Leopard
Evergreen North-east, western Ghats, Andaman & Nicobar	Jamun, Ficus, Dipterocarpus	Tiger, Leopard, Sambar, Malabar whistling thrush, Malabar Pied hornbill, tree frogs.
Deciduous- Dry	Teak, Ain, Terminalia	Tiger, Chital, Barking deer, Babblers, Flycatchers, Hornbills
Thorn and scrub, Semiarid forests	Babul, Ber, Neem	Blackbuck, Chinkara, Fourhorned antelope, Partridge, Monitor lizard
Mangrove Delta Forest	Avicenia	Crocodile, shorebirds- sandpipers, plovers, fish, crustacean.

*Source: www.ugc.ac.in

sediments — between the Yamuna and Brahmaputra drainages. This is known as the **Terai Duar Grassland** A major part of the grassland is destroyed by man for agriculture. The Terai-Duar floodplain grasslands has huge populations of one-horned rhinoceros, Asian elephant, gaur, nilgai, water buffalo, an impressive diversity of deer, pygmy hogs and Bengal tigers.

(iii) Lowland Grassland

There are grasslands which are also found on the fringes of lowland desert and semidesert. An example of such kind is the Rann of Kutch in northwestern India, where the Luni River descends out of the Aravalli Hills to a complex of desert and seasonal salt marsh inland of the Gulf of Kachchh. The predominant animals found here are large mammals, most notably the Asiatic wild ass, blackbuck, nilgai and chinkara, Indian wolf, striped hyena and caracal. The park's open country also provides critical habitat for other grassland specialists, such as the lesser florican and harrier hawks, which gather here in their greatest global roost.

(iv) Desert ecosystem

A **desert** is a barren area of land with scanty rainfall and hostile living conditions for plant and animal life. About one third of the land surface of the world is arid or semiarid. This includes much of the polar regions where little precipitation occurs and which are sometimes called “cold deserts” In India .cold deserts are found in Ladakh (high plateau of Himalayas There are a number of ways of classifying deserts including by the amount of precipitation that falls, by the temperature that prevails, by the causes of desertification or by the geographical location of the desert.

Although rainfall in the deserts is scarce, there are occasional downpours that can result in flash floods. There are frequent dust storms which result in the formation of sand dunes. In India such type of desert is seen in that desert of Rajasthan. There are also areas covered with sparse grasses and a few shrubs, which grow if it rains.

The Great and Little Rann of Kutch are highly specialised arid ecosystems. In the summers the landscape is similar to that of a desert but as this place is near to the sea, it gets converted into salt marshes during the monsoons and attract aquatic birds such as ducks, geese, cranes, storks, etc. The Great Rann is famous, as it is the only known breeding colony of the Greater and Lesser Flamingos in our country. The Little Rann of Kutch is the only home of the wild ass in India. Desert and semi arid regions have a number of highly specialized animals. Animals need to keep cool and find enough food and water to survive. Many are nocturnal and stay in the shade or underground during the heat of the day. They tend to be efficient at conserving water, extracting most of their needs from their food and concentrating their urine. The rare animals include the Indian wolf, desert cat, desert fox and birds such as the Great Indian Bustard and the Florican.

An **aquatic ecosystem** is an ecosystem of water body. Plants and animals that can survive in the environment of water live in aquatic ecosystems. Aquatic ecosystems are divided into two main categories that is marine ecosystems and freshwater ecosystems

(i) Marine Ecosystem

Marine ecosystems cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water. They are distinguished from freshwater ecosystems by the presence of dissolved compounds, especially salts (mainly sodium chloride) giving an average salinity of 35 parts per thousand (ppt) of water. Actual salinity varies among different marine ecosystem. Ecosystems.

Marine ecosystems can be divided into many zones depending upon water depth and shoreline features. The oceanic zone is the vast open part of the ocean where animals such as whales, sharks, and tuna live and near-shore zones can include estuaries, salt marshes, coral reefs, lagoons and mangrove swamps the base of the food web.

(ii) Estuaries

An estuary is a unique environment where fresh water and saltwater come together. Estuaries are generally found on the coast where a river or bay or wherever the river can enter the sea. Since estuaries are affected by the tides hence salinity, temperature and other physical properties in an estuarial system can change making the organisms tolerant to change. Even with that consideration, estuaries are amongst the most fertile places in the world, where all kinds of plants and animals live.

Freshwater ecosystems cover 0.80% of the Earth's surface and inhabit 0.009% of its total water. Freshwater ecosystems contain 41% of the world's known fish species and can be subdivided into:

- Lentic: slow moving water, including pools, ponds, and lakes.
- Lotic: faster moving water, for example streams and rivers.
- Wetlands: areas where the soil is saturated or inundated for at least part of the time.

(iii) Lake Ecosystem

A lake is a body of water completely surrounded by land and can have either saline or fresh water. Lakes are not permanent because the water can both sink into the ground and evaporate. In order for a lake to remain, it must be constantly fed by a river or rainfall. Plants which are mainly found in lakes are algae, which derives energy from the sun. There are fish that are herbivorous and are dependent on algae and aquatic weeds. The small animals such as snails are used as food by small carnivorous fish, which in turn are eaten by larger carnivorous fish.

(iv) Streams and Rivers

Streams and rivers are flowing water ecosystems in which all the living forms are specially adapted to different rates of flow. Rivers which generally come from mountain springs, melting glaciers or lakes, can either flow on land or underground like in deserts and seas. A river's contribution to the water cycle is that it collects water from the ground and returns it to the ocean. The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, and hence supports more biodiversity. Upland and lowland rivers are the result of distinction of the velocity gradient. Some plants and animals such as snails and other burrowing animals can withstand the rapid flow of the hill streams. Other species of plants and animals such as water beetles and skaters can live only in slower moving water. Some species of fish, such as Mahseer, go upstream from rivers to hill streams for breeding. They need crystal clear water to be able to breed. They lay eggs only in clear water so that their young can grow successfully. As deforestation occurs in the hills the water in the streams that once flowed throughout the year become seasonal. This leads to flash floods in the rains and a shortage of water once the streams dry up after the monsoon. Environmental threats to rivers include loss of water, dams, chemical pollution and introduced species.

(v) Ponds

Ponds are small bodies of freshwater water over 1 m square that is inundated, "wet" for more than 8 months of the year. They have shallow and still water, can be marshy, and support aquatic plants. The size and depth of ponds often varies greatly with the time of year. Many ponds are produced by spring flooding from rivers. A large number of plants and animals live in ponds giving rise to a food web and biodiversity. There is usually a diverse array of aquatic life, with a few examples including algae, snails, fish, beetles, water bugs, frogs, turtles and sometimes even alligators.

EXERCISES

1. Explain the concept of an ecosystem with their structure and function.
2. What do you understand by Ecological succession?
3. Explain with the help of the diagram the energy flow in an ecosystem?
4. Why do tertiary consumers occur at a low density in an ecosystem?
5. What are the two components of an ecosystem. Give examples.
6. With the help of examples explain producers, consumers and decomposers.
7. What do you understand by food chain and food web? How does the interlinks between the food web break.
8. Explain ecological pyramid. Is it different from energy pyramid.
9. How does the nutrients and the energy flow from one organism to the other
10. Why our grassland species are vanishing? What will be its consequences?
11. What is grassland ecosystem? What are the threats to grassland ecosystem?
12. What are the threats to forest ecosystem? How forest ecosystem can be conserved?
13. What is a desert ecosystem? How can desert ecosystem be conserved?
14. How does an aquatic ecosystem support a wide range of biodiversity?



UNIT

3

Biodiversity and its Conservation

"It is reckless to suppose that biodiversity can be diminished indefinitely without threatening humanity itself".

– Prof. Edward O. Wilson "Father of Biodiversity"

Objectives

- Introduction
- Biogeographical Classification of India
- Value of Biodiversity
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3.1 INTRODUCTION

Biological diversity means that variety of plants and animals and other living things in a particular area or region. It also means the number or abundance of different species living within a particular region. Everything that lives in an ecosystem is part of the web of life, including humans. Each species of vegetation and each creature has a place on the earth and plays a vital role in the circle of life. Plant, animal, and insect species interact and depend upon one another for what each offers, such as food, shelter, oxygen, and soil enrichment.

Maintaining a wide diversity of species in each ecosystem is necessary to preserve the web of life that sustains all living things.

3.1.1 Three levels of biodiversity

Biodiversity refers to the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it. Biodiversity includes not only species we consider rare, threatened, or

endangered, but every living thing, even organisms, such as microbes, fungi, and invertebrates.

Biodiversity is generally understood at three levels genetic, species, and ecosystem. These levels are all interrelated yet distinct enough that they can be studied as three separate components.

Genetic Diversity

Genetic diversity is the variety present at the level of genes. Genes, made of DNA, are the building blocks that determine how an organism will develop and what its traits and abilities will be. This level of diversity can differ by alleles (different variants of the same gene, such as blue or brown eyes), by entire genes (which determine traits, such as the ability to metabolize a particular substance), or by units larger than genes such as chromosomal structure.

Genetic diversity can be measured at many different levels, including population, species, community, and biome. Which level is used depends upon what is being examined and why, but genetic diversity is important at each of these levels.

The amount of diversity at the genetic level is important because it represents the raw material for evolution and adaptation. More genetic diversity in a species or population means a greater ability for some of the individuals in it to adapt to changes in the environment. Less diversity leads to uniformity, which is a problem in the long term, as it is unlikely that any individual in the population would be able to adapt to changing conditions. As an example, modern agricultural practices use monocultures, which are large cultures of genetically identical plants. This is an advantage when it comes to growing and harvesting crops, but can be a problem when a disease or parasite attacks the field, as every plant in the field will be susceptible. Monocultures are also unable to deal well with changing conditions.

Within species, genetic diversity often increases with environmental variability, which can be expected. If the environment often changes, different genes will have an advantage at different times or places. In this situation genetic diversity remains high because many genes are in the population at any given time. If the environment didn't change, then the small number of genes that had an advantage in that unchanging environment would spread at the cost of the others, causing a drop in genetic diversity.

In communities, it can increase with the diversity of species. How much it increases depends not only on the number of species, but also on how closely related the species are. Species that are closely related (*e.g.* two species of neem) have similar genetic structures and makeup and therefore do not contribute much additional genetic diversity. These closely-related species will contribute to genetic diversity in the community less than more remotely-related species (*e.g.* neem and peepal) would.

An increase in species diversity can also affect the genetic diversity, and do so differently at different levels. If there are many species, the genetic diversity at that level will be larger than when there are fewer

species. On the other hand, genetic diversity within each species can decrease. This can happen if the large number of species means so much competition that each species must be extremely specialized, such as only eating a single type of food. If they are so specialized, this specialization will lead to little genetic diversity within any of the species.

Species Diversity

Biodiversity studies typically focus on species. They do so not because species diversity is more important than the other two types, but because species diversity is easier to work with. Species are relatively easy to identify by eye in the field, whereas genetic diversity requires laboratories, time and resources to identify and ecosystem diversity needs many complex measurements to be taken over a long period of time. Species are also easier to conceptualize and have been the basis of much of the evolutionary and ecological research that biodiversity draws on.

Species are well known and are distinct units of diversity. Each species can be considered to have a particular role in the ecosystem, so the addition or loss of single species may have consequences for the system as a whole. Conservation efforts often begin with the recognition that a species is endangered in some way, and a change in the number of species in an ecosystem is a readily obtainable and easily comprehensible measure of how healthy the ecosystem is.

Ecosystem Diversity

Ecosystem-level theory deals with species distributions and community patterns, the role and function of key species, and combines species functions and interactions. The term “ecosystem” here represents all levels greater than species: associations, communities, ecosystems, and the like. One of the difficulties in examining communities is that the transitions between them are usually not very sharp. A lake may have a very sharp boundary between it and the deciduous forest it is in, but the deciduous forest will shift much more gradually to grasslands or to a coniferous forest. This lack of sharp boundaries is known as “open communities” (as opposed to “closed communities,” which would have sudden transitions) and makes studying ecosystems difficult, since even defining and delimiting them can be problematic.

Some researchers think of communities as simply the sum of their species and processes, and don’t think that any of the properties found in communities are special to that level. Many others disagree, claiming that many of the characteristics of communities are unique and cannot be extrapolated from the species level. Examples of these characteristics include the levels of the food chain and the species at each of those levels, guilds (species in a community that are functionally similar), and other interactions.

3.2 BIOGEOGRAPHICAL CLASSIFICATION OF INDIA

India is the seventh largest country in the world and Asia's second largest nation with an area of 3, 287, 263 sq.km. encompassing a varied landscape rich in natural resources. India is shielded by the world's highest mountains, the Himalayas, in the north. The southern part of India takes the shape of a peninsula and divides the Indian Ocean into the Bay of Bengal to the southeast and the Arabian Sea to the southwest. The southern tip of Kanyakumari is washed by the Indian Ocean. The Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep group of islands in the Arabian sea are also a part of India.

India has a great diversity of natural ecosystems from the cold and high Himalayan ranges to the sea coasts, from the wet northeastern green forests to the dry northwestern arid deserts, different types of forests, wetlands, islands and the oceans. India consists of fertile river plains and high plateaus and several major rivers, including the Ganges, Brahmaputra and Indus. The climate of India is determined by the southwest monsoon between June and October, the northeast monsoon between October and November and dry winds from the north between December and February. From March to May the climate is dry and hot.

India, being a vast country, shows a great diversity in climate, topography and geology and hence the country is very rich in terms of biological diversity. India's biological diversity is one of the most significant in the world, since India has only 2% of the total landmass of the world containing about 6% of the world's known wildlife.

The country has 10 different biogeographic zones and 26 biotic provinces.

Table 3.1

S.No.	Biogeographic zones	Biotic provinces
1.	Trans-Himalaya	Ladakh mountains, Tibetan plateau
2.	Himalaya	Northwest, West, Central and East Himalayas
3.	Desert	Thar, Kutch
4.	Semi-arid	Punjab plains, Gujarat Rajputana
5.	Western Ghats	Malabar plains, Western Ghats
6.	Deccan Peninsula	Central highlands, Chotta-Nagpur, Eastern highlands, Central Plateau, Deccan South
7.	Gangetic plains	Upper and Lower Gangetic plains
8.	North-East	Brahmaputra valley, Northeast hills
9.	The Indian	Andaman and Nicobar
10.	Coasts	West and East coast, Lakshadweep

Source: Wildlife Protected Area Network in India: A Review, Wildlife Institute of India, 2000.

1. Trans-Himalayan Region

This area is very cold and arid (4,500 – 6,000 mts. above msl). The only vegetation is a sparse alpine steppe. Extensive areas consist of bare rock and glaciers.

The faunal groups best represented here are wild sheep and goats (chief ancestral stock), ibex, snow leopard, marbled cat, marmots and black-necked crane.

2. Himalayas

The Himalayas consist of the youngest and loftiest mountain chains in the world. The Himalayas have attained a unique personality owing to their high altitude, steep gradient and rich temperate flora.

The forests are very dense with extensive growth of grass and evergreen tall trees. Oak, chestnut, conifer, ash, pine, deodar are abundant in Himalayas. There is no vegetation above the snowline. Several interesting animals live in the Himalayan ranges. Chief species include wild sheep, mountain goats, ibex, shrew, and tapir. Panda and snow leopard are also found here.

3. The Indian Desert

This region consists of parts of Rajasthan, Kutch, Delhi and parts of Gujarat. The climate is characterised by very hot and dry summer and cold winter. Rainfall is less than 70 cms. The plants are mostly xerophytic. Babul, Kikar, wild palm grows in areas of moderate rainfall. Thar desert possesses most of the major insect species. 43 reptile species and moderate bird endemism are found here. The black buck was once the dominant mammal of the desert region, now confined only to certain pockets. The gazelle is the only species of the Indian antelope of which the females have horns. Nilgai the largest antelope of India and the wild ass, a distinct subspecies, is now confined to the Rann of Kutch which is also the only breeding site in the Indian subcontinent for the flamingoes. Other species like desert fox, great Indian bustard, chinkara and desert cat are also found. Camels, wild asses, foxes, and snakes are found in hot and arid deserts.

4. Semi-Arid Areas

Adjoining the desert are the semi-arid areas, a transitional zone between the desert and the denser forests of the Western Ghats. The region includes the arid desert areas of Thar and Rajasthan extending to the Gulf of Kutch and Cambay and the whole Kathiawar peninsula. The natural vegetation is thorn forest. This region is characterized by discontinuous vegetation cover with open areas of bare soil and soil-water deficit throughout the year.

Thorny scrubs, grasses and some bamboos are present in some regions. A few species of xerophytic herbs and some ephemeral herbs are found in this semi-arid tract. Birds, jackals, leopards, eagles, snakes, fox, buffaloes are found in this region. The lion of Gir is the endemic species in this zone.

5. Western Ghats

The mountains along the west coast of peninsular India are the Western Ghats, which constitute one of the unique biological regions of the world.

The Western Ghats extend from the southern tip of the peninsula (8°N) northwards about 1600 km to the mouth of the river Tapti (21°N). The region covers only 5% of India's land surface but are home to more than about 4,000 of the country's plant species out of which 1800 are endemic. The monsoon forests occur both on the western margins of the ghats and on the eastern side where there is less rainfall. This zone displays diversity of forests from evergreen to dry deciduous.

The mountains rise to average altitudes between 900 and 1500 m above sea level, intercepting monsoon winds from the southwest and creating a rain shadow in the region to their East.

The varied climate and diverse topography create a wide array of habitats that support unique sets of plant and animal species. Apart from biological diversity, the region boasts of high levels of cultural diversity, as many indigenous people inhabit its forests. The Nilgiri langur, lion tailed macaque, Nilgiri tahr, Malabar grey hornbill and most amphibian species are endemic to the Western Ghats.

6. Deccan Peninsula

The Deccan Peninsula is a large area of raised land covering about 43% of India's total land surface. It is bound by the Satpura range on the north, Western Ghats on the west and Eastern Ghats on the east. The elevation of the plateau varies from 900 mts. in the west to 300 mts. in the east. There are four major rivers that support the wetlands of this region which have fertile black and red soil. Large parts are covered by tropical forests. Tropical dry deciduous forests occur in the northern, central and southern part of the plateau. The eastern part of the plateau in Andhra Pradesh, Madhya Pradesh and Orissa has moist deciduous forests.

Fauna like tiger, sloth bear, wild boar, gaur, sambar and chital are found throughout the zone along with small relict populations of wild buffaloes, elephants and barasingha.

7. Gangetic Plain

In the North is the Gangetic plain extending up to the Himalayan foothills. This is the largest unit of the Great Plain of India. Ganga is the main river after whose name this plain is named. The Great Plains cover about 72.4 mha area with the Ganga and the Brahmaputra forming the main drainage axes in the major portion.

The thickness in the alluvial sediments varies considerably with its maximum in the Ganga plains. The physiogeographic scenery varies greatly from arid and semi-arid landscapes of the Rajasthan Plains to the humid and per-humid landscapes of the Delta and Assam valley in the east.

Topographic uniformity, except in the arid Western Rajasthan is a common feature throughout these plains. The plain supports some of the highest population densities depending upon purely agro-based economy in some of these areas. The trees belonging to these forests are teak, sal, shisham, mahua, khair etc. The fauna includes elephants, black buck,

gazelle, rhinoceros, Bengal florian, crocodile, freshwater turtle and a dense waterfowl community.

8. North-East India

North-east India is one of the richest flora regions in the country. The tropical vegetation of northeast India is rich in evergreen and semievergreen rain forests, moist deciduous monsoon forests, swamps and grasslands. It has several species of orchids, bamboos, ferns and other plants. Wild species of cultivated plants such as banana, mango, citrus and pepper are also found.

Mammalian fauna includes 390 species of which 63% are found in Assam. The area is rich in smaller carnivores. The country's highest population of elephants are found here.

9. The Indian Islands

It is a group of 325 islands: Andaman to the north and Nicobar to the south. The two are separated by about 160 kms by the Ten Degree Channel of the sea. The rainfall is heavy, with both Northeast and Southwest monsoons. About 21 of the 325 islands in the Andaman & Nicobar Islands are inhabited. Many unique plants and animals are found here. About 2,200 species of higher plants are found here of which 200 are endemic. The Andaman Si Nicobar Islands have tropical evergreen forests and tropical semi evergreen forests as well as moist deciduous forests, littoral and mangrove forests.

112 endemic species of avifauna, the Andaman water monitor, giant robber crab, 4 species of turtles, wild boar, Andaman day gecko and the harmless Andaman water snake are found only in these islands. The Narcondam hornbill found only in Narcondam is a large forest bird with a big beak. Coral reefs are stretched over an area of 11,000 sq.km. in the Andamans and 2,700 sq.km. in Nicobar.

10. Coasts

India has a coastline extending over 5,500 kms. The Indian coasts vary in their characteristics and structures. The west coast is narrow except around the Gulf of Cambay and the Gulf of Kutch. In the extreme south, however, it is somewhat wider along the south Sahyadri.

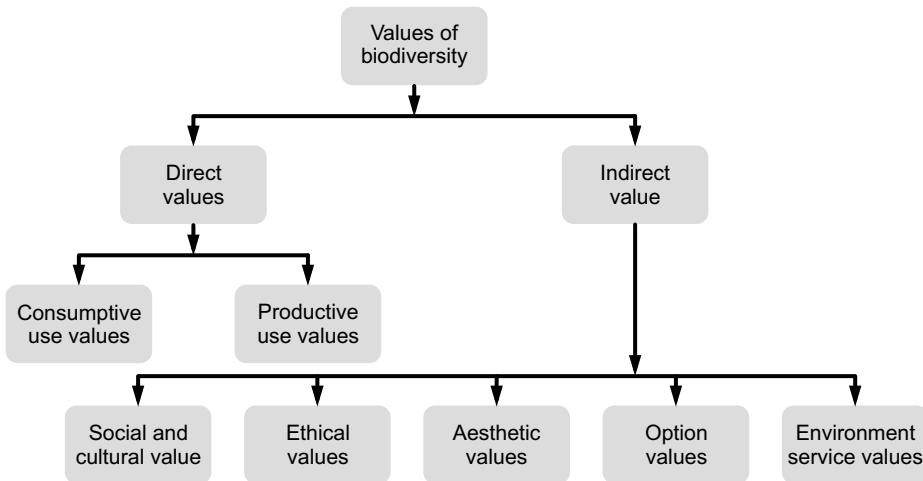
The backwaters are the characteristic features of this coast. The east coast plains, in contrast are broader due to depositional activities of the east-flowing rivers owing to the change in their base levels.

Extensive deltas of the Mahanadi, Godavari, Krishna and Kaveri are the characteristic features of this coast. Mangrove vegetation is characteristic of estuarine tracts along the coast for instance, at Ratnagiri in Maharashtra.

Larger parts of the coastal plains are covered by fertile soils on which different crops are grown. Rice is the main crop of these areas. Coconut trees grow all along the coast.

3.3 VALUE OF BIODIVERSITY

The value of biodiversity is classified into direct and indirect values:



Direct values

The direct value include food resources like grains, vegetables, fruits which are obtained from plant resources and meat, fish, egg, milk and milk products from animal resources. These also include other values like medicine, fuel, timber, fiber, wool, wax, resin, rubber, silk and decorative items.

The direct values are of two types (i) Consumptive use value and (ii) Productive use value.

Consumptive use value: These are the direct use values where the biodiversity products can be harvested and consumed directly. Example: Food, fuel and drugs. These goods are consumed locally and do not figure in national and international market.

(a) Food:

- (i) *Plants:* The most fundamental value of biological resources particularly plants is providing food. Basically three crops i.e. wheat, maize and rice constitute more than two third of the food requirement all over the world.
- (ii) *Fish:* Through the development of aquaculture, techniques, fish and fish products have become the largest source of protein in the world.
- (b) *Fuel:* Since ages forests have provided wood which is used as a fuel. Moreover fossil fuels like coal, petroleum, natural gas are also product of biodiversity which are directly consumed by humans.
- (c) *Drugs and medicines:* The traditional medical practice like ayurveda utilizes plants or their extracts directly. In allopathy, the pharmaceutical industry is much more dependent on natural products. Many drugs are derived from plants like

- (i) *Quinine*: The famous anti malaria drug is obtained from cinchona tree.
- (ii) *Penicillin*: A famous antibiotic is derived from pencillium, a fungus,
- (iii) *Tetracycline*: It is obtained from bacterium.
- (iv) Vinblastin and vincristine, two anti cancer drugs have been obtained from catharanthus plant which has anti cancer alkaloids.

Productive use Values: These are the direct use values where the product is commercially sold in national and international market. Many industries are dependent upon these values. *Example*: Textile, leather, silk, paper and pulp industry etc. Although there is an international ban on trade of products from endangered species like tusks of elephants, wool from sheep, fur of many animals etc. These are traded in market and fetch a booming business.

Indirect Values

Biodiversity provides indirect benefits to human beings which support the existence of biological life and other benefits which are difficult to quantify. These include social and cultural values, ethical values, aesthetic values, option values and environment service values.

Social and cultural value: Many plants and animals are considered holy and sacred in India and are worshipped like Tulsi, peepal, cow, snake etc. In Indian society great cultural value is given to forest and as such tiger, peacock and lotus are named as the national animal, bird and flower respectively.

Ethical: These values are related to conservation of biodiversity where ethical issue of 'all life forms must be preserved' is laid down. There is an existence value which is attached to each species because biodiversity is valuable for the survival of human race. Moreover all species have a moral right to exist independent of our need for them.

Aesthetic value: There is a great aesthetic value which is attached to biodiversity. Natural landscapes at undisturbed places are a delight to watch and also provide opportunities for recreational activities like bird watching, photography etc. It promotes eco-tourism which further generates revenue by designing of zoological, botanical gardens, national parks, wild life conservation etc.

Option values: These values include the unexplored or unknown potentials of biodiversity.

Environment service values: The most important benefit of biodiversity is maintenance of environment services which includes

- (i) Carbon dioxide fixation through photosynthesis.
- (ii) Maintaining of essential nutrients by carbon (C), oxygen (O), Nitrogen (N), Sulphur (S), Phosphorus (P) cycles.
- (iii) Maintaining water cycle and recharging of ground water,
- (iv) Soil formation and protection from erosion,

- (v) Regulating climate by recycling moisture into the atmosphere,
- (vi) Detoxification and decomposition of waste.

3.4 BIODIVERSITY AT GLOBAL, NATIONAL AND LOCAL LEVELS

Global Biodiversity

Humans share the planet earth with as many as 8.7 million different forms of life. Researchers who have analysed the hierarchical categorisation of life on Earth to estimate how many undiscovered species exist say that the diversity of life is not equally divided between land and ocean. Three-quarters of the 8.7 m species - the majority of which are insects – are on land; only one-quarter, 2.2 m, are in the deep, even though 70% of the Earth's surface is water.

Many species are being lost because of human activity, but the magnitude of species lost can only be estimated once we know what species are there. It is reported that, 86% of all plants and animals on land and 91% of those in the seas have yet to be named and catalogued. The conservative estimates by biologists show that the various forms of life on the planet included 7.8 million species of animal, 298,000 species of plant and 611,000 species of mushrooms, mould and other fungi along with 36,400 species of protozoa, single-called organisms, and 27,500 species of algae.

3.4.1 National Biodiversity

India has a rich biological diversity of flora and fauna. Overall 6% of global species are found in India. It is estimated that India ranks 10th among the plant rich countries of the world, 11th in terms of the number of endemic species of higher vertebrates and 6th among the centre of diversity and origin of agricultural crop.

India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rainforests to alpine vegetation and from temperate forests to coastal wetlands.

Of the estimated 5-50 million species of the world's biota, only 1.7 million have been described to date (Groombridge, and Jenkins, 2000), and the distribution is highly uneven. About 7% of the world's total land area is home to half of the world's species, with the tropics alone accounting for 5 million. India contributes significantly to this latitudinal biodiversity trend. With a mere 2.4% of the world's area, India accounts for 7.31% of the global faunal total with a faunal species count of 89,451 species (MoEF, 1999).

India has two major realms called the Palaearetie and the Indo-Malayan, and three biomass, namely the tropical humid forests, the tropical dry/ deciduous forests, and the warm desert/semi-deserts.

Some salient features of India's biodiversity are:

- India is one of the 12 centres of origin of cultivated plants.
- India has 5 world heritage sites, 12 biosphere reserves, and 6 Ramsar wetlands.
- Amongst the protected areas, India has 88 national parks and 490 sanctuaries covering an area of 1.53 lakh sq. km.

3.5 INDIA AS A MEGA-DIVERSITY NATION

India is one of the 17 mega-diversity nations in the world. Mega-diversity, is a term used by an international organization (World Bank Technical paper no. 343). The mega-diverse countries are a group of countries that harbor the majority of the Earth's species and are therefore considered extremely biodiverse. All these countries are located in, or partially in, tropical or subtropical regions. India is located in south Asia, between latitude 6° and 38° N and longitudes 69° and 97° E. Biogeographically, India is situated at the tri-junction of three realms Afro-tropical, Indo-Malayan and Paleo-Arctic realms, and therefore, has characteristic elements from each of them. This assemblage of three distinct realms makes the country rich and unique in biological diversity. The Indian landmass extending over a total geographical area of about 3029 million hectares is bounded by Himalayas in the north, the Bay of Bengal in east, the Arabian Sea in the west, and Indian Ocean in the south. Two areas in India have been identified as megadiversity hot spot areas, which are western ghat forests and eastern Himalayan forests, but India as a whole country is a megadiversity nation. Miller Meier says, 'India is remarkable in both species richness and endemism although it ranks 10th position.

The large species richness and abundance are due to immense variety of climatic and altitudinal condition in country. These vary from the humid tropical Western Ghats to the hot desert of Rajasthan, from cold desert of Ladakh and the icy mountain of Himalayas to the warm cost of peninsular India. The ecosystem diversity is highest in the world, which represents forest ecosystems, grassland ecosystems, wetland ecosystems, coastal and marine ecosystems and the desert ecosystems. There are 10 biogeography zones and 26 biogeography provinces, which are representatives of all the major ecosystems of the world. The country constitutes only 2.4% of the world's land area, but having 11% of flora and 6.5% of fauna of the world. Approximately 65% of the total geographical area has been surveyed so far. Based on this, over 46,000 species of plants which accounts for 15% of the known world plants in this 15000 species of the flowering plants, out of these 35% are endemic and located in 25 endemic centres and 588 genera of monocotyledons 22 are strictly endemic and 81,000 species of animals have been described by the Botanical Survey of India (BSI) established in 1890 and Zoological Survey of India (ZSI) established in 1916, respectively. This list is being constantly upgraded, specially in lower plants and invertebrate animals. India also possesses 40 species of insectivorous plants, 130 species of primitive plants, 130 species of parasites and 70 species of saprophytes. There are about 15000 species of angiosperms, 65 species of gymnosperms, 1232 species of pteridophytes, 2850 species of bryophytes, 6990 species of algae, 2075 species of lichens, 14500 species of fungi and more than 850 species of virus and bacteria are found in India. It contains 1,27,000 species of the world of which more than 45,000 species are plants and more than 80,000 species are animals. India contains about 75000 animal species out of which 80% are insects. In

Source: Sinha et al. EnviroNews, Vol. 16(4), 2010.

animals 62% of amphibians and 32% of reptiles are endemic. There is no clear estimation about marine biota in Indian sub-continent. Long coast line have abundance of fish, crustaceans, corals, reptiles, seaweeds, molluscs and mammals. In India, mangroves occur along the coast-line comprising a total area of 6740 sq.kms; which is nearly 12% of the world's mangrove areas. The country also has four Coral Reef areas located in Gulf of Mannar, Gulf of Kutch, Lakshadweep and Andaman and Nicobar Islands. The Western Ghats in peninsular India, which extend in the southern states are a treasure house of species diversity and has about 5000 species. It is estimated that almost one third of animals varieties found in India are in Western Ghat of Kerala alone. The country is also one of the 12 primary centres of origin of cultivated plants and domesticated animals. It is considered to be the homeland of 167 important plant species of cereals, millets, fruits, condiments, vegetables, pulses, fibre crops and oilseeds, and 114 breeds of domesticated animals.

India contains a great wealth of biological diversity in its terrestrial and aquatic areas. This richness is shown in absolute numbers of species and the proportion they represent of the world total.

Table 3.2 Comparison between the Number of Species in India and the World

Group	Number of species in India (SI)	Number of species in the world (SW)	SI/SW (%)
Mammals	350	4629	7.6
Birds	1224	9702	12.6
Reptiles	408	6550	6.2
Amphibians	197	4522	4.4
Fishes	2546	21730	11.7
Flowering Plants	15000	250000	6.0

3.6 HOT-SPOTS OF BIODIVERSITY

Biodiversity hotspots are areas that support natural ecosystems that are largely intact and where native species and communities associated with these ecosystems are well represented. These are also areas with a high diversity of locally endemic species, which are species that are not found or are rarely found outside the hotspot.

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans. The concept of biodiversity hotspots was originated by Norman Myers, a British environmentalist, specialising in biodiversity. To qualify as a biodiversity hotspot on the hotspot-map, a region must meet two strict criteria: it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation. Around the world, 25 areas qualify under this definition, with nine other possible candidates.

Source: Myers, N. et. al., 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858

These sites support nearly 60% of the world's plant, bird, mammal, reptile, and amphibian species, with a very high share of endemic species.

India is one of the richest countries in the world in terms of biodiversity. It lies within the Indo-malaya eco-zone and completely houses two of the thirty-four biodiversity hotspot in the world. The two hotspots are: The Eastern Himalayas and the Western Ghats. The third, Indo-Burma, lies partially within the Indian North-East. There is a huge species diversity in India, with several of the species being endemic to their native ranges in India.

Eastern Himalayas

Phytogeographically, the Eastern Himalayas form a distinct floral region. The area comprises Nepal, Bhutan, and neighbouring states of northern India, along with a continuous sector of the Yunnan province in southwest China. Although all Himalayan forests lie well north of the Tropic of Cancer, and some of them are at altitudes of 1780 to 3500 metres, they can be considered tropical forests since they occur largely within the climatic tropics.

It is believed that forest cover in the Eastern Himalayas has dwindled from 340,000 km² to 110,000 km² with a mere 53,000 km² of primary forests. Despite this loss, the north-eastern region is home to some botanical rarities. One of these is the *Sapria* Himalayana, a parasitic angiosperm that has been sighted only twice since 1836.

This region is the meeting ground of the Indo-Malayan and Indo-Chinese biogeographical realms as well as the Himalayan and Peninsular Indian elements, formed when the peninsular plate struck against the Asian landmass, after it broke off from Gondwana land.

- The Eastern Himalayas display an ultra-varied topography, a factor that fosters species diversity and endemism.
- Many deep and semi-isolated valleys are exceptionally rich in endemic plant species. In Sikkim, in an area of 7298 km², of the 4250 plant species, 2550 (60%) are endemic (Myers, 1988). In India's sector of the area, there are about 5800 plant species, of which roughly 2000 (36%) are endemic.
- In Nepal, there are around 7000 plant species, many of which overlap with those of India, Bhutan, and even Yunnan. Of these species, at least 500 (almost 8%) are believed to be endemic to Nepal.
- Bhutan possesses an estimated 5000 species, of which as many as 750 (15%) are considered to be endemic to the Eastern Himalayas.

Western Ghats

Of India's 49,219 plant species, 1600 endemics (40% of the total number of endemics) are found in a 17,000 km² strip of forest along the seaward side of the Western Ghats in Maharashtra, Karnataka, Tamil Nadu, and Kerala (WCMC, 1992). Forest tracts up to 500 metres in elevation, comprising one-fifth of the entire forest expanse, are mostly evergreen, while those in the 500-1500 metres range are semi-evergreen. There are two main

centres of diversity, the Agastyamalai Hills and the Silent Valley/New Amambalam Reserve basin (Myers, 1988).

Very little has been documented recently about the status of the forest cover, except that it seems to have declined between 1972 and 1985 at a rate paralleling that for India as a whole, which implies a loss of over 2.4% annually. If we extrapolate from 1986 to 1989, this means a total loss of almost 34% for 1972 to 1989. According to Myers et al, (2000), only 6.8% of the original extent of vegetation exists today. Still worse is the decline of the primary forest: the amount remaining seems to be no more than 8000 km². All but isolated pockets of original forest have been opened up by shifting cultivation, allowing a take-over by deciduous species and bamboo among other forms of 'degenerate' vegetation.

3.7 THREATS OF BIODIVERSITY

Biodiversity is under serious threat as a result of human activities. The main dangers worldwide are population growth and resource consumption, climate change and global warming, habitat conversion and urbanisation, over-exploitation of natural resources and environmental degradation.

Table 3.3 The table below summarise the main threats, a country, usually faces:

Main threats	Some underlying causes
<i>Threats in terrestrial areas:</i>	
Degradation, destruction and natural habitats	Spread of the urbanised areas, road network and industrial areas and associated problems (noise, pollution); abandon of former agricultural practices that were favourable to biodiversity
Decrease in the capacity of the agricultural areas to host wildlife	Intensification of agricultural practices (yielding pollution and disturbance) and disappearance of landscape elements that provide food and shelter that are exploitable by wildlife (such as hedges, trees, ponds, etc.)
Pollution of soils, air and water	Excess of heavy metals (industry, roads), manure and pesticides (agriculture) and other pollutants
Invasions by alien species	International trade and transport (roads, railways, rivers), gardening practices, exotic trees in forestry, exotic pests released in the wild, climate change, etc.
Epidemics affecting wildlife	Arrivals of pathogens that are favoured by the introduction of exotic species, pollution and the destruction of habitats
Climate change	Carbon emissions, deforestation and other land use changes due to human activities
Dessication of soils and wetlands	Excess pumping of underground water tables

Main threats	Some underlying causes
Recreation and leisure	Overuse of green open spaces and wild areas, little respect for nature, mountain biking and motor sports in fragile areas, dogs not on leash
<i>Threats in marine areas:</i>	
Overfishing and decline of species	Industrial fishing, over exploitation of target species, by-catch
Pollution and eutrophication	Land-based activities (river run-off), atmospheric deposition, maritime traffic
Degradation and destruction of the sea floor	Beam trawling, dredging, sand and gravel extraction
Alien species introduction	Maritime trade (ballast waters, fouling), leisure navigation, mariculture, climate change
Leisure and tourism	Coastal development, water quality in summer (high population), mechanical beach cleaning, noise and other perturbations due to the high population

India's biodiversity is one of the most significant in the world. However, this rich biodiversity of India is under severe threat owing to habitat destruction and over exploitation. The country has several problems such as overpopulation, large number of cattle heads, growing demand for land, energy and water supply. Unplanned developmental works and over exploitation of resources have made its living resources most vulnerable. The major causes and issues related to threat to biodiversity are discussed below:

Habitat Loss

Habitat loss is one of the biggest threats to biodiversity and the largest reason for species going extinct. Cutting forests to create fields, filling in wetlands to build houses, and creating dams that change river flow are all examples of habitat destruction. The rapidly growing human population is putting more and more pressure on existing habitats. In most of the countries, original forest cover is lost and converted to farmlands. This has ecological consequences and many countries now have national parks, sanctuaries and other ways of preserving land for future use. In India, several rare butterfly species are facing extinction with the fast rate of habitat destruction in the Western Ghats.

Poaching of Wild Life

Another major problem is the poaching and killing of animals and birds. Many species of animals and birds are hunted for their fleshes, skins, furs, feathers, bones, tusks, horns, and venoms and so on. This unjustified killing is going on even today. Apart from poachers and smugglers, various

ethnic groups or Adivasis kill faunal wealth for satisfying their faith, taboo or for amusement. In addition, the clearing of natural forests to make room for commercial plantations causes innumerable damage to wildlife.

In the first half of the century, lion and in particular tiger have been decimated by the British and the Indian royalty for purposes of sport. At present tiger is being killed on account of the sale of its bones and other parts to meet the unprecedented demand for traditional Chinese medicine. The illegal poaching and unauthorized hunting has harmed the fauna to such an extent that many species of animals have become extinct and many are on the verge of extinction. At least 30% of the trade is illegal and stands next only in value to narcotics trade. As long as this type of money is involved, rare animals will continue to be killed illegally.

There is a conflict between biodiversity conservators and general public because the public is not taking interest in wildlife management. A general awareness has to be developed. People's participation and more stringent implementation of anti poaching laws and better backup facilities like faster vehicles, modernised weapons and more power to tackle poachers at the field level can perhaps reduce the magnitude of the problem of indiscriminate poaching and extermination of many rare species.

Man-Wildlife Conflict

When wild animals leave the protected areas (forests) to raid human settlements in search of food and water it gives rise to a conflict between man and wildlife. The main reason for this conflict is the growing anthropogenic pressure on wildlife habitat which results in:

- Fragmentation and honeycombing of animal habitat.
- Loss of corridors and migratory routes for long-range animals such as elephants, big cats (tigers, leopards, bears) besides others.
- Loss of food and water in their habitat due to the shrinking of forest cover and loss of biodiversity.

When wild animals destroy crops causing economic and food losses to farmers, affect water supplies, kill or injure humans and cause havoc in the lives of human beings, they retaliate by killing the wild animal.

The conflict is fast becoming a critical threat to the survival of many globally endangered species such as the Sumatran tiger, Asian Lion, Snow Leopard, Red Colobus Monkey and many more. It has also been observed that the more volatile species are more prone to extinction because of injury and death caused by humans, traffic (road, railway track) or other accidents (for example, falling into traps, wells, poisoning, electric fences and so on).

Considering that this conflict will always remain, strategies are being evolved by government wildlife managers, scientists and local communities, not just for the protection of humans but also for the conservation of biodiversity (wildlife).

This multi-faceted problem can be minimized with good management practices and approaches involving low-cost strategies such as electric

fencing, community-based natural resource management schemes, incentives, and insurance programmes along with regulated harvesting and wildlife or human translocation.

CASE STUDY

Man-Wildlife Conflict

In India, people living in and around the protected areas mainly depend on forest products, agriculture and agro-pasture. As a result, very often man-wildlife conflicts result in crop loss, injury or loss of human life and sometimes the death of wild animals.

About 1,07,770 people live in 117 villages in and around the Sariska Tiger Reserve Project in Rajasthan. Agriculture and rearing livestock are the main sources of livelihood for them. Many species of wild herbivores such as the Nilgai and wild boars are to be blamed for 50 per cent of the damage to their crops while sambar, Chital, the common langur, rhesus monkeys and parakeets are blamed for the rest. Wild carnivores such as tigers and leopards are responsible for livestock loss. Tigers prey on big domestic animals like cattle and buffalos while leopards prey on goats, sheep and calves.

3.8 ENDANGERED AND THREATENED SPECIES OF INDIA

A species is said to be **extinct** when it is not seen in the wild for fifty years at a stretch like dodo, passenger pigeon. A species is said to be in **vulnerable** category if its population is facing continuous decline due to overexploitation or habitat destruction. Such species are still abundant but under a serious threat of becoming **endangered** if causal factors are not checked. Species those are not endangered or vulnerable at present, but are at a risk, are categorised as **rare** species. These species are usually localised within restricted area i.e., they are usually endemic. Sometimes they are thinly scattered over a more extensive area.

A species is said to be endangered when its number has been reduced to a certain level or whose habitats have been drastically reduced and if such species is not protected and conserved, it is in immediate danger of extinction. The International Union for Conservation of Nature and Natural Resources (IUCN) publishes the Red Data Book which includes the list of endangered species of plants and animals. The red data symbolises the warning signal for those species which are endangered and if not protected are likely to become extinct in near future. Critically Endangered species in India According to the Red Data Book of IUCN, there are 47 critically endangered species in India. The Red list at Rio +20 Earth Summit, 2012, has listed 132 species of plants and animals as Critically Endangered from India.

Botanical Survey of India (BSI) has published a Green Book which lists rare plant species growing in protected areas like botanical gardens. In India, nearly 450 plant species, 150 mammals and 150 species of birds are estimated to be threatened and identified in the categories of endangered or rare while an unknown number of species of insects are endangered.

Few of the endangered mammals, reptiles, amphibians, fishes, birds and spiders are listed below:

Mammals: The Pygmy hog, Himalayan wolf, Kashmir stag, Javan Rhinoceros, red fox, sloth bear, red panda, tiger, leopard, striped hyena, Indian lion, golden cat, desert cat.

Reptiles: Gharial, green sea turtle, leatherback turtle, Sispara day gecko, hawksbill turtle.

Amphibians: Kerala Indian frog, White-spotted bush frog, Munnar bush frog, Tiger toad.

Fishes: The Ganges Shark, large-tooth sawfish, knife-tooth sawfish

Birds: Great Indian Bustard, Siberian Crane, Bengal Florican, Forest owl, Pink-headed duck, Himalayan Quail, Indian Vulture, Red-headed vulture.

Spiders: Rameshwaram Ornamental Spider, Gooty Tarantula.

3.9 ENDEMIC SPECIES OF INDIA

An endemic species is one whose habitat is restricted to a particular area. The term could refer to an animal, a plant, a fungus, or even a microorganism. The definition differs from “indigenous,” or “native,” species in that the latter, although it occurs naturally in an area, is also found in other areas. Endemic species are often endangered, and particular examples may become a focus point for campaigns to protect biodiversity in a given environment. Some have become national, or regional, emblems.

There are two ways in which a species may become endemic to a particular area. An initially widely distributed population may disappear from many of its habitats, due to changes which have occurred. These could be climate changes, an influx of predators, or human activities. Eventually, the organism may be confined to just one area: this type is known as a *paleo-endemic species*. Alternatively, various factors could cause two populations of a given species to become isolated from one another. For example, as a result of plate tectonics, a continent may split apart, forming two new continents, each with its own population of a given organism. Over long periods of time, these two populations evolve differently, because they cannot interbreed with one another, and eventually they are sufficiently different from one another to be classified as separate species. These are known as *neo-endemic species*.

India has many endemic plant and animal species. Among plants, species endemism is estimated at 33%. More than 140 endemic genera exist, but there are no endemic families (Botanical Survey of India, 1983). Areas rich in endemic species are north-east India, the Western Ghats and the

Source: Critically endangered animal species of India, March 2011, Min. of Env. and Forests, www.nhmnic.in

north-western and eastern Himalayas. A small pocket of local endemism also occurs in the Eastern Ghats. The Gangetic plains are generally poor in endemics, while the Andaman and Nicobar Islands contribute at least 220 species to the endemic flora of India (Botanical Survey of India, 1983). In India, the locations recognised for conservation action are the Agastyamalai Hills, Silent Valley and New Amarambalam Reserve and Periyar National Park (all in the Western Ghats), and the Eastern and Western Himalaya. Endemism among mammals and birds is relatively low. Only 44 species of Indian mammal have a range that is confined entirely within Indian territorial limits. Four endemic species of conservation significance occur in the Western Ghats. They are the Lion-tailed macaque *Macaca silenus*, Nilgiri leaf monkey *Trachypithecus johni*, Brown palm civet *Paradoxurus jerdoni* and Nilgiri tahr *Hemitragus hylocrius*. Only 55 bird species are endemic to India, with distributions concentrated in areas of high rainfall. They are located mainly in eastern India along the mountain chains where the monsoon shadow occurs, south-west India and the Nicobar and Andaman Islands. In contrast, endemism in the Indian reptilian and amphibian fauna is high. There are around 214 endemic reptiles, and 110 endemic amphibian species.

3.10 BIODIVERSITY CONSERVATION

Biodiversity is a wealth to which no value can be put. The survival of the human race is dependent on conservation of biodiversity. It is evident that this invaluable heritage is being destroyed at an alarming rate due to several reasons. Measures are being taken up at national and international levels to address this issue. The Earth Summit produced a plan of action on a number of issues (Agenda 21) including conservation of biodiversity during the 21st century.

There are several strategies which are adapted for conservation of Biodiversity Some of these are:

1. Legislation

Formal policies and programmes for conservation and sustainable utilisation of biodiversity resources dates back to several decades. The concept of environmental protection is enshrined in the Indian constitution in articles 48a and 51a(g) Major central acts relevant to biodiversity include:

- Environment Protection Act, 1986
- Fisheries Act, 1897
- Forest Act, 1927
- Forest (Conservation) Act, 1980
- Wildlife (Protection) Act 1972 and Wildlife (Protection) Amendment Act 1991

2. In-situ Conservation

Conserving the animals and plants in their natural habitats is known as *in situ* conservation. The established natural habitats are:

Source: Sinha et al. EnviroNews, Vol. 16(4), 2010

- National parks and sanctuaries
- Biosphere reserves
- Nature reserves
- Reserved and protected forests
- Preservation plots
- Reserved forests

The first such initiative was the establishment of the Corbett National Park in 1936. National Parks are highly protected by law. No human habitation, private land holding or traditional human activity such as firewood collection or grazing is allowed within the park. Sanctuaries are also protected but certain types of activities are permitted within these areas.

Biosphere Reserves are another category of protected areas. Under this, a large area is declared as a Biosphere Reserve where wildlife is protected, but local communities are allowed to continue to live and pursue traditional activities within the Reserve. The Government of India has set up seven biosphere reserves: Nokrek (Meghalaya), Nilgiri (Karnataka, Kerala, Tamil Nadu), Namdapha (Arunachal Pradesh), Nanda Devi (Uttar Pradesh), Sundarbans (West Bengal), Great Nicobar (Andaman & Nicobar Islands), Gulf of Mannar (Tamil Nadu).

Several special projects have also been launched to save certain animal species which have been identified as needing concerted protection effort. These projects are designed to protect the species *in situ*, by protecting and conserving their natural habitat. Project Tiger, Project Elephant, Save the Barasingha campaign are examples of this initiative. Other strategies include offloading pressure from reserve forests by alternative measures of fuelwood and fodder need satisfaction by afforestation of degraded areas and wastelands.

A programme “Eco-development” for *in-situ* conservation of biological diversity involving local communities integrates the ecological and economic parameters for sustained conservation of ecosystems by involving local communities with maintenance of earmarked regions surrounding protected areas.

Approximately, 4.2% of the total geographical area of the country has been earmarked for extensive *in-situ* conservation of habitats and ecosystems. A protected area network of 85 national parks and 448 wildlife sanctuaries has been created. This network have been significant in restoring viable population of large mammals such as tiger, lion, rhinoceros, crocodiles and elephants.

3. Ex-situ Conservation

Ex-situ conservation of plants and animals preserve/or protect them away from their natural habitat. This could be in zoological parks and botanical gardens or through the forestry institutions and agricultural research

centres. A lot of effort is under way to collect and preserve the genetic material of crops, animal, bird and fish species. This work is being done by institutions such as the National Bureau of Plant Genetic Resources, New Delhi, the National Bureau of Animal Genetic Resources, etc. Reproduction of an animal or plant into the habitat from where it has become extinct is another form of *ex situ* conservation. For example, the Gangetic *gharial* has been reintroduced in the rivers of Uttar Pradesh, Madhya Pradesh and Rajasthan where it had become extinct. Seed banks, botanical, horticultural and recreational gardens are important centres for *ex-situ* conservation. *Ex-situ* conservation measures complement *in-situ* conservation.

4. Recording Indigenous Knowledge

The lives of local communities are closely interwoven with their environment, and are dependent upon their immediate resources for meeting their needs. These communities have a vast knowledge about local flora and fauna which is very important for biodiversity conservation. Much of this knowledge is orally passed on from generation to generation. Such indigenous knowledge needs to be recorded and preserved before it is lost. Several organizations have recognized this and are working to record the knowledge and preserve it for posterity.

5. Community Participation in Biodiversity Conservation

It is being recognized that no legal provisions can be effective unless local communities are involved in planning, management and monitoring conservation programmes. There are several initiatives to do this, both by government as well as non-governmental organizations. For example, the Joint Forest Management philosophy stresses involvement of village communities in regenerating and protecting degraded forest land in the vicinity of villages. Successful conservation strategies will have to have the confidence and participation of the local communities.

6. International Conservation Strategies

Conserving biodiversity is not an issue confined to any one country or community. It is a crucial global concern. Several international treaties and agreements are in place in the attempt to strengthen international participation and commitment towards conserving biodiversity. Some of these are:

- **The Convention on Biological Diversity:** This was signed during the Earth Summit in 1992. It focuses not only on conserving biodiversity but also on sustainable use of biological resources and equitable sharing of benefits arising from its use.
- **The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES):** This is an international treaty which is designed to protect wild plants and animals affected by international trade. The treaty, in force since 1975, controls the export, import and re-export of endangered and threatened wildlife.

- **The Convention on Wetlands of International Importance:** This Convention, also known as the Ramsar Convention, was signed in Ramsar (Iran) in 1971 and came into force in December 1975. It provides a framework for international cooperation for the conservation of wetland habitats which have been designated to the 'List of Wetlands of International Importance'.

Saving biodiversity - Saving life

Following are some conservation actions that we can take up:

- Plant trees. Grow native species of plants (trees, shrubs and climber) where possible, this would attract local wildlife such as birds, butterflies and insects.
- Grow local vegetables in your school garden that are not usually available in the markets. This would allow help conserve them for generations to come.
- Initiate, organize and participate in responsible citizen action against existing or proposed activities that harm or are likely to harm local biodiversity.
- Make a list of different kinds of trees in your campus or locality. For each one find out the names, uses, flowering season, animals and birds that depends on it. Present this information in an interesting way, and put it up by the tree. Many people will stop by to read this information and know more about the tree.
- Curb our greed for products made out of animal parts like skin, fur, ivory, bones, nails, etc., to discourage wildlife traders and poachers, and spare the lives of the remaining animals.
- Adopt vegetarianism which would require fewer animals to be fattened for slaughtering and more plants to be grown for food.
- Avoid using insecticides, pesticides and inorganic fertilizers and try to use natural plant- based substitutes wherever possible. Paper and cloth should replace non-biodegradable plastic and polyester which damage the ecosystem.
- Make children aware of their surroundings and the need for biodiversity.
- Promote bio-farming which is less intensive and environmental-friendly.
- Make use of sustainable technologies like smokeless chulhas, ground water recharging unit, wind energy, solar power, etc.
- Set up 'Community Sanctuaries' for free ranging animals, migratory birds and endemic species. Establish voluntary 'Village Reserves' for plants and animals.
- Assist National level Bodies in recording and preserving rare and endemic species
- Create 'Biodiversity Registers' in communities, schools, villages.

EXERCISES

1. What is meant by biodiversity? Describe the uses and importance of biodiversity.
2. Explain the levels of biodiversity.
3. Discuss various biogeographic zones of India.
4. What are the hotspots of biodiversity? Discuss the hotspots of India.
5. Write a short note on threats to biodiversity.
6. Discuss the consumptive and productive values of biodiversity.
7. What are extinct, endangered, vulnerable and rare species? Discuss giving examples.
8. How are poaching and human-wildlife conflicts responsible for depletion of biodiversity?
9. What do you understand by endemic species? Give examples of the endemic species of India.
10. What are the various approaches for conservation of biodiversity? Discuss each in detail.
11. Comment upon Indian biodiversity with special reference as a mega diverse nation.
12. Write short notes on: (i) Red data book, (ii) Habitat loss (iii) Endangered species



UNIT **4**

Natural Resources: Problems and Prospects

The, Earth provides enough to satisfy every body's needs but not for any body's greed.

Mahatma Gandhi

Objectives

- Introduction
- Classification or Types of Resources
- Forest Resources
- Water Resources
- Mineral Resources
- Food Resources
- Energy Resources
- Land Resources
- Resource Management Sustainable Development

4.1 INTRODUCTION

Everything available in our environment which can be used to satisfy our needs, provided it is technologically accessible, economically feasible and culturally acceptable can be termed as 'Resource'. Thus any part of our environment such as land, air, water, wild life, minerals, forest and even human population that human beings themselves can utilise to promote their welfare by their intellectual efforts and technologies may be regarded as resource. In other words one can say that the five basic ecological variables i.e., energy, matter, space, time and diversity together can be known as resource. These resources form the backbone of the economy and prosperity of a nation.

4.2 CLASSIFICATION OR TYPES OF RESOURCES

Natural resources can be classified into two categories on the basis of origin:

(i) Biotic Resources

These are obtained from the biosphere and have originated from some living organisms or have life such as human beings, flora and fauna, fisheries, livestock and some fossil fuels like coal, petroleum etc. The biotic resources could be renewable or non-renewable type.

(ii) Abiotic Resources

All those things which are of non-living origin are termed as abiotic resources for example minerals, rocks, metals, soil, water etc.

Resources can also be classified on the basis of duration and availability of resources into two categories:

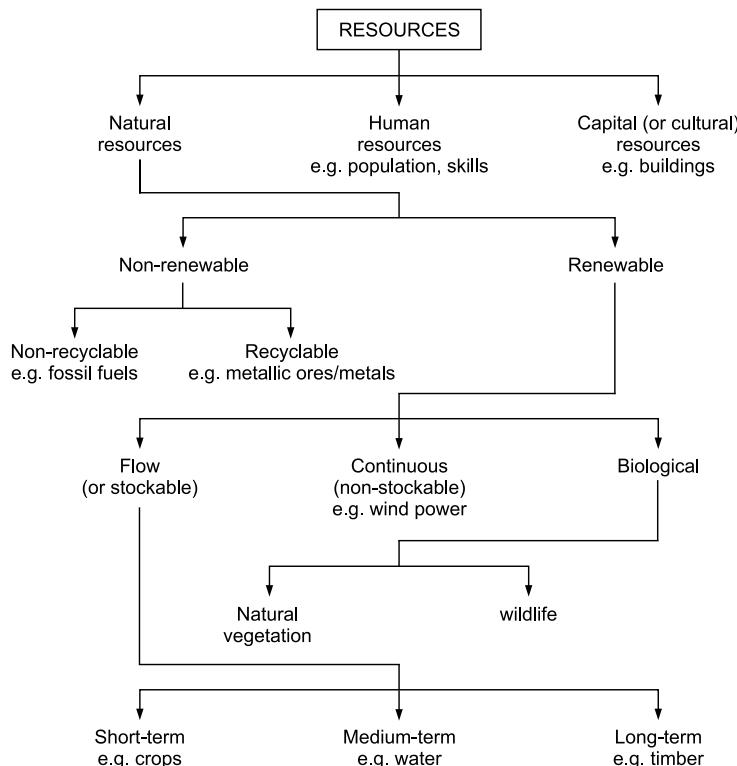
(i) Renewable Resources

The resources that are non-exhaustible in nature and can be renewed or reproduced by physical, chemical or mechanical processes are known as renewable or replenishable resources. For example, solar and wind energy, water, forests and wildlife etc.

The renewable resources may further be divided into flow, continuous and biological.

(ii) Non-renewable Resources

These occur over a very long geological time. Mineral and fossil fuels are examples of such resources. These resources take millions of years in their formation. Fossil fuels by no means can be recycled and get exhausted with their use, while some of the resources like metals are recyclable and reusable.



Resources are vital for any developmental activity. But irrational consumption in the relentless march towards development have plundered the earth's natural resources which have finally threatened human survival on earth. Thus conservation i.e. judicious and planned use of resources becomes essential as it aims at sustainable benefit to the present generation. It also maintains a potential to meet the needs and aspirations of future generations.

4.3 FOREST RESOURCES

The forest is a complex ecosystem consisting mainly of trees that shield the earth and support innumerable life forms. They play a major role in enhancing the quality of environment. They clean the air, cool it on hot days, conserve heat at night, and act as excellent sound absorbers. Forests also control soil erosion, regulate stream flow, support a variety of industries, provide livelihood for many communities and offer opportunities for recreation. They also are a natural habitat for the wildlife. The National Forest Policy (1988) emphasises the role of forests in maintaining the life support system.

The forests of India are ancient in nature and composition. They are rich in variety and shelter a wide range of flora fauna. India possesses a distinct identity, not only because of its geography, history and culture but also because of the great diversity of its natural ecosystems. The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar islands, the Western Ghats and the north-eastern states, to dry alpine scrub high in the Himalaya to the north. Between the two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone and temperate montane forests.

For the purpose of administration, forests in India are classified into three types, namely:

- Reserved forests
- Protected forests
- Unclassed forests

Reserved forests are those which are permanently earmarked either to production of timber or other forest produce and in which right of grazing and cultivation is seldom allowed. In **protected forests** these rights are allowed subject to a few minor restrictions. **Unclassed forests** consist largely of inaccessible forests.

Forests are also classified according to density namely: **dense**, **open** and **mangrove**.

Dense forests are those which have the crown cover density greater than 40%; while forests having crown cover densities between 10% to 40% are included in the **open forests**. The vegetated areas, where the crown density is less than 10% are known as scrub lands and are usually not included in the forest land.

Mangrove forests are mainly found along stretches of tropical ocean. They usually grow in places near quiet ocean waters. These forests often

grow in shallow waters along bays, lagoons and river mouths. The thousands of stilt-like roots of a mangrove tree catch silt and sand, which piles up in the shore water. These roots slow down the current and help settle the silt. The mangroves, thus, help in building up dry land.

In India, at present, forest areas cover about 2.9 billion hectares of land, which is about 22 per cent of the total geographical area. Of the total forest cover, 54.5 per cent are reserved, 29.2 per cent protected and 16.4 per cent unclassed forests (Fig. 4.1). About 59 per cent of the forest area are dense, 40 per cent open, and less than one per cent is mangrove forests (Fig. 4.2).

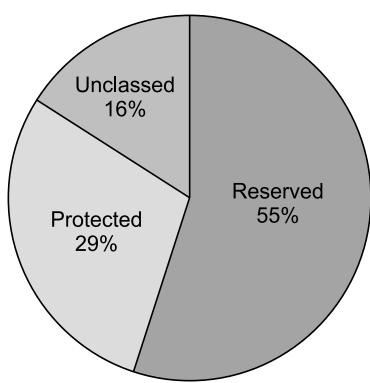


Fig. 4.1 Types of forests in India

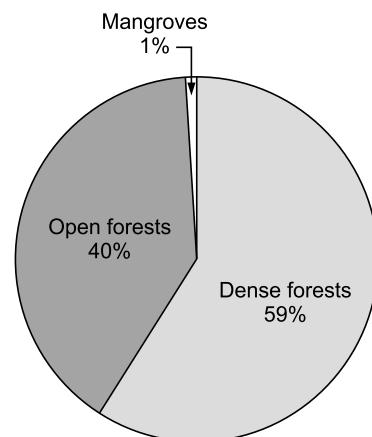


Fig. 4.2 Forest cover by density class.

4.3.1 Importance of Forests

Functions of a forest may broadly be classified into following three categories:

- (i) **Protective functions:** These include the protective role of forests against soil erosion, droughts, floods, intense radiation etc.
- (ii) **Productive functions:** Forests are the source of wood and many other products like gums, resins, fibers, medicines, honey, pulp, paper etc.
- (iii) **Accessory functions:** These include the role of forests in recreation, aesthetics and as abode of many animals and tribal people. It maintains the biodiversity of nature.

Thus forests are important both ecologically and economically.

Ecological Significance

The forests help in balancing oxygen and carbon dioxide level in atmosphere, regulate earth's temperature regime and hydrological cycle. It increases local precipitation and water holding capacity of soil, thus preventing drought situation. Vegetation cover provided by forest impedes the velocity of run off on soil surface, checks soil erosion, silting and landslides thus reducing the danger of flood. The litter derived from fallen leaves maintains fertility of soil by returning the nutrients in form of humus. Forests also act as

refuge for wild animals and provide protection to them against strong, cold or hot and dry winds, solar radiation, rain and enemies.

Economic Significance

Wood which has various applications in domestic and industrial processes, is the chief product of forest. Wood when used as fuel, has certain advantages over coal as its sulphur and ash contents are very low but, at the same time, excessive use of fuelwood means pressure on forests which have many functions to serve. Wood may also be converted to solid and gaseous fuels. Timber is an important material in building construction and day-to-day uses. Forests provide raw material for various wood based industries viz., pulp and paper, composite wood, rayon and other man-made fibers, sport goods, furniture, matches etc. Miscellaneous products like bamboos, resins, gums, some oils, fibers medicines etc. are also obtained from forests.

4.3.2 Forest Cover of the Earth

It is accepted that, ideally, the Earth should have a forest cover of one third of its land area, which should extend to 66 per cent forest cover in the hilly regions. At the beginning of the twentieth century, the Earth had a forest cover of 5 billion hectares (38.5 per cent of the land area). But presently it is estimated that the forests occupy an area of 2.9 billion hectares, which works out to just 22 per cent of the land area. This figure represents the world average. It is a fact that forest loss into enormous proportions is mainly in developing countries. It is estimated that the developing world is losing 6.5 per cent of its forests per decade. This is in contrast to the industrialized world, which is gaining forest land.

Forest Cover in India

India's forests cover an area of approximately 67.5 million hectares, 20.6 per cent of the geographical area of the country. These forests are classified as

Table 4.1

	<i>Area km²</i>	<i>Percent of geographical area of the country</i>
(i) Dense forests (with a canopy cover greater than 40% of the wooded area)	416,809	12.7
(ii) Open forests (with a canopy cover of 10-40% of the wooded area)	258,729	7.9
Total		20.6
(iii) Scrubs	47,318	1.4

Source: Dept. of Forests, Govt. of India 2003-2004 data.

Forest Cover per Person

The forest cover of India is comparable with that of the world average. But the forest cover per person is meagre as the country has about 17 per cent of the world's population of 6.2 billion. The forest cover of India works out to $634 \text{ m}^2/\text{person}$, which, compared to that of the United States, Canada, Russia and the Latin American countries, is very small.

There has been a fast disappearance of tropical forests in our country, at a rate of about 7.3 million ha per year. The major cause for the depletion of forest cover is the expansion of agricultural practices in the country. The areas with rich biological diversity were shifted by the modern practices into the areas of cultivation with a few species of hybrid crop plants.

Another cause for over exploitation of forest resources due to reclamation activities of building dams, factories, highways, mining operations etc. Over population in third world countries is often cited as major cause of over exploitation of forest resources.

4.3.3 Deforestation

Forests are the biggest source of materials and land for modern society. Deforestation has become inevitable for supporting human activities. The need of fuelwood and timber for construction and furniture continues to increase as population is expanding.

India has 67.5 million hectares of forest land out of a total geographical area of 329 million hectares. It is on record that the country had 80 per cent forest cover 5000 years ago which has now been reduced barely to 22 per cent as discussed above. Per capita forest land is 0.1 hectare compared to the world average of 1 hectare. This shows the poorest record of India. We are losing 1.3 million hectares of forest cover every year and at this rate of deforestation we are likely to lose all the forest cover and face total disaster within the next 25 years.

During 1951-2000 i.e. almost 50 years after Independence, India witnessed maximum loss of forests, namely, 6.0 million hectares of forest area. This overconsumption has been due to population explosion (both human and livestock population) accompanied by rapid urbanization and industrialization as well as change of life style. There has been tremendous pressure on forest systems to meet ever-increasing demands on fuel or fire wood, timber and pulp wood for housing, furniture, agricultural implements, railway slippers, sports goods, ship and boat building, paper and pulp industries etc. Annual consumption of fire wood in the country is about 170 million tons while 10-15 hectares of forest cover is destroyed each year to meet fuel requirements. The consumption of fire wood is 80 per cent in villages and 20 per cent in urban areas. There is a shortfall of about 195 million m^3 in the demand and supply of fuel wood. Similarly the gap for timber between demand and supply is about 15 million m^3 .

The forests are subjected to at least five times more pressure than what they can withstand. **The imbalance between demand and production of fuelwood and timber is one single factor that has contributed most to the depletion of forests in the country.**

Excessive grazing, frequent fires, and other biotic factors have adversely affected the natural regeneration of our forests. Nearly 73.6% of the forest area does not have regeneration of important species, and the percentage of forest area with no regeneration varies from 15% (West Bengal) to 90% (Jammu and Kashmir). These are indicators of deteriorating situation leading to progressive degradation of forests. The forest area lost due to various reasons during the period 1952-80 is inferred to be nearly 43.280 km² with an average loss of 1550 km² annually. The impact of agriculture on the denudation of forests has been the maximum as exemplified by the diversion of the largest forest area (26.230 km²) to agriculture during this period. However, on the enactment of the Forest Conservation Act in 1980, the forest area diverted for non-forest uses between end-1980 and mid-1993 was 3040 km², reducing the rate of diversion to approximately 250 km² per annum. Nearly 7000 km² of forest land was encroached upon between 1951 and 1982.

Shifting Cultivation (Jhumming): A low-energy budget and a low-investment system of subsistence husbandry — is practised in about 16 states of India, and is most prevalent in the seven north-eastern states and Orissa. Since there is not enough area for the system to function, forest degradation is rampant.

Forest fire: It is one of the most dangerous sources of damage to forests and wildlife. On an average, 53.1% of the forest area is affected by fire and it ranges from as low as 6.8% to as high as 97%. About 8.92% of the forest area is being affected by frequent fires and 44.25% by occasional fires.

The pressures of **increasing livestock population** and migratory graziers are a potent force, responsible for the continual degradation of forests, and grasslands, causing widespread devastation. It is estimated that currently over 100 million heads of livestock or 110 million cow units graze in the forests of the country. Considering the degraded state of the forests, and a minimum requirement of 2 ha of land for one cow unit, the grazing pressure on the forests is more than three times, which is far beyond the carrying capacity of this resource.

4.3.4 Consequences of Deforestation

The process of deforestation results in many undesirable environmental impacts at multiple scales. The local impacts include **decreasing soil stability, increasing erosion and sediment transport** into streams, **reduction in biodiversity** through loss of habitat and **alterations to microclimates** that typically increase local temperatures because of loss of vegetation. **Degradation of air quality** is often at the regional scale if deforestation is being driven by burning down slash as in shifting cultivation. This promotes high levels of **air pollution** (mainly particulate matter, carbon monoxide, sulphur oxides and nitrogen oxides) that is harmful to both human and wildlife. Deforestation can also produce impacts on global scale. Cutting and burning of large forest tracts liberates large amounts of carbon and **increase levels of green house gas**, carbon dioxide

in the atmosphere. Removing forest vegetation further disrupts the global carbon balance by eliminating the living trees that served as a sink for carbon dioxide.

4.3.5 Conservation of Forests

Over the past few decades both the government and local communities have resisted the temptation of indiscriminate exploitation of forest resources, and thus conservation of forests in India has become significant. Of further significance is the fact that forest conservation in India started well before the global concerns of climate warming and decline of biodiversity, and thus represents an indigenous response to environmental concerns and not a response to external pressure.

The factors that have contributed to forest conservation in India are as follows:

The forest Conservation Act, 1980. This bans off unnecessary and avoidable forest conversion to non-forest use. Only 46000 ha of forest have officially (FSI 1988) been diverted to non-forest use in the 7 years after 1981, mainly for river valley projects, compared to 4.3 Mha officially diverted between 1951 and 1980.

Compensatory Afforestation Any permission given for forest conversion must be accompanied by compensatory afforestation on degraded land.

Establishment of National Parks and Wildlife Sanctuaries 12.6 Mha of forest has been dedicated to nature reserves.

Afforestation Programme India has launched a large afforestation programme in degraded forests, village commons, and farm land. The area afforested in India from 1980 to 1990 was 14.4 Mha.

Joint Forest Management: Under the legislation of 1988 and 1990, a joint programme involving local communities and the Forest Department has been launched with the aim of protecting and promoting natural regeneration in degraded forest lands. Under such a programme, in three districts of West Bengal, 191750 ha of degraded forest land was revegetated between 1984 and 1990.

Removal or Reduction of Subsidies to Industry Earlier, industry enjoyed a guaranteed supply of timber at low or nominal rates from forests. With the reduction in subsidies, industry is expected to use forest resources efficiently.

Environmental Movements, Free Press and Judiciary Environmental movements, starting with the 'Chipko movement' in the Himalayas, have spread to several states. India's free press and judiciary is generally progressive and supports forest conservation efforts and acts as a check on any indiscriminate deforestation.

National Forest Policy, 1988

The following are the main objectives outlined in the National Forest Policy of India, 1988:

- Maintenance of environmental stability through preservation and where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country.
- Conservation of the natural heritage of the country by preserving the remaining natural forests along with their vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country.
- Control of soil erosion and denudation in the catchment areas of rivers, lakes, and reservoirs in the interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs.
- Checking the extension of sand dunes in the desert areas of the Rajasthan and along the coastal tracts.
- Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded, and unproductive lands.
- Meeting the requirements of fuel wood, fodder, minor forest produce, and small timber of the rural and tribal populations.
- Increasing the productivity of forests to meet essential national needs.
- Encouraging efficient utilization of forest produce and maximizing substitution of wood.
- Creating a massive people's movement, with the active involvement of women, for achieving these objectives and to minimize the pressure on existing forest areas.

4.3.6 Timber Extraction

Wood is an important component of a forest thus its removal has immediate implications on it. It is commonly used as a building material, for making furniture as a fuel. Good quality and durable wood which is used as a building material and for making furniture is commonly known as *Timber*. With growth of population and industrialization, the demand for timber is increasing, which has led to the loss of natural forests.

Impact of Timber extraction

Loss of biodiversity: Removal of forest cover leads directly to a loss of animal habitat and plant species thus a decline in biodiversity. The increased spring run-off coupled with summer drought, soil erosion and land-slips results in hotter summers and cooler winters. The drying of the forest areas lead to an increased risk of forest fires.

Loss of Carbon Storage Capacity: Carbon dioxide emissions in the atmosphere due to intense use of fossil fuels during the course of industrialization has led to global warming. The present concentration of CO₂ in the atmosphere is 387 ppm. Forests, apart from being a source of

CO₂, also provides opportunity for reducing atmospheric CO₂ concentration. Mitigation potential of forestry sector at global level is estimated to be 60 to 87 Gt C during the period 1995 to 2050 (Brown, 1996). Carbon can be removed through the growth of forests. (CO₂ sequestration discussed in detail in the next unit) Trees act as a sink and thus, forests represent the largest carbon storage mechanisms in the global carbon cycle. When the forests are destroyed the carbon storage capacity is lost. Moreover the additional carbon is released into the atmosphere through decay and burning.

4.3.7 Case Study

CASE STUDY

Chipko-Movement

Chipko-movement started in Nineteen Seventees in a small hill village of the upper reaches of Himalayas. Tribal people of Tehri-Garhwal district of Uttarakhand realised the importance of forests and decided against giving its products to the people of other areas. They stood against the ruthless butchery of nature and the axes of greedy contractors. At the initial stage of the movement (in December, 1972), the women of Advani village in Tehri-Garhwal protested against indiscriminate felling of trees. In March 1973, a sports goods factory was to cut the Ash trees near the village Mandal in Chamoli district. The local people prevented the same by hugging (vern. Hindi Chipko) the marked trees. In 1994, a group of women led by Gaura Devi successfully prevented felling of trees near village Reni. The movement became famous in 1978 when the women of Advani village in Tehri-Garhwal faced police firing and later courted arrest. The Chipko Movement spread slowly to all nearby areas under the leadership of Shri Sunderlal Bahuguna of silyara in Tehri region and Shri Chandi Prasad Bhatt of Gopeshwar.

Chipko movement has challenged the old belief that forests mean only timber. It emphasises that important gift of tree to us is not timber, but soil, water and oxygen. The slogan of Chipko movement is infact planting five Fs-food, fodder, fuel, fiber and fertiliser trees.

The tribals of the other parts of the country got inspiration from Chipko movement and started similar movements in their areas. One such movement reached to Karnataka as Appiko movement under the leadership of Pandurange Hegde. The other parts of the country where this movement reached are – Santhal Parganas, Chhatisgarh, Thane and the Aravali regions.

4.3.8 Dams and Their Effect on Forest and Tribal People

In India, national development has been largely equated with economic growth and surplus. Large, centralized industries, irrigation projects have been symbols of such development, which through the process of industrialization promised to set the country on the path of modernization and development. One of the inevitable outcomes of this has been massive environmental degradation and 'development induced displacement'.

Immediately after independence, a series of large dams were planned and built on some of the major rivers in India. Large dams promised to solve the problem of hunger and starvation by providing irrigation and boosting food production, controlling floods and providing much needed electricity for industrial development. It was this grand promise that prompted Pandit Nehru, our first Prime Minister, to call dams "*secular temples of modern India*". Environmental and social costs of such large dams were thought to be an inevitable price that one had to pay for such development. *Socio ecological costs of large dams were grossly underestimated and largely ignored.*

A large dam inevitably alters the course of nature and because of the play of complex and largely unknown forces, *the ecological consequences are very serious*. The forest cover bears the brunt of dam construction in a severe manner. The forest area which is supposed to get submerged, is cleared off by the contractors. The people who are displaced also are rehabilitated on the forest land that too is acquired and cleared off. The forest is also cleared for approach roads, offices, residential quarters and for storage of construction material. With the reduction in the forest cover and the entry of people for dam construction, the pressure on remaining forest increases. The people's need for firewood leads to further denudation. The construction of a dam, therefore has a ***multiplier effect***. The large number of *tribal people get displaced* and affected by dam construction. The estimates show that dams are the single largest cause of displacement accounting for 75 to 80% of the total displacement.

Table 4.2. Independent estimate of total person displaced by dams during 1950-90 (in lakhs)*

Category	Number (in lakhs)	Percentage (%)**
Total number of persons displaced	164	100%
Total number resettled	41	25%
Backlog	123	75%
Total number of tribal persons displaced	63.21	38%
Total tribal persons resettled	15.81	25%
Backlog	47.40	75%

***Source:** Amita Patwardhan, Dams and tribal people in India, Dams and Development: A new framework for decision-making, 2000.

** Percentage is out of total tribal persons displaced.

It has been estimated that large majority of the people are Scheduled Tribes and Scheduled Castes. The tribal communities are often forced to migrate to urban slums in search of employment or become landless labourers. They never share the benefits of the projects which have displaced them, be it irrigation or electricity.

Anti dam movement in India also has a long history. The first struggle against a dam was fought in early 1920s by peasants in Western Maharashtra who opposed the Mulshi dam built by the Tatas. In recent past, from 1970s till today several anti dam struggles have posed a major challenge to dam building in India. Silent valley was one of the first success stories where a dam threatening to submerge rich forest was scrapped. One of the longest and most well known struggle against large dams was in the Narmada valley against the Sardar Sarovar Project, known as Narmada Bachao Andolan (NBA), led by Medha Patkar. The struggle began in the mid-1980s and it had a profound impact on the debate on large dams and role of people's movement in India. NBA, along with other movements, has brought some of the most of the most fundamental issues regarding equality, social justice and the notion of development of the forefront.

4.3.9 Case Study

CASE STUDY

Narmada Valley Project

Narmada is the largest western flowing river arising from the Kantaka plateau in Shahdol district. Millions of people live in the basin of this river and use the basin as a resource for their livelihood. Narmada Valley Project was planned with a view to using its water utilization capacity to an optimum level for the benefit of the people. The plan included construction of two large dams (Sardar Sarovar and Narmada Sagar Projects) and many small dams. It would lead to generation of electric power, irrigation of million hectare of land in Gujarat, Madhya Pradesh and Rajasthan and making availability of drinking water. The entire project and the World Bank's role in supporting it till 1993 created controversy. While the project brought benefits as mentioned above, it threatened the livelihood of thousands of people in the area to be flooded by Sardar Sarovar Dam. Also, the project would have enormous environmental impacts. The dam has been designed to divert water from Narmada river into canal and irrigation systems.

The anti-dam stir started in the valley in 1985 in Gujarat, Maharashtra and Rajasthan to stall the building of Sardar Sarovar and Narmada Sagar Dams. In 1989, Narmada Bachao Andolan (NBA), which had the support of other NGO's, became a major force to resist the government efforts that would result in the destruction of

environment and bring miseries to people especially tribals. NBA has been holding demonstrations, courting arrests led by Medha Patkar, demanding in 1990, that the project be suspended. NBA succeeded in influencing the suspension of Japanese aid. Baba Amte, a noted social worker, supported NBA and started a march from Madhya Pradesh to the site of the dam.

4.4 WATER RESOURCES

It is believed that life first originated in water before it invaded land. Water is in fact a precondition of life and essential for the sustenance of all forms of life, food production, economic development and for general well being.

The **primary source of water on the earth is precipitation** that comes in the form of rain and snowfall. India receives annual precipitation of about 4000 km³ including snowfall.* Out of this, monsoon rainfall is of the order of 3000 km³. India is gifted with a river system comprising more than twenty major rivers with several tributaries. The rivers are the main source of surface water in India apart from ponds, tanks and reservoirs etc. The mean annual flow of the Indian rivers is estimated to be about 1869 billion cubic meters (bcm). About 690 bcm or 37% of it is available for use. The Indus, the Ganga and the Brahmaputra carry 60% of the total surface water. On the basis of their hydrology, the Indian rivers are divided into two categories: the Himalayan and Peninsular. Most of the Himalayan rivers have their sources in the glaciers and snowfields and therefore are perennial in nature, while the peninsular rivers depend entirely on monsoon rains and hence are seasonal. Thus, the peninsular rivers demand storage of water for irrigation and power generation.

Apart from the water available in the various rivers of the country, **the ground water is also an important source of water for drinking, irrigation, industrial uses etc.** It accounts for about 80% of domestic water requirement and more than 45% of the total irrigation of the country. As per the international norms, if per capita water availability is less than 1700 m³ per year then the country is categorized as water stressed and if it is less than 1000 m³ per capita per year then the country is classified as water scarce. In India per capita surface water availability in year 2001 was 1900 m³ and it is projected to reduce to 1400 m³ by the year 2025 (Kumar et. al., 2005). This water scarcity is an outcome of large and growing population and consequent greater demands for water. An ever increasing growth in population alongwith intensive industrialization and urbanization means more water not only for domestic use but also to produce more food.

Hence to facilitate higher food production, water resources are being over exploited to expand irrigated areas and dry-season agriculture alongwith other developmental activities like production of hydroelectricity, water supply for industrial and domestic use, recreation, inland navigation and fish breeding.

*Source: Rakesh Kumar et.al., Current Science, 89(5), 2005.

4.4.1. Over-utilization of Surface and Groundwater

Worldwide the largest use of water is for irrigation (70%), second is for industry (20%) and third is for direct human use (10%). The total annual requirement of water in India for various sectors has been estimated in the table 4.3.

Table 4.3. Annual water requirement for different uses. (in km³)

Use	1997-98			2010			2025			2050		
	Surf- ace Water	Gro- und Water	Total	SW	GW	Tot.	SW	GW	Total	SW	GW	Tot.
Irrigation	318	206	524	339	218	557	366	245	611	463	344	807
Domestic	17	13	30	24	19	43	36	26	62	65	46	111
Industries	21	9	30	26	11	37	47	20	67	57	24	81
Power	7	2	9	15	4	19	26	7	33	56	14	70
Inland Naviation	—	—	0	7	—	7	10	—	10	15	—	15
Environment-Ecology	—	—	0	5	—	5	10	—	10	20	—	20
Evaporation losess	36	—	36	42	—	42	50	—	50	76	—	76
Total	399	230	629	458	252	710	545	298	843	752	428	1180

Source: Integrated water resources development - A plan for action, Report of the National Commission for Integrated Water Resources Development, Ministry of Water Resources, New Delhi, 1999.

In view of the existing status of the water resources and increasing demands of water for meeting the requirements of the rapidly growing population of the country, the need of the hour is to conserve and manage our water resources. We have to safeguard ourselves from health hazards, to ensure food security, continuation of our livelihoods and productive activities and also to prevent degradation of our natural ecosystems. Over exploitation and mismanagement of water resources will impoverish this resource and cause ecological crisis that may have serious impact on our lives.

4.4.2 Consequences of Over Exploitation of Surface Water Resources

To trap and control flowing surface water, dams and reservoirs are built. The stored river water alongwith rainwater in a dam or a reservoir is used for irrigation, electricity generation, water supply for domestic and industrial uses, flood control, recreation, inland navigation and fish breeding.

These dams and reservoirs have enormous ecological impacts. When a river is dammed, valuable fresh water habitats are lost. Sometimes the river's flow is diverted to cities or croplands, which **affects the fishes and the aquatic organisms**. The **wildlife** that depends on the water or the food chains involving aquatic organisms is also **adversely affected**. Sometimes fishes swim up river from the ocean to *spawn* are seriously affected by reduced water level. The reservoirs which are created on the **floodplains also submerge** the existing vegetation and soil leading to its decomposition

over a period of time. Due to diversion in the river's flow, estuaries are also affected because less fresh water enters and flushes the estuary. Consequently salt concentration increases profoundly *affecting the estuary's ecology*.

4.4.3 Consequences due to the Depletion of Groundwater

If the groundwater withdrawals exceed its recharge, the **water table falls**. When the water table falls, the springs and seeps start drying up and even the stream and the rivers are affected. Thus **surface water diminishes** and this creates the same results as the diversion of surface water. Over the ages, groundwater has leached cavities in the ground. The water fills these spaces and helps support the overlying rock and soil. Due to fall in water table this support is lost and there may be a gradual settling of the land, known as **land subsidence**.

Land subsidence may cause building foundations, roadways, and water and sewer lines to crack. In coastal areas this phenomenon may cause flooding.

Another problem resulting from dropping water tables is **saltwater intrusion**. In the coastal areas, the springs of overflowing groundwater may lie under the ocean. As long as a high water table is maintained a sufficient head of pressure is available in aquifer and freshwater will flow into the ocean. Thus wells in the coastal areas have fresh water. Lowering of water table at a rapid rate reduces pressure in the aquifer and thus permitting salt water to flow into the aquifer and hence into wells.

4.4.4 Water Conservation and Management

Water resources can serve more people by wise use and good management. Every human being has the responsibility to conserve water used in the various activities. Several approaches to conserve and manage the water resources are:

- **Avoid Polluting**—Pollution makes water unfit for use. Renewing takes time and nature may not be able to renew it if the pollution is bad. Properly dispose off oil so it does not get into water. Use pesticides sparingly and do not use excess of detergents and soap.
- **Dispose off properly**—Proper disposal of wastewater helps protect natural supplies. Wastewater can be partially renewed in treatment plant facilities.
- **Install conservation practices**—Many approaches can be used to conserve water supplies and quality. Approaches that conserve soil also conserve water. Terraces, ponds, and mulches can be used to reduce water runoff. Factories can seek more efficient ways of using water.
- **Have good equipment**—Pipes, pumps, and other facilities should be free of leaks. Leaky equipment wastes water. It also costs more to operate a leaky system because more water must be pumped just to have enough to do what is needed. More energy is needed to power the pumps.
- **Reuse**—Water used for one purpose can often be used for other purposes before it is released. The additional uses may help clean

the water. An example is using wastewater to raise fish and grow non edible plants. Both activities remove nutrients in wastewater from food manufacturing operations.

- **Renew used water**—Renewing wastewater is helping nature do its job. It may involve filtering to remove solid materials. In holding reservoirs, it might include promoting the growth of microbes so processes occur, such as the nitrogen cycle.
- **Efficient use of water**—Everyone can make better use of water by consuming a little less water for the daily chores.

Water Harvesting for Conservation

In India, from the ancient times there exists an extraordinary tradition of water-harvesting system. People have in-depth knowledge of rainfall regimes and soil types and thus have developed various techniques to harvest rain water, ground water, river water and flood water in keeping with the local ecological conditions and their water needs. In hills and mountainous regions, people build **diversion channels** like the 'kuls' of the Western Himalayas for agriculture. **Roof top rain water harvesting** is commonly practiced to store drinking water in Rajasthan. Huge underground tanks are built inside the main house or courtyard and are connected to the sloping roofs of the houses through a pipe. Rain water falling on the rooftops flows down into the tanks through the pipes. This technique is being intensively used in villages of Kerala and Karnataka. In Meghalaya, a very old system of tapping stream and spring water by using bamboo pipes which is known as **Bamboo drip irrigation system** is prevalent. About twenty liters of water enters the bamboo pipe system and gets transported over hundreds of meters and finally reduces to forty to fifty drops per minute at the site of irrigation.

4.4.5 Floods

Flood is a general or temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters or from the unusual and rapid accumulation or runoff of surface waters from any source. **Flooding and flash flooding are the deadliest of natural disasters.** Floodwaters claim thousands of lives every year and render millions homeless. One of the more frightening things about flooding is that it can occur nearly anywhere, at any time. It can result from excess water jams on rivers, even moderate rain, or a single very heavy downpour.

Heavy downpour in the form of rain brings down more water than can be disposed off by combined factors natural and man-made systems causing flooding. The rivers overflow embankments may be breached. Generally rains following storm and hurricane are heavy and bring unmanageable amount of water causing floods.

In India, floods bring much havoc causing loss of life and property each year. Due to flood, the plains become silted with mud and sand, thus affecting the cultivable land areas. The worst suffering states are Assam, Bihar, Orissa, U.P. and West Bengal.

Effects of Flood

- (i) **Damage to buildings and other constructions:** Buildings and houses are washed away due to the impact of water under high stream velocity. They get destroyed and dislocated so severely that their reconstruction is not feasible. Sometimes damage is caused by inundation of buildings which means that the foundation remains intact while the damage to materials may be severe. In many cases the velocity of water may scour and erode the foundation of the buildings and other structures.
- (ii) **Health effects:** The large amount of pooled water remaining after the floods leads to an increase in mosquito populations. Mosquitoes are most active at sunrise and sunset. People are exposed to malaria, dengue etc. Swiftly moving shallow water can be deadly, and even shallow standing water can be dangerous for small children. Cars or other vehicles do not provide adequate protection from flood waters. Cars can be swept away or may breakdown in moving water.
- (iii) Many wild animals are forced from their natural habitats by flooding, and many domestic animals are also without homes after the flood. General public is exposed to rabies. Animals are disoriented and displaced too. Rats may be problem during and after a flood. Flood waters can bury or move hazardous chemical containers of solvents or other industrial chemicals from their normal storage places. This can lead to accidents due to leakage or damage to the containers.

Flood Management

Flood forecasting has been recognized as one of the most important, reliable and cost-effective non-structural measures for flood management. Recognizing the crucial role it can play, Central Water Commission, Ministry of Water Resources has set up a network of forecasting stations covering all important flood prone interstate rivers. The forecasts issued by these stations are used to alert the Public and to enable the administrative and engineering agencies of the States/UT's to take appropriate measures.

Central Water Commission started flood-forecasting services in 1958 with the setting up of its first forecasting station on Yamuna at Delhi Railway Bridge. At present Central Water Commission has network of 159 flood forecasting stations.

4.4.6 Drought

Drought may be defined as an extended period - a season, a year or more - of **deficient rainfall** relative to the statistical multi-year average for a region. It is a normal and recurrent feature of climate and may occur anywhere in the world, in all climatic zones. Its features or characteristics, of course, vary from region to region.

In simple words, drought is a period of **drier-than-normal conditions** that lead to water-related problems. When rainfall is below normal for weeks,

months or even years, it brings about a decline in the flow of rivers and streams and a drop in water levels in reservoirs and wells. If dry weather persists and water supply-related problems increase, the dry period can be called a 'drought'.

The major drought years in India were 1877, 1899, 1918, 1972, 1987 and 2002. Large parts of the country perennially reel under recurring drought. Over 68% of India is vulnerable to drought. The 'chronically drought-prone areas' - around 33% - receive less than 750 mm of rainfall, while 35%, classified as 'drought-prone' receive rainfall of 750-1,125 mm. The drought-prone areas of the country are confined to peninsular and western India - primarily arid, semi-arid and sub-humid regions.

Drought Classification

There are a number of classifications for drought. A **permanent** drought is characterised by extremely dry climate, drought vegetation and agriculture that is possible only by irrigation; **seasonal** drought requires crop durations to be synchronised with the rainy season; **contingent** drought is of irregular occurrence; and **invisible** drought occurs even when there is frequent rainfall, in humid regions.

Physical aspects are also used to classify drought. They may be classified into three major groups:

Meteorological drought is related to deficiencies in rainfall compared to the average mean annual rainfall in an area. There is, however, no consensus on the threshold of deficit that makes a dry spell an official drought. According to the India Meteorological Department (IMD), meteorological drought occurs when the seasonal rainfall received over an area is less than 75% of its long-term average value. If the rainfall deficit is between 26-50%, the drought is classified as 'moderate', and 'severe' if the deficit exceeds 50%.

Agricultural drought occurs when there is insufficient soil moisture to meet the needs of a particular crop at a particular point in time. Deficit rainfall over cropped areas during their growth cycle can destroy crops or lead to poor crop yields. ***Agricultural drought is typically witnessed after a meteorological drought, but before a hydrological drought.***

Hydrological drought is a deficiency in surface and sub-surface water supply. It is measured as stream flows and also as lake, reservoir and groundwater levels.

A sequence of impacts may be witnessed during the progression of a drought from meteorological, agricultural to hydrological. When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water. Soil water can deplete rapidly during extended dry periods.

If precipitation deficiencies persist, then people dependent on other sources of water begin to feel the effects of the shortage. Those who rely on groundwater, for instance, are usually the last to be affected.

When the situation returns to normal, and meteorological drought conditions have abated, the 'recovery cycle' follows the same sequence. Soil water reserves are replenished first, followed by stream flows, reservoirs/lakes and groundwater.

Causes of Drought

The principal cause of drought may be attributed to the ***erratic behaviour of the monsoon***. The southwest monsoon, or 'summer monsoon' as it is called, has full control on agriculture, the Indian economy and consequently, the livelihoods of a vast majority of the rural population. The southwest monsoon denotes the rainfall received between the months of June and September and accounts for around 74% of the country's rainfall.

The coastal areas of peninsular India also receive rain from October to December due to periodic cyclonic disturbances in the Bay of Bengal (the north-east monsoon, or post-monsoon system)

Most parts of the peninsular, central and north west India, the regions most prone to periodic drought receive less than 1,000 mm of rainfall. There are other reasons, mostly man made, which aggravate drought or create drought like situations in the country. India is well-endowed in terms of rainfall, with Cherrapunji receiving an annual rainfall of around 11,000 mm. Even Saurashtra and the Kutchh region record rainfall of around 578 mm. India's average rainfall is around 11,70 mm, yet the country suffers recurrent drought.

The ***over-exploitation of surface and groundwater*** is another major cause of water stress leading to drought situations in the country.

India has seen a sharp decline in groundwater levels, leading to a fall in supply, saline water encroachment and the drying of springs and shallow aquifers. Around 50% of the total irrigated area in the country is now dependent on groundwater, and 60% of irrigated food production depends on irrigation from groundwater wells.

In some regions of Gujarat, Rajasthan, Tamil Nadu, Karnataka, Punjab and Haryana the decline in water levels due to over exploitation has been to an extent of 1 - 2 meters/yr.

The ***rapid depletion of forest cover*** is also seen as one of the reasons for water stress and drought. India has 22% of its total geographical area under forest cover, which is much lower than the prescribed global norm of 33%. Although the scientific evidence is inadequate, forest-water linkages are widely acknowledged, especially the watershed functions of forests, greater availability of water, less soil erosion, more rainfall, flood and landslide control, etc.

Impact of Drought

Drought has a direct and indirect impact on the economic, social and environmental issues of the country. Depending on its reach and scale it could bring about social unrest.

The immediate visible impact of monsoon failure leading to drought is felt by the agricultural sector.

- The surface water and the ground water levels drop.
- The food grain production goes down.

Water and fodder shortages during drought situation cause considerable stress on the bovine population also.

The impact of droughts can be reduced through mitigation and preparedness. Planning well in advance to mitigate drought could relieve the most suffering and at lesser expense.

4.4.7 Conflicts Over River Water

Water availability in different parts of a basin, and the linkage between land use and water use entails that activities of one kind in one part of the river basin can negatively or positively influence other activities in different parts of the basin. The failure to perceive this inter-relation in the planning of water utilisation has become a major source of conflict over water use in river basins.

Water allocation between conflicting demands for water have rarely taken full account of the underlying conflicts and have therefore aggravated the problems of inequalities and maldistribution. The four major categories of use on which water planning is based are:

1. Domestic
2. Agricultural
3. Industrial
4. Power generation

Rarely the internal conflicts in each sector or between sectors are clearly defined in water development projects. On the contrary it has been assumed, for instance, that multi-purpose river valley projects that provide irrigation as well as generate hydro-power do not have conflicting uses. However, the very location of these projects is primarily determined on the basis of either of these objectives and water releases are also determined by priorities for power or for irrigation. Other inter-sectoral conflicts include diversion of water for irrigation from drinking water, or for industry from agricultural and domestic use. Not only do diverse uses conflict with each other inter-sectorally, they can also conflict intra-sectorally on the basis of conflicting interests between the rich and powerful and the poor and marginal. The category 'domestic' as an undifferentiated one conceals the conflict between the poor rural peasants requiring a pot full of drinking water and the rich urban elite using large quantities of water for meeting the requirements of water-intensive sewage systems, space cooling, gardening, etc. Domestic requirements vary for different people and the high demands from urban areas are often met by diverting water from rural areas. Similarly, an undifferentiated category of agriculture conceals conflicts between water-intensive cultivation of commercial crops for high cash returns and prudent water use for protective irrigation of staple food crops essential for survival.

Social conflicts over water can also be analysed at different societal levels. Thus, inter-state conflicts are generated when water projects of upstream states influence the quality and quantity of water flow in the basin and reduce the possibilities of water use by downstream states. Major inter-

basin water transfers in rivers flowing through many states also generate conflicts by disturbing the rights of states. Conflicts also arise between the state and the people when official planning and policies lead to changes in water use and utilisation pattern and therefore undermine people's access to water. Thus, state planned quarrying of minerals or timber extraction in the river catchments affect the river flow and generate conflicts downstream. Similarly, state planned agricultural production based on large irrigation projects to generate marketable surpluses of cash crops conflicts with people's needs for local food production. Such projects also lead to conflicts between the state and the people by eroding traditional water rights which are often communal in nature and ensure the survival of all members of the community. Local common management of water resources and the ethics and values on which it is based are frequently modified by government planned and managed water projects aimed at the expansion of commercial agriculture. Finally, state plans tend to serve the interests of the economically and politically powerful groups of society and hence generate new gaps between the rich and poor in terms of access to water resources.

4.4.8 Case Study

CASE STUDY

Kaveri River Water Dispute

The water of the river Kaveri has been the cause of a serious conflict between Karnataka and the state of Tamil Nadu. Over the years, the dispute has become increasingly complex due to the stubborn attitude of the parties involved, particularly those of the states of Karnataka and Tamil Nadu. The dispute at its root is a question of the sharing of the waters of the river Kaveri. While the state of Tamil Nadu has historically enjoyed a vastly greater usage of the waters compared to Karnataka. Karnataka on the other hand, sees it as a grave historic injustice that has been forced upon it. The origin of this disparity itself, lies in two controversial agreements signed in 1892 and then in 1924 between the Madras Presidency and the Princely State of Mysore.

Karnataka claims that these agreements were in favour of the Madras Presidency. It claims that these agreements dealt its own interests and therefore wants a renegotiated settlement based on equitable sharing of the water. Tamil Nadu on the other hand, pleads that it has already developed almost 3,000,000 acres ($12,000 \text{ km}^2$) of land and as a result has come to depend very heavily on the existing pattern of usage. Any change in this pattern, will adversely affect the livelihood of millions of farmers in the state.

Decades of negotiations between the parties involved bore no fruit and the Government of India finally constituted a tribunal in 1990 to

look into the matter. The tribunal after hearing arguments of all the parties involved for the last 16 years, delivered its final verdict on February 5, 2007. In its verdict, the tribunal allocated 419 billion ft³ (12 km³) of water annually to Tamil Nadu and 270 billion ft³ (7.6 km³) to Karnataka; 30 billion ft³ (0.8 km³) of Kaveri river water to Kerala and 7 billion ft³ (0.2 km³) to Puducherry. The dispute however, seems far from over with all four states deciding to file review petitions seeking clarifications and possible renegotiation of the order.

4.4.9 Dams-benefits and Problems

India is one of the largest dam building nations in the world. There are almost 4291 dams in India. 3596 have been built and 695 are under construction (World Commission on Dams, Report 2000). Dams offer huge benefits in terms of electrical power generation and irrigation.

The various benefits of dams are:

- (i) *Hydroelectric power*– Electrical power generation is a major benefit which may be cheaper and environmentally safer than energy.
- (ii) *Irrigation*– Regions with poor or unpredictable rainfall can be turned into fertile farmland.
- (iii) *Water supply*– Provide dependable water supply for urban and industrial use.
- (iv) *Flood control*– Holding back and channeling potentially dangerous water flow.
- (v) *Navigation*– Multipurpose river valley projects also provide for inland water navigation.

Some problem associated with dams are:

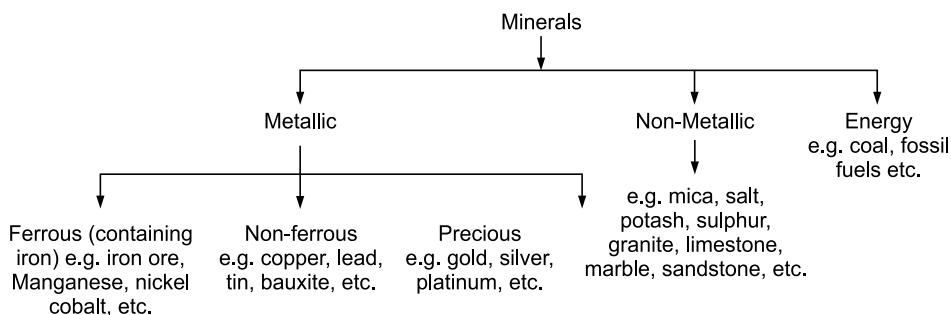
- (i) *Environmental*– Dams may destroy wild life habitats, drain wetlands and cause river pollution by reducing the river flow to a level where the river can no longer self-cleanse. Farmland can be ruined by salt produced by the irrigation process.
- (ii) *Risk of failure*– Sometimes dam fails due to landslides or earthquakes which can be catastrophic.
- (iii) *Submergence*– of fertile fields and human settlements.
- (iv) Dams have serious consequences with regards to the *displacement of tribal people*. This displacement results in transfer of resources from weaker sections of the society to the more privileged sections.
- (v) *Cost*– Dams are very expensive to build and may not provide sufficiently economical electrical power generation, water supply for irrigation.

4.5 MINERAL RESOURCES

India is rich in mineral resources. It has fairly abundant reserves of iron ore and mica and adequate supplies of manganese ore, titanium, bauxite and coal. There is a deficiency of copper, lead, zinc and gold. The country earns foreign exchange from the export of minerals like iron ore, titanium, manganese ore, bauxite and granite. In all there are over 3000 mines in India. About 8 lakh people are employed in the mining sector. It accounts for about 11% of the country's industrial output. Industrial development of the country depends upon this sector.

4.5.1 Classification of Minerals

Geologists classify minerals according to their chemical composition and crystalline structure. Generally minerals are classified into three categories metallic, non-metallic and energy. Metallic minerals are subdivided into ferrous (containing iron), non-ferrous (containing metals other than iron) and precious (Table given below):



Minerals occur in different types of rocks. Some are found in igneous rocks, while others in sedimentary rocks. Almost all metals are found in the form of ore. The ore contains impurities and therefore processing is required before use.

4.5.2 Distribution of Minerals and their use

Iron Ore

It is the back bone of modern civilization. It is used for manufacturing of machines, agricultural implements and items of general use. India shares about 20% of the world reserve of iron ore. Most of the mines in the country are in Chhattisgarh, Jharkhand, Orissa, Goa and Karnataka. About half of the iron ore produced in the country is exported primarily to Japan, Korea, European countries and gulf countries.

Manganese Ore

It is used for making iron and steel and preparing alloys. It is also used to manufacture bleaching powder, insecticides, paints and batteries. About one-fifth of the world's deposits of manganese ore are found in India. The country stands second in the reserve of manganese ore in the world after

Zimbabwe. The main reserves are in Karnataka, Orissa, Madhya Pradesh, Maharashtra and Goa and Madhya Pradesh produces more than half of the national total.

Copper

It is used for making utensils, electric wire and alloys. Indian copper ore contains less than 1% of copper (international average is 2.5%) and hence its mining and smelting is costly affair. About 90% of the reserves are concentrated in Madhya Pradesh, Rajasthan, Jharkhand, Karnataka and Andhra Pradesh. Production of copper in the country is less than the requirement, hence it is imported.

Lead

The ore of lead is known as galena. It is a soft and heavy metal and is a bad conductor of heat. It is used in cable covers, ammunitions, paints, glass and rubber making. Lead ore occurs in Rajasthan, Andhra Pradesh and Tamil Nadu. India produces about 25% of its requirement and thus rest is imported from Australia, Canada and Myanmar.

Bauxite

It is an ore from which aluminium is extracted. Aluminium is a light metal used in the manufacturing of aeroplanes, utensils and other household goods. India has vast reserves of bauxite and occurs mainly in Jharkhand, Orissa, Gujarat, Maharashtra, Chhattisgarh, Madhya Pradesh and Tamil Nadu.

Mica

It has insulating properties and can withstand high voltage, hence its major use is in electrical and electronic industries. Mica reserves occur in Jharkhand, Bihar, Andhra Pradesh and Rajasthan. India produces about 60% of world's production of mica.

Limestone

It is found associated with rocks composed of calcium carbonates or calcium or magnesium carbonates. Major use (about 75%) of limestone is in cement industry; rest is used for smelting of iron and in chemical industries. Almost all states have some quantities of limestone, but about three fourths of the country's production comes from Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Rajasthan, Gujarat, Karnataka and Himachal Pradesh.

4.5.3 Exploitation of the Mineral Wealth

Minerals often require quite a lot of processing to get the desired metals from them. The steps involved are:

- (i) locating a supply of mineral**
- (ii) mining**
- (iii) processing the mineral to get desired products.**

Locating Minerals

Minerals could be sometimes located below the surface of the Earth's crust. They may be mixed with other materials that have almost no value. Thus geologists study the surface of the earth carefully and prepare maps showing mineral deposits. On-site inspections alongwith aerial photography, remote sensing and global positioning systems gives additional information for the exploration and finding new locations where mineral deposits could be found. Drilling may be used to collect samples below the surface. The ocean water contains vast quantitites of mineral, but most of these are too widely diffused to be of economic significance. However, common salt, magnesium and bromine are largely derived from ocean waters. The ocean beds, too, are rich in manganese nodules.

Mining

Depending upon the location of the ores, the following methods are adopted for their extraction:

- (i) ***Surface mining***
- (ii) ***Sub-surface mining***

Surface Mining

This is adopted when the mineral is above or just below the surface. The layers of rock and soil covering the mineral deposits are first scrapped off and discarded as spoils. The minerals are then removed using appropriate technology. The type of surface mining employed depends upon the mineral and the topography of the mine. Thus different methods are adopted in surface mining:

Open-pit and Strip Mining Open-pit surface mining is digging a large hole in the earth to get the minerals. The large pit is a *quarry*. Granite iron and copper ore and sand are often mined with open pits.

Strip mining is digging a long trench to get the minerals. A series of strips are dug. The strips are parallel to each other. The soil and rock that are not extracted are put into the previous strip. Rows of dug-out materials, known as spoil banks, are created on the surface.

Subsurface Mining

A subsurface mine is deep inside the earth to remove minerals such as coal and valuable minerals like gold ore. The surface of earth may be disturbed very little. A mass of tunnels or shafts may be used to go into the deposits of minerals. Thus these mines are also termed as *deep shaft mines*. This type of mining is more expensive and complex than surface mining. The shafts may be dug straight down to the mineral ore or they may slope downward. The tunnels and benches are formed inside the earth so that the ore can be extracted and transported out. Although the environment is not visibly harmed, there is always the risk of roof collapse, explosion of gases, and disturbance to underground water movement.

Processing the Mineral

Ore needs to be separated from material that does not contain the desired metal. The processing needed varies with the mineral and its use. Common processing procedures include:

- **Grinding and crushing:** Grinding and crushing are used to get materials into the desired sizes. Grading may be used to separate the materials based on size.
- **Sorting:** Various ways may be used to separate valuable metals from the ore. Water may be used to ‘float’ metal materials from the ore. One function of sorting is to separate metal from ore.
- **Smelting:** Smelting is heating ore so the metal separates from the undesirable material. The process may also be used to cast the metal into the desired products. Large furnaces are used in smelting. Most smelting produces several products that can be used. Iron smelting usually produces silicon and phosphorus. Copper smelting may produce sulfur and other materials. Both iron and copper smelting produce slag. Since iron melts at 1,535°C, iron ore may be heated to 1,600°C. The iron is molten or liquid-like. The melting points of other metals vary. In liquid form, the metal separates from the gases and solid materials. The metals with the lowest melting points become liquid earlier and can be removed.
- **Purification:** Various methods are used to purify the metal from the ore. Smelting often involves some purification.

Some minerals like limestone, sand, gravel and kaolin require less processing. No smelting or purification is needed.

After processing a lot of solid waste materials, known as Tailings, remain depending upon the yield of ore. For e.g. copper ore produces only about 1% copper. This means that a ton of copper ore will result in nearly a ton of tailings.

4.5.4 Conservation of Minerals

The human beings have a strong dependence upon mineral deposits for the growth and development of the nation. In this process the mineral resources are being rapidly consumed. The geological processes of mineral formation are so slow that the rates of replenishment are infinitely small in comparison to the present rates of consumption. Mineral deposits of the country are thus, valuable but shortlived possessions. A serious effort has to be made in order to use the mineral resources in a planned and sustainable manner. Improved technologies need to be constantly evolved to allow use of low grade ores at low costs. Recycling of metallic scrap like steel, copper, aluminium, zinc, lead etc. should be encouraged and facilitated by fixation of appropriate standards for classification and grading of scrap and adoption of fiscal measures. Similarly utilisation of low grade minerals, mineral waste and rejects should also be encouraged through appropriate incentives.

4.5.5 Environment Impact of Mineral Use

Locating minerals, mining and processing minerals affects the environment. There is no way to get and use minerals without some intrusion into the environment. Using good practices helps keep damage to the environment to a small extent.

Mining Damage: Mining can disrupt the earth's natural landscape and forest ecosystems. Forests are destroyed and wild animals are driven away. Several species may become extinct. Excavations makes the surface unsightly causing land degradation. The top soil may be removed and large areas excavated to expose minerals. These areas may collect water and create polluted run-off. Sometimes these areas become breeding ground for mosquitoes. Large piles of tailings are sometimes left. Excavated land can erode and damage water quality. Mined areas may have substances that react with water to form acid. Water that seeps or runs out of mine may contain acid. For example, iron ore often has sulfur mixed in it. Runoff from the mine will have a high acid content. Streams and lakes may be damaged by the acid runoff. With other minerals toxic materials like lead from lead mine may enter the runoff.

The land areas damaged by mining can be filled and graded to a natural contour. Grasses and trees may be planted on the land. Often little top soil is available for plants. Some mine sites may contain toxic substances that kill common vegetation. Special kinds of plants may be needed to grow in these places.

Waste Disposal: Tremendous amounts of solid waste materials may result from processing minerals. Often 80 percent or more of the ore may be waste after processing. The amount of tailing produced is greater with low-grade ore. Large piles of tailings may be seen at smelting plants. The tailings are sometimes used as fill for low land areas.

Some solid waste products from smelting are put to good use. Slag is used as a source of phosphorus and calcium in fertilizer. Slag is also used in road paving and making lighter-weight concrete.

Emissions Control: Smoke, steam, particulates, and other materials may be released by mining. Some of these cause serious pollution problems.

Burning coal to heat minerals in smelting releases substances into the air. The minerals themselves also give off gases in smelting. Sulfur, nitrogen, and carbon are commonly released causing air pollution. These materials also find their way into the water and soil. It may result to acid rain, unproductive soil, and water without living organisms.

The Clean Air Act and Clean Water Act regulate air and water pollution. Mining and processing are covered in these Acts from the standpoint of what can be released into the air and water.

4.5.6 Case Study

CASE STUDY

No Mining in Aravalis

In a deed to preserve the ecology of sensitive Aravali hill, the Supreme Court rejected pleas for lifting the ban on mining activities in the

range. The court had for the first time on May 6, 2002 banned mining activities in the Aravali hill on noticing that several illegal mining activities in the range were harming the range putting immense pressure on the ecology of the area.

The Court has now constituted a high-level Monitoring Committee to suggest ways and means for its "overall ecological restoration". Declaring that "ecology of the Aravali Hills has to be preserved at any cost", the Court directed the Committee to go into all issues pertaining to mining in the area and suggested remedial measures for eco-restoration. The court said that the Committee, apart from suggesting methods for "overall ecological restoration", would monitor implementation of several reports submitted previously by various other committees. The committee would also inspect and assess the mines that were operational till the ban orders came into force in May 2002 and recommended whether these could resume operation on the basis of "sustainable development principle", it said. The Court, however, made it clear that each mine owner, before applying for renewal of mining lease, should have to obtain environmental assessment clearance from the concerned authorities.

Attaching a premium to green areas, the apex Court said that under no circumstances mining could be allowed in areas where afforestation efforts have been undertaken. In the same breadth, Court said that if the Committee found that the legally permitted mining going on in the area was "adversely affecting the ecology of the hill range", then it could consider suggestions for an absolute ban on these activities in the area.

Aravali hills, spanning three states of Delhi, Haryana and Rajasthan, stand as a natural barrier to the Thar desert from extending into the plains.

4.6 FOOD RESOURCES

The basic necessity for the survival of human beings is food. The food humans eat are composed of several major types of biological molecules necessary to maintain health: carbohydrates, proteins and lipids. In addition to these, humans require minerals, vitamins and water in their diet.

The three main food sources are:

- Croplands that provide 76% of the total foodgrains.
- Rangelands that produce meat and milk from grazing livestock, accounting for 17% of total food.
- Fisheries that supply the remaining 7%.

Food production is probably the most important natural resource issue facing the world today. Population growth has necessitated a continuing

expansion of agricultural output. The expansion must take place in the context of severe constraints on the availability of agricultural land and on the ability of natural biogeochemical cycling processes to supply agricultural inputs such as water and absorb waste products such as nitrogen. Thus we have to achieve almost a double agricultural output over the next half century through more intensive use of existing lands while minimising the environmental impacts of this intensification.

4.6.1 World Food Problems

The U.N. Food and Agricultural Organisation (FAO) in 2004 estimated that more than eight hundred million people lack access to the food needed for healthy, productive lives. Most of these people live in the rural areas of the poorest developing countries. The two regions of the world with the greatest food insecurity are South Asia, with an estimated two hundred seventy million hungry people, and Sub-Saharan Africa, with an estimated one hundred and seventy five million (Sub-Saharan Africa includes all African countries located south of the Sahara Desert).

The average human must consume enough food to get approximately 2600 Kcal per day. (The average man requires 3000 Kcal per day whereas the average woman requires 2200 Kcal per day). If a person consumes less than the required amount over an extended period, his or her health and stamina decline, even to the point of death. People who receive fewer calories than needed are **undernourished**. Worldwide, one hundred and eighty two million children under the age of five suffer from **undernutrition** and are seriously underweight for their age, according to the World Health Organization (WHO). This accounts to almost one-third of all children under five in developing countries.

The total number of calories consumed is not the only measure of good nutrition. People can receive enough calories in their diets but still be **malnourished** because they are not receiving enough of specific, essential nutrients such as proteins, vitamin A, iodine or iron. For example, a person whose primary food is rice can obtain enough calories, but a diet of rice lacks sufficient amounts of proteins, lipids, minerals, and vitamins to maintain normal body functions. Adults suffering from **malnutrition** are more susceptible to disease and have less strength to function productively than those who are well fed. In addition to poor physical development and increased disease susceptibility, children who are **malnourished** do not grow or develop normally. Because **malnutrition** affects cognitive development, **malnourished** children do not perform as well in school as children who are well fed. Currently, WHO estimates that more than 3 billion people worldwide—the greatest number in history—are malnourished. In addition, more than half the deaths in children less than 5 years old in developing countries are associated with **malnutrition**.

The two most common diseases of malnutrition are **marasmus** and **kwashiorkor**. Marasmus (from the Greek word **marasmos**, meaning ‘a washing away’) is progressive deterioration caused by a **diet low in both total calories and protein**. Marasmus is most common among children in their first year of life—particularly children of poor families in developing nations. Symptoms include a pronounced slowing of growth and extreme

atrophy (wasting) of muscles. It is possible to reverse the effect of marasmus with an adequate diet.

Kwashiorkor (a native word in Ghana meaning 'displaced child') is malnutrition resulting from **protein deficiency**. It is common among children in all poor areas of the world. The main symptoms include edema (fluid retention and swelling); dry, brittle hair; apathy; stunted growth; and sometimes mental retardation. One of the most typical features of kwashiorkor is a pronounced swelling of abdomen. Kwashiorkor is treated by gradually restoring a balanced diet.

People who eat food in excess of that required are **overnourished**. Generally, a person suffering from **overnutrition** has a diet high in saturated (animal) fats, sugar, and salt. Overnutrition results in obesity, high blood pressure, and an increased likelihood of such disorders as diabetes and heart disease. In nutrition experiments, **overnutrition** in rodents resulted in a higher incidence of cancer compared with rodents fed a calorie-restricted diet, but evidence that links overnutrition to cancer in humans is sparse. Many human studies show a correlation between diets high in animal fat and red meat and certain kinds of cancer (colon and prostate). **Overnutrition** is most common among people in highly developed nations, such as the United States, where the Pan American Health Organization estimates that two out of three adults are overweight, and nearly one in three is obese. **Overnutrition** is also emerging in some developing countries, particularly in urban areas. As people in developing countries earn more money, their diets shift from primarily cereal grains to more processed foods and livestock products.

The figure below shows the scale of undernourishment, 1999–2001 (millions).

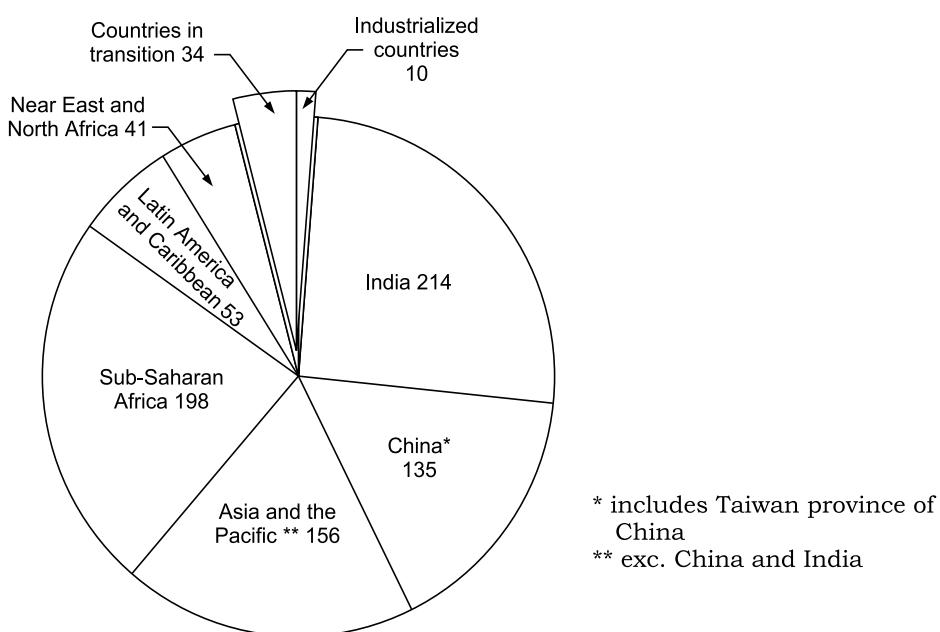


Fig. 4.3

4.6.2 Impacts Caused by Agriculture

Agricultural activities represent an enormous transformation of natural ecosystems occurring over very large portions of the Earth's surface. As such, they inevitably cause vast environmental impacts. These impacts could be broadly classified into:

- On-site impacts
- Off-site impacts

On-site impacts include soil erosion and range land degradation.

Soil erosion on agricultural lands takes place through three major processes; overland flow (or run off), wind and streambank erosion. Of these processes, overland flow erosion is the most visible and widespread, and in most agricultural areas it is quantitatively the most important. Wind erosion occurs on exposed soil if strong winds blow at times when the soil surface is relatively dry. Streambank erosion is limited to fields that border streams, and though locally significant it is not a major factor in soil erosion worldwide.

Rangeland Degradation Range, or grazing land, provides forage for limited numbers of domestic animals. *Overgrazing* occurs when the number of animals on these lands exceeds carrying capacities. Several areas of the world, notably the dry lands around the Mediterranean Sea, have been long overgrazed, with resulting problems of devegetation, erosion, and ultimately the threat of desertification. *Desertification* is land degradation in dryland regions resulting mainly from adverse human impact. It occurs in parts of all the major semiarid regions of the world and affects some of these regions more than others.

The **off-site impacts** include water pollution from agricultural run-off, air pollution from blowing dust or dispersal of agricultural chemicals like fertilizers and pesticides.

4.6.3 Types of Agriculture

Agriculture can be roughly divided into two types:

- industrialized or modern
- subsistence agriculture

Most farmers in highly developed countries and some in developing countries practice **industrialized agriculture** or high-input agriculture. It relies on large inputs of capital and energy, in the form of fossil fuels, to produce and run machinery, irrigate crops and produce agrochemicals such as commercial inorganic fertilizers and pesticides. This type of agriculture produces high yields enabling forests and other natural areas to remain wild instead of being converted to agricultural land.

In the developing countries most farmers practice **subsistence agriculture**, the production of enough food to feed oneself and one's family with little left over to sell or reserve for hard times. Subsistence agriculture, too, requires a large input of energy, but from humans and draft animals rather than from fossil fuels.

Shifting cultivation is a form of subsistence agriculture in which short periods of cultivation are followed by longer periods of fallow (land left uncultivated) in which the land reverts to forest.

Shifting cultivation supports relatively small populations. Slash-and-burn agriculture is one of several distinct types of shifting cultivation that involves clearing small patches of tropical forests to plant crops. Because tropical soils lose their productivity quickly when they are cultivated, farmers using slash-and-burn agriculture must move from one area to another every three years or so, thus this agriculture is land-intensive.

Nomadic herding in which livestock is supported by land too arid for successful crop growth, is another type of land-intensive subsistence agriculture.

Intercropping is another form of intensive subsistence agriculture that involves growing a variety of plants simultaneously on same field.

4.6.4 The Green Revolution

By the middle of the 20th century, serious food shortages occurred in many developing countries including India. It was widely recognized that additional food supplies were needed to feed their growing populations. The development and introduction during the 1960's of high yielding varieties of wheat and rice gave the chance to provide the people with adequate supplies of food. But the yielding varieties required intensive cultivation methods, including the use of commercial inorganic fertilizers, pesticides and mechanized machinery, to realize their potential. These agricultural technologies were passed from highly developed nations to developing nations.

Using modern cultivation methods and the high-yielding varieties of certain staple crops to produce more food per acre of cropland is known as the **green revolution**. The two most important problems associated with higher crop production are the high energy costs built into this form of agriculture alongwith the serious environment problems caused by the use of the commercial inorganic fertilizers and pesticides.

4.6.5 Effects of Modern Agriculture

The practices of industrialised agriculture have resulted in several environmental problems that impair the ability of non-agricultural terrestrial and aquatic ecosystems to provide essential ecosystem services.

The agricultural use of fossil fuels and pesticides produces air pollution. Untreated animal wastes and agricultural chemicals such as fertilizers and pesticides cause water pollution that reduces biological diversity, harms fisheries etc. The agricultural practices are one of the major cause of surface water pollution in India. Nitrates from animal wastes and commercial inorganic fertilizers are probably the most widespread groundwater contaminant in agricultural areas.

Fertilizers and Pesticides

Average yields of grains worldwide more than doubled between 1960 and 1990, owing mostly to increases in the use of *fertilizers*. Fertilizer use increased over four times in that same 30-year period. One of the main reasons for this prominence is the development of high-yielding plant varieties that require

large inputs of fertilizer to realize their potential. In addition, fertilizers may make production possible on otherwise marginal land.

The three most important nutrients required by plants are nitrogen, phosphorus, and potassium. Nitrogen is ultimately derived from the atmosphere, but it is made available to plants by nitrogen-fixing bacteria. It is the nutrient that is most often deficient and that is most widely applied to crops. Additions in amounts of 45 to 90 pounds/acre (50 to 100 kg/ha) may increase yields from 1.5 to 3 times, depending on plant variety and inherent soil fertility. Natural gas is an important raw material in the manufacture of most nitrogen fertilizers. The most commonly used forms are ammonia (NH_3) and urea ($\text{CO}[\text{NH}_2]_2$). Phosphorus is usually present in small quantities in soils, but it is often found in relatively unusable forms. It is usually applied as superphosphate or as phosphoric acid, which are manufactured from phosphate rock deposits. In soils, potassium generally is found in larger quantities than phosphorus because it is a more abundant constituent of most rocks. Plants also demand it in large quantities, and in many areas potassium fertilization is important. In some areas, local soil conditions or the particular needs of plants require that other fertilizers be added, with lime (a source of calcium and magnesium as well as a regulator of soil pH) being the most common.

Organic fertilizers (primarily manure) have historically been the most important source of nutrients, especially nitrogen. Organic fertilizers also help maintain good soil structure and water-holding capacity by keeping soil organic matter content high. In the wealthy nations, inorganic fertilizers are now more important, but in the developing nations manure is still a common fertilizer. In most areas, manure supplies are quite limited, and manure is more difficult to apply than other forms of fertilizer. Manure is low in nutrient content relative to synthetic fertilizer and is not capable of providing the large inputs of nutrients demanded by high-yielding crop varieties. Increasingly, therefore, inorganic sources of nutrients have been replacing organic sources.

Pesticides is a general term referring to any of the number of chemical agents used to control organisms harmful to plants, including insects, fungi, and some types of worms. Pesticides include insecticides, rodenticides, fungicides and others. Herbicides are used to control weeds. The use of pesticides and herbicides has accounted for a large part of recent increases in crop yields. Thousands of different kinds of pesticides and herbicides are in use, and the vast majority are complex organic compounds manufactured using petroleum as an important raw material. Among insecticides, organochlorines, organophosphates, and carbamates are important types.

The first widely used insecticides were organochlorines such as DDT, aldrin, dieldrin, and chlordane. In the 1960s and 1970s, these were largely replaced by organophosphates for most uses, in part because insects began to develop resistance to the effects of organochlorines and in part because organophosphates break down more rapidly and therefore are less likely to accumulate in the environment. Today many different types of chemicals and application methods are used. Among the small-grain crops, pesticides and herbicides are used most intensively on corn and soybeans. Most fruits

and vegetables are susceptible to damage by insects, fungi, and other pests, and various pesticides are used depending on specific circumstances.

One of the consequences of indiscriminate use of pesticide is the adverse health impact on society in general and vulnerable population like children in particular. Some of the well-known health effects of pesticide exposure include acute poisoning, cancer, neurological effects, reproductive and developmental harm. The major causes of concern are bio-accumulation of pesticides and time period that it takes to express the negative health consequences.

Indian Scenario

After independence the use of fertilizers in India in the last 50 years has grown nearly 170 times. In 1950 use of fertilizer per hectare in India was 0.55 kg but by 2001-02 this figure has increased to around 90.12 kg per hectare. Green revolution during 1960s and subsequent increased intensification of agriculture were major causes behind this growth as seen in Fig. 4.4.

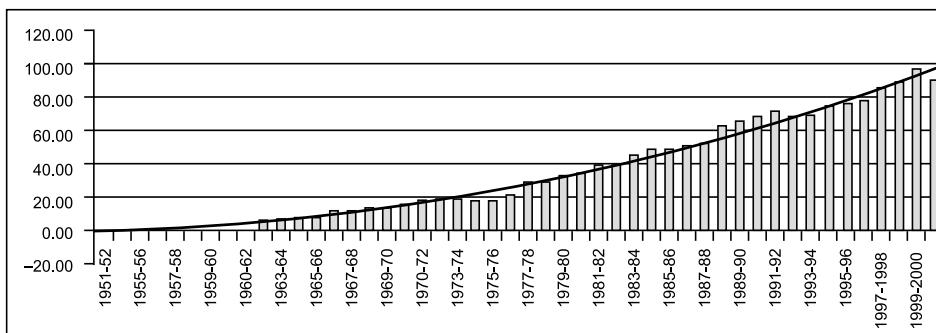


Fig. 4.4 Consumption of Total Plant Nutrient per hectare of Gross Cropped Area (in kg)

In India consumption of insecticide in agriculture has been increased more than 100% from 1971 to 1994-95. For instance, insecticide consumption in India, which was 22013 tonnes has increased to 51755 tonnes by 1994-95. Consumption of all of these pesticides in same duration has increased more than two times, that is from 24305 tonnes to 61357 tonnes (Fig. 4.5).

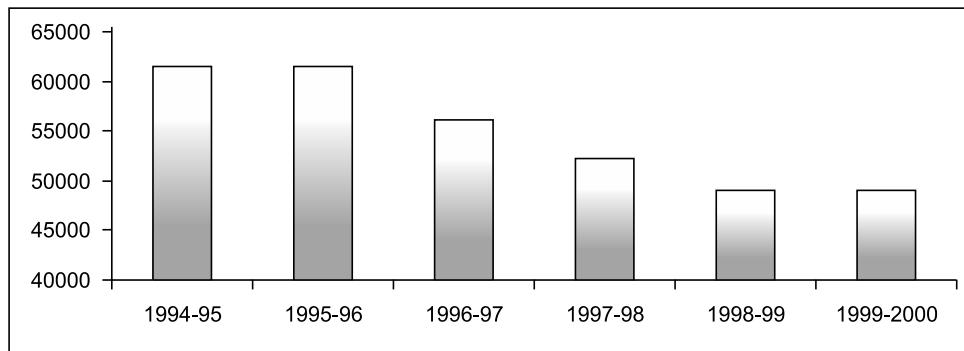


Fig. 4.5 Consumption of Pesticides in India (in tonnes)

But in recent past, change has been observed in trends of pesticides consumption. As a consequence of adoption of bio-intensive Integrated Pest Management Programme in various crops the consumption of chemical pesticide (Tech. Grade) has come down from 66.36 thousand MT during 1994-95 to 43.59 thousand MT during 2001-02 with a reduction of 27.69% (Thirty Seventh Report of Standing Committee on Petroleum and Chemicals 2002).

4.6.6 Salinity and Waterlogging

Salinity can be of natural occurrence in drylands, arid area and irrigated rural areas where the concentration of soluble salts in the soil increases. This is mostly due to low rainfall, poor drainage and high temperatures, when water evaporates quickly leaving behind the highly concentrated salts.

Where human activity interferes with the natural process of 'movement of water', then it will directly contribute to salinity and water-logging by causing water-tables to rise especially in those areas where natural geological features and conditions make them more prone to rising water-tables

Salinity can be prevented or checked by

- Improving the drainage
- Reclamation of salinated lands by leaching with plenty of water.

Due to intensive agricultural management practices in Haryana and Punjab, many hectares of good agricultural land turns saline every year.

Waterlogging occurs when the soil-surface area becomes saturated and soil pores are full of water.

Water logging could occur due to

- Periods of heavy rain.
- Poor irrigation management
- Poor drainage
- Rising water table (as discussed above)

Water table could also rise due to overwatering with irrigation, because it is the unused or excess portion of water applied that recharges the ground water system causing the water table to rise.

Effects of water logging are

- Water-logged soil pores have no oxygen. Plants need oxygen to breathe and grow.
- Vegetation can turn yellow, growth is stunted and thin.
- Trees and plants can die and bare patches of soil appear.
- Plants species more tolerant of saturated conditions will take over (e.g. sedges, pinrushes, dock).

Prevention:

- Management of drainage lines for efficient water flow.
- Management of surface water-flow to avoid surface ponding.

- Increase deep rooting vegetation for greater utilisation of water from the soil.

In India waterlogging is prevalent in the coastal areas of Mumbai and Kerala, estuarine deltas of Ganges, Andaman and Nicobar islands.

4.6.7 Sustainable Agriculture

In every agricultural region of the world, negative impacts of agriculture are being felt. The effects of soil degradation and agricultural pollution are more severe in some areas than in others, but there is universal recognition that while food production must increase to meet the needs of a growing population, the productive capacity of agricultural lands must be preserved and nurtured. Farm practices that seek to balance production and preservation are known as *sustainable agriculture*.

Although it is difficult to define precisely which farming techniques constitute sustainable agriculture, they generally involve intensive soil conservation measures and minimal use of pesticides and inorganic fertilizers. At the present time, the number of farmers using these methods is relatively small, mostly in specialized crops such as fruits and vegetables. But the number of farmers producing grain, meat, and dairy products using sustainable methods is increasing, and this trend is likely to continue as long as the costs of chemical inputs remain high and the need to maximize yield per acre is low.

One key feature of the drive toward sustainable agriculture is the reduced use of farm chemicals, especially pesticides. Pesticides have been a boon to modern technological agriculture, but they also have harmful side effects. The side effects of most concern are health hazards to agricultural workers using the pesticides, health effects on the general population through contamination of food, water, air and adverse ecological effects.

The most severe human health hazards of pesticides are those associated with the occupational exposure of farm workers handling the substances. Workers in the field at the time of application are exposed, as are those handling crops at harvest time. Accidental exposure is also a major concern. Although pesticides have been regulated to limit effects beyond the farm as well as on it, major problems remain. For example, nonpersistent pesticides that are generally used today do not accumulate in high concentrations in the environment. However, they are highly toxic at the time they are applied, hence those in contact with pesticides at that time are most at risk.

The general population is also exposed to agricultural chemicals, primarily through consumption of foods containing these substances but also through transport of pollutants in water and air. Although these exposures are less acute than those faced by agricultural workers, the number of people affected is much greater.

The combined hazards of pesticide use are great, but so too are the benefits in terms of increased yields. Concern for the problems associated with massive pesticide use has prompted research on alternative methods of pest control, most importantly integrated pest management. This approach recognizes that several different means can be used to control

pests, including pesticides, crop rotation and other habitat controls, biological controls such as predator introduction, and other techniques. No single technique is likely to be completely successful in any given place, but for each particular set of agricultural needs and pest problems it should be possible to use a mix of different control techniques tailored to the situation. This approach will require considerable research and development before it can be widely used, but it offers the greatest promise in solving pest problems without poisoning humans or the environment.

4.7 ENERGY RESOURCES

Energy is an indispensable requirement in modern life. It is involved in all developmental activities of the world. Abundant and dependable sources are vital for the modern economic activities. The amount of energy consumption increases with increase in the per capita income of the country. All the amenities of modern world which are making our lives easy and comfortable are energy driven.

There are several sources of energy like coal, petroleum, natural gas, solar energy, wind energy and hydro energy etc. These sources are divided into two categories:

- (i) **renewable** (an energy source that can be replenished in a short period of time)
- (ii) **non-renewable** (an energy source that cannot be replenished in a short period of time).

Renewable and non-renewable energy sources can be used to produce secondary energy sources including electricity and hydrogen.

Sources of energy can also be categorised as: Conventional and non-conventional.

- (i) **Conventional** (Coal, petroleum, natural gas and electricity (both thermal and hydel))
- (ii) **Non-conventional** (solar, wind, tidal, geothermal, atomic energy and biogas)

On the basis of use, there are two categories:

- (i) **non-commercial** (biofuels e.g. firewood, cow dung, charcoal and agricultural waste).
- (ii) **Commercial** (coal, petroleum, natural gas, hydro-electricity and nuclear energy.)

4.7.1 Renewable Sources of Energy

4.7.1.1 Solar Energy

India, being a tropical country has enough scope for production and utilisation of solar energy. Our country is fortunate to receive solar energy for greater part of the year. This is an enormous energy resource, which is clean and pollution-free. It requires to be converted into other forms of energy by suitable technologies.

It has been estimated that India receives solar energy equivalent to more than 5000 trillion kWh (5000×10^{18} kWh) during a year. Under clear cloudless sky conditions the daily average of solar energy varies from 4 to 7 kWh/m².

There are two main ways of using solar energy to produce electricity:

- (i) Solar cells
- (ii) Solar thermal technology

(i) Solar cells

Solar cells are photovoltaic cells that turn sunlight into electricity in an environmentally clean manner. Solar photo voltaic (SPV) systems have emerged as useful power sources for applications such as lighting, water pumping, telecommunications and power plants for meeting the requirements of villages, hospitals, lodges etc. 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 streetlight and solar pump (for irrigation). Solar powered small pumps are being used in Delhi, Haryana and Himachal Pradesh. Electricity in Ladakh in the Himalayas is generated using solar panels, and this has brought about a tremendous change in people's lives. There are several companies in India that offer solar home-lighting systems. One 100×50 cm solar panel can easily power eight lamps. It is desirable to use solar cookers in villages on a large scale so that extensive deforestation can be prevented. About 1 ton of wood per head per year can be saved by this process.

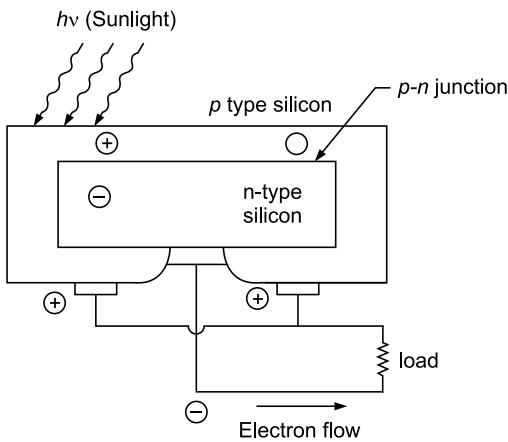


Fig. 4.6 Solar Cell for Electricity Generation.

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, consists of a sandwich of a n-type and p-type silicon semiconductors (e.g. silicon, germanium is a crystalline substance which is intermediate between a metallic conductor on 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.

The strength of current produced depends on the brightness of the light and the efficiency of solar cell. A potential difference (or voltage) of about 0.5 V is generated between the top and bottom surface of a solar cell. At present, the best designed solar cells can generate 240 W/m^2 in bright sunlight, with a maximum efficiency of about 25%.

The electric power generated by a single solar cell is quite small. Thus, to put solar cells to effective practical use, a large number of such cells are used together in the form of a solar panel. A solar cell panel consists of a large number of solar cells joined together in a definite pattern and provided with a protective encapsulation.

Through a solar cell panel (also called SPV system), solar energy is changed to dc electricity. This electricity can either be used as such or it can be stored in the batteries.

Merits of solar cells panels

- These are particularly useful for meeting the electricity requirements of decentralized applications. (As shown in figure 4.7)
- These are easy to install and maintain.
- These are noiseless, pollution free and have long life.

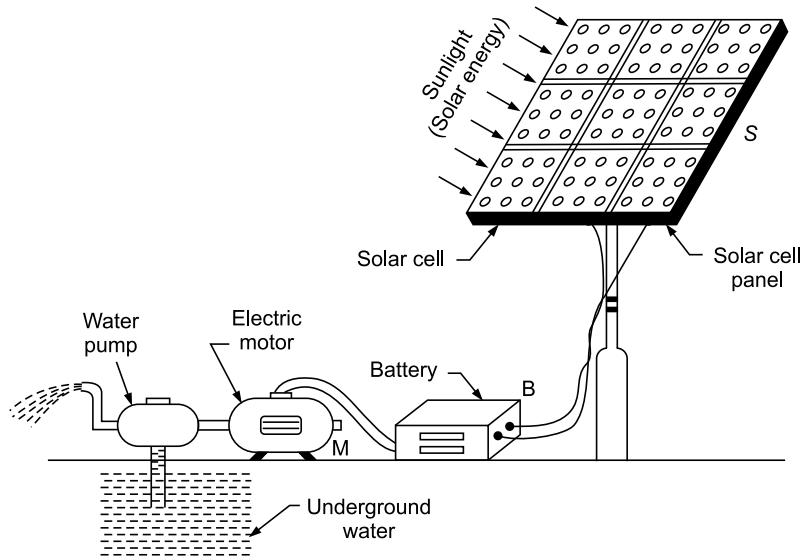


Fig 4.7 A solar cell panel is being used for running a water pump in a remote and inaccessible village where power transmission lines do not exist.

Limitations of solar cell panels

- The initial cost of installing an SPV system is high as silicon, wafer used in making solar cells and silver used in connecting solar cells to form a solar cell panel are costly.

- The electricity (dc) produced by solar cell panels is stored by charging dc batteries which are first to be converted to ac by using inverters.
- The efficiency of energy conservation is low as compared to other methods of generating electricity.

Developing countries such as Dominican Republic, Sri Lanka and Zimbabwe are leading users of solar cell panels.

(ii) Solar thermal technology

This uses heat gained directly from sunlight. The best known use of this technology is in:

1. Solar water heating
2. Solar heating of buildings
3. Solar dryer for food grains and other agricultural products
4. Solar distillation (for water purification)
5. Solar cooker (for cooking)
6. Solar powered vehicles
7. Solar thermal power generation

Solar thermal power generation

Of the various contributory factors to the global greenhouse effect, energy-related CO₂ emissions are the single largest source with power plants contributing about 11% of the CO₂ emissions. In this scenario, a cleaner energy technology like solar thermal power generation is imperative. Today, solar thermal power generation can competitively replace fossil fuel-based power generation at fuel price levels equivalent to US \$100 per barrel, depending on radiation, infrastructure, and operational mode. Apart from grid-connected centralized power plants, solar thermal plants can also operate in stand alone mode in decentralized applications like rural electrification and in remote locations like islands. The world market is predicted to be 5.1 GW per year during 2010-15 including 800 MW per year potential in India.

4.7.1.2 Wind Energy

Atmospheric air is almost in a state of fast continuous motion due to unequal heating of landmasses and waterbodies by solar radiation. This kinetic energy possessed by air due to its velocity is called wind energy and can be used to do work. This energy was harnessed by windmills in the past to do mechanical work. For example in a water-lifting pump, the rotatory motion of windmill is utilised to lift water from a well. Today, wind energy is also used to generate electricity. A windmill essentially consists of a structure similar to a large electric fan that is erected at some height on a rigid support. To generate electricity, the rotatory motion of the windmill is used to turn the turbine of the electric generator. The output of a single windmill is quite small and cannot be used for commercial purposes. Therefore a number of windmills are erected over a large area, which is known as wind energy farm. The energy output of each windmill in a farm is coupled together to get electricity on a commercial scale.

Wind power potential of India

India is ranked fourth in the world for wind resource availability. The total wind power potential in India is estimated at 45,000 MW, out of which about 6000 MW is located in Tamil Nadu and 5000 MW in Gujarat. A total capacity of more than 1700 MW has already been installed which will increase further with the coming up of new facilities.

India's largest wind energy farm established near Kanyakumari in Tamil Nadu can generate 380 MW of electricity.

Various initiatives have been taken by the Ministry of Non-conventional Energy sources for the development of the wind power programme. The introduction of fiscal benefits and promotional incentives in terms of subsidy have attracted private investors which has provided a fillip for promotion of the technology. Guidelines for wheeling, banking and purchasing power from wind power projects have been sent to the states. It has been proposed that they may consider purchasing power at least at the rate of Rs. 2.25 per kWh. In addition to this, private sector can also avail loans from the Indian Renewable Energy Development Agency Limited (IREDA).

Merits of wind energy

- It is a non-polluting, environmental friendly and sustainable source of energy.
- The gestation period is low and the power generation starts immediately after commissioning of the windmill.
- Power generation is cheaper as there is no shortage of input (i.e., wind). The recurring expenses are almost nil.

Limitations of wind energy

- Wind energy farms can be located only in vast open areas in favourable wind conditions as the minimum velocity for a windmill to function is 15 km/h.
- The cost of construction of a wind energy farm is high.
- The appearance of windmills on the landscape and their continuous whirling and whistling is irritating.
- The location of wind energy farms should not be on the routes of migratory birds otherwise it will play havoc with the birds.
- There should be some backup facilities (like storage cells) to take care of the energy needs during a period when there is no wind.
- The tower and blades are exposed to rain, sun, storm and cyclone they need a high level of maintenance.

Note: IREDA was established in March 1987 as a public sector enterprise for the promotion, development and financing of new and renewable sources of energy technologies.

4.7.1.3 Hydroenergy

This renewable source of energy is produced from the kinetic energy of flowing water or the potential energy of water at height. This energy has been traditionally used for rotating the water-wheels and drive water-mills to grind wheat to make flour. This energy has been modified to generate electricity by establishing hydro-power plants. At hydro-power plants, the energy of falling water (or flowing water) is tapped by using a water turbine which drives the generator (Fig. 4.8). At present, the total electric power generated in our country, almost one-fourth is contributed by hydroelectricity. 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 6500 megawatts of hydroelectricity is generated. About 80% of the developed hydel projects lie in Maharashtra, Tamil Nadu, Karnataka, Kerala, Punjab, Himachal Pradesh, Jammu and Kashmir and Uttaranchal.

Advantages of hydel power Plants

- Hydroelectric power is pollution free and the most versatile source of energy out of all the known sources of energy.
- Hydel projects have a very low generation and maintenance cost, reliable and have a relatively long life. The life expectancy of a hydel power plant equipment is about 50 years or more.
- They have a very high efficiency over a considerable load and have quick start up and stopping time and rapid response to change in power demand.
- Hydel power enables us to conserve our coal resources as for every horse power (hp) of hydel power generated, about four metric tonnes of coal is saved.
- These projects are labour-intensive in nature, i.e., they enable us to tackle problem of unemployment.
- Hydroelectric power projects are multi-purpose projects as these enable us to use their water for irrigation, industrial and domestic purposes, control flood, develop recreational sites, etc.

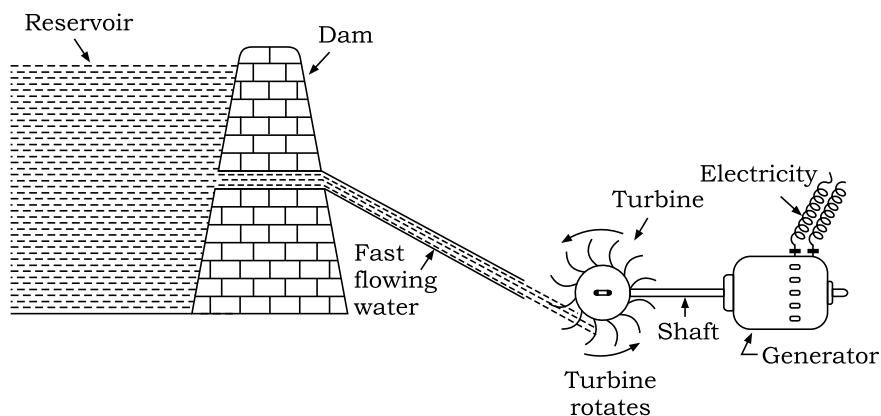


Fig. 4.8 Working of a hydro-power plant.

Demerits of Hydel Power Plants

1. The initial investment is very high and the gestation period is very long.
2. These projects cause population displacement, damage the environment and fertile land thereby creating a host of social problems as in the case of the Tehri Dam (on river Ganga) and Sardar Sarovar Projects (on river Narmada).
3. Hydroelectric generation is not suitable for all rivers and for all areas.

4.7.1.4 Biomass Energy

Biomass is the organic matter which is used as a fuel to produce energy. It is the oldest renewable source of heat energy still widely used as a fuel for domestic purposes. It includes fuelwood, agricultural wastes like crop residues, bagasse etc. (Bagasse is solid residual mass left after extracting juice from sugar cane) and cowdung. In India more than 70% of the rural population depends upon biomass as a source of energy. These are also burnt in rural industries and in the urban service establishments. It is common to use bagasse in the sugar industry and rice husk in rice mills. India is experiencing rapid economic and population growth leading to more energy requirement. The use of fuelwood alone in India is predicted to increase by a factor of three upto 2015.

These fuels however do not produce much heat on burning and a lot of pollutants like particulate matter, SO_2 , NO_x and another trace gases are given out when these are burnt. Therefore, technological inputs to improve the efficiency of these fuels are necessary. Wood undergoes carbonization to produce charcoal which burns without flames, is comparatively smokeless and has higher heat generation efficiency.

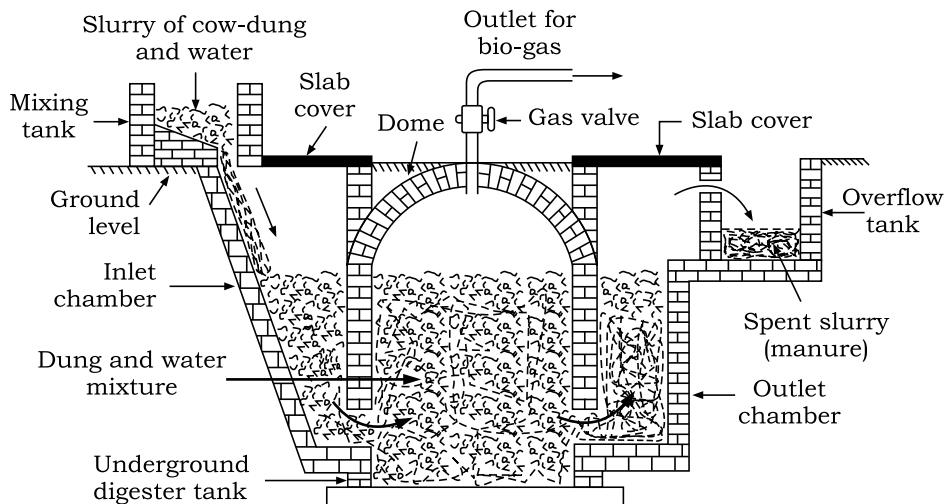


Fig. 4.9: Working of a Biogas plant.

Note: Carbonization is the process of heating the fuel in absence of air, to a sufficiently high temperature, so that the wood undergoes decomposition and yields a residue which is richer in carbon content than the original fuel. During this process moisture content and volatile matter is removed.

Similarly cowdung, crop, residues, vegetable waste, poultry droppings and sewage are decomposed in the absence of oxygen (anaerobic decomposition) to give bio-gas (Fig. 4.9). It is an excellent fuel as it contains upto 75% methane. It burns without smoke, leaves no residue and has high heating capacity. The slurry left behind is removed periodically and used as excellent manure, rich in nitrogen, phosphorus and potassium. Biogas has a high calorific value (5000 - 5500 kcal/kg) and can be used for domestic purposes, operating small scale industries, lighting and as fuel for the boilers, generators etc. The large scale utilisation of biomass wastes and sewage materials for producing biogas provides safe and efficient method of waste-disposal besides supplying energy and manure.

Government's Initiatives Towards the Promotion of Biomass Energy:

(i) Biogas plants

The national project on biogas development was started in 1981/82 for the promotion of family-type biogas plants. The project aims at providing a clean and inexpensive energy source, producing enriched manure, improving sanitation, and elevating the status of women in rural areas. Against a potential of setting up 12 million plants based on cattle dung, about 2.7 million plants have been set up. A 10 MW rice straw based thermal plant has been commissioned by BHEL (Bharat Heavy Electricals Limited) at Jhalkhari in Punjab. A pilot plant to generate electricity from garbage and municipal wastes has been installed at Timarpur in Delhi.

(ii) Biomass gasifiers for thermal applications

The techno-economic feasibility of utilizing biomass gasifiers for a variety of thermal applications has also been established. The capacity rating of these gasifiers is up to 150 kg of biomass/hour (equivalent to 400000 kcal/hour energy). The lower capacity gasifiers are used in small-scale industries like silk reeling, dyeing, and drying and in community cooking, etc. The bigger sized gasifiers can be used in industrial applications such as carbon dioxide manufacturing, and magnesium chloride production, etc. Moreover, there is a demand for large gasifiers in industries like cement, sugar, and calcium chloride for meeting the process of heat requirement. The use of gasifiers offers substantial reduction in fuel consumption and reduction in harmful emissions. A 100 kW gasifier system has been established in Port Blair and a 15 kW sugar cane-water based system is under field evaluation.

(iii) Improved cookstoves

The National Programme on Improved cookstoves was launched in 1984/85 with the objectives of fuel conservation, reduction of smoke, conservation of forests and the environment, providing employment, and elevating the status of women and children in rural areas. Improved cookstoves have a thermal efficiency of 20% - 35% as compared to the traditional cookstoves which have an efficiency of 10%. In addition, the improved cookstoves (ICs) are estimated to save about 11 million tonnes

of fuelwood equivalent every year. A minimum thermal efficiency of 20% and 25% has been prescribed for the fixed and portable type cookstoves, respectively. The pattern of subsidies for the promotion of ICs has been further rationalized to encourage market support.

4.7.1.5 Geothermal Energy

Geothermal energy is the heat of the earth and is the naturally occurring thermal energy found within rock formations and the fluids held within those formations.

In the molten core lying deep inside the Earth, the temperatures are as high as 4000°C. The thermal energy from this molten core forms an inexhaustible source of energy. Though the total quantity of heat stored in the Earth is vast, geothermal energy can be exploited only in particular areas, called the hot spots (e.g., volcanoes, geysers and bubbling mud holes). These hot spots are formed when geological changes push the molten rocks, called magma, upwards where it gets settled at some depths below the Earth's surface.

The underground hot water in contact with hot spots changes into steam. As the steam is trapped between the rocks, it gets compressed to high pressure. At some places, hot water and steam gush out from the Earth's surface after making their way through large cracks between the rocks and form natural geysers. Geothermal energy carried by natural geysers is utilized for generating electricity.

At some places, the steam trapped between the rocks is extracted by sinking pipes through holes drilled upto hot spots. The steam which comes out at high pressure is utilized to turn the turbine of an electric generator to produce electricity.

Although the most potent sources of geothermal energy are volcanos, hot springs and geysers, there are some other areas where geothermal energy can be harnessed under controlled conditions. This is done by pumping water down through an injection well where it passes through joints and fractures in hot rocks and then rises to the surface through a recovery or production well. This hot water is converted into steam by a heat exchanger. Dry steam is then passed through turbines to produce electricity.

Merits of geothermal energy

- Geothermal energy is the most versatile and least polluting renewable source of energy.
- It can be harnessed for 24 hours throughout the year and is relatively inexpensive.
- As compared to solar energy and wind energy, the power generation level of geothermal energy is higher.
- Geothermal energy can be used for power generation as well as direct heating.

Limitations of geothermal energy

- Geothermal hot spots are scattered and usually some distance away from the areas that need energy.
- The overall power production has a lower efficiency (about 15%) as compared to that of fossil fuels (35% to 40%).
- Though as a whole, geothermal energy is inexhaustible, a single bore has a limited life span of about 10 years.
- Noise pollution is caused by drilling operations at geothermal sites.

Geothermal power potential of India

India has vast potential for geothermal power. North-Western Himalayas and the Western Coasts are considered geothermal areas. The Geological Survey of India has already identified more than 350 hot water springs with average temperatures of 80°C–100°C. A 5 kW geothermal pilot power plant has been commissioned at Manikaran in Himachal Pradesh. The Puga Valley in Ladakh region has the most promising geothermal field with a potential of 4.5 MW power. A project on an experimental basis for the cultivation of mushrooms and poultry farming has been implemented.

4.7.1.6 Ocean Energy Systems

Oceans are large water bodies covering about 75% of the Earth's total surface area. Apart from being large reservoirs of water, they are huge reservoirs of energy also. Oceans store energy in many forms which can be obtained for useful purposes in the following ways:

- (i) Tidal Energy
- (ii) Wave Energy
- (iii) Ocean Thermal Energy

(i) Tidal energy

Water level near the coasts rises up and falls twice a day. This movement of water level along the coasts is known as tides. Tides are due to gravitational pull of the Moon on waters in the ocean. This pull varies during the monthly cycle rotation of the Moon around the earth. High tides occur on every new moon day and full moon day and can raise the level of water by few meters. Tidal energy is harnessed by constructing a dam across a narrow opening to the sea. A turbine fixed at the opening of the dam converts tidal energy to electricity (Fig. 4.10)

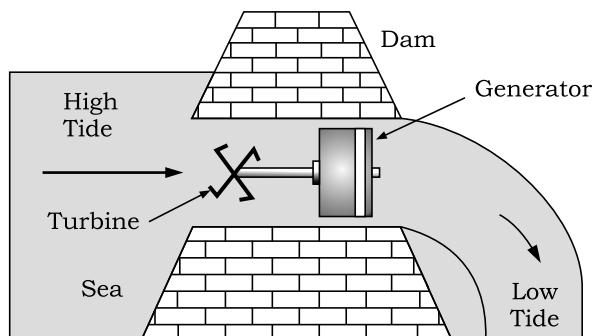


Fig. 4.10

Merits of tidal energy

- It is an inexhaustible, pollution free and renewable source of energy.
- It is independent of uncertainty of rainfall. Even if there is a continuous dry spell for many years, there is no effect on tidal power generation.
- A tidal power plant does not require large area of valuable land as it is built on the bay or the estuary.

Limitations of tidal power

- Due to variation in tidal range, the power output is variable and power generation is intermittent and not very large.
- There are very few suitable sites available for construction of dams.
- The most difficult problems in the use of tidal power is the barrage construction in areas of high tidal flow; and corrosion of barrage, sluiceways and turbines by salty sea waters.

Tidal power potential of India

India has an estimated tidal power potential of about 15,000 MW and the sites that have been identified are:

Gulf of Cambay (7000 MW), Gulf of Kutch (1000 MW) and Sunderbans (100 MW). Other suitable sites are near Lakshadweep Islands, Andaman and Nicobar Islands and Coasts of Orissa, Tamil Nadu, Karnataka, Kerala and Maharashtra. Asia's first tidal power plant costing Rs. 5000 crore and of 800 - 1000 MW capacity is proposed to be set up in the Hanthal Creek in the Gulf of Kutch in Gujarat.

(ii) Wave Energy

Due to blowing of wind on the surface of sea very fast water waves move on its surface. Due to their high speed, sea-waves have a lot of kinetic energy in them. The energy of moving sea waves can be used to generate electricity. A wide variety of devices have been developed to trap sea-wave energy to turn turbines and drive generators for the production of electricity:

- (a) The floating generators are set-up in the sea. These move up and down with sea-waves and this movement drives the generators to produce electricity.
- (b) The sea waves are made to move up and down inside large tubes. As the waves move up, the air in the tubes is compressed. This compressed air can be used to turn a turbine of a generator to produce electricity.

The total amount of power available in the World from wave energy is roughly 2 to 3 million MW. But the number of sites where this energy can be converted into useful energy is limited because only those areas with an average energy density of 40 MW/km of coastline are economically viable.

Merits of wave energy

- It is a free, renewable and pollution free source of energy.
- Wave power projects do not require large land areas.
- After extracting energy from the waves, the sea water is left in a relatively calm state.
- Wave power projects do not require a specific site (as in the case of tidal power projects) as same energy exists on almost any coastline.

Limitations of wave energy

- The power output is of variable nature.
- Wave energy extraction equipments must be capable of withstanding very severe peak stresses in storms.
- Wave power is expensive with the presently available technologies.
- Marine mammal and seabird population could be affected due to the presence of wave energy structures.

Wave power potential of India

The wave energy potential of 6000 km long Indian coast is estimated to be about 40,000 MW. Trade wind belts in Arabian Sea and Bay of Bengal are the ideal locations for harnessing wave energy. The first wave energy project with a capacity of 150 MW has been set up at Vizhinjam near Trivandrum.

(iii) Ocean Thermal Energy

Large amount of solar energy is stored in the oceans and seas. On an average, 60 million square kilometers of tropical seas absorb solar radiation which is equivalent to the heat content of 245 billion barrels of oil. If this energy can be tapped, a large amount of energy will be available to the tropical countries and the other countries as well. The sun warms the ocean water at the surface and the wave motion mixes the warmed up water downwards to the depth of about 100 m. This mixed warm layer is separated from the deep cold water layer and the temperature difference between these layers ranges from 10°C to 30°C. It is this temperature difference between the surface of the ocean and the depths of about 2 km which is used to produce electric power. The process of harnessing the ocean thermal energy is popularly known as ocean thermal energy conversion (OTEC). In the OTEC power plant, the warm surface water is used to boil a volatile liquid like ammonia. The vapours of the liquid are then used to run the turbine of generator. The cold water from the depth of the ocean is pumped up and condense vapour again to liquid.

Merits of ocean thermal energy conversion (OTEC) process

- The electric power from OTEC is continuous, renewable and pollution free. It is one of the most clean power production technologies.
- These systems transfer nutrients from the unproductive deep waters to the warmer surface thereby enriching the fishing grounds.
- OTEC process does not have daily or seasonal variations in their output as in the case with other solar energy devices.

Limitations of the process

1. This process requires a lot of capital investment.
2. Due to small temperature difference between the surface water and the deep water, the conversion efficiency is low (3–4%).

OTEC Potential of India

India has large potential of OTEC which could be of the order of 50,000 MW. Some of the best sites for this process plant are situated near the Lakshadweep, Andaman and Nicobar islands. An OTEC plant is proposed off the coasts of Tamil Nadu.

The energy potential from the sea (tidal, wave and ocean thermal energy) is quite large, but efficient commercial exploitation is still difficult.

4.7.2 Non-Renewable Sources

(a) Fossil fuels:

Fossil fuels are remains of prehistoric plants and animals which got buried deep inside the earth millions of years ago due to natural processes. These are energy rich compounds of carbon made by the plant and animal remains with the help of solar energy. Thus we can say that fossil fuels have stored solar energy in them.

(i) Coal

It is a complex mixture of compounds of carbon, hydrogen, oxygen and small amount of nitrogen and sulphur compounds. It is found in deep coal mines under the surface of earth. The coal found in the earth at different places has different percentages of carbon and so is classified according to the state of mineralization into the following types:

Types of coal	% Carbon content
Peat	11%
Lignite	38%
Bituminous	65%
Anthracite	96%

Lignite and bituminous coals burn faster and release a great deal of pollutants in the atmosphere on account of their lower carbon content. Anthracite burns slowly and releases much less smoke and delivers more energy and such is a best quality coal.

When coal is subjected to destructive distillation or carbonization (in the absence of air), then all volatile matter is removed from it to form coke. This residue is lustrous, dense, strong porous and coherent mass which is a better fuel than coal and does not produce smoke on burning. Also important and valuable by-products like tar, ammonia, naphthalene, benzol and H_2S are recovered during the carbonization process.

Coal mining in India dates back to 18th century. India has about 75118 mt which is approximate 7% of World's known coal reserves and these are

mainly found in Tamil Nadu, Gujarat, Pondicherry, Rajasthan, Jammu and Kashmir, Bihar, Orissa, Madhya Pradesh. Coal supplies 50% of the country's total energy requirement. By current estimates, the reserves are sufficient to meet the country's demand for at least another 100 years. The largest coal consuming sectors are power, iron and steel and cement industries. The share of the thermal power sector in coal consumption is almost 75%.

(ii) Petroleum

Petroleum literally means rock oil. It is a complex mixture of several solid, liquid and gaseous hydrocarbons mixed with water, salt and earth particles. Small amounts of other compounds of carbon containing oxygen, nitrogen and sulphur are also present in petroleum. It is a thick black liquid and is not used as a fuel in its natural form. It undergoes fractional distillation to obtain a number of useful products like fuel oil, Diesel oil, Kerosene, Petrol or Gasoline, Petroleum Gas, Asphalt, lubricating oil and paraffin wax. The aggregate consumption of petroleum products upto year 2000 was 85 mt. The largest consumers of petroleum products are the transport, residential and industrial sectors.

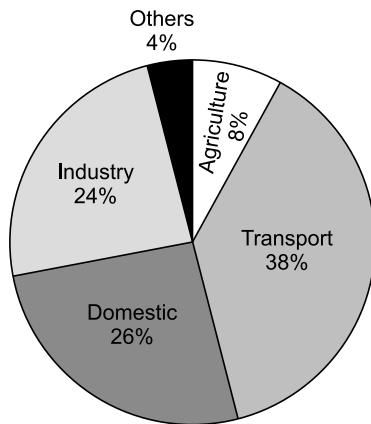


Fig. 4.11: Sectoral consumption pattern of petroleum products.

Source: Tata Energy Research Institute Energy Data (TEDDY) directory and Year book 2012–13.

(iii) Natural Gas

It is usually found underground near an oil source. However, there are some oil wells which give only natural gas. It is a mixture of methane (about 95%), ethane, propane and butane. Other components found are carbon dioxide, helium, hydrogen sulphide and nitrogen. It is highly inflammable, odourless, colourless gas. It is the cleanest burning fossil fuel found around the world but its largest reservoirs are in the former Soviet Union and the Middle East. Compressed Natural Gas (CNG) in liquid form is used as a fuel in transportation. It is a good alternative to petrol and diesel in reducing air pollution. It has a high calorific value of about 55 kJ/g.

Natural gas currently accounts for about 8% of the energy consumption in our country. The current demand is 89 mcmd as against domestic availability of 63 mcmd. The total gas consumption is around 20 bcm with a sectoral distribution as illustrated in Fig. 4.12.

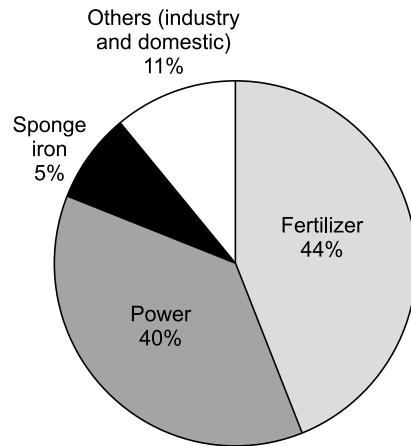


Fig 4.12: Natural gas end-use pattern (sectorwise).

Source: TEDDY, 2012–13.

The aggregate natural gas production is about 25 bcm and is likely to peak in future. However a wide gap is expected to prevail unless major gas discoveries materialize following future exploration by PSU's and private companies.

Also Liquefied Natural Gas (LNG) imports can ease the shortage of primary energy supply provided it can be sourced at competitive prices with respect to domestic and imported alternative fuels. In India, LNG is being imported from Qatar.

4.7.3 Nuclear Energy

Nuclear energy is released when atoms undergo nuclear fission. When heavy atoms like uranium, plutonium or thorium are bombarded with low-energy neutrons, a tremendous amount of energy is released. The fission of an atom of uranium for example, produces 10 million times the energy produced by the combustion of an atom of carbon from coal. Currently all commercial nuclear reactors are based on nuclear fission. But there is a possibility of nuclear energy generation by a safer process of nuclear fusion. Sun derives its energy from the fusion of hydrogen nuclei into helium nuclei, which is going on inside it all the time. In a nuclear reactor designed for electric power generation such nuclear fuel could be a part of a self sustaining fission chain reaction that releases energy at a controlled rate. The released energy can be used to produce steam and further generate electricity.

Nuclear power reactors located at Tarapur (Maharashtra), Rana Pratap Sagar (Rajasthan), Kalpakkam (Tamil Nadu), Narora (UP), Kaprapar (Gujarat) and Kaiga (Karnataka) have the installed capacity of less than 3% of the

total electricity generation capacity of our country. However many industrialised countries are meeting more than 30% of their electric power needs from nuclear reactors.

Advantages of Nuclear Energy

- It produces a large amount of useful energy from a very small amount of nuclear fuel (like uranium-235).
- Once the nuclear fuel is loaded into the reactor, the nuclear power plant can go on producing electricity for two to three years at a stretch. There is no need for putting in nuclear fuel again and again.
- It does not produce gases like carbon dioxide which contributes to greenhouse effect or sulphur dioxide which causes acid rain.

Disadvantages of Nuclear Energy

- The waste products of nuclear reactions (produced at nuclear power plants) are radioactive which keep on emitting harmful nuclear radiations for thousands of years. So, it is very difficult to store or dispose off nuclear wastes safely. Improper nuclear waste storage or disposal can pollute the environment.
- There is the risk of accidents in nuclear reactors (especially the old nuclear reactors). Such accidents lead to the leakage of radioactive materials which can cause serious damage to the plants, animals (including human beings) and the environment.

4.7.4 Alternate Energy Sources - Green Fuel

The recent excitement over the Kyoto protocol pertaining to global climate change, the rising prices of fossil fuels has led India and other developing countries to look for an environmentally friendly and economically viable alternative fuel. Several initiatives have been taken in recent times on the energy front such as large scale promotion of wind energy farms for power generation, blending of ethyl alcohol with petrol and developmental efforts towards bio fuels or green fuels.

Biofuels include:

1. Vegetable oils (rape, hemp, sunflower, soy, palm, olive etc.)
2. Biodiesel (obtained from oil extracted from Jatropha Curcas seeds.)
Production of Biodiesel is two step approach; the extraction of the Jatropha oils from the seed, and the conversion of the extracted oil to Biodiesel, according to the following transesterification reaction.



3. Ethanol (obtained by distillation from energy crops like sugarcane, maize, switch grass and populous tree etc and residues)
4. Methanol (wood alcohol obtained by pyrolysis from energy crops or waste)
5. Methane (gas obtained by bacteriological decomposition from landfill sites, sewage sludge etc.)

Carriage, storage and handling safety

Vegetable oils and biodiesel are ***biodegradable, non-toxic, non-carcinogenic, non-mutagenic and non-allergenic***. This is of considerable ecological advantage when considering the pollution that has been caused by petrofuels following large-scale marine oil spills - vegetable oils having been used to clean up oil slicks. Flash point* is around 179°C (diesel fuel 74°C), which means that the ***transport, storage and use is easier*** as the fire hazard is far below any other currently available liquid transport fuel.

Both ethyl and methyl alcohols are of similar safety hazard. Highly volatile (BP 78.3°C; 64.6°C; petroleum 27°C), flashpoints are also low, but comparable with petroleum for fire and explosion hazard.

Methane is a naturally occurring greenhouse gas, which is also the major component of CNG. It requires only 0.29 mJ energy to ignite, with an explosive concentration in air of 5 to 13%. This is 15 times the energy required to ignite a hydrogen/air mixture, but far lower levels of concentration are required. It is non-toxic and carries the same safety precautions as any of the liquefied gases currently dispensed from pressurised containers.

Environmental Effects

Growing biofuels should be considered essentially non-polluting in the longer term, given proper agricultural and process management. In addition by absorbing carbon dioxide from the atmosphere, ***energy crops act as a carbon sink*** throughout the year. This is released only when the fuel is used or the by-products burned. ***Longer term carbon sequestration*** (as discussed in Unit III) ***is achieved*** through the roots and stubble of the plants being ploughed into the ground.

There is a wide range of plants available, world-wide, as oil-producing energy crops. Other major benefit of energy crops is the oxygen by-product from photosynthesis.

Ethanol, methanol, vegetable oil and biodiesel are all oxygenated fuels. That is, they contain oxygen in their molecular structure. This is significantly advantageous to the burning process in an internal combustion engine, not only in improving the efficiency of the fuel but also in ***turning noxious oxides into less harmful dioxides*** (carbon and nitrogen). This also applies when used as fuel extenders.

In addition, none of them contain any sulphur at all unless minute traces are acquired through crop dusting, acid rain during growth or contaminated alcohols used during manufacture. Biodiesel is a better burning fuel than petrodiesel, and ***has a higher cetane number***. This is due to the molecular oxygen content of the fuel, which reacts under pressure and temperature faster than the subsequent fuel/air mixture. This causes the fuel to burn at a higher temperature, resulting in the formation of a higher level of nitrogen oxides. By simply retarding the fuel injection timing by two to three degree (depending on the engine design), the burning temperature is reduced, thereby reducing the amount of NOx gases formed.

***Flash point:** The lowest temperature at which the vapour of a flammable liquid ignites in air. Flash point is generally lower than the autoignition temperature.

Energy Production

Vegetable oil is the most energy positive fuel to produce requiring only agricultural input and seed pressing. 1 tonne of oil produced from rape seed per hectare gives an energy yield of 11 MWh at a cost of 2 MWh - a positive transport energy yield of 550%.

Biodiesel requires an energy input of up to 1 MWh per hectare, a positive transport energy yield of over 375%.

Since the importance of green fuels as alternate energy sources has been well recognised in India, the various organizations such as Indian Oil Corporation and Indian Railways, as well as several Universities and private institutions have initiated technology development plans for the use of bio-fuels. Many states like Tamil Nadu, Rajasthan, Karnataka and Andhra-Pradesh governments have introduced schemes to encourage investments in Jatropha plantations. The government plans to introduce 10% ethanol blended petrol from October 2008 instead of 5% blend that is currently mandatory. But Tata Motors have indicated to Ministry of shipping, road transport and highways that the higher blend would impact vehicles designed before 2002 and reduce fuel efficiency (*Hindustan Times*, Dec. 15, 2007). *The technical barrier to the encouragement of bio-fuels as a transport fuel is lack of suitable engines.* Despite the fact that Dr. Rudolph Diesel ran his new engine over a hundred years ago on peanut oil, subsequent engineering developments have been based on petroleum fuel. Thus India has to work and find out path to an ecologically sound, energy efficient future.

4.8 LAND RESOURCES

Land is the most important natural resource. It forms about 1/5th of earth's surface covering approximately 13, 393 million hectares. It supports natural vegetation, wildlife, human life, economic activities, transport and communication systems. The increasing human population has put a great pressure on the land resource, which is of finite magnitude. Therefore it is important to use the land resources with proper planning.

4.8.1 General Topography

India's mainland comprises four broad geographical areas: the Northern Mountains which has the great Himalayas, the vast Indo-Gangetic plains, the Southern (Deccan) Peninsula bounded by the Western and Eastern Ghats, and fourthly, the coastal plains and islands.

(i) **Northern Mountains:** Corresponding with the Himalayan Zone, alongwith country's northern boundaries including the Jammu and Kashmir (J&K), Himachal Pradesh (H.P.), North-West Uttar Pradesh (U.P.), Sikkim, part of Assam, and the North-Eastern States of Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. The Himalayas comprise of mountain ranges which form an indomitable physical barrier as the world's biggest and largest mountain range. The Himalayas also contain the cold arid deserts and fertile valleys.

- (ii) **The Great Plains:** Also known as the Indo-Gangetic plain is formed by the basin of three distinct river systems - the Indus, the Ganga and the Brahmaputra. The Plains extend from Rajasthan in the West to Brahmaputra valley in the East. The region covers the entire States of Punjab, Haryana, and the Union Territory of Chandigarh and Delhi and major parts of U.P., Bihar, West Bengal, and parts of Assam. These plains comprise one of the world's greatest stretches of flat and deep alluvium and are among the most densely populated areas of the world (456 persons per sq.km). The desert region, which contains the Great Thar desert, extends from the edge of Rann of Kutchh to larger parts of Rajasthan (Western) and lower regions of Punjab and Haryana.
- (iii) **The Deccan Peninsula:** This zone covers the whole of South India which includes the States of Tamil Nadu, Karnataka, Andhra Pradesh and Kerala. The Region also covers the State of Madhya Pradesh, and parts of Bihar, Orissa, Puriliya district of West Bengal. Density of population is 202 persons per km². The Indo-Gangetic plains and the peninsular plateau are separated by mountain and hill ranges known as the Aravali, Vindhya, Satpura, Ajanta and Maikala ranges.
- (iv) **The Coastal Plains and Islands:** The peninsula is flanked on either side by the Eastern Ghats and the Western Ghats. On either side of the Ghats outward to the sea lies a coastal strip. The Western coastal plain lie between the Western Ghats and the Arabian sea in the West, whereas the Eastern Coastal Plains face the Bay of Bengal in the East. This is also a region with very high-density population (349 persons per km²).

The country's geographical area of 328 mha covers only 2.4% of the world's total area, on which 16.7% of the world's population and about 18% of the world's livestock population survive. Of the total area of 328 mha, landuse statistics are available for roughly 305 mha accounting for 93% of the total land area. Of this, roughly 264 mha of land is available for agriculture, forestry and related purposes.

4.8.2 Land Utilization

The land resources are utilised for the following purposes (Table 4.4)

1. Forests
2. Area under non-agricultural use e.g. land occupied by buildings, roads and railways, housing, recreational purposes, industrial sites and irrigation systems.
3. Barren and unculturable land, are generally unsuitable for agricultural use either because of the topography or because of their inaccessibility e.g. desert areas in Rajasthan, the saline lands in parts of Rann of Kutchh in Gujarat, the weed infected and ravine lands in Madhya Pradesh and alkaline lands in Uttar Pradesh.
4. Permanent Pasture and Grazing lands.
5. Fallow lands are left uncultivated from less than a year to five years or more.

6. Cropped areas: Area sown more than once in an agricultural year plus the net sown area.

Table 4.4 Statistical distribution of total land area in India

A. Total Land Area	328.7 mha
Area which is enumerated in the census	306.50 mha
Forests	67.0
Area under non-agricultural use	21.8
Barren and Unculturable Land	19.4
Permanent Pasture and Grazing Lands	12.0
Fallow Lands	24.0
Cropped Area	142.5
— Area under Food Grain Cultivation	123.5
— Of this, Area under Rainfed Farming Systems	89

(Source: *Census of India, 2001*)

4.8.3 Land Degradation

The growth in the population and developmental activities have not only brought about degradation of land but have also aggravated the pace of natural forces to cause damage to land. At present there are about 130 million hectares of degraded land in India. Approximately 28% of it belongs to the category of Forest degraded area, 56% of it is water eroded area and the rest is affected by saline and alkaline deposits.

The terms land degradation and soil degradation are synonymous. Soil is integral part of land, hence, any deterioration in its quality, mass or volume, either singly or in combination, is also a deterioration of land. The term soil degradation is more specific and is directly related to crop production, while land degradation is a more comprehensive term.

Causes of Land Degradation

If natural hazards are left aside, the causes of land degradation can be divided into *direct* and *underlying* causes. Direct causes are inappropriate land use and unsuitable land management practices, e.g. the cultivation of steep slopes without soil conservation measures. Underlying causes are the reasons why these inappropriate practices take place, e.g. the slopes may be cultivated because the landless poor need food, and conservation measures are not taken because farmers lack security of tenure.

There are four direct causes of land degradation:

- deforestation and removal of natural vegetation;
- over-exploitation of wood cover for domestic use;
- overgrazing;
- agricultural activities.

Deforestation is a cause of degradation when the land that is cleared is steeply sloping or has shallow or easily erodible soils, and when clearance is not followed by good management.

Overtopping of vegetation occurs when people cut forests, woodlands and shrublands to obtain timber, fuelwood and other products at a pace exceeding the rate of natural regrowth. This is frequent in semi-arid environments, where fuelwood shortages are often severe.

Overgrazing is the grazing of natural pastures at stocking intensities above the livestock carrying capacity; the resulting decrease in the vegetation cover is a leading cause of wind and water erosion.

Agricultural activities that can cause land degradation include shifting cultivation without adequate fallow periods, absence of soil conservation measures, cultivation of fragile or marginal lands, unbalanced fertilizer use, and a host of possible problems arising from faulty planning or management of irrigation.

The role of population factors in land degradation processes are the underlying causes. In India, it is indeed one of the two major basic causes of degradation along with land shortage, and land shortage itself ultimately is a consequence of continued population growth in the face of the finiteness of land resources.

Population pressure also operates through other mechanisms. Improper agricultural practices, for instance, occur only under constraints such as the saturation of good lands under population pressure which leads settlers to cultivate too shallow or too steep soils, plough fallow land before it has recovered its fertility, or attempt to obtain multiple crops by irrigating unsuitable soils.

There are major soil problems in India which cause the degradation of soil. This soil degradation in general contribute to land degradation. These factors are:

i) Soil Erosion

This is the process by which top soil is detached from land and either washed away by water, ice or sea waves or blown away by wind. This process is also referred to as the creeping death of land. The processes of soil formation and erosion go on simultaneously and generally there is a balance between the two. This balance is disturbed due to the following human activities:

- (a) **Deforestation:** Removal of vegetation cover has caused widespread erosion in Western Ghats, Uttar Pradesh and in Himachal Pradesh.
- (b) **Faulty Cultivation methods:** For instance, in the Nilgiris, land has been opened for cultivation of tuber crops like potato and ginger without undertaking anti-erosion measures like tracing of slopes. Also forests on slopes have been cleared at places to make way for plantation crops. Such faulty cultivation methods have caused soil erosion. Landslides are common feature in these areas.
- (c) **Shifting Cultivation:** An ecologically destructive and uneconomic cultivation method is slash and burn or shifting cultivation which is practiced in hill areas of North-East, Chhotanagpur, Orissa, Madhya Pradesh and Andhra Pradesh. Vast areas have suffered erosion of soil in hill areas of North-East because of shifting cultivation.

- (d) **Overgazing:** A surplus of livestock population in our country is a big strain on grasses and fodder. The tread of cattle hardens the soil and prevents new shoots from emerging. Overgrazing by goats is a serious problem in certain stretches of the Aravalis and in Punjab and Himachal hills. The goats not only pull off leaves and branches, but they also uproot grass, as opposed to sheep, which only nibble the top shoots.
- (e) **Diversion in Natural Drainage Channels by Railway Embankments and Roads:** Railway tracks and roads have to be constructed in such a manner that they are at a higher level than the surrounding area. But sometimes, road and rail embankments come in the way of natural drainage channels. This causes water logging on one side and water loss on the other side of embankments. All these factors contribute to erosion in one way or the other.
- (f) **Lack of Proper Surface Drainage:** Because of lack of proper lack of drainage, water-logging occurs in low lying areas which lossens the top-soil and makes it prone to erosion.
- (g) **Denuding Forest Fires:** These fires, sometimes natural but often man made, are very destructive. As a result of these, the forest cover is lost forever and soil is exposed to erosion.

(ii) Loss of Fertility by Mismanagement

The most important cause of soil degradation specially in tropics is the loss of fertility. In general, the loss of fertility by mismanagement includes - unscientific cropping practices, imbalancing of nutrients, nonjudicious use of fertilizers, loss of organic matter content and soil pollution.

- (a) **Unscientific cropping practice:** Man, in his urge to derive the maximum yield to satisfy vast needs of a rapidly growing population, has been resorting to various scientific inputs like irrigation, fertilisers, pesticides etc. At the same time, unscientific cropping practices are sometimes followed. As discussed earlier at some stretches of Western Ghats, commercial tuber crops like potatoes and ginger are grown on slopes, after clearing the forests. These unscientific farming practices and an excessive use of inputs result in problems like soil erosion, loss of natural nutrients, water-logging and salinity and contamination of ground and surface water.
- (b) **Imbalancing of Nutrients:** A sudden rise in the use of chemical fertilisers and pesticides has harmed the long term fertility of soil and caused water pollution.
- (c) **Loss of Organic Matter:** Loss of organic matter is a form of soil degradation, not so much because of the direct effects of organic matter, but more importantly because of the many indirect effects. In addition to the buffering effect on nutrient ion concentrations, and the complexing of potentially toxic ions, the indirect benefits include the stabilizing effects on soil aggregates, and the support offered to the fungal and microbial soil population.

(d) **Soil Pollution:** Soil pollution originates from the development of industry, use of pesticides, chemical fertilisers, use of sewage, sludge, city composts etc which is the major factor of loss of fertility.

(iii) Salinity/Alkalinity

This problem occurs in areas of temporary water surplus and high temperatures. Due to over-irrigation or high rainfall, the moisture percolates down and dissolves the underground salts in it. During the dry period, this solution comes to the surface by capillary action. The water gets evaporated, leaving behind a crust of salts of sodium, magnesium and calcium which has a fluorescent appearance. This salt layer plays havoc with the fertility of top soil and renders vast stretches of useful land infertile. This problem is particularly serious in areas with assured irrigation in Punjab, Haryana, Uttar Pradesh, Western Maharashtra, Bihar and Northern Rajasthan (the Indira Gandhi Canal command area). An area of around 7 mha suffers from the problem of salinity/alkalinity.

(iv) Acidity

It is a chemical degradation of soil including toxicity of certain metallic ions for the normal crop growth. Acid soils are characterised by low pH values, low base saturation and high amounts of exchangeable hydrogen and aluminium resulting from intense leaching. These soils cover an area of about 49 million ha. In high rainfall zones of Himalayan belt, north-eastern region, Western Ghats, Eastern Ghats and coastal belt of Kerala. Nearly 26 million ha of acid soils have pH values below 5.5, whereas 23 million ha have pH ranging from 5.5 to 6.0. The acid sulphate soils of Kerala have more of polysulphides in the form of pyrites, free sulphuric acid and sulphates of Fe and Al. In extreme case pH of sulphate soils drops below 2.0 with concurrent breakdown of clay lattice and release of free iron and aluminium.

(v) Waterlogging

Waterlogging is defined as the state whereby soil becomes saturated with water within the depth of the root zone for a period that affects yield and quality of crops.

This happens when the water table gets saturated for various reasons—over-irrigation, seepage from canals, inadequate drainage etc.

National commission on Agriculture reported an area of about 6 million ha affected by waterlogging over 17 states in India. Out of this 3.4 million ha area suffering from surface flooding mostly in the states of West Bengal, Orissa, Andhra Pradesh, Punjab, Uttar Pradesh, Gujarat, Tamil Nadu, Kerala and M.P. about 2.6 million ha has a problem of waterlogging owing to high watertable. However, central groundwater board reported that during monsoon period, an area of 36.36 million ha is temporarily waterlogged. The land under waterlogged conditions can be used neither for agriculture nor for human settlements. In dry areas, waterlogging leads to salinity and alkalinity.

(vi) Deterioration of Soil Structure

Deterioration of soil structure is the commonest form of physical degradation. It is most commonly found where heavy machinery is used to cultivate the soil. Problems occurs mostly in soils of intermediate texture and low organic matter content. It involves: loss of stability of aggregates in surface soils, leading to sealing compaction and crusting, and consequently poorer infiltration rates and greater run off and erosion. Lack of organic matter and high percentage of fine silt are the factors contributing to sealing. Crusting is the formation of more compact, hard and brittle layer on the soil surface.

(vii) Floods and Droughts

Both these hazards have the harmful effect of limiting the use of good soil. This has already been discussed earlier. One nagging effect of floods is that each year a new area is affected.

(viii) Desertification

The clay and humus are the most important components of soil for both nutrient - and water-holding capacity. As clay and humus are removed, nutrients are removed as well, because they are bound to those particles. The loss of water-holding capacity is even more serious, however. Regions that have sparse rainfall or long, dry seasons support grass, scrub trees, or crops only so far as soils have good water-holding and nutrient-holding capacity. As these soil properties are diminished by the erosion of top-soil, such areas become deserts, both ecologically and from the standpoint of production. The term desertification is used to denote this process. Desertification doesn't mean advancing deserts; rather, the term refers to the formation and expansion of degraded areas of soil and vegetation cover in arid, semiarid, and seasonally dry areas, caused by climatic variations and human activities. These lands are traditionally called drylands.

The problem of desertification is serious in areas adjoining the Thar desert in Rajasthan. The affected areas lie in the states of Punjab, Haryana, Dehi, Madhya Pradesh and the Aravalis in Rajasthan.

Even though variations in climate often play a role in the processes of desertification, it is human agency that is the greatest threat to the dryland ecosystems. The three major practices that expose soil to erosion and lead to desertification are:

- **Overtcultivation**
- **Overgrazing**
- **Deforestation**

4.8.4 Lands Slides

Landslides are among the major hydro-geological hazards that affect large parts of India, especially the Himalays, the Northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhya, in that order. In the Himalayas alone, one could find landslides of every fame,

name and description - big and small, long and short, quick and creeping, ancient and new.

India has a sensational record of catastrophes due to landslides. The Darjeeling floods of 1968 destroyed vast areas of Sikkim and West Bengal by unleashing spate of landslides, causing considerable death and destruction. These landslides occurred over a three-day period with precipitation ranging from 500 to 1000 mm in an event of a 100-year return period. The 60 km mountain highway to Darjeeling got cut off at 92 places resulting into loss of lives and total disruption of the communication system. Yet another landslide tragedy of an unprecedented dimension was the great Alakananda Tragedy in July 1970 in Uttaranchal State that resulted from the massive floods in the river Alaknanda, upon breach off a landslide dam at its confluence with river Patal Ganga. A few years ago, the Malpa rock avalanche tragedy in August 1998, instantly killed 220 people and wiped out the entire village of Malpa on the right bank of river Kali in the Kumaun Himalaya of the state of Uttaranchal.

The economic losses due to landslides in India are enormous and recurring.

Man as the agent of change

Who is responsible for the alarm in the areas affected by landslides? Let us take the example, the Himalayas. Today these face the greatest danger of landslides? Himalaya's immature geology, meandering rivers, snow bodies, climatic variations, cloudbursts, flash floods etc., have always been there. For centuries, formidable snow avalanches did hurtle down the slopes in the higher Himalaya as they do now.

The real chaos on slopes came when the man entered the scene. Vast areas of Western Sikkim, Kumaun, Garhwal, Himachal Pradesh, Kashmir and several other hilly regions fell to his axe and were robbed of the protective vegetal cover to less than 30 per cent as against twice as much considered desirable. *Cutting of trees for fuel or fodder, overgrazing, increased domestic and industrial consumptions of timber were chiefly responsible for deforestation.* For example, close to the India-Bhutan border near Phuentsholing (Bhutan) and Jaigoan (India), spurt of human settlements has increased the number and frequency of Landslides, over the period of past few decades. Deforestation did add to the fragile geological environment and adverse climatic conditions to cause degradation of inter bedded quartzite and phyllites. The slopes without vegetation could not be expected to hold soil cover together and widespread erosion was the natural consequence.

Nature takes nearly 1000 years to produce a few centimetre of top soil but destabilizing forces of nature in the mountainous areas wipe away millions of cubic metre in just one second. The rate of erosion in the catchment area of the Himalayan rivers has increased five-fold in the geological time scale; the present rate being upwards of 1 mm per year.

As the pressure of population rapidly grew, more and *more of human settlements, roads, dams, tunnels, water reservoirs, towers and other public utilities were added.* The network of roads in the Himalayan region is today well over 50,000 km. Some of the roads exist even at altitudes as high as

5,000 metre surrounded by mountain ranges such as Kanchenjunga (8,586 m). Khardung La at 5,600 m is perhaps the highest motor road in the world.

Construction of roads requires imaginative planning and methodical construction but when engineers work against time, they may not even have the basic data on geological formation, topography, drainage pattern etc. and as a result, *some of the hill roads begin with landslides as witness to their inauguration functions.*

Likewise, a number of dams have been built in the Himalaya including the mighty Tehri Dam on river Bhagirathi. The Dam projects over the Ganga and its tributaries in the hills alone exceed two dozen. Such constructions include large scale deforestation, huge excavations, resettlement problems, and consequent threats to life and property. A number of tunnels are also being made. Microwave, TV, Transmission Line and other towers are also spread over the hilly areas. Quarrying and mining, for example, in the Doon Valley, Jhirioli (Almora) and Chandhak (Pithoragarh) have inflicted heavy damages to slopes and to the associated environment.

Influxes of tourists into the hilly region have brought about tremendous pressure on land due to construction of new buildings and tourist complexes including aerial ropeways and other utilities. For water storage, underground water tanks are being built without any special instructions or precautions despite considerable bad experience of slope instability from similar tanks, as at Mussoorie in Uttarakhand and Shimla in Himachal. Some of the constructions are coming up on old landslide masses without adequate pretreatment and investments on hillside stability, compounding the problem. Our rich cultural heritage and monuments are also under severe threat due to landslides and slope instability.

The time has come when the problem due to land slides should be recognised and Government should ensure that protective measures are taken for any development activity to start in the hilly region.

Source: R.K. Bhandari, The Indian Lanslides, Scenario, Strategic issues and action points, Indian Disaster Management Congress, New Delhi, November 2006.

EXERCISES

Short Answer Questions

1. Define the term 'resource'.
2. Distinguish between renewable and non-renewable resources with examples.
3. Briefly explain the importance of forests.
4. How are forests important in keeping an ecological balance?
5. What are the negative impacts of timber extraction?
6. Discuss the benefits and problems of dams.
7. Write a short note on common approaches towards water conservation.
8. Write short notes on the following

1. Floods	2. Droughts
3. Conflicts over water in India	4. Saltwater intrusion
5. Land subsidence.	

- 9.** Write a short note on mineral resources of India.
 - 10.** Write a short note on the classification of minerals
 - 11.** Write short notes on
 - (a) Surface and subsurface mining
 - (b) Processing the mineral
 - 12.** Write short notes on
 - (a) Green revolution
 - (b) Water logging
 - (c) Salinity
 - 13.** List the environmental problems associated with
 - (i) chemical fertilizers, and
 - (ii) pesticides
 - 14.** Write short notes on
 - (a) Wind energy
 - (b) Biomass energy
 - (c) Hydroenergy
 - (d) Ocean thermal energy
 - (e) Nuclear energy
 - 15.** Discuss in brief the advantages and disadvantages of non-conventional sources of energy.
 - 16.** Write notes on
 - (a) man induced landslides
 - (b) desertification
 - (c) water logging
 - (d) salinity in soil.
 - 17.** (a) Distinguish between Under nutrition and Malnutrition
(b) What are renewable, non-conventional energy sources? Give examples.
(c) Why is recycling usually more efficient than mining new raw materials?
 - 18.** (a) What are the causes of deforestation in India? Describe briefly its effects on the environment.
(b) What are the different types of energies which can be derived from ocean? Explain briefly.
(c) What are the major approaches to conserve water resources? How is water harvesting practiced in India?
 - 19.** (a) Write short notes on:
 - (i) Solar Energy
 - (ii) Salinity and Water logging
(b) What are Green Fuels? Why are these considered non-polluting and clean fuels?

Long Answer Questions

1. What do you mean by natural resources? Enumerate the various natural resources.
 2. How can you classify the forests? What is the importance of forests in our life?
 3. Explain the major causes of deforestation? Briefly describe the effects of deforestation on environment.
 4. What do you mean by deforestation? Explain its causes and ill-effects.
 5. What are the factors which have contributed to the conservation of forests in India?
 6. Discuss the impacts of dams on the forests and tribal people.
 7. What are the alternative energy resources? Differentiate between renewable and non-renewable natural resources.
 8. Describe in detail the consequences of overexploitation of water resources.
 9. Explain the types of drought and their inter-relationship.
 10. Identify and explain the core causes of water crisis in the world.
 11. Discuss the distribution and uses of mineral wealth in India.

- 12.** What are the different methods adopted for the extraction of mineral wealth.
- 13.** Write a note on environmental impact of extracting mineral resources.
- 14.** What are the different types of minerals. Describe the effects of mineral extraction on the environment.
- 15.** Discuss in detail the major food problems. How is under nourishment different from malnourishment?
- 16.** Write a detailed note on negative impact of modern agriculture on environment.
- 17.** Discuss the various types of agricultural practices.
- 18.** What do you mean by water logging and salinization? What are their causes and how do they influence the agricultural yields? Suggest measures to minimise them.
- 19.** Write a brief note on sustainable agriculture.
- 20.** Name and explain in brief the various ways in which, energy from oceans can be obtained.
- 21.** What is Geothermal energy? Discuss its merits and demerits.
- 22.** Describe various non-renewable energy sources in detail.
- 23.** Discuss the importance of green fuel as an alternate source of energy.
- 24.** Discuss the various cause of land degradation.
- 25.** Explain causes of soil erosion and enumerate the methods of prevention of soil erosion.



UNIT 5

Green Technology and Green Chemistry

"Green Chemistry represents the pillars that hold up our sustainable future. It is imperative to teach the value of green chemistry to tomorrow's chemists".

Daryle Busch

Objectives

- Introduction
- Green Technology
- Green Chemistry and its Basic Principles
- Concept of Atom Economy
- Tools of Green Chemistry
- Zero waste technology

5.1 INTRODUCTION

Chemical Manufacturing has brought revolution in the life on earth. It is the source of many useful products like drugs, antibiotics, plastics, fuels (like gasoline), agricultural chemicals (like pesticides and insecticides, fertilisers; synthetic fabrics (like nylon, rayon, polyesters) and many others. The ill effects of the chemical industries are also not less in magnitude. The recipient of the ill effects is not only man but also the environment. The alarming increase in the level of pollution forced the governments all over the world to make laws to minimize it. This gave rise to the birth of **Green Technology** and **Green Chemistry** by the middle of 20th century.

Green chemistry is environment friendly chemical synthesis in which schemes are designed in such a way that environment pollution is minimized. It is based on this age old principle "**Prevention is better than cure**". In this field, attempts are made to prevent wastes during chemical synthesis so that later cleaning up the environment does not become a problem. Here the starting materials, solvents, catalysts etc. are so chosen that they have no or minimum toxic effects on the environment. For instance the use of Benzene, Toluene etc. are discouraged as solvents since they are carcinogenic in nature. If possible, the reactions are carried out in the aqueous phase. Thus, alternate methods of chemical synthesis developed in Green Chemistry should be applied to the maximum to minimize the ill effects of pollution.

5.2 GREEN TECHNOLOGY

Whenever the term “Green” is used, it refers to the environment friendly objects and “Technology” means the application of knowledge for practical purposes. Since Green Chemistry involves new methodologies hence Green Chemistry or Technology means the same in the broader sense. The concepts of Green Technology is described in details in Chapter 1 under the topic ‘Introduction of the concept of Green Technology’.

5.3 GREEN CHEMISTRY AND ITS BASIC PRINCIPLES

As defined by Paul T. Anastas and J.C. Warner “**Green chemistry or environmentally benign chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances**”. This emerging field has gained importance not only in the areas of research and development but in the world of both academics and industry.

Basic Principles of Green Chemistry

Green Chemistry (defined in the previous section) basically aims at reducing the environmental pollution by involving various innovations in the chemical synthesis. Paul Anastas and John Warner in their publication (1998) titled, Green Chemistry: “Theory and Practice” have developed 12 principles (given in the box) to give guidelines for chemists for developing Green Chemistry.

The Twelve Basic Principles are Explained below:

Prevention of Waste

The by-products formed in a chemical reaction constitute the waste. The unreacted starting materials (which may or may not be hazardous) also forms part of the waste. Chemical synthesis should be designed in such a way that the waste products are minimized. This is because sometimes the cleaning and disposal of waste becomes so expensive that it adds tremendously to the overall production cost. By prevention of waste generation, the associated problems such as hazards associated with waste storage, transportation and treatment is minimized.

Atom Economy

Chemical Synthesis should be designed to maximize the incorporation of the starting materials and reagents in the final products. This concept developed by B.M. Trost is described in detail in a separate section of ‘Concept of Atom Economy’.

Minimization/Prevention of Hazardous Chemical Synthesis

Wherever practicable, synthesis should be designed to use and generate substances imposing minimum or no toxicity to human health and environment. For instance if for a particular reaction, a range of reagents

are available, then the reagents are such chosen that they not only pose less risk but also generate only benign by products. For example, synthesis of adipic acid explained in section 5.5.1)

Twelve Principles of Green Chemistry¹

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficiency of function while reducing toxicity.
5. The use of auxiliary substances (e.g., solvents, separation agents) should be made unnecessary wherever possible and innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. Unnecessary derivitization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. Chemical products should be designed so that at the end of their function they do not persist in the environment and breakdown into innocuous degradation products.
11. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

¹Anastas and Warner, *Green Chemistry*, 1998.

Design Safer Chemicals

The reaction products should be designed in such a way that they should be fully effective without having any toxic effects. For example, 'thalidomide' a drug used for lessening the effects of vomiting during pregnancy by expecting mothers resulted in the birth defects of the children born to these mothers (having missing or deformed limbs). The medicine has now been banned totally. With the advancing technologies, now it has become possible to manipulate the chemical structure to produce safer chemicals. Using this principle, new products can be designed which are not only safer but also highly effective for target applications.

Use of Safer Solvents and Auxiliaries

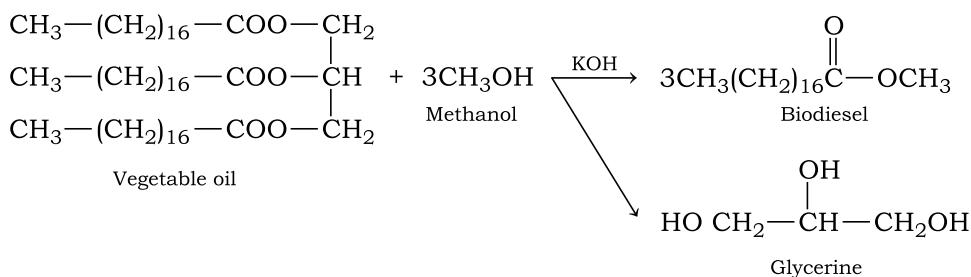
The use of auxiliary substance (e.g. solvents, separating agents etc.) should be avoided. If these chemicals are necessary safer chemicals should be used. Many solvents like carbon tetrachloride, chloroform, perchloroethylene etc. which are used in large quantities in industry are not only harmful to human health and environment but can also create other dangers like explosion or fire hazards. Sometimes it is possible to substitute safer solvents like water or liquid carbondioxide. For example in the new dry-cleaning processes for clothing, liquid carbondioxide instead of perchloroethylene is used for dissolving grease. Efforts should also be made to reduce the volume of the solvent. A large number of synthesis, also involves purification hence, wherever possible the use of auxiliary supports like chromatographic supports etc. for such purifications be avoided.

Design for Increase in Energy Efficiency

The chemical reactions should be carried at ambient temperatures and pressure whenever possible, to minimize the environmental economic impacts. In the exothermic reactions, sometimes extensive cooling is required, which adds to the overall cost. If the final product obtained in any reaction is impure again energy is required for purification by distillation, recrystallization, ultrapurification etc. Thus the process should be designed such that there is no need for separation or purification. Energy to a reaction can also be supplied by photochemical means, microwave and incineration.

Selection of Renewable Feedstocks as Starting Material

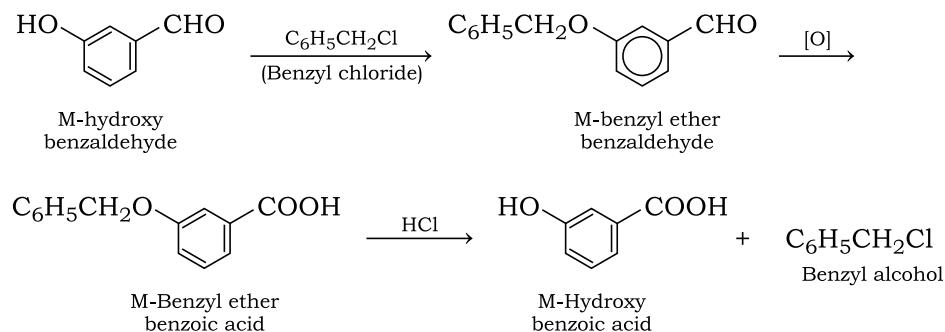
Raw materials and feedstocks that are renewable should be preferred over that of depleting ones. Biodiesel which is Methyl or Ethyl ester of fatty acid is made from virgin or used vegetable oils (both edible and non-edible) and animal fats. It can be either used in its pure form as a fuel or it can be blended at any level with petroleum diesel to create a biodiesel blend. It is also considered as a clean fuel because it has no sulfur, no aromatics and has 10% built in oxygen, which helps it to burn completely.



Avoid of Chemical Derivatives

In a chemical reaction, the blocking groups, protection/deprotection or any temporary modification of physical/chemical process should be avoided (if possible). Derivates use additional reagents and generate waste. For

example in the synthesis of M-hydroxy benzoic acid from M-hydroxy benzaldehyde by the conventional method, Benzyl chloride (a known hazard) is used as the protecting group for “OH” group. The waste generated after the deprotection should be handled properly. This reaction is also less atom economical since a lot of waste is generated.

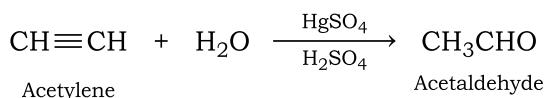


Use of Catalysts and Non-Stoichiometric Reagents

The waste is minimized if the catalytic reagents are used since the catalytic reactions are highly specific and are needed in very small amounts. The reactions are also energy efficient (take place at lower temperature). The stoichiometric reagents are used in excess and work only once and hence should be avoided (if possible).

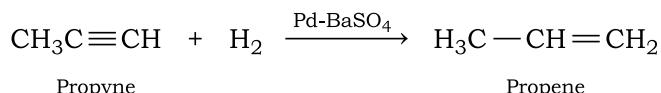
Few advantages of catalytic reactions are as follows:

- Reaction is feasible with a catalyst which is otherwise not possible under ordinary conditions.



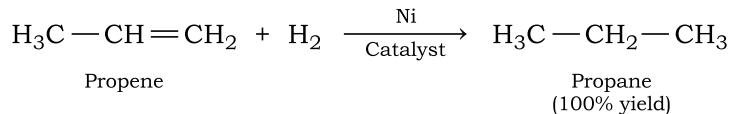
- ## 2. Selectivity is increased

Hydrogenation of propynes to propenes



- ### **3. Better yield is obtained**

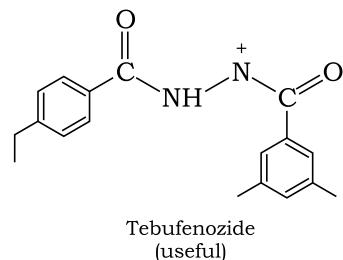
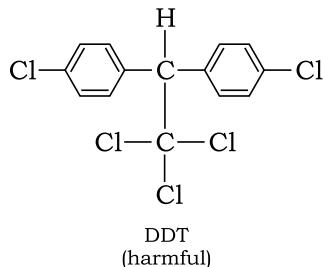
Reduction of olefins in the presence of Nickel Catalyst gives excellent yield.



Products Designed should be Biodegradable After Use

The chemical products should be such designed so that they breakdown into safer substance after use and not accumulate in the environment.

Pesticides and insecticides like aldrin, dieldrin and DDT remain in the environment for a longer period as they are non-biodegradable and hence have a detrimental effect on human health and environment. Whereas, the diacetylhydrazines (Tebufenozone, Halofenozone etc.) developed by Rohm and Hass company are useful insecticides and also biodegradable.



Strengthening of Analytical Techniques for Pollution Prevention

The in-process real-time monitoring and control should be designed during synthesis (that is monitoring the progress of the reaction to know whether the reaction is complete or incomplete) and that the formation of by-products is minimized and detected. For instance placement of accurate sensors to monitor the generation of hazardous by-products is very important so that it can be controlled. Also, for the minimum usage of chemicals in a reaction, the unreacted reagents (chemicals) should be recycled.

Design of Manufacturing Plants to Minimize the Potential for Accidents

The chemicals and their forms (solid, liquid, or gas) should be chosen to minimize the potential for not only the chemical accidents but also explosions, fires and release of toxic substances to the atmosphere. A number of accidents have been found to occur in industrial units for example the infamous Bhopal Gas Tragedy (December 1984)*, resulted not only in loss of thousands of human lives but also left many people in the next generation disabled.

CASE STUDY

The Bhopal Gas Leak Disaster

On December 3, 1984, disaster struck Bhopal, the capital city of the state of Madhya Pradesh located in Central India.

The Union Carbide Factory involved in the manufacture of carbamate type of pesticide used Methyl iso-cyanate (MIC) as a intermediate product. Due to the alleged functional failure of “vent scrubber” outlet, 30 tonnes of a potentially toxic, methylisocyanate

gas escaped from the underground storage tanks of the pesticide manufacturing plant. As a consequence there were nearly 2500 deaths and severe disability of more than 1,00,000 survivors.

Inhalation of MIC causes vomiting, violent coughing, suffocation, removal of oxygen from the lungs, pulmonary disorders, cardiac failure, and death due to choking. Burning sensation in the eyes caused eye infections (conjunctivitis) and eventual blindness in the survivors. The survivors were disabled not merely for a lifetime but even beyond, because serious genetic effects would pass on the disabilities to the future generations as well.

It is indeed ironical that the disaster occurred towards the end of the Golden Jubilee celebrations of Union Carbide Limited **and the simple precaution of breathing through a wet towel could have saved so many lives.**

This worst ever disaster in Bhopal is an example of an industrial pollution accident caused due to the failure in handling a toxic material in large-scale chemical processing.

SOME OF THE FINEST EXAMPLES OF GREEN CHEMISTRY/TECHNOLOGY'S ACHIEVEMENTS ARE AS FOLLOWS

1. Barry Trost's concept of Atom Economy for expressing the efficiency of a reaction (discussed in section 5.4)
2. New Synthesis of Ibuprofen.
3. Use of waste carbon dioxide as a blowing agent instead of CFC's for foam polystyrene synthesis.
4. Development of CO₂ as a solvent for dry cleaning.
5. Development of oxidant activators for hydrogen peroxide in the manufacture of paper.
6. Development of new insecticides.

5.4 CONCEPT OF ATOM ECONOMY

The concept of atom economy was developed by Barry Trost in 1991 which is a method of expressing the efficiency of a particular reaction in which reactant atoms are incorporated into the desired final product. The main objective of this concept is to develop a new methodology or design a new synthesis in which most of the reactant atoms become incorporated into the final desired product thus reducing the waste or the by products.

The percentage yield of any reaction is calculated by:

$$\% \text{ yield} = \frac{\text{Actual yield of the product}}{\text{Theoretical yield of the product}} \times 100$$

A reaction may have a percentage in yield of 100% but may not be considered as green synthesis if large amounts of by-products are obtained. Typical examples are Grignard and Wittig reactions which give a yield of 100% along with large amount of by-products. For a reaction to be considered

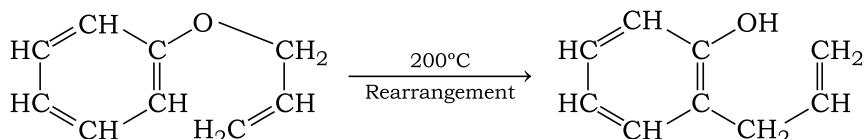
as green synthesis, the percentage of atom economy is calculated by the following equation.

$$\% \text{ atom economy} = \frac{\text{Mass of atom in desired products}}{\text{Mass of atoms in reactants}} \times 100$$

Let us consider some common reactions and find which has more percentage of atom economy.

Rearrangement Reactions

Allyl phenyl ether gives O-Allyl phenol by heating at 200°C.



Allyl phenyl ether
(M.W. = 134.175 g)

O-Allyl phenol
(M.W. = 134.175 g)
(desired product)

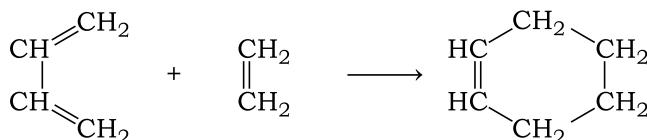
$$\% \text{ Atom economy} = \frac{134.175}{134.175} \times 100 \\ = 100.$$

This is a 100% atom economical reaction.

Addition Reactions

(a) Cycloaddition reactions of Butadiene to Cyclohexene

$$\% \text{ Atom economy} = \frac{82}{82} \times 100 \\ = 100$$

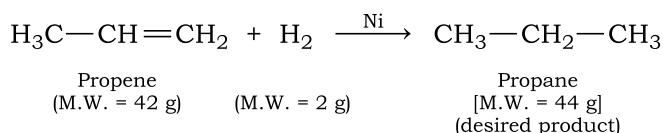


Butadiene
[M.W. = 54 g]

Ethene
[M.W. = 28 g]

Cyclohexene
[M.W. = 82 g]
(desired product)

(b) Catalytic addition reaction

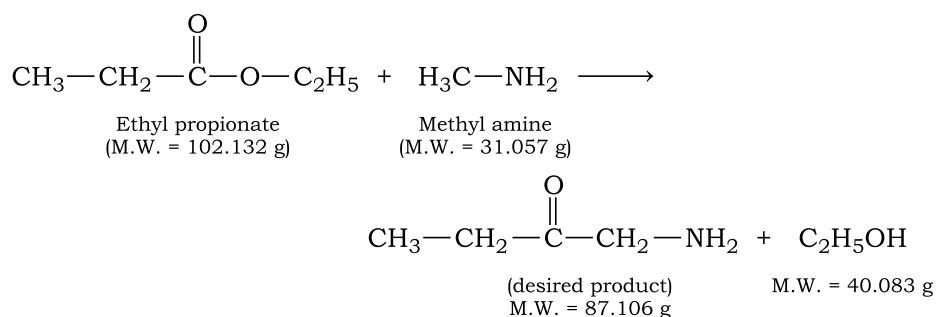


$$\% \text{ Atom economy} = \frac{44}{44} \times 100 = 100$$

Since Ni is used as a catalyst, it can be recovered fully after the reaction. Thus both type of addition reactions give an atom economy of 100%.

Substitution Reaction

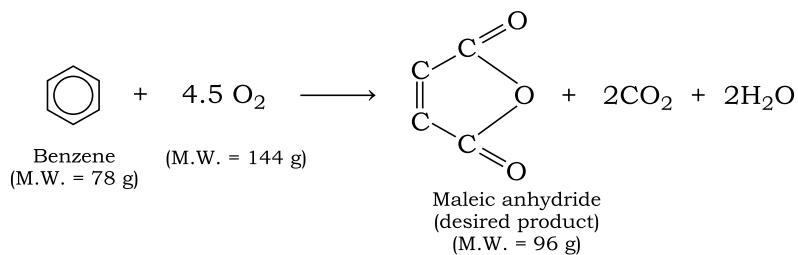
Let us consider a substitution reaction of Ethyl propionate with Methyl amine



$$\begin{aligned}
 \% \text{ Atom economy} &= \frac{87.106}{102.132 + 31.057} \times 100 \\
 &= \frac{87.106}{133.189} \times 100 \\
 &= 65.40
 \end{aligned}$$

Oxidation Reaction

Conversion of Benzene to maleic anhydride

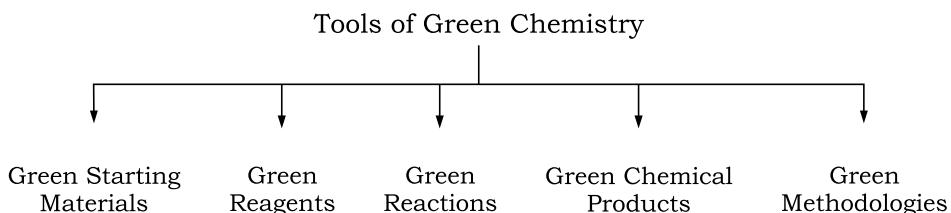


$$\begin{aligned}
 \% \text{ Atom economy} &= \frac{96}{78 + 144} \times 100 \\
 &= 43.
 \end{aligned}$$

A very important example of atom economy is the synthesis of Ibuprofen. The conventional method used six steps with an atom economy of just 40.1%. In the 1990s the HCC developed a new three stage process with an atom economy of 77.4%, now a commercial method. This reaction won the *Presidential Green Chemistry Challenge Award* in 1996 in U.S.A.

5.5 TOOLS OF GREEN CHEMISTRY

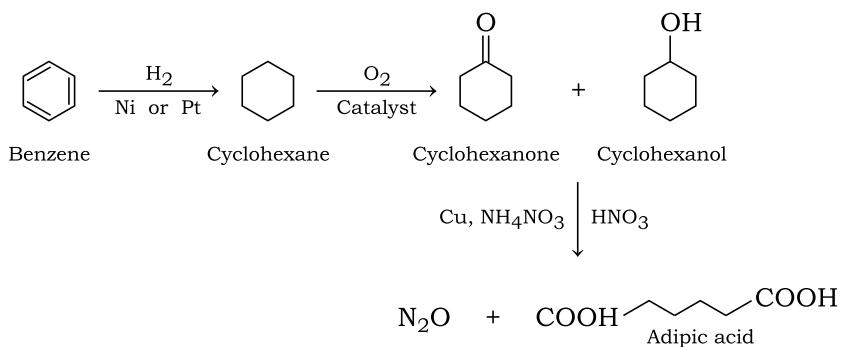
The objectives of green chemistry is to reduce the toxicity in the environment. In order to achieve this, the new areas have to be found where improvements can be made. These areas serve as ‘tools’ for Green Chemistry. The identified areas (i.e. tools of Green Chemistry) are as follows:



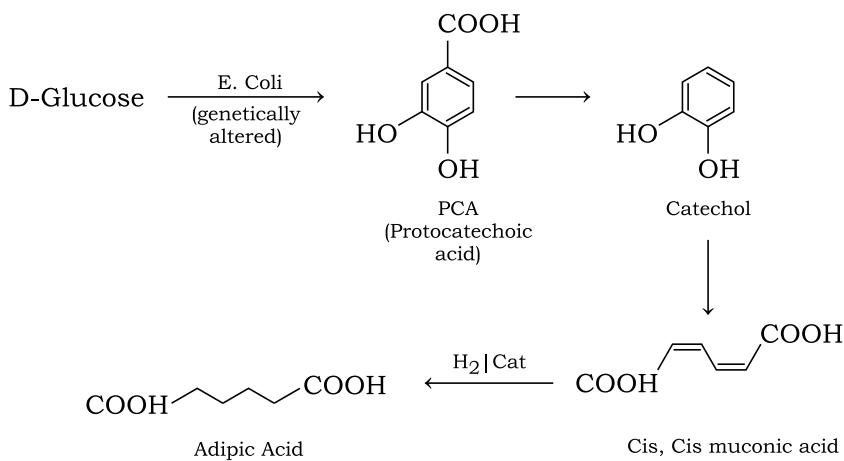
GREEN STARTING MATERIALS

The starting material is said to be green when it is non toxic, preferably renewable and does not degrade the quality of the environment*. Adipic acid which is an important chemical used in the synthesis of nylon, plasticisers and lubricants is conventionally prepared from benzene which is carcinogenic. An environmentally benign synthesis of Adipic acid is from D-glucose (a nontoxic and renewable source) and the solvent used is water instead of organic solvents.

Conventional Synthesis of Adipic Acid



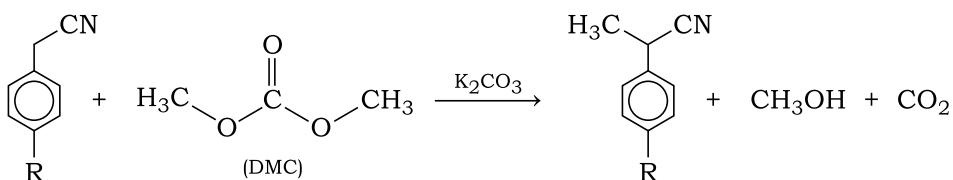
Green Synthesis of Adipic Acid from D-Glucose



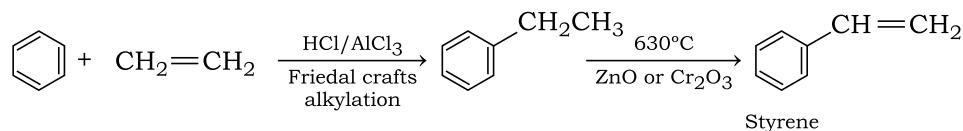
GREEN REAGENT

The reagents are said to be green when they are easily available (preferably from natural renewable sources), non-toxic, give maximum atom economy and the waste products formed (if any) are non-toxic and biodegradable.

Conventionally methylation reactions were carried by using Methyl halides or Methyl Sulphate which are very toxic, hence the synthesis is undesirable. Tundo developed a method to methylate active methylene compounds using Dimethyl Carbonate (DMC) without producing any inorganic salts.



In the conventional method Styrene (the Monomer used for the manufacture of polystyrene) used in large quantities every year is made from Benzene (carcinogenic) by Friedal-Crafts alkylation.



In the green synthesis which is developed by Chapman, a single step is used to convert mixed Xylenes to Styrene. (better atom economy)

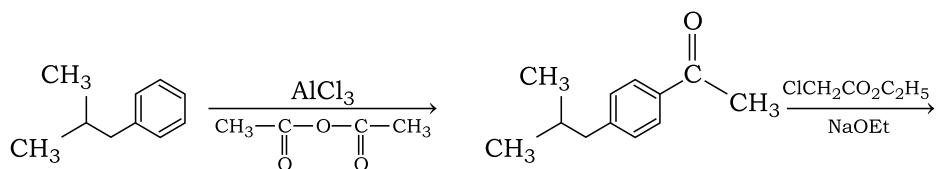
GREEN REACTIONS

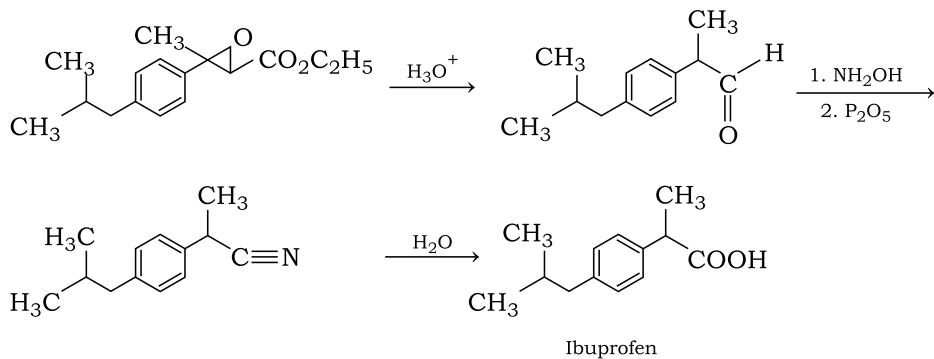
'Green Reactions' is based on the "Concept of Atom Economy". The concept of Atom Economy is described in details in the earlier section. Few examples of Green Reaction are given below:

Synthesis of Ibuprofen

The conventional synthesis of Ibuprofen was developed by Boots Company of England in 1960. This is a six step process with an atom economy of 40.1% where as the green Synthesis developed by BHC company is a three step process with atom economy of 77.4%.

Conventional Synthesis of Ibuprofen

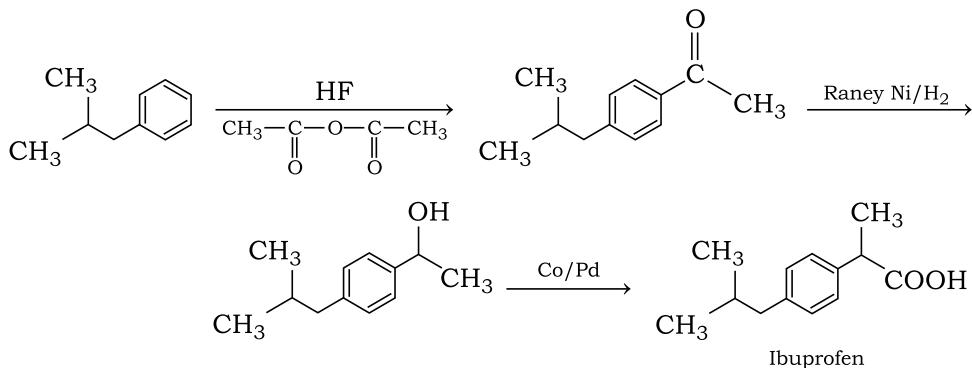




Atom economy by this process is only 40.1%.

Green Synthesis

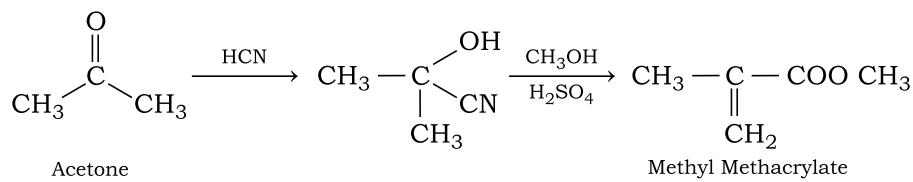
Atom Economy by this process is 77.4%.



Synthesis of Methyl Methacrylate

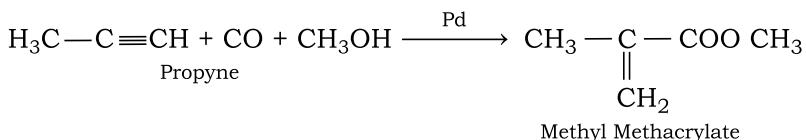
Methyl methacrylate is used in large quantities for the manufacture of polymers. The conventional method uses HCN (highly poisonous) with an atom economy of only 47% whereas the green synthesis developed by Shell corporation uses Pd catalyst with an atom economy of 100%.

Conventional Method



Atom economy is only 47%.

Green Synthesis



Atom Economy by this method is 100%.

Synthesis of Adipic Acid

Adipic acid which is required in large quantities for the synthesis of polymers was conventionally prepared from Benzene (carcinogenic). The by product formed by this method is N_2O which contributes to greenhouse effect as well as results in the destruction of Ozone layer. The green synthesis of Adipic acid is environmentally benign and is synthesized from D-Glucose using biocatalyst. This was developed by J.W. Frost and K.M. Draths (Reaction is described in details in the section of green starting material).

GREEN METHODOLOGIES

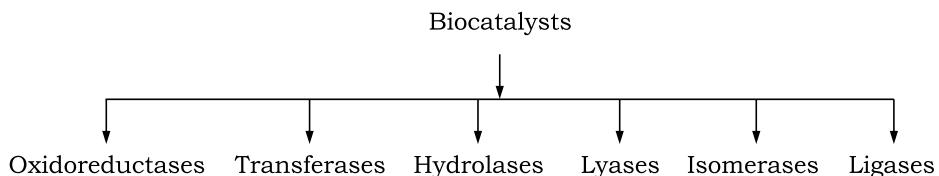
New methodologies are designed as an alternative to the existing methods, so that toxic starting materials, reagents, catalysts, by products or intermediates are either minimized or totally eliminated. Few methods for the environmentally benign synthesis are:

Use of Biocatalysts

Enzymes are also known as biocatalysts. The use of biocatalysts have the following advantages.

- The reactions are performed at ambient temperatures and pressures.
 - Most of the reactions are carried out in aqueous medium.
 - The conversions are normally single step conversions.
 - Atom economy is maximized.
 - Conversion are stereospecific.

The Biocatalysts are classified into six major classes.



1. **Oxidoreductases:** These enzymes catalyze oxidation reduction reaction.
 2. **Transferases:** They catalyze the transfer of various functional groups.
 3. **Hydrolases:** These enzymes catalyse hydrolytic reactions.

4. **Lyases:** Carry out the addition and eliminations of small molecules on sp^3 hybridized carbon atom.
5. **Isomerase:** Responsible for the isomerisation reactions.
6. **Ligases:** They catalyse the formation or cleavage of sp^3 hybridized carbon.

Use of Aqueous Medium as Solvents

The advantage of using water as a solvent instead of organic solvents is that, it is cheaply available, safe (non-inflammable), non-carcinogenic and simple in operation. It has the highest value of specific heat. The few reaction carried out in aqueous medium are.

1. *Diels Alder reaction:* Heterocyclic compounds with Nitrogen or Oxygen containing dienophiles are synthesised using this reaction.
2. *Claisen Rearrangement:* The thermal rearrangement of Allyl vinyl ether to give aldehyde in pure water.
3. *Michael Reactions:* 2-Methyl-cyclopentane-1, 3-dione when reacted with vinyl ketone in water gave a 5–6 fused ring system without using a basic catalyst (as in conventional method).
4. *Aldol Condensation:* Vinyl ketones can be obtained by the reaction of 2-alkyl -1, 3, diketones with aqueous formaldehyde using 6 – 10 M aqueous potassium carbonate as base.

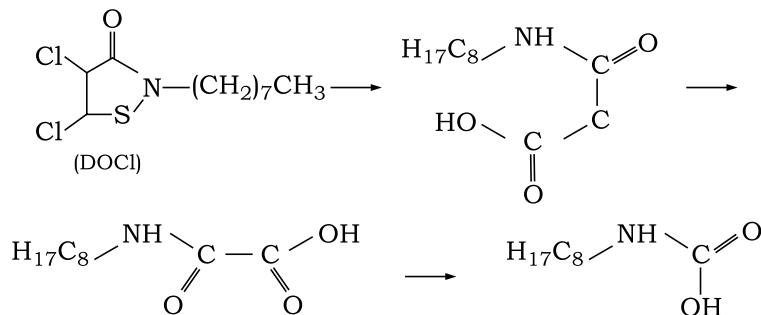
Attempts are also being made to carry out the reactions in the solid state. Some of the solid phase reactions which are already carried out successfully are halogenation, hydrohalogenation (addition of HBr), Michael Addition, Dehydration of Alcohols to Alkenes, Aldol condensation, Grignard reactions and many others.

GREEN CHEMICAL PRODUCTS

The green products are those which serve the same function without themselves being toxic or breaking down into toxic subs. For examples many insecticides use organochlorines, organophosphates, or carbamates. Organochlorine compounds (like aldrin, dieldrin) are readily incorporated into the food chain, whereas organophosphates and carbamates although are less persistent in the environment (DDT), but they readily decompose in the environment and tend to be toxic to human beings and other non-target organism. A new class of insecticides (diacetyl hydrazine) developed by Rohm and Hass is non-toxic.

The conventional antifouling agent used on boats is Tributyltin (TBT) compounds. Antifouling agents are used on boat hulls to reduce the build up marine organisms, such as algae, plants, diatoms etc). TBT compounds are persistent in the environment and result in bioaccumulation in various microorganism.

Rohm and Hass developed DCOI {4, 5 dichloro-2-n-octyl-4-iso thiazolin-3-one} as antifouling agent which is less persistent in marine environment as well as the product of metabolism are also non toxic.

**Metabolic reactions of DCOI**

5.6 ZERO WASTE TECHNOLOGY

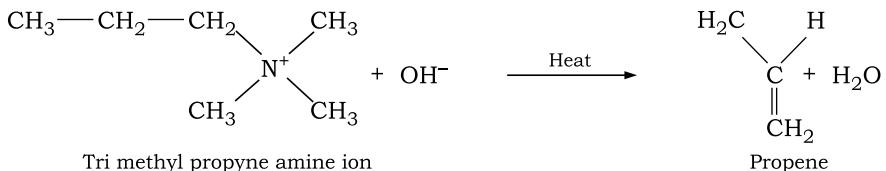
Zero waste technology is the essence of green chemistry. In this concept methodologies are devised for the synthesis in such a manner that there are no by products formed during a reaction, or if any waste by products are formed they can be used as raw materials or starting materials of other units. **Thus zero waste is the recycling of all materials back into the nature or the market place is a manner that protects human health and environment.**

This can be explained by the following examples.

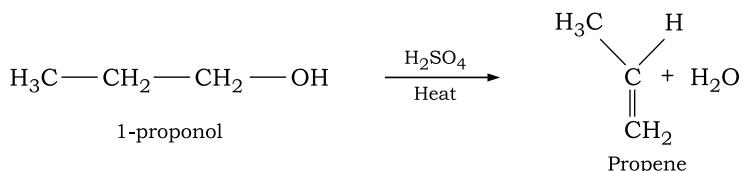
1. The glass milk bottle which is used for distributing milk to the consumers is made of silica. In the normal waste methods, the bottles can be disposed to a landfill by the municipality. But in the zero waste method, the bottle can be recycled, reduced to its constituent part and formed into a new milk bottle or any other glass product.
2. Carbon dioxide which is formed is a by product from ammonia manufacturing and natural gas units is used as a blowing agent for making extruded polystyrene foam sheet. Earlier chlorofluoro carbons and hydrofluor O carbons were used instead of liquid and supercritical carbon dioxide. When CFC's are released into the atmosphere, they rise through the troposphere into the stratosphere where they are decomposed by UV radiations. The photo chemical decomposition of CFC's results in the formation of atomic chlorine which results in the depletion of the ozone layers from the atmosphere which is responsible for causing skin cancer and cataract among many other diseases. The use of supercritical CO_2 as a blowing agent in making polystyrene foam sheet (green Synthesis) has the following advantages.
 - (i) From the ammonia manufacturing units, the by product formed i.e. CO_2 is removed hence it does not contribute to green house effect.
 - (ii) It replaces CFCs (which results in ozone depletion) thus reducing the adverse impact on the environment.
 - (iii) Apart from other advantages, CO_2 is economical, easy to handle, and neither forms smog or depletes the ozone layer.

EXERCISES

1. What is Green Technology?
 2. What are the basic principles of green Chemistry?
 3. Which principle of green chemistry refers to ‘Atom Economy’?
 4. Benzene is oxidized to maleic anhydride. Calculate the ‘Atom Economy’ for this reaction.
 5. It is said “Prevention is better than cure” Justify this statement in context to ‘Green Chemistry’.
 6. What are the various tools of Green Chemistry?
 7. Write Short notes on:
 - (a) Zero waste Technology.
 - (b) Green Reagents.
 - (c) Atom Economy.
 - (d) Green Starting Materials.
 8. Chemists sometimes refer to “by-products” rather than “waste”. List one advantage and one disadvantage of using this term.
 9. Consider the following two reactions:



Reaction 1



Reaction 2

Which of the two reactions have a better Atom Economy?

- 10.** What do you understand by the term ‘sustainability’?
 - 11.** Illustrate with examples ‘Green Reactions’.
 - 12.** How do the green starting materials help to improve the environmental conditions.
 - 13.** What is “Waste” product? How does the law of Conservation of Matter justify this word.
 - 14.** How is the new synthesis of Ibuprofen better than the conventional synthesis.
 - 15.** Why unnecessary deactivation in a reaction should be avoided?



UNIT 6

Eco-Friendly Polymers

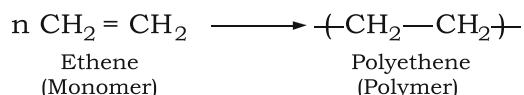
“Every great advance in science has issued from a new audacity of imagination.”
— John Dewey

Objectives

- Introduction
 - Classification of Polymers
 - Functionality
 - Polymer Synthesis
 - Chain Growth Polymerization and Step Growth Polymerization
 - Copolymerization
 - Environmental Degradation of Polymers
 - Environmental Degradable Polymers
 - Photodegradable Polymers
 - Hydrolysis and Hydro-Biodegradable Polymers
 - Biopolymers and Bioplastics
 - Thermal Degradation of Polymers through recycling
 - Number Average and Weight Average Molecular Weight of Polymers

6.1 INTRODUCTION

The word 'polymer' is derived from the classical Greek words *poly* meaning 'many' and *meres* meaning 'parts'. Simply stated, a polymer is a molecular compound with high molecular mass, ranging into thousands and millions of gram. It is composed of a large number of repeating units of identical structure called *monomers*. For example, polythene is a polymer formed by linking together of a large number of ethene molecules.



Certain polymers, such as proteins, cellulose, and silk are found in nature and hence are called **natural polymers**, whereas, a number of polymers are produced by synthetic routes and are called **synthetic polymers**. In some cases, naturally occurring polymers can also be prepared synthetically. For e.g. rubber, which is also known as polyisoprene.

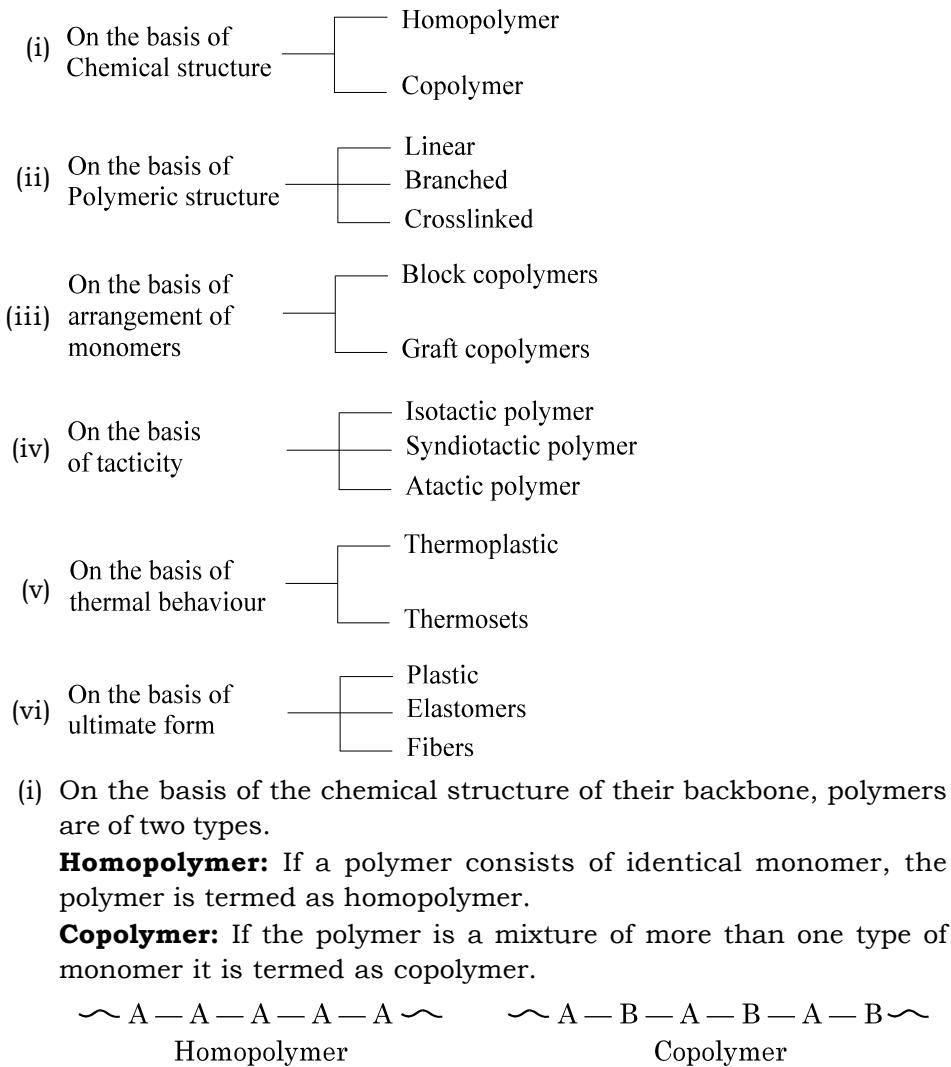
Both natural and synthetic polymers impinge on every aspect of our existence. The idea is often expressed that we live in "a plastic age". The range of polymeric materials is so wide that they have found applications in practically every branch of industry. About 80% of today's chemists, including biochemists, work with polymers.

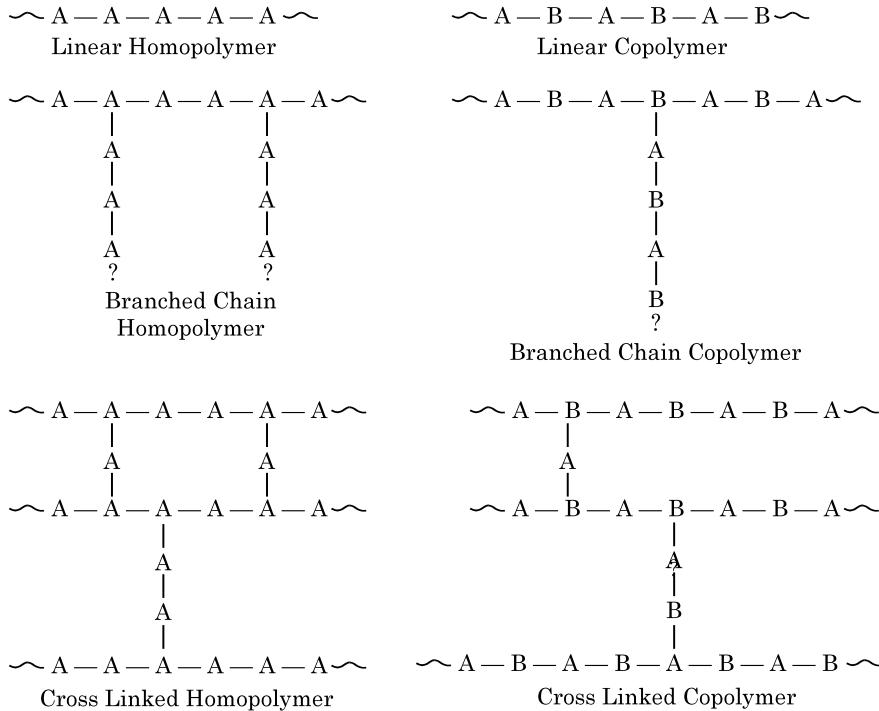
The number of repeating units in a chain formed in a polymer, is known as the "**degree of polymerization**". Polymers with high degree of polymerization are termed as "high polymers" and those with low degree of polymerization are called oligopolymers.

6.2 CLASSIFICATION OF POLYMERS

Synthetic polymers have been classified into various groups, in various manners.

6.2.1 Classification of Polymers



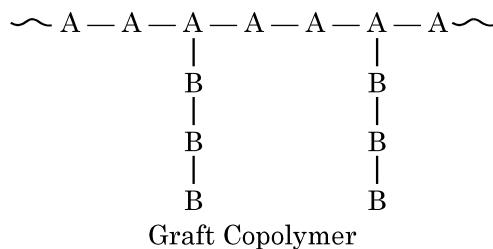


- (iii) Depending upon the arrangement of the monomers in the case of copolymers, the polymers are divided into block copolymers and graft copolymers.

Block Copolymers: Linear polymers in which the identical monomeric units occur in relatively long sequences are called block co-polymers.



Graft Copolymers: Graft copolymers are branched copolymers in which the backbone is formed from one type of monomer and branches are formed of the other, i.e. the monomer segments on the branches and backbone are not the same.

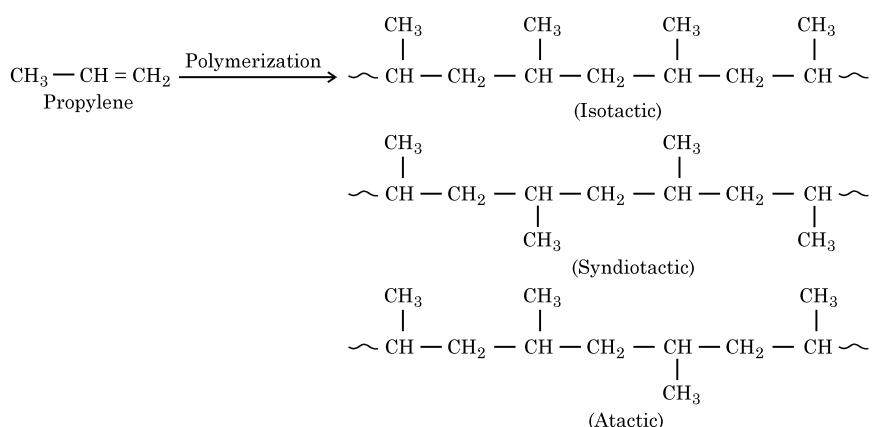


- (iv) Depending upon the orientation of monomer units in a polymer molecule: With respect to the main chain the polymers are classified as:

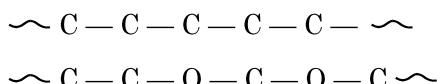
Isotactic polymer: If the side groups of the monomers lie on the same side of the chain, it is called an "isotactic" polymer.

Syndiotactic polymer: If the side groups are arranged in an alternate fashion, it is called syndiotactic polymer.

Atactic polymer: If the side groups are arranged in irregular fashion or randomly around the main chain, it is called atactic polymer.



- (v) If the main chain is composed of the atoms of the same species, the polymer is called homochain and if the main chain is made up of different atoms then they are called heterochain polymers.



- (vi) According to their behaviour on heating, the polymers are divided into two groups

Thermoplastics: Those polymers which soften on heating and become plastic so that they can be converted to any shape by moulding are known as thermoplastics.

Thermosets: Those polymers which change irreversibly into hard and rigid materials on heating and cannot be reshaped, once they are set are called thermosets. They form infusible and insoluble mass on heating.

- (vii) Depending on their ultimate form and use, a polymer can be classified as:

Plastics: All the synthetic polymers (other than elastomers) are usually referred to as plastics. The polymers which are shaped into hard and tough utility articles by the application of heat and pressure are called plastics. At some stage of manufacture, these are in plastic condition (Plasticity is the property by virtue of which a material undergoes permanent deformation under stress).

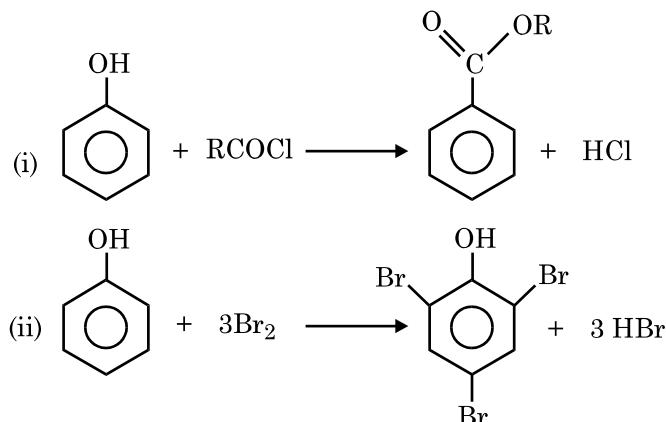
Elastomers: The polymers which are capable of being stretched rapidly at least 150 percent of their original length without breaking and return to their original shape on release of stress are known as elastomers. Synthetic rubbers constitute important examples of this group.

6.3 FUNCTIONALITY

The functionality of a molecule is the number of reactive sites it has. For a substance to act as a monomer, it must have two reactive sites. In other words, they should have a functionality of atleast two. A compound assumes functionality because of the presence of reactive functional groups like $-OH$, $-COOH$, $-NH_2$, $-SH$ etc. The number of functional group present in a compound defines its functionality. For example-

Compound	Chemical Formula	Functionality
Acetic Acid	$CH_3 COOH$	1
Malonic acid	$HOOC CH_2 COOH$	2
Ethyl alcohol	$C_2 H_5 OH$	1
Ethylene glycol	$HOCH_2 CH_2 OH$	2
Lactic acid	$CH_3 CH(OH) COOH$	2
Tartaric acid	$HOOC(CHOH)_2 COOH$	4

Some compounds, however, do not contain any reactive functional groups but the presence of double or triple bonds in the molecules makes them bifunctional or polyfunctional. Hence these act as monomers. For example, in olefins the double bond can be considered as a site for two free valencies. When a double bond is broken, two single bonds become available for combination Thus,



Acetylene, on the other hand, has a functionality of four.

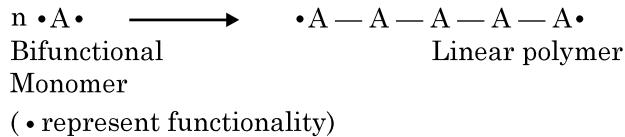


There are some other compounds in which the presence of easily replaceable hydrogen atoms impart functionality. For example, phenol. It has got $-OH$ groups as a functional group but can also undergo substitution reaction at three sites replacing its three hydrogen atoms. For example,

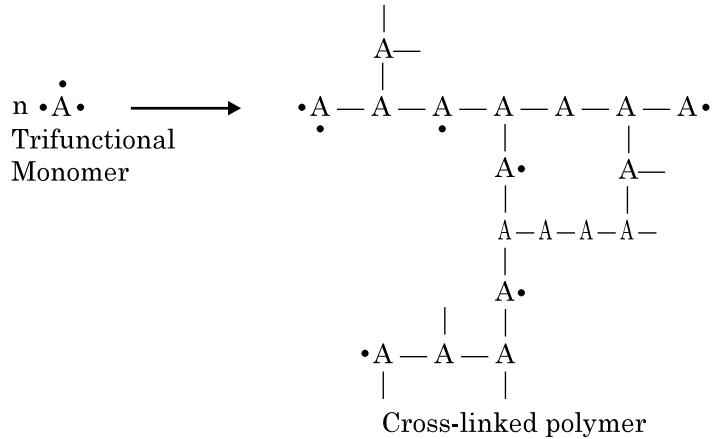
in reaction (i), phenol exhibits monofunctionality and in reaction (ii), it exhibits a functionality of three.

Depending on the functionality of the monomers used, we get linear, branched or three dimensional cross-linked polymers.

- (i) In case of bifunctional monomers, each molecule can add two more molecules and give a linear polymer as shown:



- (ii) In case of trifunctional monomers, we get a cross-linked polymer:



6.4 POLYMER SYNTHESIS

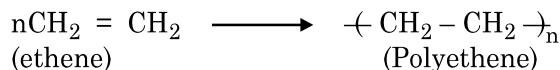
Polymers can be synthesized from monomers by two processes:

1. Addition Polymerization,
2. Condensation polymerization.

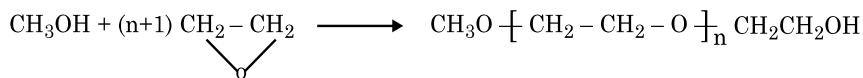
6.4.1 Addition Polymerization

Addition polymerization is characterized by self-addition of the monomer molecules to each other, without the loss of any material. The product is an exact multiple of the original monomeric molecule. Examples:

- (i) Addition by breaking up of multiple bonds:



- (ii) Addition by opening up of ring structures:



Vinyl compound ($\text{CH}_2 = \text{CHX}$), allyl compounds ($\text{CH}_2 = \text{CH}.\text{CH}_2\text{X}$), olefins ($\text{CH}_2 = \text{CHR}$) and dienes ($\text{CH}_2 = \text{CR}-\text{CH} = \text{CH}_2$) typically undergo addition

polymerization. Since a majority of these fall under the 'vinyl' category, addition polymerization is also customarily termed as vinyl polymerization.

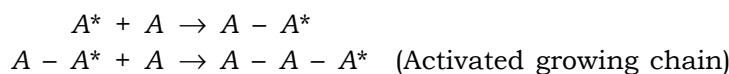
Mechanism of Addition Polymerization

Addition polymerization is a typical chain reaction and consists of three important steps:

- (i) Addition by breaking up of multiple bonds:



- (ii) Chain propagation



- (iii) Chain termination or removal of active centre.



The process of addition polymerization can be brought about by three methods:

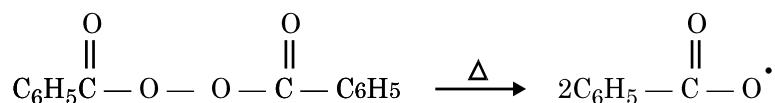
1. Free radical mechanism
2. Ionic mechanism (Anionic and Cationic)
3. Coordination mechanism

The three types of mechanisms for addition polymerization, depending upon the active centres formed, are discussed below.

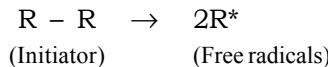
1. **Free Radical Addition Polymerization:** The free radical addition polymerization involves the formation of free radicals in the initiation step, which can be produced by decomposition of compounds called initiators. The free radical polymerization has three principal steps:

- (i) **Initiation:** Initiation in a free radical polymerization consists of two steps. The first is the generation of the free radical species, followed by the second step which involves the addition of a single monomer molecule to the free radical.

The generation of free radical takes place as a result of homolytic dissociation of an initiator, which may take place in the presence of heat energy, light energy or catalysts. A number of low molecular weight compounds, comprising mainly of azo compounds, peroxides, hydroperoxides, peracids and peresters are useful as initiators. An important example of a free radical initiator is benzoyl peroxide which dissociates as:



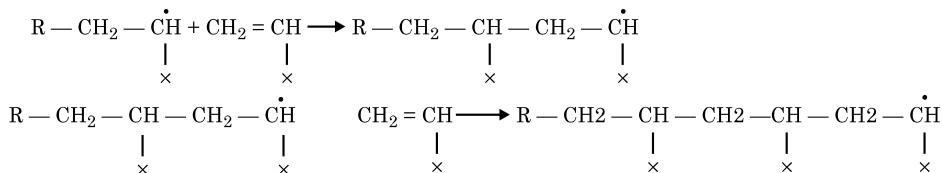
In general, the dissociation of the initiator ($\text{R}-\text{R}$) to form free radical species can be represented as



In the second step of initiation, the free radical so formed gets attached to the monomer molecule (M) to form the chain initiating species



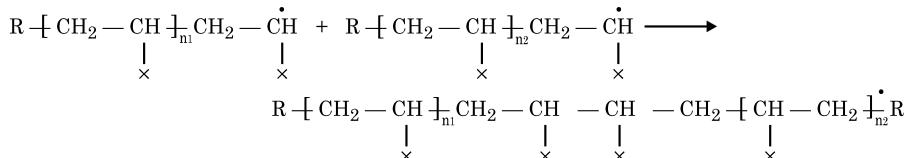
- (ii) **Propagation:** In the next step, additional monomer units are added to the initiated monomer species, as.



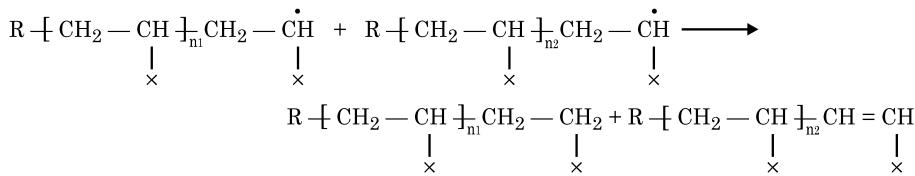
The propagation step involves a continuing attack on fresh monomer molecules which, in turn, keep successively adding to the growing chain one after another.

- (iii) **Termination:** Propagation will continue until some termination process takes place. The propagating polymer chain is terminated by any of the following reactions.

(a) *By combination:* Since the decomposition of the initiator produces many free radicals at the same time, each one of them can initiate and propagate the growth of a number of chains simultaneously. The two growing chains may come close and collide with each other and get deactivated.

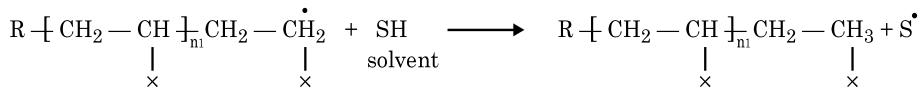


(b) *By disproportionation:* In some cases, one hydrogen atom from one growing chain is abstracted by the other growing chain and results in the formation of two polymer molecules, one saturated and other unsaturated. In this case the termination process results in the formation of two polymer molecules of shorter chain length as against a single molecule of a longer chain length obtained by first method.



Thus the products so formed do not contain any reactive sites and may be termed as dead polymers as these cannot grow further.

- (c) In addition to the above two methods of chain termination, chain transfer by hydrogen abstraction from solvent molecule, may also terminate the growing chain.



In this reaction the original growing chain is terminated whereas the new chain gets initiated by the solvent free radical, hence this is called termination by chain transfer. Certain chemical compounds which are capable of inhibiting or completely stopping the chain growth process are called radical inhibitors. Phenolic compounds are widely used as inhibitors, because phenolic hydrogen can be easily abstracted by the polymer chain. The phenolic free radical so formed is highly stabilized and no further reaction is possible. Hydroquinone is often added as inhibitor.

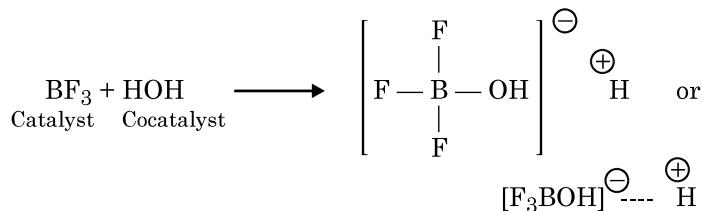
Polythene, polypropylene, styrene etc are some of the polymers that can prepared by free radical polymerization. Branching and crosslinking during the free-radical addition polymerization:

2. **Ionic Addition Polymerization:** Ionic polymerization follow the same basic steps as free-radical addition polymerization i.e initiation, propagation and termination. In this process, the initiation step involves the formation of carbonium ion or the carbanion as the active site and hence the polymerization can be termed as cationic or anionic polymerization respectively.

(i) **Cationic Polymerization**

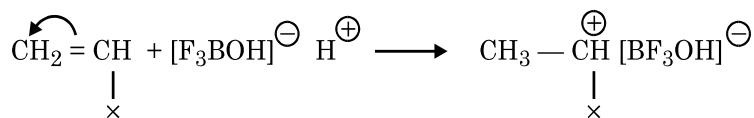
Cationic polymerization takes place in the presence of catalyst that is regenerated at the end of polymerization (in contrast to free radical and anionic polymerization where the catalyst added become incorporated into the terminated polymer chain). Polymerization of vinyl monomers with an electron-donating group (such as $-OC_2H_5$, $-OCH_3$, $-C_6H_5$ etc.) may take place by a cationic mechanism which involves the following steps.

Initiation: This step involves the formation of a carbonium ion by the attack of a proton on the monomer. Any strong Lewis acid like BF_3 , $AlCl_3$ etc can be used as a catalyst. In this case a cocatalyst like water is required to provide the proton source.

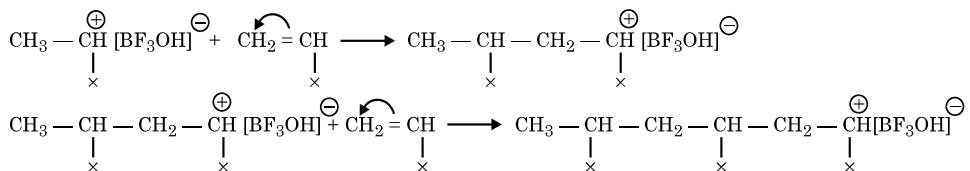


H^+ is the initiator and $[\text{F}_3\text{BOH}]^\ominus$ is the counter ion.

The H^+ now attacks the π electron of the monomer and forms the carbonium ion. The counter ion $[\text{F}_3\text{BOH}]^\ominus$ anion faces the growing chain end.



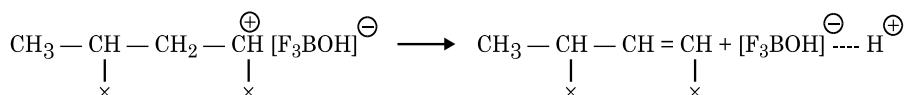
Propagation: The propagation reaction involves the addition of monomer units and simultaneous transfer of the charge to the newly added monomer unit.



More and more units are added up and the chain keeps on growing. The electron pair of the adding monomer units are pulled in a direction opposite to the growth of the chain and the positive charge keeps on moving in the direction of the chain growth. The counter ion $[\text{BF}_3\text{OH}]^\ominus$, moves along the positive charge all the time.

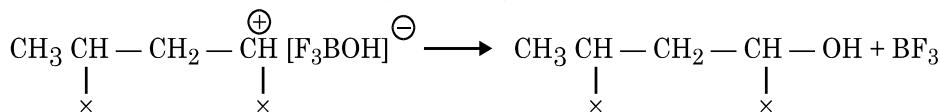
Termination: Termination takes place when the growing polymer chain having C^+ collides with an anion, which may be added deliberately or with the counter ion. The possible reactions may be:

- (a) Donation of a proton to the counter ion by the growing polymer chain: This results in the formation of a double bond at the end of growing polymer molecule.



Thus the initiator or catalyst is regenerated.

- (b) Formation of covalent bond between the carbonium ion and the counterion (coupling):



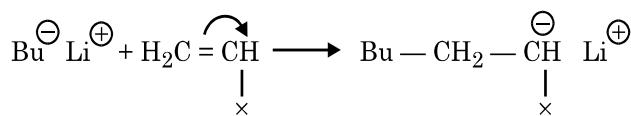
In this case also the regeneration of the initiator takes place.

Examples of the monomers that can undergo cationic polymerization are isobutylene, styrene, methyl styrene and many vinyl ethers. Cationic polymerization proceeds at a very fast rate even at low temperatures. For example, polymerization of isobutylene is completed within a few seconds at -100°C .

(ii) Anionic Polymerization

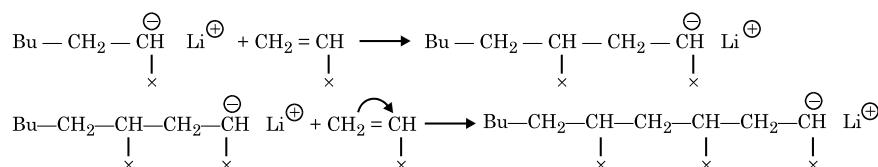
Anionic polymerization involves the formation of the carbanion in the initiation step. Polymerization of vinyl monomers with an electron withdrawing group can proceed by an anionic mechanism, involving the following steps:

Initiation: The initiators or the catalysts used in anionic addition polymerization are strong bases such as organo alkali compounds (alkyl or aryl derivatives of alkali metals) like n-butyl lithium, ethyl sodium etc. Alkali metal amides, hydroxides etc can also be used.



The electron pair in this case is pushed to the end of the molecule forming the carbanion. Li^+ is the counter ion.

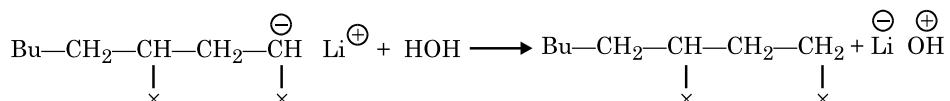
Propagation: The carbanion formed, propagates the chain growth by attacking the second monomer unit, pushing its π electron pair further away to the end and forming a sigma bond with the new monomer unit.



In the case of anionic polymerization the movement of the π electrons is towards the direction of the chain growth (in cationic polymerization, the movement of the π electrons is opposite to the chain growth).

Termination: The termination in anionic polymerization is not a spontaneous process. If the starting reagents are pure and no impurities are present, propagation can proceed indefinitely or until all the monomer is consumed. Thus, anionic polymerization is also referred to as "living polymerization", because the carbanions at the chain ends remain potentially active. If a fresh quantity of monomer is added, polymerization again goes on until the added monomer is consumed.

Termination is generally accomplished by the transfer of negative charge to a species which is not directly involved in the reaction. For example CO_2 , methanol, water etc.



It may be noted that like free radical polymerization, the initiating specie (Bu) has been incorporated as the end group of the terminated polymer. Thus Butyl-lithium is an initiator rather than a catalyst.

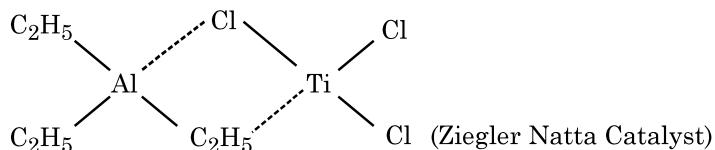
Monomers capable of undergoing anionic polymerization include butadiene, isoprene, styrene, acrylonitrile.

The strong electron withdrawing groups have stabilizing effect on the carbanion so formed and hence anionic polymerization takes place with the monomers having – CN, – COOR, and – CH = CH_2 groups.

Moreover, the reactivity of carbanions with oxygen, carbon dioxide is very high, hence the system should be free of these impurities.

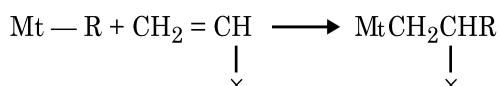
3. Coordination Polymerization: Polymerization reactions, taking place in the presence of organo metallic compounds as catalysts, are termed as coordination polymerizations.

Ziegler (1953) and Natta (1955) discovered that in the presence of a catalyst which is a combination of a transition metal halide (like TiCl_4 or TiCl_3) with an organo-metallic compounds (like triethyl aluminium), stereoregular polymers can be prepared. The combination is often referred to as, ZieglerNatta catalyst. The commonly used Ziegler-Natta catalyst is triethylaluminium in combination with titanium trichloride.

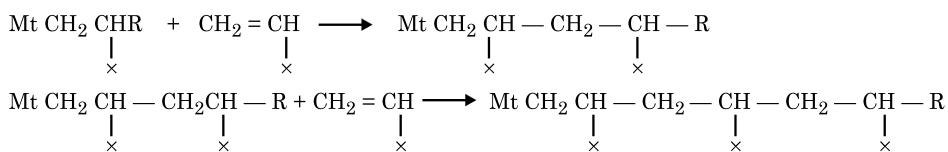
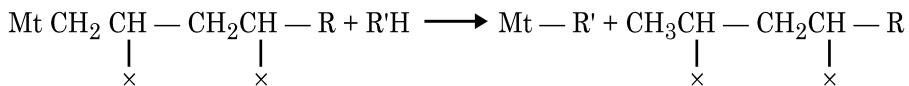


In the formation of the monomer catalyst complex, a co-ordinate bond is involved between a carbon atom of a monomer and metal atom of the catalyst, that is why, this type of polymerization is known as coordination polymerization. The co-ordinated metal-carbon bond formed in the monomer-catalyst complex acts as an active center from where propagation starts.

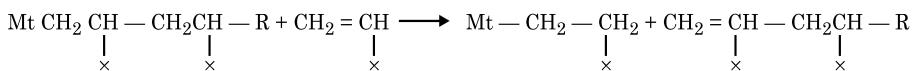
Mechanism of coordination polymerisation can be illustrated as follows:
Initiation:



The alkene is inserted in between the metal - carbon bond of the catalyst

Propagation:**Termination:** (a) By active hydrogen compound

(b) By transfer with monomer



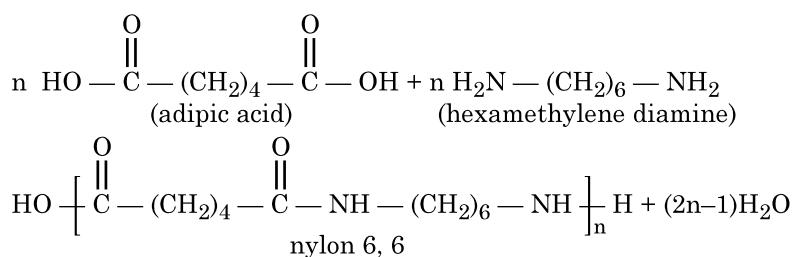
Coordination polymerization is used to prepare stereospecific polypropylene, polydiene etc. Polypropylene of nearly 90% isotacticity can be prepared. The exact mechanism of coordination polymerization is still unclear.

Advantages of Coordination Polymerization

1. Coordination polymerization provides a method to produce stereoregular polymers. The stereoregularity is important in determining the properties of the polymer. For example, the stereoregular isotactic polypropylene exhibit better mechanical properties over a wide range of temperatures.
2. The stereoregular control of the coordination polymerization process produce the polymers, which have fewer branches and therefore could be obtained in a higher degree of crystallinity. For example high density polyethylene produced by coordination polymer has higher degree of crystallinity as compared to the one produced by other methods. This is because the polyethylene having less branching pack more efficiently resulting in high degree of crystallinity.

6.4.2 Condensation Polymerization

Condensation polymerization is brought about by monomers containing two or more reactive functional groups with the elimination of small molecules like H_2O , HCl etc. For example,



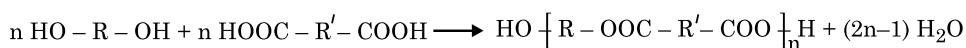
It is seen from the above reaction that the polymer formed still contains both the reactive functional groups at its chain ends and hence, is 'active' and not 'dead'.

In the above example, the different type of reactive functional groups, viz., $-\text{NH}_2$ and $-\text{COOH}$ are present on two different monomers. In some cases, both the reactive groups may be present on the same monomer and hence lead to self condensation reaction. For example, polycondensation of amino acids.



Some polycondensation reactions leading to different types of polymers are:

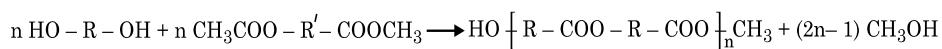
- (i) Polycondensation of dihydric alcohols and dicarboxylic acids leads to the formation of **polyesters**.



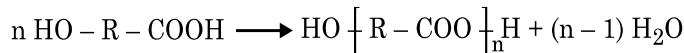
- (ii) Polycondensation of dicarboxylic acids and diamines to give **polyamides**.



- (iii) Polycondensation of dihydric alcohols and methyl esters of dicarboxylic acids to give **polyesters**.



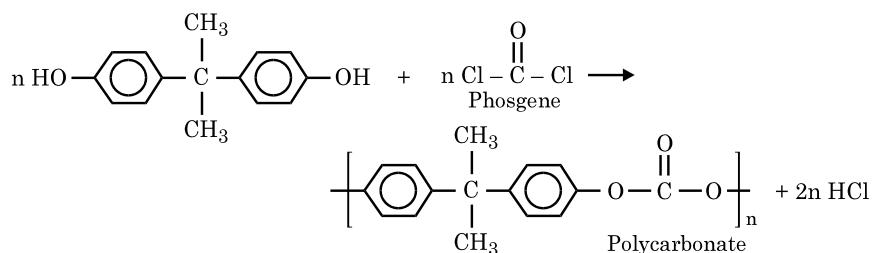
- (iv) Self condensation of α -hydrogen acids yields **polyesters**.



- (v) Self condensation of amides to form **polyamides**.



- (vi) Polycondensation of bisphenol A and phosgene to form **polycarbonate**.



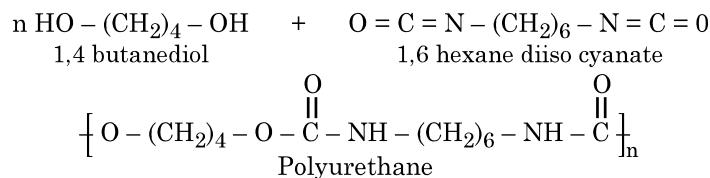
6.5 CHAIN GROWTH POLYMERIZATION AND STEP GROWTH POLYMERIZATION

Recently, another classification scheme based on polymerization kinetics has been adopted over the traditional addition and condensation categories. According to new scheme, all polymerization mechanisms are classified as either chain growth or step growth polymerizations.

Chain Growth Polymerization: During chain growth polymerization, high molecular weight polymer is formed early during polymerization and polymer yield gradually increases with time. Chain growth polymerizations require the presence of an initiating molecule that is used to activate the monomer molecule at the start of the polymerization. Most of the addition polymers are chain growth polymers and hence in most of the books the term chain growth and addition polymerization are used interchangeably.

Step Growth Polymerization: In step growth polymerization, high molecular weight polymer is formed only near the end of the polymerization. Most of the condensation polymers are step growth polymerization, but a number of important exceptions exist. In step growth polymerization, the reaction takes place in stepwise manner and polymer build-up is slow (unlike chain growth, where the polymer build-up is very rapid).

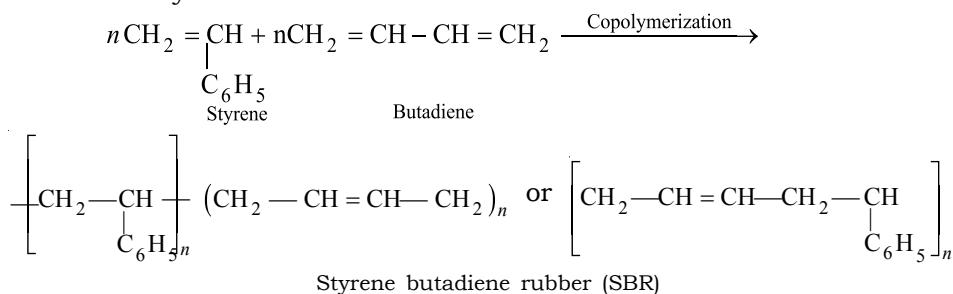
Apart from condensation reactions discussed earlier, step growth polymerization include some addition reactions also. Example, the non-condensation step growth polymerization of a polyurethane prepared by ionic addition of a diol (1, 4 butanediol) to a diisocyanate (1, 6-hexane diisocyanate.)



6.6 COPOLYMERIZATION

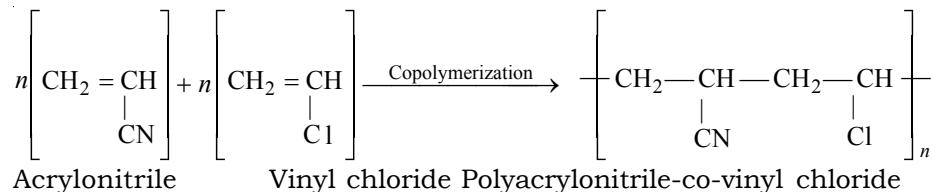
Commonly available natural and synthetic polymers suffer from many disadvantages and therefore cannot be used for special purposes. However, it is possible to modify a number of natural and commercially available synthetic polymers to give products which can be utilized for performing desired functions.

Copolymerization is the most general and powerful method of affecting modification in polymers and is widely used in the production of commercial polymers. It provides a technique to combine the properties of two or more different polymers into a single polymer. *Copolymerization can be defined as any process whereby two or more monomers are copolymerized to form a single polymer.* The resulting high molecular weight compound is known as copolymer. For example, butadiene and styrene, copolymerize to form butadiene-styrene rubber.

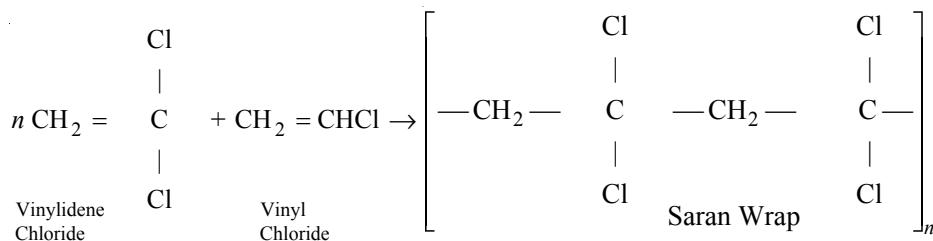


The styrene butadiene rubber so formed has better overall properties than polystyrene or polybutadiene alone.

Similarly, acrylonitrile and vinylchloride are copolymerized to form a copolymer. The copolymer so formed is readily soluble in acetone, whereas polyacrylonitrile and polyvinyl chloride are soluble only in high boiling solvents



A polymer of vinylidene chloride and vinyl chloride is known as saran wrap.



Saran wrap has a high tensile strength and excellent sealing properties as compared to the individual polymers involved in its preparation.

It should be clearly understood that copolymer is not a mixture of two or more separate polymers but it consists of the chains which contain both the units.

6.7 ENVIRONMENTAL DEGRADATION OF POLYMERS

Since the development of (plastics) polymers, these have become a popular material which has almost replaced materials such as metal, glass, wood, paper, fiber etc. Today plastics are used in packaging, automobile, building construction, biomedical fields, electronics industry to name a few. In nutshell, the use of plastic has become an integral part of our modern day living. **However, the same properties that made the synthetic polymers to be so useful have contributed to a huge environmental pollution problem.**

Most of today's plastics and synthetic polymers are produced from petrochemicals. These polymers persist in the environment and do not degrade or decompose easily. Therefore, the disposal of these products poses a serious environmental problem and their unhygienic recycling also causes great concern and pose a serious health and environmental menace.

Considering, the above it becomes essential to produce eco-friendly polymers so that their by-products or wastes can be easily degraded.

Bio-based or biopolymers represent an attractive alternative to conventional plastics because these are biodegradable. Before, discussing the biodegradable polymers, it is worthwhile to understand the term **'degradation of polymers'** and types of degradation in brief.

6.7.1 Degradation of Polymers

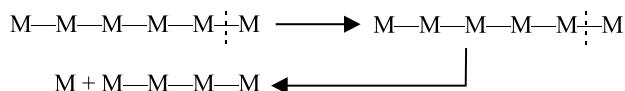
Any change in a polymer during its service, whether good or bad, can be technically termed as degradation. For example, if a plastic bucket is left for long in the sun and rain, it loses its lustre and strength. In other words it has undergone degradation. In the process of degradation, the molecular weight of the polymer is reduced.

A polymer can suffer degradation at two stages -

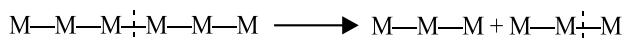
- (i) During the fabrication process which involve heating, which a polymer may not withstand and degrades.
 - (ii) During its usage where the polymer is subjected to mechanical stresses, radiation, atmospheric oxygen, moisture etc.

Types of polymer degradation: Polymer degradation can be of two types:

- (i) *Chain end degradation:* In chain end degradation, the degradation starts from the chain ends resulting in the release of monomer units.



- (ii) *Random degradation:* It takes place at any random point along the polymer chain



In this type of degradation, the polymer undergoes degradation into low molecular weight fragments but unlike first case, no monomer units are released.

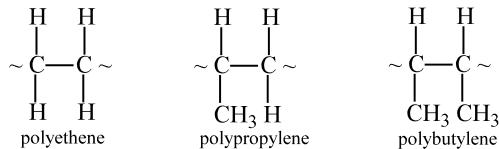
Factors responsible for degradation: Degradation of polymers can be brought up by -

- physical factors such as heat, light etc.
 - chemical agents such as oxygen, ozone, acid or alkalies.

We will be discussing these under the following heads.

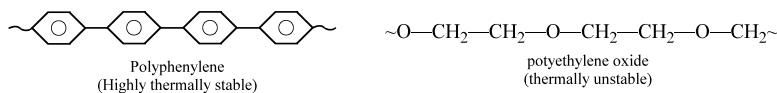
- #### (i) Thermal Degradation:

Degradation under the influence of heat is known as thermal degradation. The thermal stability of the polymer is dependent upon the stability of C—C bond of the backbone. Generally, bulkier substituents decrease the stability of C—C bond. For example,

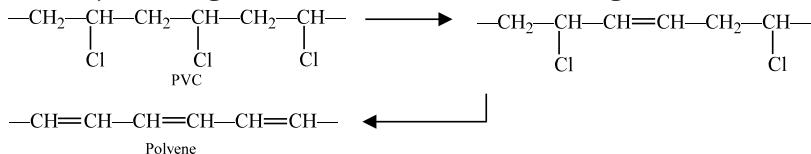


in the above polymers, as one moves from polyethene to polybutylene, bulkier substituent ($-\text{CH}_3$) replaces H and hence the stability of C—C bond also decreases. Thus polyisobutylene is least stable whereas polyethene is most stable.

- Also, aromatic groups in polymer backbone increase the thermal stability whereas presence of oxygen atom in the polymer chain decreases the thermal stability.



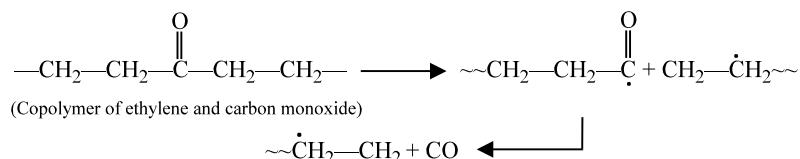
- Polymer degradation is also possible because of the breaking of the substituent groups, but not the main chain. Example poly(vinyl chloride) PVC degrades at about 200°C releasing HCl.



As a result of degradation PVC changes colour from white to black (white to → pale yellow → orange → brown → black) depending upon the number of concentration of conjugated double bonds.

(ii) Photodegradation:

Photodegradation is brought about by the ultra-violet (UV) light. Some of the transparent plastics become yellowish and brittle on storage. This is due to photodegradation. The UV light has wavelength less than 400 nm corresponding to energy of 390 kJ/mole. The energy required to break a C—H, C—C and C=C bonds is 99, 83 and 145 kcal/mole respectively. Thus it is evident that homolytic bond fission will occur readily to give free-radicals. These free radicals can then react with any oxygen present, leading to the oxidation of polymer chain. This is the phenomenon of “ageing or weathering” which is seen quite often.



In order to protect the polymers from photodegradation some photo stabilizers are added to the polymer. Photodegradation is discussed in detail in the next section.

(iii) **Oxidative degradation:**

Oxidative degradation of a polymer results in hardening, discolouration and surface changes of the polymer. Oxidative degradation of a polymer is dependent upon the structure of the polymer. The double bonds in polymers such as polyisoprene or polybutadiene are easily attacked by oxygen.

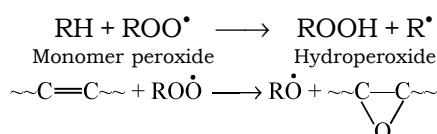
In the first stage of oxidative degradation free radicals are formed on the chain backbone of polymer by the attack of molecular oxygen or ozone. Sometimes free radicals are also formed by thermal decomposition of initiator molecule which may be present as impurity.



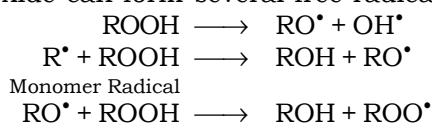
Oxygen adds on the radical site forming peroxide radical



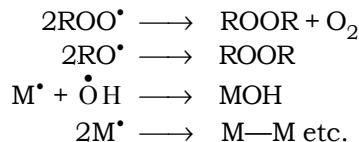
Peroxide radical attacks the polymer chain and generates a new radical site



The hydroperoxide can form several free radical sites



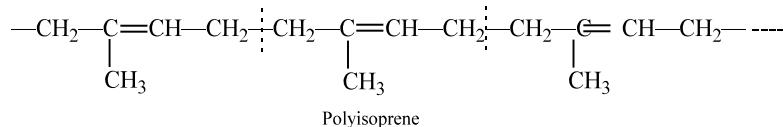
Recombination reactions of free radicals result in termination of the chain reactions



The polymers are protected against oxidative degradation by incorporating chemical compound called antioxidants.

(iv) **Mechanical degradation:**

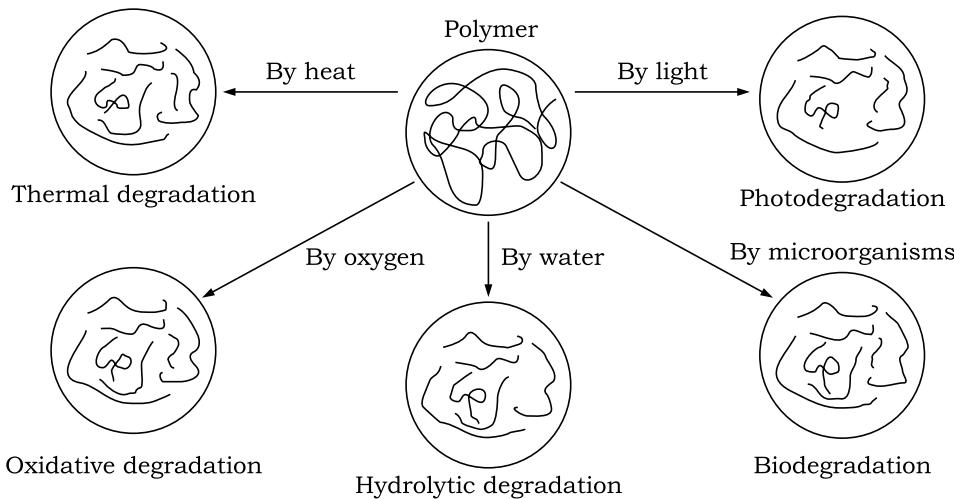
When a polymer material is subjected to a mechanical stress, the most vulnerable part of the structure gets ruptured, thus bringing about degradation in the polymer. This type of degradation is called mechanical degradation. For example when polystyrene dissolved in a suitable solvent is subjected to vigorous stirring, it undergoes considerable molecular degradation or fragmentation. In rubber industry rubber is converted into soft, supple mass from hard and tough material through mechanical degradation. The process is called mastication in which the rubber is passed through rotating rollers to decrease its molecular weight. The rubber so obtained is more processable.



The CH_2-CH_2 links undergo fission during mastication because they are the weakest links.

(v) **Biodegradation:**

Biodegradation is the breakdown of polymer by microbial organisms (such as bacteria, fungi etc.) into smaller compounds. The microbial organisms degrade the polymer through metabolic or enzymatic processes. The biodegradability of a given polymeric material is defined by the chemical structure of the polymer. Photodegradation is often subsequently followed by microbial or biodegradation. Natural products which are susceptible to biological attack are: starch, cellulose etc. Biodegradation of any organic material under controlled aerobic and anaerobic conditions produce **compost**. The process is termed as **composting**. Hence, a plastic that undergoes degradation by microbial action during composting to yield CO_2 , H_2O and inorganic compounds, leaving no toxic residue is termed as **compostable plastic**. Ideal conditions for micro organism growth are obtained during the composting process.



6.8 ENVIRONMENTALLY DEGRADABLE POLYMERS

A variety of natural, synthetic, and biosynthetic polymers are bio- and environmentally degradable. A **polymer based on the C-C backbone tends to be nonbiodegradable, whereas heteroatom-containing polymer backbones confer biodegradability**. Biodegradability can therefore be engineered into polymer by the judicious addition of chemical linkages such as anhydride, ester, or amide bonds, among others.

Many polymers that are claimed to be 'biodegradable' are in fact 'bioerodable', 'hydrobiodegradable' or 'photo-biodegradable'. These different polymer classes all come under the broader category of '*environmentally degradable polymers*'.

Thus the classes of biodegradable plastics considered, in terms of the degradation mechanism, are:

1. Biodegradable
2. Compostable
3. Hydro-biodegradable
4. Photo-biodegradable
5. Bioerodable

Biodegradable: American society of Testing and Materials (ASTM) defines 'biodegradable' as: "*capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be measured by standardized tests, in a specified period of time, reflecting available disposal condition.*"

In simple words, biodegradation is the degradation caused by biological activity, particularly by enzyme action leading to significant changes in the material's chemical structure. In essence, biodegradable plastics should break down cleanly, in a defined time period, to simple molecules found in the environment such as carbon dioxide and water.

Compostable: Compostable plastics are a subset of biodegradable plastics. Compostable biodegradable plastics must biodegrade and disintegrate in a compost system during the composting process (typically around 12 weeks at temperatures over 50°C). The compost must meet quality criteria such as heavy metal content, ecotoxicity, and no obvious distinguishable residues caused by the breakdown of the polymers.

Hydro-biodegradable and Photo-biodegradable: Two closely linked mechanisms of degradation that are frequently confused with biodegradation are Hydro-degradation (degradation via hydrolysis) and Photo-degradation (degradation via photolysis). Since both mechanisms are often subsequently followed by microbial degradation, confusion of definition frequently occurs. Hydro-biodegradable and photo-biodegradable polymers are broken down in a **two-step** process - an initial hydrolysis or photo-degradation stage, followed by further biodegradation. Single degradation phase 'water-soluble' and 'photodegradable' polymer also exist. These two types are discussed in detail in the next sections.

Bio-erodable: Many polymers that claimed to be 'biodegradable' are in fact 'bioerodable' and degrade without the action of micro-organisms - at least initially in the first step. This is also known as abiotic disintegration, and may include process such as dissolution in water, 'oxidative embrittlement' (heat ageing) or 'photolytic embrittlement' (UV ageing).

Some Biodegradable Polymers:

- Starch based products including thermoplastic starch.

- Polyester blends and Polyvinyl alcohol (PVOH) blends.
- Naturally produced polyesters including polyhydroxybutyrate (PHB).
- Renewable resource polyesters such as polylactic acid (PLA).
- Synthetic aliphatic polyesters including polycaprolactone (PCL) and polybutylene succinate (PBS).
- Aliphatic-aromatic (AAC) copolyesters.
- Hydro-biodegradable polyester such as modified PET.
- Water soluble polymer such as polyvinyl alcohol and ethylene vinyl alcohol.
- Photo-biodegradable plastics.
- Controlled degradation additive masterbatches.

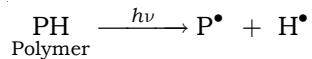
6.9 PHOTODEGRADABLE POLYMERS

A photodegradable polymer is the degradable polymer in which the degradation results from the action of natural sunlight or UV rays.

However, it must be remembered that in most cases, photo-biodegradable polymers are broken down in two stages – initial photodegradation stage followed by biodegradation.

For photodegradation to take place, the polymer must absorb the photons when exposed to UV region or sunlight. It must be emphasized that the photodegradable polymers need to contain light absorbing groups (chromophores). It is therefore, evident that if functional groups such as carbonyl groups, peroxides or hydroperoxides are present in the polymer, it can undergo photodegradation. These groups are commonly formed during oxidation of polyolefins and are introduced in trace amounts **during processing** of the polyolefins and make these photodegradable. The mechanism can be illustrated as follows:

Photodegradation begins with the production of macro radical (P^\bullet) in the amorphous regions of polymer substrate.



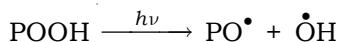
This radical rapidly reacts with oxygen to give a macroperoxy radical



The macroperoxy radical abstracts a hydrogen atom from polymer backbone to produce a hydroperoxide group



The hydroperoxide group is photolytically cleaved to produce the highly reactive radicals which continue the cycle of chain degradation in the polymer.



In most photobiodegradable polymers the final degradation step requires the material to be consumed by micro organisms (biodegradation)

Photodegradable polymers have attracted the industrial interest as a result of extensive discussions looking for waste management strategies of polymers. We know, all polymers represent potential waste management problems in the environment. Photodegradable polymers are thus produced intentionally by adding certain chemicals or photosensitive substances, called **promoters** to the otherwise non-photodegradable polymers. Promoters aid in absorption of UV rays by the polymers. Two common promoters are:

- (i) **Carbonyl Group:** (Ketone Carbonyl Copolymers) or carbon monoxide copolymers): The photodegradable polymer is produced by adding a carbonyl group, vinyl ketone comonomer or carbon monoxide to the polymer such as polyethylene and polystyrene. The resulting copolymer degrades when the carbonyl group absorbs sunlight.
- (ii) **Metal complexes:** The metal salts can be added to the polymer to initiate breakdown process. The metal complexes initiate peroxide formation from molecular oxygen. However, the main concern with these materials is the heavy toxic metal residues remaining after degradation takes place.

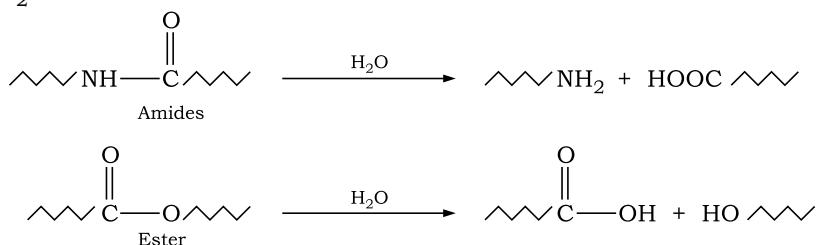
In contrast to photosensitizers, sometimes photostabilizers are added to **protect** polymer from photodegradation. 2, 4 dihydroxy benzo-phenone, 2 hydroxy, 4 methoxy benzophenone are used as photostabilizers in plastic industry.

6.10 HYDROLYSIS AND HYDRO-BIODEGRADABLE POLYMERS

Hydro-biodegradable polymers are broken down in a two-step process – an initial hydrolysis stage, followed by further biodegradation.

Polymer chains containing ester functional group in their backbone undergo degradation by hydrolysis. Though, polymers containing amides, alcohol, acetal groups, polyurethanes, etc. can also undergo hydro-biodegradation.

Polymer hydrolysis involves the susceptible molecular groups by reaction with H_2O



The amine or alcohol group formed during hydrolysis serve as auto catalyst to further cleave the amide or ester linkages.

The majority of degradable polymer types belong to the polyester family (e.g. polylactic acid (PLA); polycaprolactone (PCL); polybutylene succinate (PBS); poly(butylene succinate-co-adipate) (PBSA) copolymers; polybutyrate

adipate terephthalate (PBAT); aliphatic copolymers. Polyhydroxybutyrate (PHB) and its copolymers with polyhydroxyvalerate (PHV) are melt-processable semi-crystalline thermoplastics made by biological fermentation of renewable carbohydrate feedstocks. They represent the first example of a true biodegradable thermoplastic produced via a biotechnology process. No toxic by-products are known to result from PHB or PHV. In fact, the hydroxybutyrate monomer is normal constituent of human blood.

Hydrobiodegradable polymers are used for biomaterial applications in medicine.

The hydrolytic reactions are influenced by the properties of the polymer:

- (i) Crystalline polymers are less susceptible to hydrolysis whereas amorphous polymers are highly susceptible to hydrolysis.
- (ii) The hydrophilicity of the polymer also increases the hydrolysis.

6.11 BIOPOLYMERS AND BIOPLASTICS

Biopolymers are polymers which are present in, or created by, living organisms. These include polymers from renewable resources that can be polymerized to create bioplastics. Carbohydrates and proteins, for example, are biopolymers. Many biopolymers are already being produced commercially on large scales, although they usually are not used for the production of plastics.

Bioplastics are plastics manufactured using biopolymers, and are biodegradable. These are also called green plastics. Green plastics are the focus of an emerging industry focused on making convenient living consistent with environmental stability.

Biopolymers and bioplastics are the main components in creating a sustainable plastics industry. These products reduce the dependence on non-renewable fossil fuels, and are easily biodegradable. Also, being biodegradable make bioplastics more acceptable for long term use by society.

6.11.1 Biopolymers

Types of Biopolymers: There are two main types of biopolymers:

- (i) those that come from living organisms; and
- (ii) those which need to be polymerized but come from renewable resources.

Both types are used in the production of bioplastics.

(i) Biopolymers From Living Organisms

These biopolymers are present in, or created by, living organisms. These include carbohydrates, and proteins. These can be used in the production of plastic for commercial purposes. Examples are listed in the table below.

Biopolymer	Source	Remarks
Cellulose	In plants cellulose is synthesized from glucose. It is the main component of plant cell walls Examples include wood, cotton, corn, wheat, and others	<ul style="list-style-type: none"> Cellulose is the most plentiful carbohydrate in the world; 40 percent of all organic matter is cellulose It has β glucose as the repeat unit. Cellulose is insoluble in most of the solvents and hence it is converted to its derivatives to make it processable.
Soy protein	Soy protein and zein (from corn) are abundant plant proteins.	<ul style="list-style-type: none"> They are used for making adhesives and coatings for paper and cardboard.
Starch	Starch is found in corn (maize), potatoes, wheat, tapioca (cassava), and some other plants.	<ul style="list-style-type: none"> Starch is also made up of glucose units and is stored in plant tissues. It is not found in animal tissues. It has β glucose as the repeat unit Annual world production of starch is well over 70 billion pounds, with much of it being used for non-food purposes, like making paper, cardboard, textile sizing, and adhesives.
Polyesters	Polyesters are produced by bacteria, and can be made commercially on large scales through fermentation processes.	<ul style="list-style-type: none"> These polyesters are created through naturally occurring chemical reactions that are carried out by certain types of bacteria. They are now being used in biomedical applications
Casein	Commercially produced mainly from cow's skimmed milk	<ul style="list-style-type: none"> Casein is used in adhesives, binders, protective coatings, and other products

(ii) Polymerizable Molecules

These molecules come from renewable natural resources, and can be polymerized to be used in the manufacture of biodegradable plastics. Some of these are listed in the table below:

Biopolymer	Natural Source	Remarks
Lactic Acid	Beets, corn, potatoes, and others	<ul style="list-style-type: none"> Produced through fermentation of sugar feedstocks, such as beets, and by converting starch in corn, potatoes, or other starch sources. It is polymerized to produce polylactic acid — a polymer that is used to produce plastic.
Triglycerides	Vegetable oils mainly from soybean, flax, and rapeseed.	<ul style="list-style-type: none"> Triglycerides are another promising raw material for producing plastics.

6.11.2 Bioplastics

For bioplastics to become practical, they must have properties that allow them to compete with the current plastics on the market: Bioplastics must be able to be strong, resilient, flexible, elastic, and above all, durable.

Current research on bioplastics is focusing on how to use natural polymers to make plastics that are degradable. In other words, how to make products that allow you to control when and how it degrades, while insuring that the product remains strong while it is still in use.

There are at least three factors that affect how environment-friendly a material is:

- **renewability:** how quickly are the ingredients that go into making the plastic created in the environment?
- **degradability:** how quickly can the plastic be re-integrated into the environment after it is no longer being used?
- **production of waste:** how much pollution or waste is created during the process of actually making the plastic?

Traditional plastics fail on all three of these points. Even if only a small percentage of the biopolymers already being produced is used in the production of plastics, it would significantly decrease our dependence on manufactured, non-renewable resources

Manufacture of bioplastics

There are two methods used to produce plastics from biopolymers:

- Fermentation, and
- Growing Plastics in Plants

(i) Fermentation to Produce Plastics:

Fermentation is the use of microorganisms to break down organic substances in the absence of oxygen. Today, fermentation can be carried out with genetically engineered microorganisms, specially designed for the conditions under which fermentation takes place, and for the specific substance that is being broken down by the microorganism. There are two ways fermentation can be used to create biopolymers and bioplastics:

Bacterial Polyester Fermentation: Bacteria are one group of microorganisms that can be used in the fermentation process. Fermentation, in fact, is the process by which bacteria can be used to create polyesters. Bacteria called *Ralstonia eutropha* are used to do this. The bacteria use the sugar of harvested plants, such as corn, to fuel their cellular processes. The by-product of these cellular processes is the polymer. The polymers are then separated from the bacterial cells.

Lactic Acid Fermentation: Lactic acid is fermented from sugar, much like the process used to directly manufacture polymers by bacteria. However, in this fermentation process, the final product of fermentation is lactic acid, rather than a polymer. After the lactic acid is produced, it is converted to polylactic acid using traditional polymerization processes.

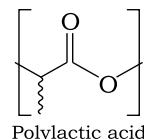
(ii) Growing Plastics in Plants

Plants are becoming factories for the production of plastics. Researchers created a plant (*Arabidopsis thaliana*) through genetic engineering. The plant contains the enzymes used by bacteria to create plastics. Bacteria create the plastic through the conversion of sunlight into energy. The researchers have transferred the gene that codes for this enzyme into the plant, as a result the plant produces plastic through its cellular processes. The plant is harvested and the plastic is extracted from it using a solvent. The liquid resulting from this process is distilled to separate the solvent from the plastic.

Some of the important bioplastics derived from the above sources are discussed below:

6.11.3 Polylactic acid

Polylactic acid or Polylactide (PLA) is a biodegradable, thermoplastic polymer derived from renewable resources. Polylactic acid can be processed like most thermoplastics into fibers and films. PLA is particularly attractive as a sustainable alternative to petrochemical-derived products, since lactic acid is now commercially produced on large scales through the fermentation of sugar feedstocks obtained from sugar beets or sugar cane, or from the conversion of starch from corn, potato peels, or other starch source. PLA is finding commercial applications in drug encapsulation and biodegradable medical devices. Moreover, packaging made from PLA is bio-degradable and reverts in less than 60 days in ideal conditions, namely in commercial composting installations.



Bacterial fermentation is used to produce lactic acid from corn starch or sugarcane feedstocks. PLA has a melting temperature of 173–178°C.

Applications

- PLA is currently used in a number of biomedical applications, such as sutures, stents, dialysis media and drug delivery devices

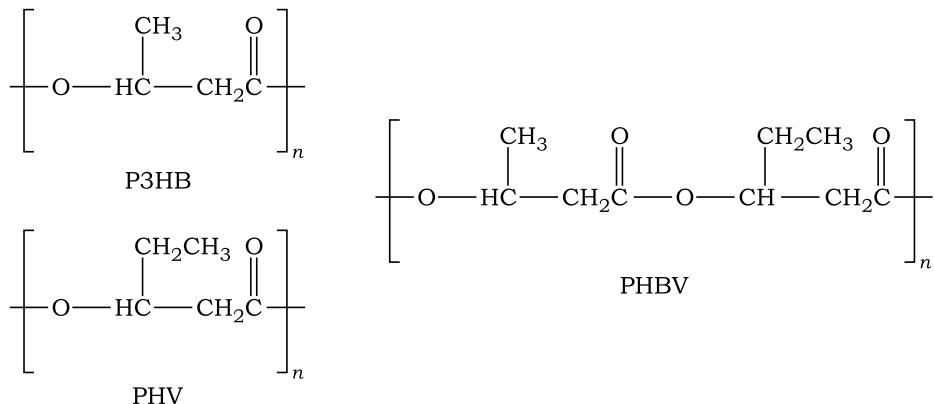
- It is also evaluated as a material for tissue engineering.
- Being biodegradable it can also be employed in the preparation of bioplastic, useful for producing loose-fill packaging, compost bags, food packaging and disposable tableware.
- In form of fibers and non-woven textiles PLA also has many potential uses, for example as upholstery, disposable garments, awnings, feminine hygiene products and nappies.

6.11.4 Polyhydroxybutyrate

Polyhydroxybutyrate (PHB) produced from fermentation of carbohydrate is a biodegradable, thermoplastic polymer derived from renewable resources. Polyhydroxybutyrate has attracted much commercial interest as a plastic material because its physical properties are remarkably similar to those of polypropylene, even though the two polymers have quite different chemical structures. While PHB appears stiff and brittle, it also exhibits a high degree of crystallinity, a high melting point of about 180 °C, but, most importantly, PHB is rapidly biodegradable, unlike polypropylene.

PHB is produced by micro-organisms, apparently in response to conditions of physiological stress. The polymer is primarily a product of carbon assimilation (from glucose or starch) and is employed by micro-organisms as a form of energy storage molecule to be metabolized when other common energy sources are not available. However PHB has a high production cost.

The poly-3-hydroxybutyrate (P3HB) form of PHB is probably the most common type of polyhydroxyalkanoate, but many other polymers of this class are produced by a variety of organisms: these include poly-4-hydroxybutyrate (P4HB), polyhydroxyvalerate (PHV), polyhydroxyhexanoate (PHH), polyhydroxyoctanoate (PHO) and their copolymers.



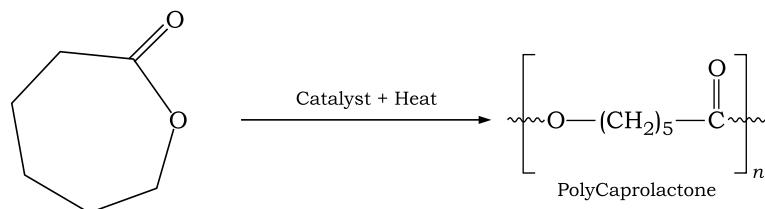
Chemical structures of P3HB, PHV and their copolymer PHBV

PHB is water insoluble and relatively resistant to hydrolytic degradation. This differentiates PHB from most other currently available biodegradable plastics, which are either water soluble or moisture sensitive. PHB sinks in water while polypropylene floats. But sinking of PHB facilitates its anaerobic biodegradation in sediments. PHB is nontoxic.

6.11.5 Polycaprolactone

Polycaprolactone (PCL) is a biodegradable polymer derived by the chemical synthesis from crude oil. Because of its degradation properties, the primary uses of PCL have been in biomedical applications and as an additive to bioplastics made from other polymers. For example, it can be added to starch to lower its cost and increase biodegradability or it can be added as a polymeric plasticizer to PVC to increase its impact resistance.

PCL can be prepared by ring opening polymerization of ϵ -caprolactone using a catalyst such as stannous octanoate.



Ring opening polymerization of ϵ -caprolactone to polycaprolactone

PCL has good water, oil, solvent and chlorine resistance. PCL has a melting temperature of around 60°C. It degrades extremely quickly in open air.

Applications:

- PCL is degraded by hydrolysis of its ester linkages in physiological conditions (such as in the human body) and has therefore used as an implantable biomaterial.
- PCL is a Food and Drug Administration (FDA) approved material that is used in the human body as (for example) a drug delivery device, suture (sold under the brand name Monocryl or generically), adhesion barrier and is being investigated as a scaffold for tissue repair via tissue engineering.
- In Odontology or Dentistry (as composite named Resilon™) is used in root canal filling.

6.12 THERMAL DEGRADATION OF PLASTICS DURING RECYCLING

Plastic recycling is the process of recovering scrap or waste plastics and reprocessing the material into useful products, sometimes completely different from their original state. Recycling involves collecting plastic products, sorting by resin type, and then depolymerizing the plastics back into their basic building blocks or monomers. The recovered monomers are then used to produce new resins of the same type so they may be fabricated into new, useful, and marketable products.

Recycling is beneficial in two ways: Plastics can be recovered from waste via mechanical recycling and it also reduces the amount of waste produced for disposal.

There are four stages of recycling;

- (i) *Primary:* Reprocessing waste plastics to produce new plastic having similar properties as those of the original plastic is defined as primary recycling,

- (ii) *Secondary*: Melt recycling is considered secondary recycling, and the products obtained have inferior properties to the original plastic.
- (iii) *Tertiary*: The waste plastic is recycled by altering its chemical structure to produce monomers through depolymerisation.
- (iv) *Quaternary*: No new products are produced. Burning plastic waste for energy recovery is considered quaternary recycling.

Depending on recyclable plastic types, desired composition and molecule weight of products, many different methods of recycling can be implemented within above areas.

Tertiary recycling is based on the decomposition of polymers by means of heat, chemical, or catalytic agent, to yield a variety of products ranging from the chemical monomers to a mixtures of compounds with possible application as a source of chemicals or fuels.

Thermal degradation during recycling involves the degradation of the polymeric materials by heating in the absence of oxygen (usually in a nitrogen atmosphere).

Most of the earlier studies on polymer thermal degradation were aimed at determining the polymer thermal stability rather than developing a feasible alternative for the degradation of the polymeric waste. It was in 1970s that the thermal degradation began to be considered as an interesting method to degrade the polymer wastes. In the recycling process, the waste material undergoes several heating processes.

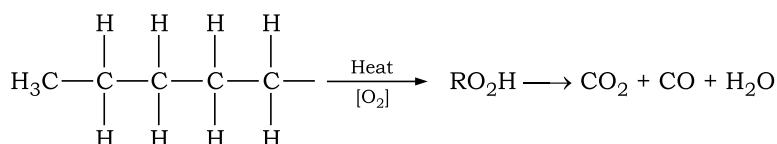
Thermal degradation of plastics proceeds through a radical mechanism, which may involve three different decomposition pathways (ref: Aguado and Serrano 1999)*:

1. Random scission at any point in the thermal backbone leading to the formation of smaller polymeric fragments as primary products, which in turn may be subjected to additional random cracking reactions.
2. End-chain scission, where a small molecule and a long-chain polymeric fragment are formed. If the small molecule released is the starting monomer, the thermal degradation process can be considered as an actual depolymerization or unzipping process.
3. Abstraction of functional substituents to form small molecules. In this case, the polymer chain may retain its length or the release of the small molecule may be accompanied by cleavage of the polymeric chain.

In many cases, several of these pathways occur simultaneously.

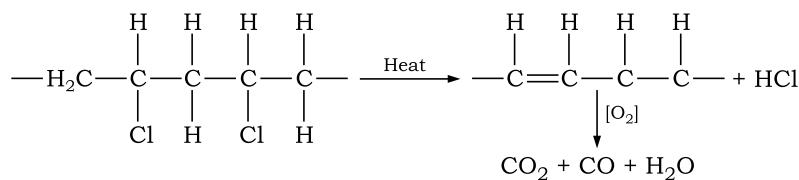
Thermal degradation of some common plastics is discussed below:

1. *Polyethylene and Polypropylene*: Polyethylene and Polypropylene are thermally degraded by both random and end chain scissions. The end products are CO_2 , CO and H_2O .

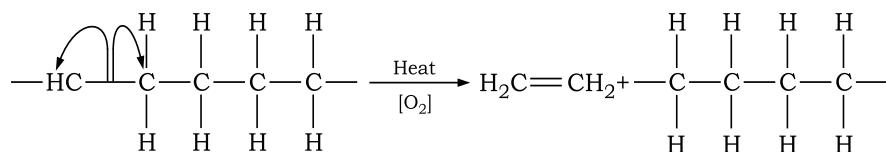


* **Reference:** Aguado J & Serrano D (1999) Feedstock Recycling of Plastic Wastes. Royal Society of Chemistry, Clean Technology Monographs. Cambridge, UK.

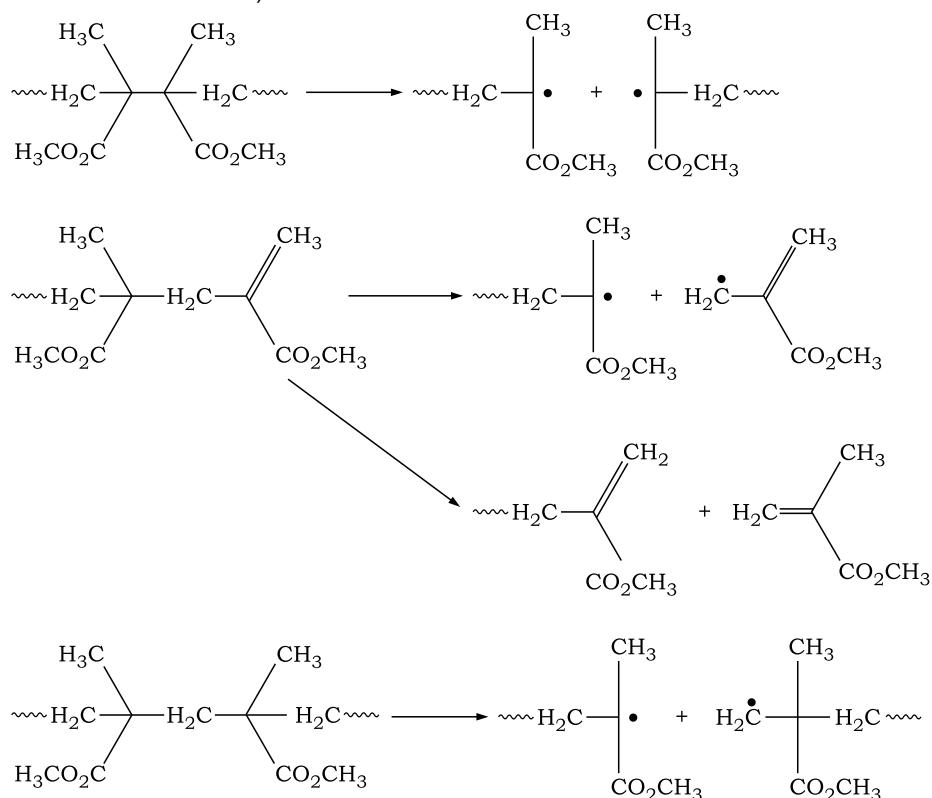
2. *Polyvinyl chloride*: In the case of PVC, the first step is the removal of HCl and subsequently decomposition of the remaining diene backbone.



3. *Polystyrene*: The thermal degradation proceeds through free radical mechanism and the product is oligomer or monomer



4. *Acrylic polymer*: Acrylic polymer proceeds in three steps: the first and easiest (scheme 1) is initiated by scissions of head-to-head linkages at about 160°C (representing one type of defect at the polymer backbone); the second (scheme 2) by scission at the chain-end initiation from vinylidene ends at around 270°C ; and the last (scheme 3) by random scission within the polymer chain (at the weakest bonds).



Three chain scission steps leading to thermal degradation in acrylic polymers

6.13 NUMBER AVERAGE AND WEIGHT AVERAGE MOLECULAR WEIGHT OF POLYMERS

The molecular weight of polymers is related to the chain length and the extent of crosslinking between different chains. The extent of cross-linking depends on the concentration of the monomer during polymerization. The length of the polymer chain depends on the random encounter between the monomer and the reactive site of the chain. Due to the randomness, some polymeric chains grow longer than the others. Thus, a polymer sample is a mixture of different molecules having different chain lengths. Hence molecular weight of a polymer is always expressed as some sort of average of molecular weight. The molecular weights can be expressed as—

(i) Number Average Molecular Weight M_n :

$$\bar{M}_n = \frac{\text{Total Mass of the polymer sample}}{\text{Number of molecules present in the sample}}$$

or

$$\begin{aligned}\bar{M}_n &= \frac{n_1 M_1 + n_2 M_2 + n_3 M_3 + \dots}{n_1 + n_2 + n_3 + \dots} \\ &= \frac{\sum n_i M_i}{\sum n_i}\end{aligned}$$

where n_1, n_2, n_3 etc. are the number of molecular species having molecular mass M_1, M_2, M_3 etc ... respectively. Measurement of an appropriate colligative property affords the Number Average Molecular Weight.

(ii) Weight Average Molecular weight M_w :

$$\begin{aligned}\bar{M}_w &= \frac{W_1 M_1 + W_2 M_2 + W_3 M_3 + \dots}{W_1 + W_2 + W_3 + \dots} \\ &= \frac{W_1 M_1 + W_2 M_2 + W_3 M_3 + \dots}{W}\end{aligned}$$

where W_1 = Total mass of the species having molecular weight M_1 .

$$W_1 = n_1 M_1$$

W = Total weight of the polymer sample

$$\therefore \bar{M}_w = \frac{\sum n_i M_i^2}{W}$$

(iii) Viscosity Average Molecular Weight, \bar{M}_v :

$$\bar{M}_v = \left[\frac{\sum N_i M_i^{(1+a)}}{\sum N_i M_i} \right]^{1/a}$$

where N_i is the number of molecules of molecular weight M_i a is the exponent in Mark-Kuhn-Houwink equation i.e. $[\eta] = KM^a$, where η is the intrinsic viscosity and K is a constant.

(iv) Degree of polymerization (\overline{DP}): It is the average number of monomer units in a chain. It can be number average degree of polymerization (\overline{DP}_n) or weight average degree of polymerization (\overline{DP}_w).

$$\overline{DP}_n = \frac{\bar{M}_n}{M_o} \text{ and } \overline{DP}_w = \frac{\bar{M}_w}{M_o}$$

where \bar{M}_n , \bar{M}_w and M_o are number average, weight average and molecular weight of the monomer respectively.

NUMERICAL PROBLEMS

Example 1. Calculate the number average molecular weight, if two polymers, having mass equal to 100 to 10,000 are mixed.

Solution: $\bar{M}_n = \frac{100 + 10,000}{2} = 5050.$

Example 2. Calculate the number and weight average molecular weights of a polymer sample containing 20% of polymer A and 80% of polymer B. The molecular weights of A and B are 3000 and 30,000 respectively.

Solution: $\bar{M}_w = \frac{0.2 \times 3000 + 0.8 \times 30,000}{0.2 + 0.8} = 24600.$

For finding out \bar{M}_n we have to calculate the number of molecules of A and B.

Number of molecules of A having

$$\frac{\text{molecular mass } 30,000}{\text{Number of molecules of } B} = \frac{80 \times 3000}{20 \times 30,000} = \frac{2}{5}$$

having molecular mass 3000

Thus for every 2 macromolecules of mass 3000, there are 5 molecules of mass 30,000. Hence,

$$\bar{M}_n = \frac{5 \times 3000 + 2 \times 30,000}{(5 + 2)} = 10714.$$

Example 3. Equal weights of polymer molecules with molecular weights 20,000 g/mol and 200,000 g/mol are mixed. Calculate \bar{M}_n and \bar{M}_w .

Solution: Let the weight of one of the polyemers = W_1

Weight of the other polymer = W_2

$$W_1 = W_2$$

Let it

$$W_1 = W_2 = 400,000 \text{ g}$$

Number of molecules of first monomer

$$n_1 = \frac{400,000}{20,000} = 20$$

Number of molecules of second polymer

$$n_2 = \frac{400,000}{202,000} = 2$$

$$\bar{M}_n = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2} = \frac{20 \times 20,000 + 2 \times 200,000}{20 + 2}$$

$$\begin{aligned}
 \bar{M}_w &= \frac{n_1 M_1 + n_2 M_2}{n_1 M_1 + n_2 M_2} = \frac{20 \times (20,000) + 2 \times (200,000)^2}{20 \times 20,000 + 2 \times 200,000} \\
 &= \frac{20 \times 2 \times 10^8 + 2 \times 2 \times 10^{10}}{8 \times 10^5} \\
 &= \frac{4 \times 10^9 + 4 \times 10^{10}}{8 \times 10^5} = \frac{4 \times 10^9 (1+10)}{8 \times 10^5} \\
 &= 110,000 \text{ g/mol.}
 \end{aligned}$$

Example 4. If 1000 g of a polymer of molecular weight 1000 g/mole is mixed with 1000 g of another polymer of molecular weight 10^6 g/mole, what is the ratio of \bar{M}_w / \bar{M}_n .

Solution:

Polymer	Weight	Mol.wt.	No. of moles in
1	1000 g	1000 g/mol	1 (n_1)
2	1000 g	10^6 g/mol	$10^{-3}(n_2)$

$$\begin{aligned}
 \bar{M}_n &= \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2} = \frac{(1 \times 1000) + (10^{-3} \times 10^6)}{1 + 10^{-3}} \\
 &= \frac{2000}{1.001} \approx 2000 \\
 \bar{M}_w &= \frac{n_1 M_1^2 + n_2 M_2^2}{n_1 M_1 + n_2 M_2} = \frac{1 \times (1000)^2 + 10^{-3} \times (10^6)^2}{(1000 + (10^6 \times 10^{-3}))} \\
 &= \frac{10^6 + 10^9}{1000 + 1000} = \frac{10^6(1+10)}{2000} = 5.5 \times 10^5 \\
 \frac{\bar{M}_w}{\bar{M}_n} &= \frac{5.5 \times 10^5}{2000} = 2.75 \times 10^2
 \end{aligned}$$

Problem: A polydisperse sample of polystyrene is prepared by mixing three monodisperse samples in the following proportions:

1 g 10,000 molecular weight, 2 g 50,000 molecular weight, 2 g 100,000 molecular weight. Using this information, determine the following:

- (a) Number-average
- (b) Weight-average.

EXERCISES

1. Define the terms: Monomer, Polymer, Degree of polymerization.
2. Define functionality of the polymer.
3. Discuss addition polymerization as a method of synthesis of a polymer.
4. Explain cationic, anionic and free radical polymerization processes.
5. Distinguish between natural and synthetic polymers.
6. What do you mean by polymer degradation? What are the factors which are responsible for thermal degradation?

- 7.** Write a short notes on:
 - (i) Photo degradation.
 - (ii) Biodegradation
- 8.** Under what conditions mechanical degradation of the polymer takes place?
- 9.** What are environmental degradable polymers?
- 10.** Explain:
 - (i) hydro-biodegradable polymers and
 - (ii) Photo-biodegradable polymers
- 11.** Give the mechanism of degradation of photo-biodegradable polymers.
- 12.** What are the additives added to make a polymer photo-biodegradable?
- 13.** What type of polymers undergoes hydro-biodegradable polymers?
- 14.** Give some examples of hydro-biodegradable.
- 15.** What do you mean by biopolymers? Give some examples.
- 16.** What do you mean by bioplastic? Give some examples
- 17.** Name the polymers that come from living organisms.
- 18.** Why there is strong need for the development of bio plastics? What are its advantages over the synthetic plastics?
- 19.** What are the methods commonly used for the manufacture of the bioplastics?
- 20.** Write short notes on PLA, PHB bioplastics.
- 21.** How does thermal degradation of plastic occur during recycling?
- 22.** Discuss thermal degradation of polystyrene, polypropylene during recycling.
- 23.** (a) What are photosensitizers or promoters? Why are these added to polymers? Discuss.
(b) Write short note on: Hydro-biodegradable polymers.
(c) Discuss briefly the addition and condensation polymerization. What is copolymerization?
(d) What are biopolymers and bioplastics? Discuss the methods used to produce bioplastics.



UNIT

7

Environmental Biotechnology

It seems to me that we all look at Nature too much, and live with her too little
—Oscar Wilde

Objectives

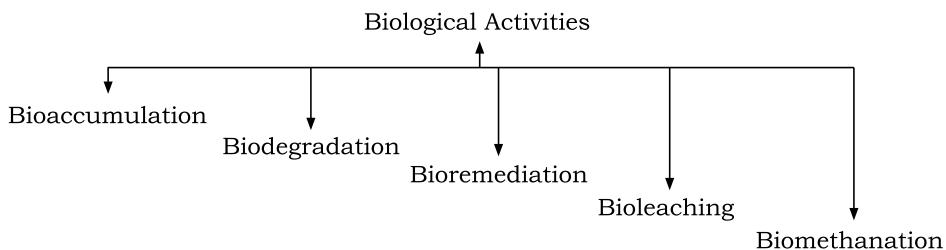
- Introduction
- Bioaccumulation
- Biodegradation
- Bioremediation
- Bioleaching
- Biomethanation

7.1 INTRODUCTION

The environmental biotechnology is going to new paths where microbes are used to clean up the environment. These technologies are such designed that their product output is high and the residues left are comparatively low and relatively non-toxic.

In other words, biotechnology in Environmental studies is the “development, use and regulation of biological systems for remediation of contaminated environment (land, air, water) and for environment friendly processes (green manufacturing technologies and sustainable developments).”

The various microbial activities are classified into the following categories



7.2 BIOACCUMULATION

Bioaccumulation in general can be defined as the accumulation of substances such as pesticides (DDT etc), methyl mercury, or any other organic chemical in an organism or part of an organism. It is an important

process in which chemicals can affect the living organism. This process results in the increase in the concentration of a chemical in a biological organism over a period of time, compared to that of the environment surrounding it. Compounds get accumulated in the organism when the rate of intake of the chemicals and its storage is faster than its metabolism or excretion. Although it is often thought, that the man made chemicals have a negative effect on the biological organism, bioaccumulation is in fact a necessary process for organism's survival because animals bioaccumulate, vitamins A, D and K, trace elements, essential fats and amino acids. But this process becomes of concern when the chemical substances get accumulated at harmful levels.

Bioaccumulation is the result of the three processes.

- (i) **Uptake:** Bioaccumulation process begins when a chemical moves, or diffuses from a place of high concentration (environment) to one of low concentration (organism's cells). This is a complex process and several factors are responsible for it. For instance chemicals which are lyophilic (fat loving) or hydrophobic (water hating) have a greater tendency to move from the water to the cells of the aquatic organisms.
- (ii) **Storage:** Some chemicals become attracted to certain sites inside the cell and get temporarily stored. One important factor in uptake and storage is the solubility of the chemicals in water. Usually chemicals which have high solubility in water have little tendency to accumulate inside the organism's cells. Once inside, they are easily removed unless they are retained in the cells by specific mechanisms. Heavy metals like mercury is an exception because it can bind tightly to specific sites within the body. If the binding of the chemicals occur, then even highly water soluble chemicals can accumulate which is best illustrated by cobalt, which despite its high water solubility binds tightly to liver. Similar accumulation processes occur for mercury, copper, cadmium and lead.
- (iii) **Elimination:** This is the third factor affecting bioaccumulation in which an organism can break down and/or excrete a chemical. The process of metabolism (breakdown of chemicals) varies among individual organisms and species and also depends on characteristics of the chemical itself.

7.2.1 Bioconcentration & Biomagnification

Bioconcentration is a specific bioaccumulation process in which an organism increases the concentration of a certain chemical directly from the surrounding environment. For example, for aquatic animals (like fish) bioconcentration after uptake through the gills (or sometimes skin) is the most important bioaccumulation process.

Biomagnification on the other hand describes a process that results in the accumulation of a chemical in an organism at a much higher level than consumed by it directly. It becomes more and more concentrated as it moves through a food chain. This can be best illustrated with an example. A toxic substance which is generated by a land based source is deposited on a lake, is absorbed by the phytoplankton (free-floating algae). They are

further eaten by zoo-plankton (free-floating animals) which are consumed by small fish, followed by large fish and many others in the chain, subsequently reaching man. As the toxicant is transferred up in the foodchain, its concentration is magnified by bioaccumulation as much as million times (shown below).

Toxic subs (deposited on lake)	→ Phytoplankton (0.0025 ppm)	→ Zooplankton (0.123 ppm)	→ Small fish (1.04 ppm)	→ large fish (4.83 ppm)	→ Man
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If the affected organism is kept in uncontaminated atmosphere, then the reverse of bioaccumulation takes place, when the toxins are released by the affected organisms to the environment. This reverse process is called **depuration**.

Nature of Toxicant

In order for biomagnification to occur, the pollutant must be:

- long-lived
- mobile
- soluble in fats

If a pollutant is short-lived, it will be broken down before it can become dangerous. If immobile, it will stay in one place and is unlikely to be taken up by organisms. If the pollutant is soluble in water, it will be excreted by the organism.

Biomagnification of Mercury

When mercury reaches an aquatic environment, it can be transformed into methylmercury which is extremely toxic. Mercury is found in all tissues of a contaminated fish. This can be fatal for humans when mercury levels are very high.

Endocrine Disruption

This is a common problem in people whose intake of animal fats, particularly meat, walrus, whale as well as fish and birds is very high. This may contribute to the accumulation of chemicals such as organochlorines in humans.

Another problem is common in Arctic region where the accumulation of vitamin A takes place since people consume large amount of livers of pure carnivores like polar bears and husky dogs.

7.2.2 Case Study

CASE STUDY

Long Island Estuary

A study was carried out in 1967 on Long Island Estuary. The levels of DDT in tissues of various animals were noted.

DDT has a half life of 15 years, which means if 100 kg of DDT is used, after 100 years there will still be over a pound of DDT left in the environment.

If it does bioaccumulate and biomagnify, much of it will be in the bodies of organisms. DDT has rather low toxicity in humans and so it was extensively used shortly after its discovery before world war II. As the first pesticide, it was overused and hence led to biomagnification and bioaccumulation.

In Long Island, the studies of DDT levels showed bioaccumulation factors of 800 times and biomagnification factors of up to 31 times. When the whole food chain was studied, the overall magnification was over 200,000 times!

DDT has a number of lethal effects for various species of birds, particularly carnivorous birds like ospeys, bald eagles, cormoants, herring gulls, etc, many of which are now extinct in the area.

However, some species have recovered following the banning of DDT in the US.

7.2.3 Factors Affecting Bioaccumulation

- The physical and chemical properties of the chemicals, including its solubility in water and fats, molecular weight and ease of metabolism.
- Environmental condition including water quality (pH, hardness, etc.)
- Nature of organism, including its ability of metabolism and lipid content, etc. Large, long-lived organisms with low rates of metabolism or excretion of a chemical will bioaccumulate more than small, short-lived organisms.
- Dietary factors (feeding rate, amount of contaminated food taken and absorption of the chemicals from the food).

Thus, bioaccumulation is a normal process that can result in injury to an organism only when the equilibrium between exposure and bioaccumulation is overwhelmed, relative to the harmfulness of the chemical.

7.3 BIODEGRADATION

Biodegradation is a process in which the organic compounds are broken by indigenous microbes. Organic compounds can be degraded aerobically (with oxygen) or anaerobically (without oxygen). Proteins, complex organic compounds and nucleic acids of dead plants and animals are converted to carbondioxide and water by the microorganisms which are present in the atmosphere. The inorganic substances attached to these organic compounds are converted into minerals by the degradation process. This process is known as **biomineralization**.

7.3.1 Methods of Measuring Biodegradation

Biodegradation can be measured under aerobic as well as anaerobic conditions. The activity of aerobic microbes are measured in terms of the amount of oxygen consumed or the amount of carbon dioxide produced during degradation.

The DR4 test or 4-day dynamic respiration index test is used to measure the biodegradation under aerobic condition for 4 days. Here the substance is aerated by passing air through it. Microbes are then introduced to the test material while incubating it under aerobic conditions. The microbes biodegrade the material and produce carbon dioxide which can be monitored.

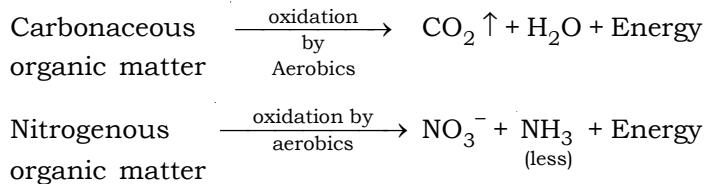
The activity of anaerobic biodegradation is produced by the amount of methane produced. **The BMP 100** test [100 day biogenic methane potential test] measures the amount of biogas produced [carbon dioxide and methane] under anaerobic conditions. The test is incubated until the biogas production ceases which could be 100 days or more. This test ensures complete degradation.

7.3.2 The Biodegradation Process

Biodegradation of the organic compounds takes place with the help of enzymes produced by the microorganism. Many enzymes are not released by the microbial cells hence the organic compounds which are to be biodegraded are either transported to the cells or they come in contact with the cells. Since enzymes are highly specific in their action hence many types of enzymes are required for the complete biodegradation making it a stepwise process. Sometimes a contaminant may not be completely biodegraded but converted into an intermediate compound which may be more harmful for the environment. The biodegradation in general may be carried out either through aerobic decomposition or through anaerobic decomposition which are described below:

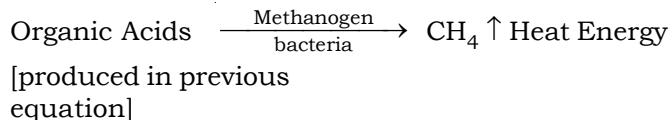
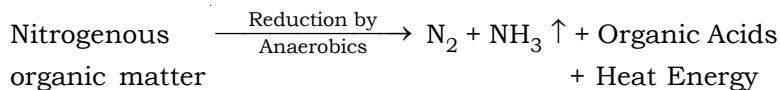
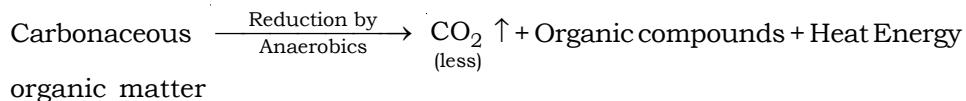
7.3.2.1 Aerobic Biodegradation

This degradation takes place in the presence of freely available oxygen by the aerobic and/or facultative bacteria which utilize the free oxygen as electron acceptor, thereby oxidizing the organic matter to stable and harmless end products. The final products of degradation are carbon dioxide in the case of carbonaceous organic matter and nitrates in the case of nitrogenous organic matter which are represented by the following equations.



7.3.2.2 Anaerobic Biodegradation

This type of degradation takes place in the absence of oxygen. The bacteria convert the carbonaceous organic matter into simple organic carbon compounds. Whereas the nitrogenous organic matter are converted to ammonia. The following equations represent the anaerobic processes.



7.3.2.3 Indicative Lengths of Degradation

• Banana peel	—	2-10 days
• Cotton rags	—	1-5 months
• Paper	—	2-5 months
• Orange peels	—	6 months
• Wool socks	—	1-5 years
• Cigarette filters	—	1-12 years
• Tetrapaks	—	5 years
• Plastic bags	—	10-20 years
• Leather shoes	—	25-40 years
• Nylon fabric	—	30-40 years
• Tin cans	—	50-100 years
• Aluminiums cans	—	80-100 years

7.3.3 Factors Affecting Biodegradation

There are a number of factors which affect the rate of naturally occurring biodegradation such as:

1. **Physical factors:** Soil moisture content, porosity, soil temperature, soil pH, soil water dissolved oxygen, soil gas oxygen content etc.
2. **Chemical factors:** Nature of the substrate compounds (saturated, unsaturated, aliphatic or aromatic), soluble salts, buffer index, presence of micronutrients like Sodium, Calcium, Magnesium, Sulphur, Boron, Copper and Zinc, presence of inorganic nitrogen nutrient (NH_3 , NO_2 , NO_3) and soluble phosphorus (o-PO_4) etc.
3. **Biological factors:** Presence of suitable microorganisms for degrading the organic contaminants. Competition amongst the

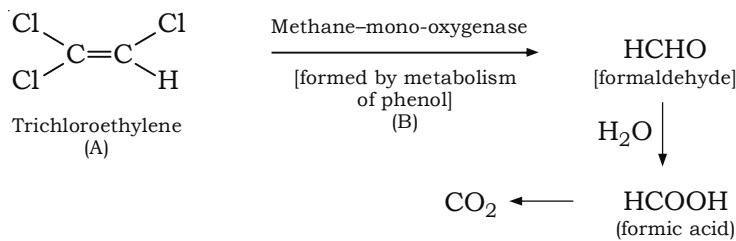
various microorganism for degradation is another important factor. The redox potential of a soil which determines its electron density is also important because biological energy is obtained from the oxidation of the reduced material.

7.3.4 Co-metabolism

Micro-organisms metabolize and decompose biodegradable organic substances or pollutants to produce energy for their own growth and survival. In some specific cases it is found that the degradation of a substance (A) occurs without the use of energy produced by its own metabolism. In such cases, a second substance (B) is used and metabolized to produce energy which can be further used in the growth and survival of the first organism (A). The metabolic degradation of the substance A, is known as co-metabolism.

Co-metabolism is therefore defined as the simultaneous metabolism of two compounds, in which the degradation of the second compound (B) serves as the primary energy or carbon source. The second substrate B is usually referred to as a 'nutrient' since its addition helps in the biodegradation of a normally non-biodegradable substance (A). Here the first substrate (A) which undergoes co-metabolism is known as the secondary substrate whereas the second substrate (B) which brings co-metabolization of first substrate (A) and acts as a primary source of energy is known as the 'primary substrate'.

This is illustrated with the example of Trichloroethylene (TCE) which is a non-biodegradable substrate under ordinary conditions. However it can be degraded easily when phenol is added to it which acts as a nutrient or a primary substrate for the growth of the micro-organism which are needed for the cometabolism of A. The methanotrophs (methane oxidizing bacteria) are developed due to the metabolism of phenol and produce an enzyme (methane-mono-oxygenase) which can react with trichloroethylene to form carbon dioxide as the final product.



It is important to note here that for the complete degradation or cometabolism of non-biodegradable pollutants, usually mixed cultures of micro-organisms are referred since the pure cultures of microorganisms [one type of microorganisms] lead to the accumulation of the initial products of cometabolism, which often does not undergo further degradation.

7.3.4.1 Advantages of Cometabolism

1. The process of cometabolism has given rise to new methods of purification of ground water and soil.
2. The addition of methane, methanol, phenol etc have been found to biodegrade the otherwise non-biodegradable chlorinated solvents like vinylchloride, trichloroethylene etc.

7.3.4.2 Disadvantages of Cometabolism

1. When the subsurface of a pollutant is irregular, then it is difficult to cometabolise the pollutants uniformly.
2. Since methane is also used as a nutrient in case of many pollutants, all the ignition sources in the area should be removed as methane is inflammable.

7.4 BIOREMEDIALION

Bioremediation is the use of living organism, primarily microorganisms which degrade the toxic substances in the environment to less toxic forms. In this process the microorganisms enzymatically attack the pollutants and convert them into harmless products. This process uses naturally occurring bacteria, fungi or plants to detoxify the hazardous substances to human health and environment. The microorganism can be either indigenous to a contaminated area or may be isolated from other sites and brought to the contaminated sites. Since the microbes are used to clean up the harmful chemicals, the ambient temperature, nutrients and right amount of oxygen should be present in the soil and groundwater. These conditions help the microbes to multiply. If the required conditions are not supplied to the microbes, they grow too slowly or they die which can also create other harmful chemicals.

7.4.1 How does Bioremediation Work?

Bioremediation depends on the natural biological processes of microorganisms, one of which is METABOLISM.

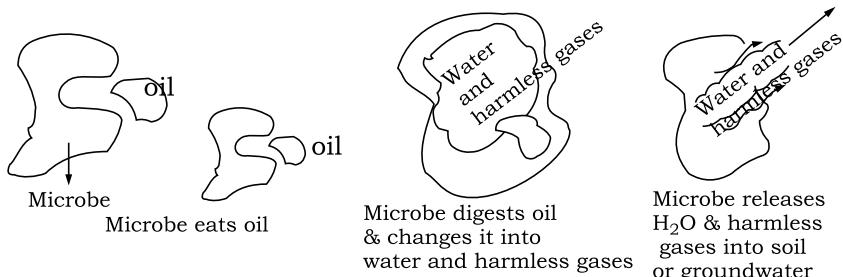
Metabolism refers to the chemical reactions occurring in a cell of organism. All living processes are based on a complex series of chemical reactions. The process of metabolism can be divided into two parts which are:

Anabolism: Processes that build up complex molecular structures from simpler molecular structures.

Catabolism: The processes which break down complex molecules into simpler ones is called catabolism.

Chemicals present at contaminated sites become part of the anabolism and catabolism processes. Petroleum products at the sites are a rich source of energy and some organisms take advantage of this and use hydrocarbons as a source of food and energy to carry out their cellular functions.

This results in the breakdown of these complex compounds into simpler forms like carbon dioxide and water.



For bioremediation to be effective, microorganisms must enzymatically attack the pollutant and convert them into harmless products. This can only happen when environmental conditions permit microbial growth and activity. Therefore the process of bioremediation often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate.

7.4.2 Factors Affecting Bioremediation

The control and optimization of bioremediation process is a complex system and consists of many factors:

- (i) The existence of a microbial population capable of degrading the pollutants
- (ii) The availability of contaminants to the microbial population
- (iii) The environmental factors (type of soil, temperature pH, pressure of oxygen, other electron acceptors and nutrients).

Microbes have an immense adaptability, because of which these can be used to degrade or remediate environmental hazards. The main requirements are an energy source and a carbon source.

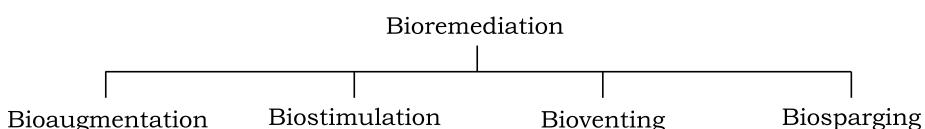
Although the microorganisms are present in contaminated soil, they cannot necessarily be there in the numbers required for bioremediation of the site. So therefore growth and activity must be stimulated.

7.4.3 Types of Bioremediation

Different techniques are employed depending on the degree of saturation and aeration of an area to successfully remove the contaminants from the soil.

- (i) IN SITU techniques are defined as those that are applied to soil and ground water at the site with minimal disturbance.
- (ii) EX SITU techniques are those that are applied to soil and ground water which has been removed from the site via excavation (soil) or pumping for water.

There are four basic methods employed for the process of bioremediation. They are as follows:



- (i) **Biostimulation:** It involves supplying oxygen and nutrients by circulating aqueous solutions through contaminated soils to stimulate naturally occurring bacteria to degrade organic contaminants. It can be used for purification of soil and groundwater. The disappearance of contaminants is monitored to insure that remediation occurs.
- (ii) **Bioaugmentation:** Microorganisms that can clean up a particular contaminant are added to the contaminated soil or water. Bioremediation frequently involves the addition of microorganisms indigenous or exogenous to the contaminated sites.
- (iii) **Bioventing:** It is the most common insitu treatment and involves supplying air & nutrients through wells to contaminated soil to stimulate the indigenous bacteria. It employs low air flow rates & provides only the amount of oxygen necessary for the biodegradation while minimizing volatilization and release of contaminants to the atmosphere.
- (iv) **Biosparging:** Biosparging involves the injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of degradation of contaminants by bacteria. It increases the mixing in the saturated zone and thereby increases the contact below even soil and groundwater.

7.4.4 Advantages of Bioremediation

1. Bioremediation is a natural process & is therefore perceived by the public as an acceptable water treatment process. Microbes able to degrade contaminants increase in number when the contaminant is present. The residues are usually harmless including carbon dioxide water and cell biomass.
2. Polluted soil & groundwater can be cleaned at the site without having to move them somewhere else. This allows clean up workers to avoid contact with polluted soil & groundwater.
3. It prevents the release of harmful gases into the air. Instead of transferring the contaminants from one medium to another, the complete destruction of target pollutants is possible.
4. Bioremediation can prove less expensive than other technologies that are used for cleanup of hazardous water, as it does not require as much equipments or skilled labourers.

7.4.5 Disadvantages of Bioremediation

1. Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptible to rapid and complete degradation.
2. Biological processes are often highly specific. The factors required for success of the process include presence of capable microbes, environmental conditions and levels of nutrients & contaminants.
3. It often takes longer time than other treatment options.
4. Research is needed to develop & engineer bioremediation technologies that are appropriate for sites with complex mixtures of contaminants that are not evenly dispersed in the environment. Contaminants may be present as solids, liquids or gases.

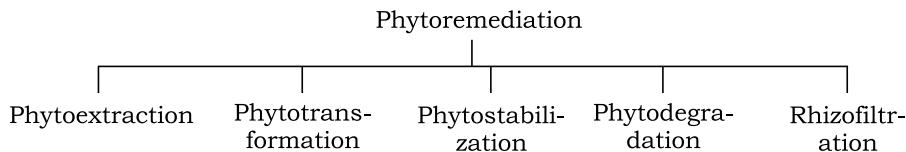
CASE STUDY

TERI (Tata Energy Research Institute) in India, has developed a mixture of bacteria called 'OILZAPPER' which can degrade the pollutants of oil contaminated sites. In this bioremediation technique no harmful residues are left behind. This technique apart from being environment friendly is also cost effective.

7.4.6 Phytoremediation

Vegetation based remediation shows potential for accumulating immobilizing, and transforming a low level of persistent contaminants. In natural ecosystems, plants act as filters and metabolize substances generated by nature.

Phytoremediation is an emerging technology that uses plants to remove contaminants from soil and water to clean up the environment. This technology is comparatively new and thus requires a lot of research in the area. There are five types of phytoremediation techniques. They are:



1. **Phytoextraction:** Plants accumulate the contaminants into the roots and above ground into the shoots or leaves. This process produces a mass of plants and contaminants (usually metals) that can be recycled or disposed.
2. **Phytotransformation:** This process deals with the uptake of organic contaminants from the soil, sediments or water and transfers it into less toxic form.
3. **Phytostabilization:** This technique reduces the mobility of contaminants in soil. Leachable contaminants are absorbed and bound to the plant structure.
4. **Phytodegradation:** This technique involves the breakdown of contaminants due to the presence of proteins and enzymes produced by plants or by soil organisms such as bacteria, yeast and fungi.
5. **Rhizofiltration:** This is a water remediation technique that involves the uptake of contaminants by the roots of the plants. This technique is used to reduce the contamination in natural wetlands.

7.5 BIOLEACHING

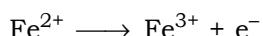
Bioleaching is a process in which the microorganisms are used to extract metals from low grade sulphide ores. This method has proved to be very useful in extracting Gold, Copper and Uranium. About 20% of the World's Copper is obtained by this process. Thermophilic bacteria can also leach Nickel, Zinc and Cobalt, but this method has proven to be uneconomical. A lot of research is being carried out for the economic viability of this process because Nickel and Cobalt are used to alloy steel and Zinc is used to alloy Magnesium.

The microorganism which are used for bioleaching are Thiobacillus ferrooxidans, Lepto-Spirillum ferrooxidans, Thiobacillus thio-oxidans, Sulfolobus, Acidiphilum, Sulfobacillus, Ascidiants and many others. The advantage of using these microorganism is that they can tolerate acids and metabolize sulfur. The process of bioleaching are used extensively in ores containing sulfur because the bacteria can feed on sulfur. The dissolution of metalsulphides follows two mechanisms that are the 'contact' and the 'non contact' mechanism:

7.5.1 Types of Bioleaching

(I) Based on the mechanism of dissolution of metal sulphides it is classified as.

- (i) **Non-contact mechanism:** The mechanism assumes that the bacteria oxidizes only the dissolved Fe^{2+} to Fe^{3+} by the reaction



The Fe^{3+} can then attack the metal sulphides and be reduced to Fe^{2+} ions.

- (ii) **Contact mechanism:** This mechanism involves the attachment of the bacteria electrostatically to the surface of the sulphide ore. The Acidithiobacillus ferrooxidans, bacterial copolymer now contains Fe^{3+} . The resulting positive charge allows attachment to the negatively charged pyrite. Then the complexed Fe^{3+} ions results in the dissolution of metal sulfides in a process similar to that of non-contact mechanism.

In both the cases the electrons extracted from the metal sulphide reduce molecular oxygen via a complex redox mechanism which is located below the cytoplasm of the leaching bacteria.

(II) Based on the type of resources (low grade, intermediate grade or high grade) to be processed. The raw material type also determines the type of microorganisms involved.

- (a) **DUMP Leaching:** Waste rock, low grade ore or concentrator tailings (low grade, oxides and secondary sulphides) are leached where placed for disposal.

* It uses *mesophilic* (ambient temperature) microorganisms i.e. bacteria.

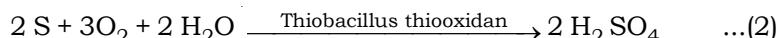
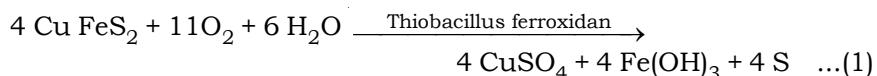
- (b) HEAP Leaching:** Newly mined run-off-the-mine (ROM) material (intermediate grade, oxides and secondary sulphides) is deposited in a heap on an impervious natural surface for leaching.
- * It uses *mesophilic* or *thermophilic* (high temperature) microorganisms i.e. archaea, depending on the mineral species present & the physical chemistry of the leach environment.
- (c) AGITATED leaching:** Intermediate to high grade, chalcopyrite concentrates are deposited in a tank and leached using mechanical agitation.
- * It uses *thermophilic* microorganisms.

7.5.2 Chemistry of Bioleaching

(i) Extraction of COPPER

- * The majority of copper minerals are sulphides, with *chalcopyrites* (CuFeS_2) being the most abundant and thus economically the most important. Sulphide minerals are *insoluble* in *water* or *acid* solutions unless they are first oxidized. While exposure to air is sufficient to oxidize these minerals the process is *slow* and *inefficient*.
- * The *kinetics* of the oxidation process are vastly improved by the introduction of *thiobacillus ferrooxidans* and *thiobacillus thiooxidans* bacteria to the system. The former catalyses *the oxidation of iron* whereas the latter catalyses *the oxidation of sulphur*.
- * There is enhanced oxidation of the mineral created by the microorganism that creates the acid-solubility required for leaching to take place.

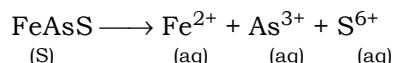
The *overall Chemical reactions* for chalcopyrites are:



- * Cu^{2+} ions are removed from solution by *Ligand Exchange Solvent extraction* method.

(ii) Extraction of GOLD

- * The extraction of gold from its ore can involve numerous ferrous and sulphur oxidising bacteria, including *Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans*
- * Bacteria catalyse the breakdown of the mineral arsenopyrite (FeAsS) by oxidising the sulphur and metal (in this case arsenic ions) to higher oxidation states whilst reducing dioxygen by H_2 and Fe^{3+} . This allows the soluble products to dissolve.



This process actually occurs at the cell membrane of the bacteria.

- * The electrons pass into the cells and are used in biochemical processes to produce energy for the bacteria to reduce oxygen molecules to water.

- * In stage 2, bacteria oxidise Fe^{2+} to Fe^{3+} (whilst reducing O_2)

$$\text{Fe}^{2+} \longrightarrow \text{Fe}^{3+}$$
- * They then oxidise the metal to a higher positive oxidation state with the electrons gained, and reduce Fe^{3+} to Fe^{2+} to continue the cycle.

$$\text{M}^{3+} \longrightarrow \text{M}^{5+}$$
- * GOLD is now separated from the ore in solution.

7.5.3 The Process

- * The exact mechanisms by which these microorganisms oxidise sulphised materials is *not precisely known*, although *both chemical and biological forces* work together to oxidise the metal *sulphide* to form *acid-soluble sulphates*. Precious metals, which are not soluble, remain with the residue. Iron, arsenic and base metals, such as copper, cobalt and zinc pass into solution, which can be separated from the residue and be treated by *conventional processing* methods.
- * The residue created by the process may contain precious metals, which can be recovered by *CYANIDATION*.

7.5.4 Advantages of Bioleaching

- 1. Economical:** It is generally *simpler* and therefore cheaper to operate and maintain, than traditional processes, since *fewer specialists* are needed to operate complex chemical plants.
- 2. Environmental:** The process is more *environmentally friendly* than traditional extraction methods. For the company this can translate into profit, since the necessary condition of limiting of sulphur dioxide emissions during smelting is expensive. *Less landscape damage* occurs, since the bacteria involved grow naturally, and the mine and surrounding area can be left relatively untouched. As the bacteria breed in the conditions of the mine, they are *easily cultivated* and recycled.

Disadvantages of Bioleaching

- 1. Economical:** The bacterial leaching is *very slow* compared to smelting. This brings in *less profit* as well as introduces a significant delay in cash flow for new plants.
 - 2. Environmental:** *Toxic chemicals* are sometimes produced in the process. A sulphuric acid and H^+ ions which have been formed can leak into the ground and surface water turning it acidic, causing *environmental damage*. Heavy ions such as iron, zinc and arsenic leak during *acid mine drainage*. When the pH of this solution rises, as a result of dilution by fresh water, these ions precipitate, forming "*yellow body*" pollution.
- * It does *not recover* the precious metals in the ore

7.5.5 Present and Future of Bioleaching in Developing Countries

- * **Nowadays**, bioleaching occupies an increasingly important place among the available mining technologies. Today bioleaching is no longer a

promising technology but an actual economical *alternative* for treating specific mineral ores. An important number of the current large-scale bioleaching operations are located in developing countries. This situation is determined by the fact that several developing countries have *significant mineral reserves* and by the characteristics of bioleaching, makes the technique especially suitable for these countries because of its *simplicity* and low capital cost requirement.

The current panorama of bioleaching is encouraging. It is expected that in the coming years several new commercial size bioleaching plants will be installed. It is likely that *heap leaching* will continue to be the choice for low grade ores and failings, while *tank bioleaching* technology will probably increase its application for gold, copper and other base-metal concentrates. The use of *thermophilic* bacteria and archea will be a major contribution, *increasing* the leaching *rates* and metal recoveries.

CASE STUDY

Examples of Current Bioleaching Operations Undergoing in Various Countries.

* Acid Mine Drainage

- Rio Tinto, Spain

* Dump Leaching

- Bagdad, USA
- Morenci, USA
- Pinto valley, USA
- Sierrita, USA

* Heap Leaching

- Cerro Colorado, chile
- Cananea, Mexico
- Collahuasi, chile
- Morenci, USA

* Gold Concentrates

- Ashants, Ghana
- Fairview, Jambia
- Wiluna, Australia

7.6 BIOMETHANATION

The production and disposal of large quantities of organic and biodegradable waste without proper treatment leads to environmental pollution. Some wastes are treated by aeration (conventional method). The anaerobic

treatment leads to the degradation of organic wastes to produce carbondioxide and methane. This process has greater economic viability and more environmental benefits.

Thus Biomethanation is defined as conversion of organic matter in the waste either solid or liquid to Biomethane (also referred as biogas) and manure by the action of the microbes in the absence of air (anaerobic condition).

The anaerobic processes could either occur naturally or in a controlled environment (biogas plant). Organic waste such as livestock manure and various types of bacteria (*Methanobrevibacter* and *Methano bacterium thermoautotrophicum*) are put in an air tight container (digester) producing approximately 55–75% methane by anaerobic process.

Biogas produced in the anaerobic digester consists of methane (50% – 80%), carbondioxide (20% – 50%) and other gases such as Hydrogen, Carbonmonoxide, Nitrogen, Oxygen, Hydrogen sulfide in traces. The relative amount of the gases produced depend on the feed material and efficiency of the process. On burning a cubic foot (0.028 m^3) of biogas yields about 10 BTU (2.52 k cal) of heat per percentage of methane composition. For example biogas consisting of 55% of methane yields 550 BTU per cubic foot.

7.6.1 Factors Affecting the Rate of Digestion

1. Temperature is the most important factor affecting the rate of digestion. The optimum temperature being 36.7°C (mesophilic) and 54.4°C (Thermophilic). In the thermophilic range, decomposition and biogas production is faster than the mesophilic range. However the advantage of mesophilic range over thermophilic range is that it is less sensitive to change in operating condition.
2. pH is another important factor although it is self regulating in most of the cases. When the waste has too much ‘green’ or is rich in Nitrogen, bicarbonate of soda is added to regulate the pH.
3. A Carbon/Nitrogen ratio should be between 20/1 to 30/1. If the nitrogen content is high, water should be added to regulate the nitrogen content.
4. Antibiotics in livestock have been known to kill the anaerobic bacteria., making the retention time an important factor.

7.6.2 Use of Effluent from the Biogas Digesters

The effluent from the digester also known as the sludge is rich in ammonia, phosphorous, potassium and many other trace elements. The sludge can be used as a solid conditioner for livestock feed additive (when dried). Any toxic compound (pesticides etc.) that are in the digester feedstock may become concentrated and come out with the sludge. Hence effluent testing becomes very important prior to its use.

EXERCISES

1. What do you understand by Environmental Biotechnology? What are the various microbial activities which are carried out?

- 2.** What do you understand by Bioaccumulation? Explain the three processes leading to Bioaccumulation.
- 3.** What are the factors affecting Bioaccumulation?
- 4.** Explain the terms 'Bio concentration' and 'Biomagnification'?
- 5.** What are the environmental factors that affect biodegradation?
- 6.** What do you understand by depuration?
- 7.** What is bioremediation? List its advantages and disadvantages.
- 8.** What do you understand by phytoremediation?
- 9.** What is bioleaching? Why although the extraction of copper through bioleaching is uneconomical, yet 20% of the world's? Copper is extracted through this process.
- 10.** What are the advantages and disadvantages of the process of bioleaching?
- 11.** What is meant by Biomethanation?
- 12.** How is anaerobic digestion more advantageous than the conventional aerobic one?
- 13.** (a) What is bioleaching? Is this process applicable to all types of ores? Justify.
(b) Discuss biomethanation briefly.
(c) What is bioremediation? Discuss its advantages and disadvantages.



UNIT

8

Environmental Pollution – I

"When the quality of life goes down for environment, the quality of life goes down for humans".

— George Holland

Objectives

- Introduction
- Environment
- Atmosphere-Composition and Structure Composition
- Pollution
- Air Pollution
- Some Common Air Pollutants
- Environmental Effects of Air Pollution
- Air Pollution Control
- Carbon Dioxide Sequestration
- Water Pollution
- Classification of Water Pollutants
- Waste water Treatment
- Waste Water Treatment Processes
- Waste Waters from Some Typical Industries

8.1 INTRODUCTION

The environmental pollution is one of the most challenging problem today. Inspite of continuous efforts of our environmental engineers, scientists and an conscious society, our problem of environmental pollution remains the same. It may be a case of polluted water at some industrial discharge point, the chloroflouro carbons (CFCs) that are attacking the earth's ozone layer, the carcinogens that are contaminating our ground water or the carbon dioxide emissions leading to climate change. The endless list of environmental pollution is a cause of great concern. Moreover radiation hazards and hazardous waste management join the array of environmental pollution problems.

Human beings depend upon the quality of environment they are living in and they also exert a tremendous impact on the environment through:

- extraction of resources
- modification and manipulation of the environment
- adding to the pollution through the process of industrialisation.

All the three basic amenities of human existence viz. air, water and land are experiencing the serious ecological imbalance. *Water* is polluted by pollutants such as sewage, solid wastes and industrial effluents. *Air* is polluted by automobile exhausts, exhaust gases from industries. *Land* is polluted by hazardous waste disposal. These environmental problems are

becoming a serious threat to our existence. Furthermore, the effects of these problems seem to be far more longer than we anticipate. For example, CFC's emitted today will be around for *decades*, carbon dioxide from our power plants will be in the atmosphere for *centuries*, and our radioactive wastes will be problematic for *thousands of years*.

Hence there is a serious need to address these issues for harmonious existence of industry and the world at large.

Environmental science is defined as - "Applying knowledge from many disciplines to the study and management of the environment. It deals with the analysis of the conditions, circumstances and influences affecting life and how life in turn responds".

Before proceeding to the environmental pollution let us have a brief idea of our environment.

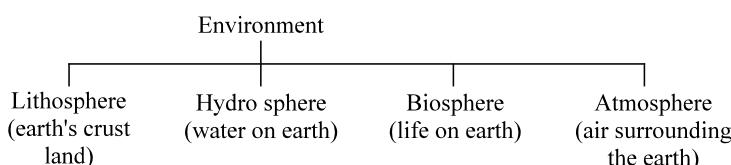
8.2 ENVIRONMENT

The human environment encompasses all physical, chemical, biological and social processes which exert a significant influence, directly or indirectly on human beings. In turn, human beings also exert influence on quality of environment. Thus, the subject of environment sciences has its roots in ecology which is the study of how living and non-living things in nature relate to one another.

The environment is not a simple distribution of gases but is highly complex and structured. It comprises of following four segments:

1. Lithosphere
2. Hydrosphere
3. Atmosphere
4. Biosphere

The names of the four sphere are derived from the Greek words for stone (litho), air (atom), water (hydro) and life (bio.).



Lithosphere

The lithosphere contains all of the hard solid land of the planet's crust (surface) and the semi-solid land underneath the crust. The surface of the lithosphere is very uneven. There are high mountain ranges, huge plains or flat areas and deep valleys along the ocean flow.

The solid and semi-solid land of the lithosphere form layers that are physically and chemically different. The outermost layer of the lithosphere consists of loose soil rich in nutrients, oxygen, and silicon. Beneath that layer lies a very thin, solid crust of oxygen and silicon. Next is a thick, semi-solid mantle of oxygen, silicon, iron, and magnesium. Below that is a

liquid outer core of nickel and iron. At the center of earth is a solid inner core of nickel and iron.

Generally, the word “lithosphere” means only the cold, hard surface of earth, not the entire inside of the planet.

Hydrosphere

The water on earth's surface constitute hydrosphere. It ranges from 10 to 20 kilometers in thickness. The hydrosphere extends from earth's surface downwards, several kilometers into the lithosphere and upwards about 12 kilometers into the atmosphere.

A small portion of the water in the hydrosphere is fresh (non-salty). This water flows as precipitation from the atmosphere down to earth's surface, as rivers and streams along earth's surface, and as groundwater beneath earth's surface. Most of earth's fresh water, however, is frozen.

Ninety-seven percent of earth's water is salty. The salty water collects in deep valleys along earth's surface. These large collections of salty water are called oceans. On the other hand, water near the poles is very cold, while water near the equator is very warm. The differences in temperature cause water to change physical states. Extremely low temperatures like those found at the poles cause water to freeze into a solid such as a polar ice-cap, a glacier, or an iceberg. Extremely high temperatures, like those found at the equator cause water to evaporate into a gas.

Frozen water (glaciers, icecaps, and icebergs) in its own sphere is called the “cryosphere”.

Biosphere

The biosphere is composed of all living organisms. This sphere includes all of the microorganisms, plants, and animals of Earth. In fact, biosphere involves the interaction of the living beings with other segments. Most of the planet's life is found from three meters below the ground to thirty meters above it and in the top 200 meters of the oceans and seas.

Atmosphere

The atmosphere is the body of air which surrounds the earth. It extends from less than 1 m below the earth's surface to more than 348 km above the earth's surface. The upper portion of the atmosphere protects the organisms of the biosphere from the sun's ultraviolet radiation. It also absorbs and emits heat. When air temperature in the lower portion of this sphere changes, weather occurs. As air in the lower atmosphere is heated or cooled, it moves around the planet. The result can be as simple as breeze or as complex as a tornado endangering the survival of life. There is a constant exchange of matter taking place between the atmosphere, biosphere and hydrosphere.

The atmospheric temperature, pressure and density vary considerably with altitude.

- The temperature varies from -100°C to $+1200^{\circ}\text{C}$.
- Atmospheric pressure varies from 1 atmosphere (at sea level) to 3×10^{-7} atmosphere (at 100 km above sea level)
- The atmospheric density at the surface of the earth is about 0.0013 g/m^3 which decreases sharply with increasing altitude.

It is interesting to note that all four spheres can be and often are present in the single location. For example a piece of soil will have mineral material from the lithosphere, there will be elements of the hydrosphere present as moisture within the soil, the biosphere as insects and plants, and even the atmosphere as pockets of air between soil pieces. A detailed description of the structure of atmosphere is given in the next section.

8.3 ATMOSPHERE-COMPOSITION AND STRUCTURE COMPOSITION

The proportions of the various constituents of the atmosphere remain more or less constant upto a height of about 16 km from the surface of earth. This region is sometimes referred to as homosphere. Above this the composition starts showing variability with altitude. In this region, called the heterosphere, gravitational separation takes place as the lightest and fastest atoms and molecules move farther from the earth.

Finally in the upper heterosphere hydrogen and heliums are the most typical gases found. The atmospheric composition of clean, dry air, near the sea-level is given in Table 8.1.

Table 8.1: Atmospheric constituents
at sea-level [%]

N ₂	78.1
O ₂	20.9
Ar	0.93
CO ₂	0.035
Ne	0.0018
He	0.00052
CH ₂	0.0002
Kr	0.00011
H ₂	0.00005
Xe	0.00001

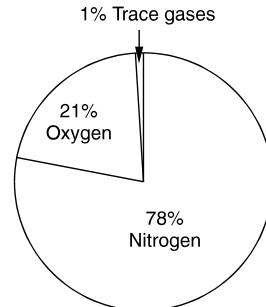


Fig. 8.1: Composition of Atmosphere

The Layers of the Atmosphere

The earth's atmosphere is highly structured. Because of earth's gravitational pull, the atmosphere is horizontally stratified. It can be divided into four zones depending on the temperature profile. (Fig. 8.2)

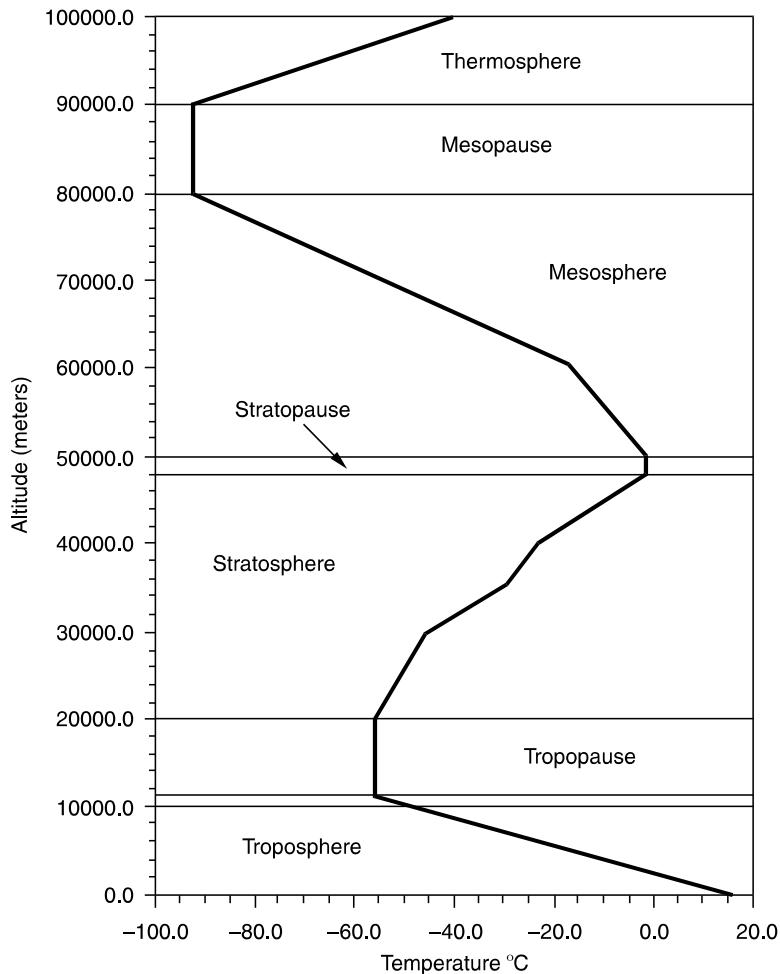


Fig. 8.2 Layers of atmosphere.

- (i) Troposphere
- (ii) Stratosphere
- (iii) Mesosphere
- (iv) Thermosphere

- (i) **Troposphere:** The word troposphere comes from tropein, meaning to turn or change. All of the weather occurs in the troposphere. It has the following characteristics:
 - It is nearest to the earth's surface and extends from the earth's surface to an average of 12 km.
 - The temperature generally decreases with increasing height upto the top of the troposphere (tropopause). It drops from about 17°C to - 52°C.
 - The troposphere ends at a point where temperature no longer varies with height. This area is known as tropopause. Tropopause marks the transition to the stratosphere.

- The density of air, in this region, decrease exponentially with increasing altitude. The lower density of molecules higher up would not give us enough oxygen to survive.
- The moisture content also decreases with height upto tropopause.
- Towards the top of the troposphere speed of the winds increases.
- The tropopause and troposphere are known as lower atmosphere.
- The top of the troposphere is extremely cold and windy place.

(ii) **Stratosphere:** The gradual change from the troposphere to the stratosphere begins at approximately 11 km high. The stratosphere has following characteristics.

- It extends upto 50 km high.
- It is dry and less dense than troposphere.
- The temperature in the lower stratosphere is extremely stable and cold at -57°C . However, from the middle of the stratosphere, and up, the temperature pattern changes, sharply increasing with height. This is due to increasing levels of ozone concentration which absorbs ultra violet radiation. The temperature reaches to 18°C in the upper atmosphere at 40 km altitude.
- The ozone layer is in the stratosphere.
- The stratopause separates the stratosphere from the next layer.

(iii) **Mesosphere:** The mesosphere has the following characteristics:

- It starts just above the stratosphere and extends to 85 km high.
- The temperature again falls in this region. It reaches to as low as -93°C with increase in altitude. This is due to low levels of ozone and other species that can absorb ultra violet species from sun.
- Mesosphere is separated from thermosphere by mesopause. Mesopause is the region of coldest temperature in the atmosphere (i.e. about -100°C).
- The regions of the stratosphere and mesosphere along with stratopause and mesopause are called middle atmosphere.

(iv) **Thermosphere:** The transition from the mesosphere to the final thermosphere layer begins at a height of approximately 81 km. Thermosphere has the following characteristics:

- The temperature rises very rapidly with attitude and hence the name thermosphere. The maximum temperature can reach a staggering 1982°C . These extreme temperatures are caused by the absorption of the sun's shortwave ultraviolet radiation.
- The UV radiation penetrates the upper atmosphere and ionizes the atoms. The charged atoms build up to form a series of layers within the thermosphere. This charged layer is sometimes referred to ionosphere. The ionosphere can deflect some radio signals.

8.4 POLLUTION

The earth's environment has been composed in a very unique way for sustaining the life on earth. Through one process, the different constituents of the atmosphere are consumed and through the other, these constituents are released into the atmosphere.

In other words, the composition of atmosphere remains constant. The oxygen cycle in the air provides a very good example. During respiration, oxygen is consumed by living beings and is again released into the atmosphere by plants through a process called photosynthesis.

The things would have been simple, had the man not interfered with the nature. But in the era of industrial revolution, the composition of the atmosphere has been changed undesirably against the nature. Thus we have increased proportions of different harmful constituents in atmosphere and decreased amount of oxygen. In other words, we have polluted the atmosphere. The same is the case with water and soil.

Thus, pollution can be defined as any undesirable change in the composition of air, water and soil or any segment of environment against nature. The pollution results in deteriorating the nature and quality of the environment.

The undesirable or unwanted foreign species causing pollution in air, water and soil are called *pollutants*.

On the basis of factors causing pollution, pollution can be classified under the following heads:

1. Air pollution
2. Water pollution
3. Soil pollution
4. Solid waste pollution
5. Hazardous waste pollution

We will discuss each one of these under the following sections.

8.5 AIR POLLUTION

Air pollution can be defined as the presence of chemicals in the atmosphere in quantities and duration that are harmful to human health and the environment. It occurs when the concentration of certain substances become high enough to cause the atmospheric environment to become toxic.

Air pollution is the most crucial from the point of human health. Every human being inhales about 15 - 22 kg of air daily and if that air is polluted, one can easily imagine the damage it can cause to human health.

Source of Air Pollution: The sources of air pollution can be natural or man made.

(i) *Natural sources include*

- Volcanic eruptions emitting poisonous gases like H_2S , SO_2 etc.
- Decay of vegetation,
- Marsh gases

- Pollen grains
 - Forest fires
- (ii) *Man made sources include*
- Increase in population
 - Deforestation
 - Fossil fuel combustion
 - Vehicular emissions
 - Industrialization
 - Use of pesticides, insecticides in agriculture.
 - Explosives used in wars.

Types of air pollutants: The undesirable component in the atmosphere, causing pollution is referred to as pollutant.

Pollutants can be classified on the basis of origin and physical state.

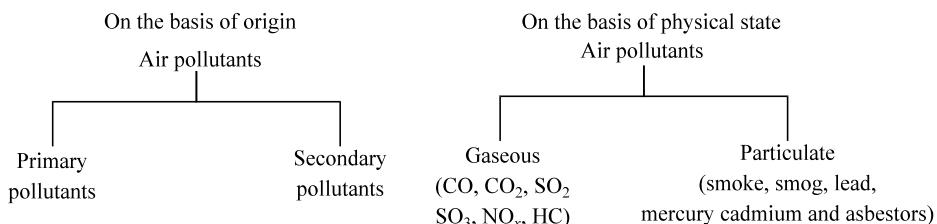
On the basis of origin, pollutants are of two types:

- (i) *Primary pollutant:* Primary pollutants are the products of natural events (like fires, volcanic eruptions) and human activities added directly to air. Examples include, CO, NO₂, SO₂ and hydrocarbons.
- (ii) *Secondary pollutants:* These are formed by the interaction of primary pollutants with each other or with normal components of the air. Examples include ozone, photochemical smog etc.

On the basis of physical state, pollutants are of two types:

- (i) *Gaseous pollutants:* These are the gases which mix with air without settling down. Gaseous pollutants include: CO, CO₂, SO₂, SO₃, NO_x, and hydrocarbons.
- (ii) *Particulate pollutants:* Particulate pollutants comprise of finely divided solids or liquids. These include dust, smoke, smog, lead, mercury, cadmium and asbestos.

Classification of Air Pollutants



8.6 SOME COMMON AIR POLLUTANTS

1. Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless, tasteless gas that is by far the most abundant of the air pollutants.

Source: CO is produced due to:

- incomplete combustion of fuels.
- automobile exhausts. (accounts for 70% of CO in the atmosphere)
- industrial operation

CO is also produced through natural processes such as volcanic activity, natural gas and marsh gas emissions.

Sink for CO: Sink is a system which absorbs/store the pollutant, thereby, nullifying its harmful effect. A large mass of CO is generated and also there is continued increase in CO emissions within recent years. So it is obvious that the amount of CO should also increase in the atmosphere. But it has been found that the amount of CO in the atmosphere remains relatively constant suggesting that a sink or scavenging process also exists in the atmosphere. The micro organisms present in the soil act as a major sink for CO.

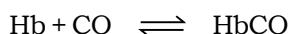
A significant amount of CO is converted into CO_2 by these micro organisms.

Effects: The levels of CO present in the urban air do not effect significantly the plants and materials. However, these levels adversely affect human health. In urban areas, the soil available is insufficient to act as a sink thereby increasing the level of CO beyond permissible limits.

Carbon monoxide interferes with the blood's ability to carry oxygen to different parts of the body. The oxygen combines with haemoglobin, which is also known as oxygen carrier, to form oxyhaemoglobin. This oxyhaemoglobin travels to the different body cells where it gives oxygen to the cell and takes up CO_2 through the lungs.



However, if large amount of CO is present in the surroundings, is inhaled, it readily binds to haemoglobin to form carboxyhaemoglobin. Carbon monoxide, in fact, has a much greater affinity for haemoglobin (about 250 times) than oxygen because it forms a stronger complex with haemoglobin.



Thus the blood (haemoglobin) would carry less oxygen to various parts which inturn affects the brain function. The symptoms include laziness, exhaustion, headache. Acute starvation of oxygen (asphyxiation) can lead to coma and death.

Physiological effects can be noted even at small percentage of COHb. As the concentration increases, the severity also increases as is evident from the following table 8.2

Table 8.2

Conc. of COHb	Effect
2.5%	Impairment in time-interval discrimination.
5%	Psychomotor response times are affected.
10%	Dizziness and headache
50%	Lethal

The maximum permissible concentrations of CO in the ambient air is 40 ppm for an exposure of 6 - 8 hours. CO concentration in urban areas range from 5 - 50 ppm but on congested red lights the concentration can increase to more than 100 ppm. Cigarette smoke contains more than 400 ppm of CO and smokers frequently have COHb levels between 5 to 10 percent.

Fortunately CO is removed from the blood stream when clean air is inhaled.

Control of CO: Control of the CO pollution can be achieved through the following techniques:

- Modification of engine design:* A low fuel-air ratio reduces NO_x emissions but increase CO emissions. So engine design should be modified so that right proportion of oxygen is maintained for complete oxidation of carbon and hydrogen to CO_2 and H_2O respectively.
- Fuel modification:* The fuels which release lesser amounts of CO are recommended to be used. These fuels include natural gas, methane and blends of light hydrocarbons.
- Treatment of exhaust gases:* Two stage catalytic converters are in use to lower the pollution from exhaust gases. In the first stage NO_x are reduced to N_2 and NH_3 in presence of catalyst such as Pt, Pd and Ruthenium in the presence of reducing gas such as CO. In second stage, oxidizing catalysts of noble metals (Pt, Ru) supported on ceramic materials are used, which ensure oxidation of CO to CO_2 .

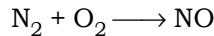
2. Oxides of Nitrogen (NO_x)

A number of oxides of nitrogen such as NO, N_2O , NO_2 , N_2O_3 and N_2O_5 are introduced into the atmosphere due to natural as well as human activity. Out of these, the two oxides NO and NO_2 are responsible for pollution and are considered as pollutants and are represented by NO_x .

NO_2 is reddish brown in colour having pungent smell and is suffocating, whereas NO is colourless and odourless gas.

Source: The source of NO_x include:

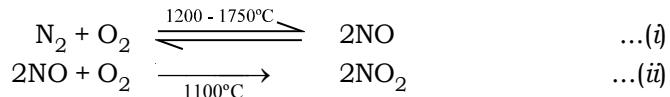
- Natural:* During lightning discharge, N_2 and O_2 in air combine to form NO



NO_x is also formed by the fixation of nitrogen from atmosphere or from nitrogen compounds present in organic matter.

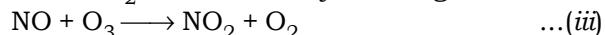
- Man-made sources:*

- NO is formed from N_2 and O_2 at very high temperatures ($\sim 1210^\circ\text{C}$ to 1765°C). This temperature is usually attained during combustion of fossil fuels in air



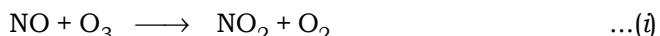
Though the (i) reaction is reversible but rapid cooling of combustion product prevents the dissociation of NO.

The formation of NO_2 by (ii) reaction is quite slow and is not more than 0.5% of the total NO_x present. However, the main reaction through which NO_2 is formed is by reacting with ozone.

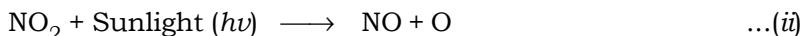


- NO_x is also produced in chemical industries as by products such as in coal based power plants, sulphuric acid and nitric acid manufacturing industries.

Sink for NO_x : The NO and NO_2 undergo various photochemical and chemical reactions in the atmosphere leading to the formation of HNO_3 . Thus NO_2 , NO, pollutants get precipitated as nitrates during rainfall. Ozone plays a significant role in these photochemical reactions.



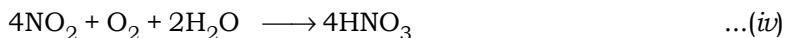
It should be noted that NO remove ozone from atmosphere and this occurs naturally in unpolluted atmosphere.



The nascent oxygen formed in the above reaction then reacts with one of the oxygen molecules producing ozone.



Thus the destruction of NO_2 (reaction ii) and regeneration of NO_2 reaction (i) is a cyclic process. Moreover the amount of ozone should also remain constant as it is used in reaction (i) and regenerated in reaction (iii). However, in the presence of volatile organic compounds, NO_2 follows an alternate path. It reacts with water in presence of oxygen resulting in the formation of nitric acid.



The HNO_3 comes down from the atmosphere to the surface of earth in the form of acid rain. Here it reacts with bases such as ammonia, lime etc. to form nitrates.

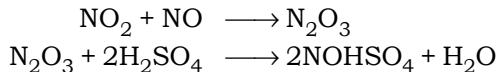
Effects

- Almost all the NO_x emissions are in the form of NO, which has no known adverse health effects at the concentrations found in the atmosphere.
- However NO can oxidize to NO_2 , which in turn may react with hydrocarbons in the presence of sunlight to form *photochemical smog* (discussed later). Photochemical smog is injurious to health.
- The HNO_3 formed by NO_2 causes *acid rain* (discussed later) which has corroding effect on marble and the metallic structures. Moreover, acid rain decreases the pH of the soil, affecting its fertility.

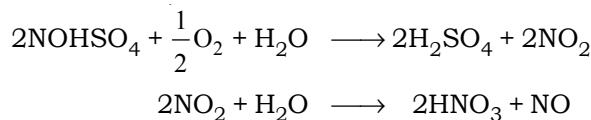
- At higher concentrations than are normally found in the atmosphere, it is an acute irritant. Prolonged exposure to relatively low concentration, has been found to cause bronchitis in children.

Control of NO_x: The control measures for NO_x emissions include the following:

- Modifying the engine design:* Reducing the amount of excess air for combustion in air helps in controlling NO_x emissions. For instance NO_x decreases from about 600 ppm at 25% excess air to 175 ppm at 1.5% excess air. The burners are so modified that the fuel and air mix more slowly reducing the intensity and temperature of combustion. Two staged combustion process is employed for the purpose.
- Scrubbing the flue gases:* The flue gases are scrubbed with H₂SO₄ in a scrubber

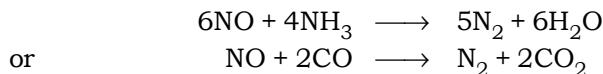


The reaction product obtained from the scrubber is then decomposed.



Excess NO and NO₂ are again circulated though the scrubber.

- Selective catalytic reduction:* The selective catalytic reduction can be achieved through CH₄, NH₃ and CO. The NO_x is added to the exhaust gases and mixture is passed over a fixed bed catalyst such as copper oxide.



It is interesting to note that the air pollution control methods also require modification of combustion methods. But the combustion process that improve CO emissions tend to make the emissions of NO_x problem worse, and vice versa. For example, to control CO, the air supply should be increased and temperature should be raised so that complete combustion takes place. This however is just the reverse if we want to control the emissions of NO_x which requires just opposite conditions.

3. Oxides of Sulphur

Oxides of sulphur, SO₂, SO₃ are represented as SO_x. SO₂ is the second most important contributer to air pollution. Though a small concentration of sulphur oxides is desirable for plants and animals but at higher concentrations, it is injurious. Both SO₂ and SO₃ are colourless gases with pungent smell.

Sources

- Natural sources such as volcanic eruptions constitute to about 67% of SO_x pollution.
- Man made sources the sulphur emissions from petroleum refining, copper smelting and cement manufacture plants.

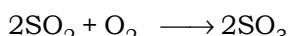


- The burning of fossil fuels in thermal power plants, electric power plants are also one of the main sources of SO_x emissions.



SO_x produced (from the fuel) from natural sources are uniformly distributed all over the globe but SO_x made from man-made sources is more in urban areas.

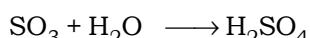
- A small amount of SO_2 undergoes photolytic oxidation in the air to form SO_3



Sinks for SO_x : The sulphur dioxide released in the atmosphere is converted to sulphur SO_3 by photolytic and catalytic processes involving ozone.



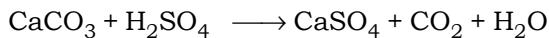
Sulphur oxides combine with water vapour to produce H_2SO_4 aerosol which give rise to the so called “acid-rain” droplets



H_2SO_4 combines with the lime-stone minerals and thus removed from atmosphere. In other words limestone minerals act as a sink for sulphur dioxide.

Effects

- Sulphur dioxide is perhaps the most damaging among the various gaseous air pollutants.
- One of the main causes of ‘acid rain’ are the oxides of sulphur.
- SO_2 and SO_3 are strong irritants to the respiratory tract. SO_2 is highly water soluble, much more so than any of the other criteria pollutants. As a result, when it is inhaled it is absorbed in the upper respiratory tract.
- If along with sulphur dioxide, the particulate matter in air is also present, the combination becomes detrimental to health. In fact, in every major air pollution episode, this combination has been found to be the major cause leading to death. This combination is suggested as one of the reasons of chronic bronchitis.
- Sulphur dioxide has a very damaging effect on plants. If plants are exposed to SO_3 even at a low concentration (0.03 ppm) for a few weeks, the formation of chlorophyll is slowed down resulting in loss of green colour of leaf. This is called chlorosis.
- Prolonged exposure to sulphur oxide which gets converted to sulphates causes serious damage to buildings, marble, lime stone. The carbonates in these materials are replaced by sulphates.

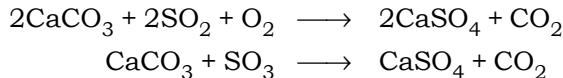


The CaSO_4 so formed is water soluble and easily washes away, leaving a pitted surface. Many of the world's historic buildings and statues are rapidly being degraded due to this exposure.

- Wool, cotton and leather materials are rotted as a result of the absorption of SO_2 and its oxidation to sulphuric acid, which attacks the proteins in these materials.
- Paper also absorbs SO_2 which is oxidised to H_2SO_4 causing paper to become brittle and fragile.

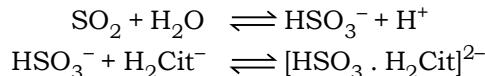
Control of SO_x : SO_x can be reduced and controlled by number of ways.

- Use of fuels having low content of sulphur.
- By removing SO_2 from the exhaust gases by using chemical scrubbers. The chemical scrubbers which are used include :
 - (a) *Lime stone:*



The flue gases (exhaust gases) are passed through the slurry of CaCO_3 which reacts with SO_2 and SO_3 to form CaSO_4 . Though this method is economical but huge amounts of CaSO_4 are produced, the disposal of which is a great problem.

- (b) *Citric acid:* Another method employs the use of citric acid which absorbs the SO_2 from the flue gases. The flue gases are passed through a solution containing citrate ions. The HSO_3^- ions, produced from SO_2 and H_2O , combine with citrate ions to form citrate complex.



The solution containing citrate ion is transferred in a closed vessel and H_2S is passed through it. Sulphur precipitates out and citrate ions are regenerated which are used again.

4. Particulates

Atmospheric particulate matter is defined to be any dispersed matter, solid or liquid, in air. The important characteristics of a particulate are

- (a) **Size:** The size of the particulate matter ranges from a diameter of $0.002 \mu\text{m}$ to $500 \mu\text{m}$.
- (b) **Concentration:** The density of particulate material vary from few hundred per cm^3 in clean air to 10^5 per cm^3 in polluted air.

A number of terms are used to categorize particulates depending on their size and phase (liquid or solid). Some of these are:

Aerosol: Aerosol is any tiny particle, liquid or solid dispersed in atmosphere.

Dust: Solid particles are called dust if they are caused by grinding or crushing operations.

Fumes: Solid particles are called fumes if they are formed when vapours condense.

Mist: Liquid particles are called mist, or more loosely, fog.

Smoke or Soot: These are the terms used to describe particles composed primarily of carbon that results from incomplete combustion.

Fly Ash: These are smaller ash particles coming alongwith the furnace flue gases and are produced due to combustion of high-ash fossil fuels as in the thermal power plants.

Source: Natural sources include the particulates released from volcanic eruptions, wind and dust storms etc. Man-made sources include the activities such as burning of wood, coal, oil and gaseous fuels, industrial processes, smelting and mining operations. The fly ash emissions from power plants, forest fires etc. release about 450 million tonnes of particulates per year.

Composition: Particulates include organic and inorganic matter. It is estimated that particulate contaminants contain nearly 22 elements. The particulate matter can be organic or inorganic.

Organic Particulates	Inorganic Particulates
Organic particulates arise from automobile exhausts, combustion of fuels. Organic particulates contain polycyclic aromatic hydrocarbons (PAH) which are carcinogenic.	Inorganic particulates include iron oxide, calcium oxide which result from combustion of coal and metallurgical operations. Lead halides are produced in automobile exhausts. Asbestos dust, a fibrous silicate material is introduced by industrial processes. Aerosol mists are generated from oxidations of SO_2 to SO_3 which form H_2SO_4 in presence of water. Cadmium, arsenic, mercury also contribute to the particulate matter.

Effects: The size and chemical characteristics of the particles in atmosphere are more significant than their concentration.

Harmful Effects on Human Life:

The ability of the human respiratory system to defend itself against particulate matter is determined by the size of the particulate matter to a large extent. Large particles that enter the respiratory system can be trapped by lining and hair of the nose. Smaller particles which move to the throat can be captured by mucus membrane and can be removed by spitting. However, smaller particles traverse right upto the lungs and may deposit there. The harmful effects of particulate matter on human life include the following:

- The smaller particles (smaller than $10 \mu\text{m}$) which are capable of reaching the lungs, accumulate there and act as excellent sites for

adsorption of carcinogenic compounds and may cause lung cancer, bronchial asthma, chronic bronchitis etc. Some of the pollutants, even in small doses, lead to cumulative poisoning i.e. these pollutants are not excreted once they enter the body. The health effects caused by different types of particulates is summarized in table 8.3.

Table 8.3

Pollutant	Source	Effect on health
Asbestos (fibrous silicate material)	Industry, used as insulation materials in floor and ceilings, fire-proofing, asbestos cement sheets.	Lung disease namely asbestosis, lung cancer known as mesothelioma and other respiratory problems.
Lead	Exhaust from leaded gasoline combustion, lead paint, contaminated soil, plumbing.	Cumulative poisoning impaired mental and physical development, loss of memory, convulsions, coma, inhibits the action of enzymes, causes anaemia, impairs kidney functions.
Silica	Dust containing free SiO_2	Silicosis, exerts a noxious or fibrotic local action in lungs.
Mercury	Spillage from thermometers, thermosets etc. mining and refining of mercury, organic mercurials used in pesticides.	<ul style="list-style-type: none"> In vapour form it adversely effect the neurological behaviour in humans, mercury poisoning cause brain damage.
Cadmium	Tobacco products, fungicides, cadmium-nickle batteries, fertilizer industries.	<ul style="list-style-type: none"> Can remain in the body for almost ten years. Lung cancer and kidney damage, bone marrow disorder and cancer. Toxic, carcinogen conjunctivitis, coagulates proteins.
Arsenic	Smoking, pesticides, rodent poisons chemical wastes.	
Fly Ash	Industrial combustion processes	Respiratory deseases, silicosis.

Harmful effects on materials

- Particulates such as fumes, dust, soot, mists and aerosols can bring serve damage to soil, buildings, sculpture and monuments.
- Corrosive particulates accelerates corrosion of the materials.
- Smoke particles stick on every surface of material, forming a film of soot.

Effects on climate

- Particulates play a significant role in maintaining radiation balance and heat balance of earth.

- They provide nuclei for condensation of water vapour leading to the formation of cloud and smoke.
- Particles can absorb free radicals thereby acting as inhibitors for free radical chain reactions.

Control of Particulate Emissions: Many techniques for the control of particulate emissions have been developed. These include:

- Gravity Settling Chamber
- Cyclone Collector
- Filters
- Scrubbers

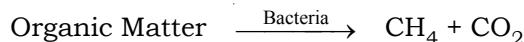
The details are discussed in section 8.8.

5. Hydrocarbons

Many different hydrocarbons are present in air. Most of these are low molecular weight and gases and volatile liquids at ordinary temperatures.

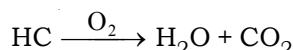
Source

- Natural sources include trees which emit large quantities of hydrocarbons into the air. Methane is the major naturally occurring hydrocarbon emitted in the atmosphere which is produced by anaerobic bacteria through decomposition of organic matter in the soil, water and sediments.



- Man made sources include motor fuels which are mixtures of hydrocarbons. Automobile exhausts emit maximum amount of hydrocarbons in the atmosphere.
- Evaporation of organic solvents used in paints, such as benzene, carbontetrachloride etc. also emit hydrocarbons in air.

Sinks: Hydrocarbons undergo a number of chemical reactions and photochemical reactions through a number of steps and form water and CO_2 in the end.



Effects

- At high concentrations hydrocarbons have carcinogenic effect on lungs.
- Inhalation of benzene, toluene etc. cause irritation in the mucus membrane.
- They are responsible for the of photochemical smog (discussed later)
- Methane causes narcotic effect on human beings.
- Acetylene and propylene at 50 - 500 ppm show toxicity towards plants, damaging their growth.
- Benzpyrine present in tobacco, charcoal etc. induces cancer.

Control

- Hydrocarbons, being thermodynamically unstable tend to get oxidized in the atmosphere by a series of chemical and photochemical reactions. This gives rise to the formation of various end-products such as CO_2 , solid organic particulates and water soluble acids. The solid organic particulates settle down and water soluble acids are washed down by rain.
- The hydrocarbons from vehicular traffic are controlled by the techniques such as incineration, adsorption and absorption.
Adsorption is carried on a bed of carbon or by passing exhaust gases through a liquid in which hydrocarbons will dissolve or become suspended. Incineration or 'after burning' completes the oxidation of hydrocarbon to CO_2 and H_2O .
- Loss of hydrocarbons by evaporation from fuel tanks and carburettor is reduced by installation of a connection system which eventually returns them to the fuel induction system.

8.7 ENVIRONMENTAL EFFECTS OF AIR POLLUTION

The air pollutants discussed above have a great impact on our environment. They are posing a threat to the Earth's general environment. The major environmental effects of air pollution are summarized in fig. 8.3

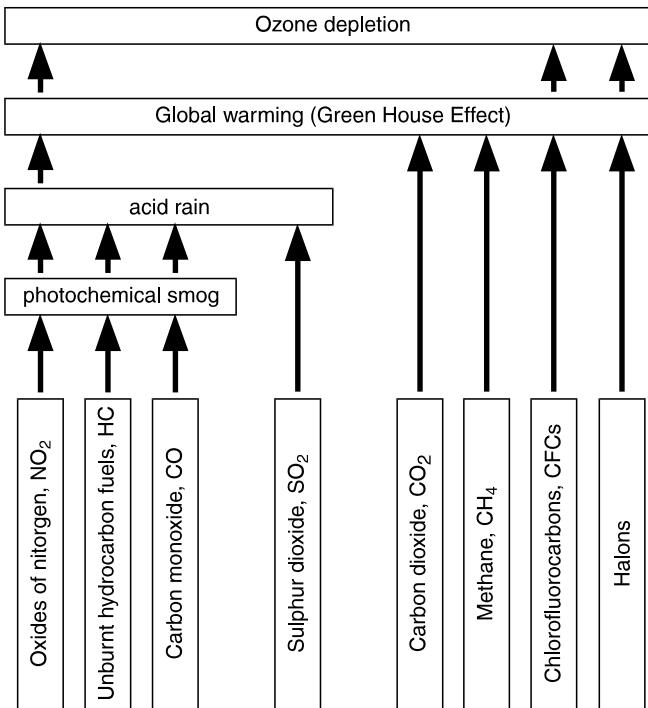


Fig. 8.3 A summary of various environmental problems caused by air pollution.

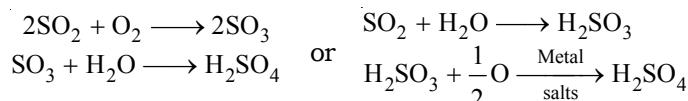
As is evident from the figure that these effects are interrelated and one leads to another. A detailed description of these effects is given below.

1. Photochemical Smog

'Smog' is the combination of two words, 'smoke' and 'fog'. The name was given because fog in the atmosphere condense on the carbon particles of smoke to form smog. However, the smog can have a number of other compositions and methods of formation. Depending upon these factors, smog is of two types:

(i) *London Smog*: The smog formed from SO_x particulates (soot, ammonium sulphate) and humidity is known as London smog. This type of smog caused the death of around 4000 people in London in 1952, hence the name. Five days of calm foggy weather created a toxic atmosphere which caused bronchitis and acute respiratory problems claiming 4000 human lives. This mixture of smoke, SO_x and fog is chemically a reducing mixture, so it is also termed as *reducing smog*.

SO_2 in the atmosphere is converted into SO_3 by a number of chemicals present in the particulates. SO_3 combines with water in the atmosphere forming a fog of sulphuric acid droplets. These droplets condense on the carbon particles of soot and are drawn into the respiratory tract during breathing.



London smog is formed in the early morning hours of winter months. After sunrise it increases due to the oxidation of SO_2 to SO_3 and subsequent combination with water to form sulphuric acid aerosol.

(ii) *Los Angeles Fog (Photochemical Smog)*: Photochemical smog results from the photochemical reactions of the atmosphere. Photochemical smog is the atmospheric haze that is formed near many large cities and it is due to the action of sunlight on the hydrocarbons and the nitrogen oxides. In this type of smog, the main unhealthy ingredient is 'ground level ozone'. This type of smog was first observed in Los Angeles in 1950 and hence is named as 'Los Angeles smog'.

Composition: In 1951, Haagen-Smit observed a key mechanism involving an atmospheric reaction between unburned gasoline-range hydrocarbons (from unburned automobile emission) and nitrogen dioxide in presence of sunlight, a photochemical reaction. The products were peroxyacetyl nitrates (PANs) and ozone. In very simplest terms, we can express the formation of photochemical smog as



Photochemical smog is mixture of substances formed by the reaction of hydrocarbons, NO_x and sunlight.

Photochemical smog is an *oxidizing smog* and should be clearly distinguished from the usual reducing 'smog' which is formed due to the combination of smoke and fog.

Thus, the formation of photochemical smog requires nitrogen oxides ($\text{NO} + \text{NO}_2$), volatile organic compounds (hydrocarbons) and ozone which lead to the formation of peroxyacetyl nitrate (PAN). An account of the source and effect of these chemical pollutants is given in table 8.4

It is worthwhile to mention than PAN was not detected until recognized in smog. It has higher toxicity to plants than ozone.

Table 8.4: Major chemical pollutants in photochemical smog: Source and environmental effects.

Toxic Chemical	Source	Environmental effects
Nitrogen oxides (NO and NO ₂)	<ul style="list-style-type: none"> combustion of oil, coal, gas in both automobiles and industry bacterial action in soil forest fires volcanic action lightning 	<ul style="list-style-type: none"> decreased visibility due to yellowish colour of NO₂ NO₂ contributes to heart and lung problems NO₂ can suppress plant growth decreased resistance to infection may encourage the spread of cancer
Volatile organic compounds (VOCs)	<ul style="list-style-type: none"> evaporation of solvents evaporation of fuels incomplete combustion of fossil fuels naturally occurring compounds like terpenes from trees 	<ul style="list-style-type: none"> eye irritation respiratory irritation some are carcinogenic decreased visibility due to blue-brown haze
Ozone (O ₃)	<ul style="list-style-type: none"> formed from photolysis of NO₂ sometimes results from stratospheric ozone intrusions 	<ul style="list-style-type: none"> bronchial constriction coughing wheezing respiratory irritation eye irritation decreased crop yields retards plant growth damages plastics break down rubber harsh odour
Peroxyacetyl Nitrates (PAN)	<ul style="list-style-type: none"> formed by the reaction of NO₂ with VOCs (can be formed naturally in some environments) 	<ul style="list-style-type: none"> eye irritation high toxicity to plants respiratory damaging to proteins irritation

Development of Photochemical Smog (Conditions required):

For photochemical smog to occur there are four necessary conditions:

- presence of nitrogen oxides
- sunlight
- hydrocarbons
- temperature above 18°C

In cities, early morning traffic increases emission of NO_x and hydrocarbons. These NO_x and hydrocarbons (volatile organic compounds) react and form NO₂. NO₂ breaks down forming by-products and atomic oxygen. Atomic oxygen combines with the molecular oxygen to form ozone.

NO_2 also reacts with VOC to produce toxic chemicals such as PAN. In the evening hours, when the sun goes down, the production of ozone is halted. The ozone in the atmosphere is consumed by different reactions.

Chemistry of Photochemical Smog

Photochemical smog formation proceeds through a sequence of reactions, all involving a free radical mechanism. The main steps can be outlined as follows:

- Nitrogen dioxide is formed as a result of one of the following reactions.
At high temperature of the combustion chamber of the vehicle N_2 and O_2 combine to form NO



The (i) reaction is endothermic so the formation of NO is favoured at high temperatures.

- NO_2 so formed is an efficient absorber of ultra-violet (UV) radiations. Thus UV rays in the sunlight cause the photodissociation of NO_2 to form NO and atomic oxygen



- The atomic oxygen formed in (iii) then reacts with abundant oxygen molecules producing ozone



Ozone can convert NO back to NO_2



Note that nitric oxide (NO) acts to remove ozone (O_3) from the atmosphere.

This set of reaction creates a cycle as represented in Fig. 8.4

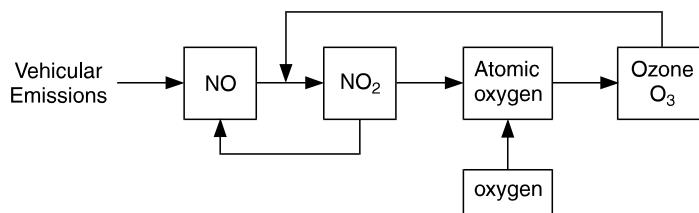
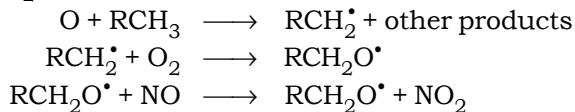


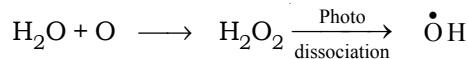
Fig. 8.4

Thus NO and O_3 produced are used up and no extra NO_2 is added up to the atmosphere. But when hydrocarbons are present, then the chain propagation reactions take place.

- The hydrocarbons combine with the oxygen atom produced by the photolysis of NO_2 , to form highly reactive intermediates (free radicals)



Oxygen atom can also react with H_2O to form hydroxyl radicals.



- The free radicals then react with O_2 or NO to produce a number of by products which are highly reactive organic oxidants i.e. secondary pollutants such as acrolein, formaldehyde, peroxyacetyl nitrate (PAN). These secondary pollutants collectively form photochemical smog.

- $RCH_2O^\bullet + O_2 \longrightarrow RCHO + H\dot{O}_2$
- $H\dot{O}_2 + NO \longrightarrow NO_2 + OH^\bullet$
- $RCHO + OH^\bullet \longrightarrow RCO^\bullet + H_2O$
- $RCO^\bullet + O_2 \longrightarrow R-C(=O)-O-O^\bullet$
- $R-C(=O)-O-O^\bullet + NO_2 \longrightarrow R-C(=O)-O-O-ONO_2 \quad (\text{PAN})$
(Acetyl proxy radical)

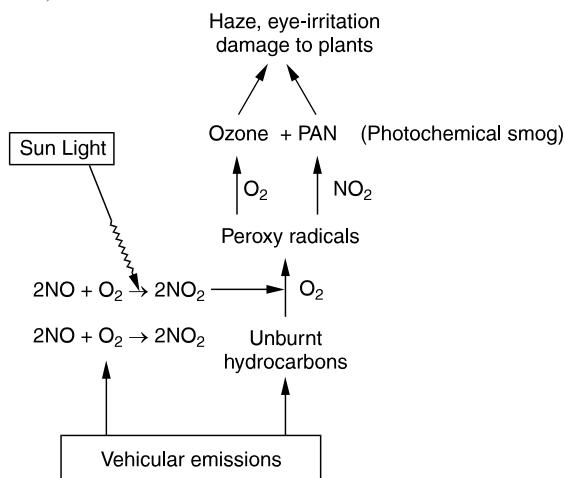
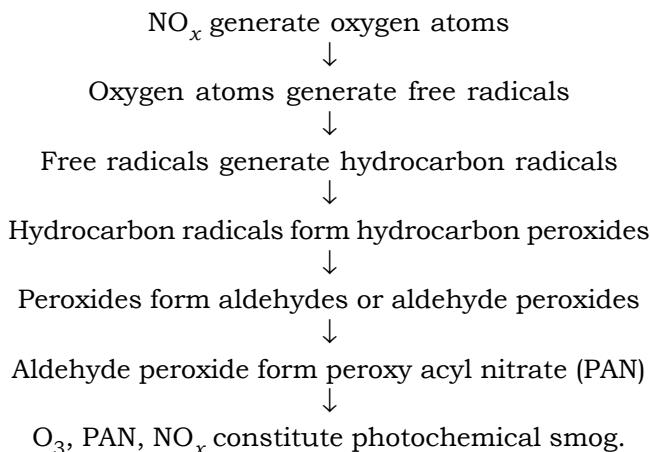


Fig. 8.5 Formation of photochemical smog.

To summarize, the sequence of photochemical smog can be represented as -



All these compounds (PAN, aldehydes, ketones, ozone) produce a number of respiratory problems and irritation in the eyes as is discussed in table 8.4.

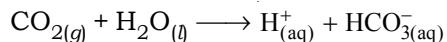
The word ‘smog’ is misnomer here because smog is a combination of smoke and fog and neither of these are present in photochemical smog which is a mixture of NO_2 , O_3 , PAN, aldehydes, and hydrocarbons. The difference between London smog and photochemical smog are tabulated in table 8.5.

Table 8.5

Classical smog (London smog)	Photochemical smog (Los Angeles smog)
<ol style="list-style-type: none"> 1. It involves smoke and fog. 2. This type of smog was first observed in London in 1952. 3. It is formed due to presence of SO_2 and humidity in the air which combine to form H_2SO_4 fog which deposits on the particulates. 4. It is formed in the months of winter particularly in the morning hours when the temperature is low. 5. It is a reducing in character. 	<ol style="list-style-type: none"> 1. This type of smog was observed in Los Angeles in 1950. 2. It is formed due to photochemical reaction taking place when air contains NO_2 and hydrocarbons. 3. It does not involve any smoke or fog. The word smog is a misnomer here. 4. It is formed in the months of summer during afternoon when there is bright sunlight so that photochemical reactions can take place. 5. It is oxidizing in character.

2. Acid Rain

Unpolluted rain water is slightly acidic due to the presence of carbondioxide in air. The CO_2 combines with water droplets to form a weak solution of carbonic acid with a pH of about 5.6



However, in polluted environments, the rain passes through an atmosphere polluted with oxides of sulphur (SO_x) and nitrogen (NO_x). The falling rain water reacts with these oxides to form a mixture of sulphuric acid and nitric acid and water. This is known as acid rain. Therefore rain water with pH value lower than 5.7 is called acid rain. In some parts of the world, a pH as low as 2.5 in rainwater has been recorded.

The term acid precipitation is often used to specifically describe wet forms of acid pollution that is found in rain, snow, fog, cloud and vapour. The term ‘acid rain’ was used by Angus Smith.

It is more correct to refer to acid rain as *acid deposition* because it may be exhibited in more physical states than rain alone.

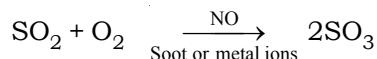
Actually acid rain is the one phase of acid deposition which can either be wet or dry.

Wet deposition: Occurs in the atmosphere and falls on earth as rain, snow, dew etc.

Dry deposition: Dust particles containing sulphates and nitrates, settled on earth, is called dry deposition.

Acid Rain Formation: It is well known that oxides of nitrogen and sulphur are present in the atmosphere. The sources of these oxides have been already discussed earlier in the chapter:

- The oxides of sulphur react with moisture to form H_2SO_4 in sequence of steps -

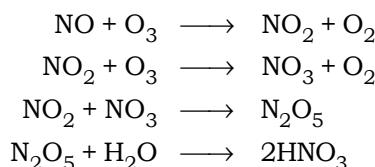


This reaction is catalysed by aerosol containing metal ions of Cu(II), Fe(II) and oxides of Pb etc. Even soot particles are also known to catalyze the reaction.

The SO_3 formed reacts with water vapour in air to form H_2SO_4 .



- Similarly the oxides of nitrogen also undergo a series of photochemical and chemical reactions to form HNO_3 .



These acid droplets are partly neutralised with bases such as particulate lime, NH_3 etc.

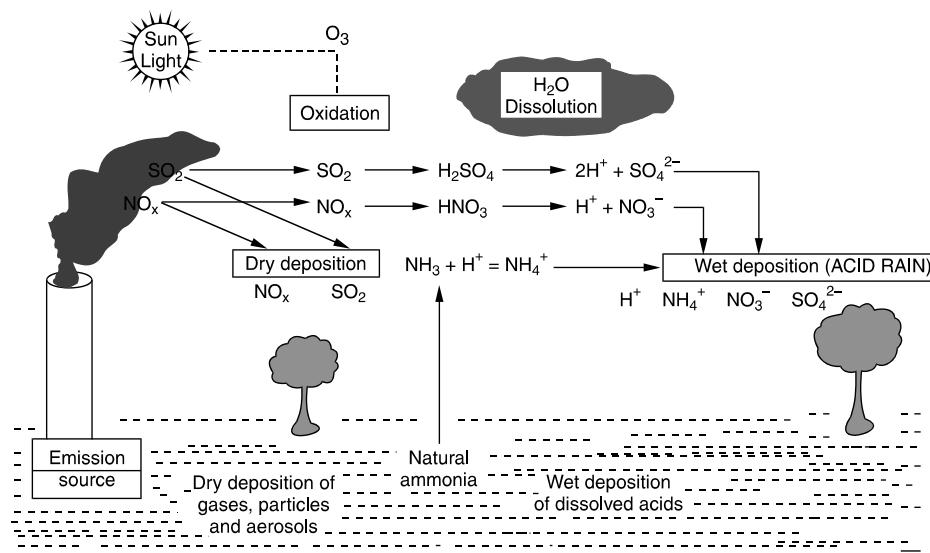


Fig. 8.6 Formation of Acid Rain.

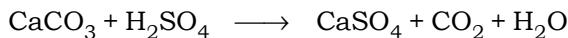


- These salts and remaining H_2SO_4 , HNO_3 droplets alongwith HCl , which is released into the atmosphere by man made and natural HCl emissions, give rise to acid precipitation, known as 'Acid Rain'. H_2SO_4 contributes maximum followed by HNO_3 which in turn is followed by HCl . Fig. 8.6 illustrates the formation of acid rain.

Effects of Acid Rain: Acid rain represents one of the major consequences of air pollution. Longer the SO_x and NO_x remain in the atmosphere, greater are the chances of their oxidation to H_2SO_4 and HNO_3 by various photochemical and catalytic chemical reactions. Acid rain can occur at a place far away from the source of pollutants.

Acid rain influence the environment in several different ways. Some of the harmful effects are discussed below:

- *Acidification of lakes and streams:* Acid rain increases the acidity of water in lakes and streams which is detrimental to fish life. At pH 5, most fish cannot hatch and at lower pH some fish die. In some lakes, acid rain has completely eliminated fish species. Moreover as acid rain flows through soils, aluminium is released from soils into the lakes. Both low pH and increased aluminium levels are toxic to fish.
- *Damage to the vegetation:* Acid rain does not usually kill trees directly. It causes damage due to:
 - damaging their leaves
 - leaching the nutrients available to the plant
 - exposing the plants to toxic substances slowly released from soil.
 - alteration of seed germination characteristics.
- *Damage to building and sculptural material:* The buildings and materials made of marble, lime-stone, mortar etc. suffer extensive damage due to acid rains. The reaction with marble takes place as



The fumes from Mathura refinery are responsible for causing acid rain in Agra, attacking the Taj Mahal. Paints on car can react with acid rain causing fading.

- *Effect on human:* Acid deposition can effect human being life by releasing toxic metals such as mercury and aluminium through the acidification of soil. These toxic metals then end up in drinking water, crops and fish. Aluminium is believed to cause Alzheimer's disease. Moreover, high amount of acidic pollution show increased frequencies of chest colds, allergies and coughs.

3. Greenhouse Effect

The greenhouse effect is the rise in temperature that the earth experiences because certain gases in the atmosphere (H_2O vapour, CO_2 , NO and methane) absorb energy from the sun. Without these gases, heat would escape back into space and earth's average temperature would be about 60°C colder.

The phenomenon has been named as green house effect, because it is similar to heat trapping effect of the glass walls in a horticultural green house. The sun's energy enter through the glass. This energy is absorbed by the soil and other structures of green house and is remitted in longer wavelengths. The longer wavelengths cannot pass through the glass and are retained in the green house making it warm and cosy for the growth of the plants. Similarly in the atmosphere the CO_2 , H_2O , methane etc. play the role played by glass in green house and hence these gases are termed as green house gases.

The Process: The earth receives a tremendous quantity of radiant energy from the sun, about 30% of which is reflected into space by the earth's atmosphere. The remaining energy passes through the atmosphere to the earth's surface. Some of this energy is absorbed by plants to drive photosynthesis and some by the oceans to evaporate water, but most of it is absorbed by soil, rock, and water to increase the temperature of the earth's surface. *This energy is in turn radiated from the heated surface mainly as infrared radiation, often called heat radiation.*

However, only a small portion of this energy actually makes it back to space. The majority of the outgoing infrared radiations, which have longer wavelengths than the solar radiations, are absorbed by the greenhouse gases present in the atmosphere. Thus CO_2 , H_2O strongly absorb infrared radiation and radiate it back into the atmosphere towards the earth. (Fig. 8.7). A net amount of thermal energy is retained by the earth and makes it warmer than it would be without these gases in the atmosphere. The average temperature of the earth's surface is 288 K. It would be – 255 K without the greenhouse gases. Without the greenhouse effect, life on this planet would probably not exist as the average temperature would be a chilly – 18°C.

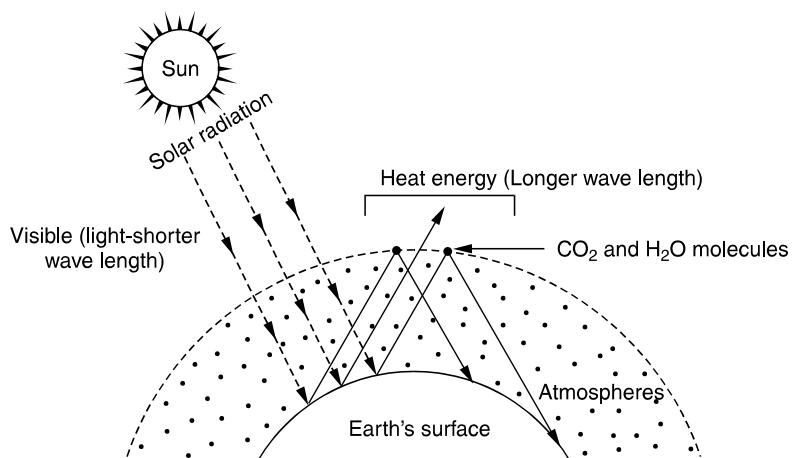


Fig. 8.7 The Visible Light Strikes the Earth and part of it is transforms into Infrared Radiation. Infrared Radiation is strongly absorbed by CO_2 , H_2O , CH_4 and N_2O in the Atmosphere keeping the Earth warmer.

Scientists use the term *albedo* to define the percentage of solar energy reflected back by a surface.

Green House Gases: The four major green house gases are carbondioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chloroflourocabons (CFCs). The CO_2 is the major contributer to green house effect as in shown in fig. 8.8

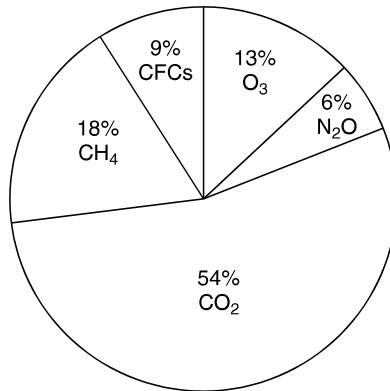


Fig. 8.8 Contribution of atmospheric gases to greenhouse effect.

Enhanced Green House Effect (Global Warming)

The green house has been described as a natural phenomenon that is responsible for life on earth. Natural greenhouse effect is good for human life. However, due to industrial revolution, the concentration of green house gases is increasing constantly as is apparent from table 8.6.

Table 8.6: Past and present concentration and sources

Greenhouse Gas	Concentration 1750 (at the beginning of industrial revolution)	Present concentration	Percent increase	Natural and anthropogenic source
Carbon Dioxide	280 ppm	360 ppm	29%	Organic decay; Forest fires; Volcanoes; Burning fossil fuels; Deforestation; Land-use change
Methane	0.70 ppm	1.70 ppm	143%	Wetlands; Organic decay; Termites; Natural gas & oil extraction; Biomass burning; Rice cultivation; Cattle; Refuse landfills

Greenhouse Gas	Concentration 1750 (at the beginning of industrial revolution)	Present concentration	Percent increase	Natural and anthropogenic source
Nitrous Oxide	280 ppb	310 ppb	11%	Forests; Grasslands; Oceans; Soils; Soil cultivation; Fertilizers; Biomass burning; Burning of fossil fuels
Chlorofluorocarbons (CFCs)	0	900 ppt	Not applicable	Refrigerators; Aerosol spray propellants; Cleaning solvents
Ozone	Unknown	Varies with latitude and altitude in the atmosphere	Global levels have generally decreased in the stratosphere	Created naturally by the action of sunlight on molecular oxygen

As a result of higher concentration of the green house gases, scientists predict that the earth's atmosphere will be warmer and will lead to global warming. The global warming will have drastic effect on climate and may even prove even disastrous to human life. That is why, we often hear about green house effect in somewhat negative terms. But the negative concerns are related to possible impacts of an *enhanced* green house effect. Some scientists fear that if proper precautions are not taken, the concentration of the green house gases in the atmosphere may double in next 50 years leading to increase in global temperature by 4 to 5°C.

Effects of Global Warming: Global warming is one of the greatest challenges of 21st century:

- Predicting the amount of warming is accomplished by computer modelling. Computer model suggest that doubling of CO₂ may raise the temperature between 1 and 3°C. Some scientists estimate that the earth's average temperature has already increased by 0.3 to 0.6°C.
- The increased temperature would lead to melting of glaciers and polar ice caps and the level of sea level may rise thereby flooding the coastal lands and change the climate radically.
- Even 1.5°C raise in surface temperature can adversely affect the food production in the world.
- Changing regional climates could alter forests, crop yields and water supplies.

Remedical Measures for Global Warming

- Reducing consumption of fossil fuels such as coal and petroleum.
- Recovering green house gases from the atmosphere.
- Reduction in CFC production
- Reforestation and conservation of forests, so that plants can take up CO₂.
- Development of environmentally compatible technologies.

4. Ozone Layer and Its Depletion

Ozone is a very small part of our atmosphere but its presence is nevertheless vital to human well-being.

Most ozone resides in the upper part of the atmosphere, called stratosphere extending from 16 km to 40 km. About 90% of ozone is contained in this ‘ozone-layer’ and remaining 10% ozone is present in troposphere. The high concentration of ozone (about 10 ppm) in stratosphere shields us from harmful ultraviolet light from sun and hence is referred to as earth’s protective umbrella.

Ozone is naturally present in our atmosphere. It is formed in the atmosphere in multistep chemical processes that require sunlight. Oxygen which make up 21% of the atmosphere undergo photolytic decomposition in presence of sunlight.

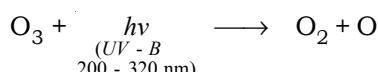


The atomic oxygen rapidly reacts with molecular oxygen to form ozone



where M represents a third body (N₂ or O₂) necessary to carry away the energy released in the reaction.

Stratospheric ozone is considered good ozone because it absorbs ultraviolet (UV - B) radiation, which are harmful for human beings.



The above combination of reactions form a long chain in which oxygen atoms are constantly being shuttled back and forth between the various molecular forms.

Other UV radiation, UV-A is not absorbed significantly by ozone, which reaches the surface of earth. However UV-A is not carcinogenic at usual exposure level of earth. Fig. 8.9 shows the two bands designated as UV-A and UV-B.

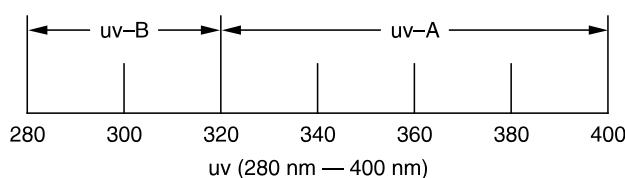


Fig. 8.9 UV bands.

Effect of Ozone Layer

- As is discussed ozone layer protects us from harmful *UV-B* rays absorbing these radiation. In absence of ozone layer these rays would reach earth and cause (i) skin-cancer (ii) damage to the plants (iii) sun burns (iv) melanoma (v) leukaemia (vi) cataracts etc.
- The absorption of *UV-B* radiation by ozone is a source of heat in stratosphere As a result ozone plays a key role in maintaining the temperature structure of earth's atmosphere.

Bad ozone (Tropospheric ozone): Ozone is also formed near earth's surface by chemical reactions caused by presence of pollutants. This ozone is considered bad because more ozone comes in contact with humans, plants and animals. Ozone strongly reacts to destroy or alter many other molecules. In humans excessive exposure to ozone can lead to chest pains, throat irritation and cough. It also contributes to global warming. It also aids in the formation of photochemical smog.

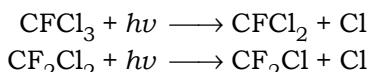
Depletion of Stratospheric Ozone: It was discovered in the mid-1970s that some human activities could destroy ozone and deplete the ozone layer. The emission of ozone depletion gases is a cause of great concern. Ozone depletion has been found to occur through following types of compounds:

- Chloroflouro carbons (freons)
- Nitric oxide
- Reactive hydroxy radicals
- Atomic oxygen

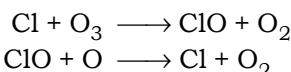
Chloroflouro carbons (CFCs): These are the compounds containing chlorine and flourine. These are introduced into the atmosphere by aerosol sprays in which they act as propellants, refrigerating equipments in which they act as coolants, and in plastic foams such as 'thermocole' or styrofoam.

CFCs are insolubel in water and are not washed out through rain. Slowly they diffuse into stratosphere, which may take several decades.

The CFCs such as CFCl_3 (Feon-II) and CF_2Cl_2 (Freon-12), absorb *UV* radiation resulting in photodissociation to give chlorine atoms.



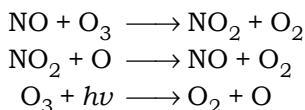
The free Cl now reacts with ozone in a catalytic manner,



Thus Cl is regenerated and can attack other ozone molecules. ClO can react with ozone six times faster than any of the nitrogen species, it becomes the dominant mechanism to destroy stratospheric ozone. It has been found that one molecule of CFC can destroy one lakh of O_3 molecules in the stratosphere Due to depletion of ozone by CFCs it was found in eighties

that a large hole has been created in the ozone layer. That is why the use of CFCs has been completely banned.

Nitric Oxide: The main source of nitric oxide in the atmosphere is nitrous oxide N_2O produced through bacterial action of the surface of the earth. It gradually crosses to the stratosphere and reacts with ozone

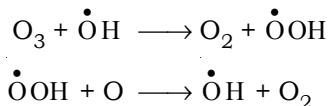


Net reaction



Thus in each cycle two molecules of ozone are destroyed to yield three molecules of oxygen.

Reactive hydroxy radicals: The hydroxy radicals enhance the reactions of CFCs and NO with O_3 . $\cdot\text{OH}$ reacts with ozone as follows:



Effect of Ozone Depletion

- The existing ozone layer screens out more than 99% of incoming *UV* radiations. The small fraction that gets through is known to cause sunburn, skin cancer, and various kinds of damage to animals and plants.
- The genetic material DNA has the capacity to absorb *UV* radiations which may cause various disruptive effects.
- A 5% depletion in ozone produces 10% increase in radiations reaching the earth according to an estimate. That is, it would produce 5 times additional skin cancer per year worldwide.
- Increased *UV* radiations impairs the growth of certain crop plants and adversely affects a wide variety of organisms.
- Exposure to *UV* radiations damages the cornea and lens of eye causing blindness.
- Ozone depletion has a strong effect on climate. Ozone depletion itself is not the principal cause of climate change. However because ozone is a greenhouse gas, ozone changes and climate change are linked in important ways.

Substitute for CFCs: CFCs are found to be the major culprit in ozone depletion hence the use of CFCs has been totally banned worldwide.

Montreal Protocol, an international agreement on substances that deplete the ozone layer, established legally binding controls for about 185 nations on the production and consumption of ozone depleting gases.

Thus substitutes for CFCs were worked out and these days hydrochlorofluoro carbons (HCFC) are being substituted for CFCs in air

conditioning and refrigerating units. Because HCFC are chemically removed primarily in the troposphere and hence do not cause ozone depletion inspite of chlorine atom present. Hydroflouro carbons (HFCs) are also used as substitute compounds for CFCs. HFCs contain no chlorine atom they do not contribute to ozone depletion. However, these may contribute to global warming.

The ozone layer is expected to recover by the middle of 21st century if nations comply with Montreal Protocol.

8.8 AIR POLLUTION CONTROL

The most effective method of dealing with air pollution problem is to prevent the formation of pollutant or to reduce their emissions at the source itself. Some of the industrial processes may be suitably modified so as to minimize the extent of pollution.

Main routes to cutting pollutant emissions are:

- (i) Reducing the consumption of fossil fuels.
- (ii) Better designing of the equipment to control emissions.
- (iii) Removing pollutants from exhaust and gases (source correction methods)

Based on the above points various pollution control methods have been adopted. Some of which are discussed below;

1. Source Correction Methods: Air pollution can be minimised at source by taking the following measures:

- (a) *Substitution of the raw material:* A simple control of air pollution is to use pure-grade raw material for combustion. For example, use of low-sulphur oil and coal is recommended.
- (b) *Modification in the process:* It involves changes and modification in industrial technologies aimed at reducing the atmospheric emissions of pollutants. For example, the use of exhaust hoods and ducts over several types of industrial ovens allow the recovery of various solvents that could have become air pollutants. H_2S emissions can be recycled and used to recover sulphur.
- (c) *Alternations in equipment:* By suitably modifying the carburation and ignition systems in an automobile engine, air pollution can be reduced. For example, the basic oxygen furnace which are replacing open hearth furnace in steel industry pose much less air pollution problems. Evaporation from petroleum refineries can be minimised by suitable design modification of the tanks.

2. Air pollution control devices: Even if the above measures are taken, in certain cases emissons of pollutants cannot be prevented and pollution control devices are employed depending upon the type of pollutant (gaseous or particulate).

(i) **Devices for controlling Particulate Emissions:** Particulate matter in gaseous effluents consists of discrete and minute particles of sizes ranging from $0.1\text{ }\mu\text{m}$ to $100\text{ }\mu\text{m}$. The device selection is based upon physical and chemical characteristics of particulates, size, temperature and humidity. The equipments presently available use one of the following techniques:

- (a) *Gravitational Settling:* This technique is generally employed to remove large particulates ($> 50\text{ }\mu\text{m}$) from the gaseous effluents. In this the velocity of the horizontal carrier gas is reduced adequately so that the particles settle by gravitational force. The collector efficiency is improved by dividing the setting chambers by a number of trays. (Fig. 8.10)

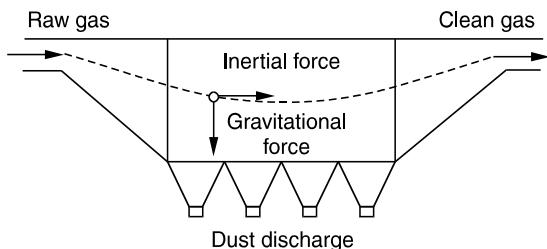


Fig. 8.10 Gravitational settling chamber

- (b) *Cyclonic separators:* In this method, gas containing particulates is allowed to flow into a tight circular spiral-fitted chamber. Now the particulates present in the gaseous stream possess greater inertia than the gas molecules and experience greater centrifugal force, which drive these particulates towards the wall of the chamber. From there they settle down due to force of gravity. These type of cyclone separators one used in power plants and industries dealing with rock products. (Fig. 8.11)

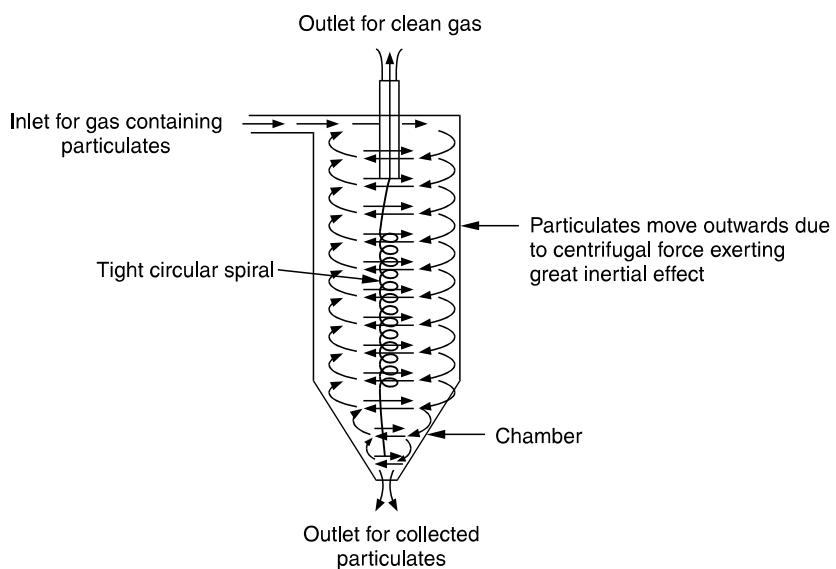


Fig. 8.11 A cyclone collector.

The cyclone collector is most efficient for the removal of large particles of size ranging from 5 - 20 μm (smoke, dust etc.). This technique is more efficient than gravitational settling because centrifugal force on particles in a spinning gas stream is much stronger than the force of gravity.

- (c) *Fabric filters:* Small solid particles are removed effectively by the use of fabric filters. The exhaust gases are forced through bags of very fine cloth-like mesh which are capable of retaining small particles. Fabric filters generally consist of cotton, wool, nylon, dacron or coated glass cloth. Fabric filters are used in industries dealing with rock products, pigments etc. (Fig. 8.12).

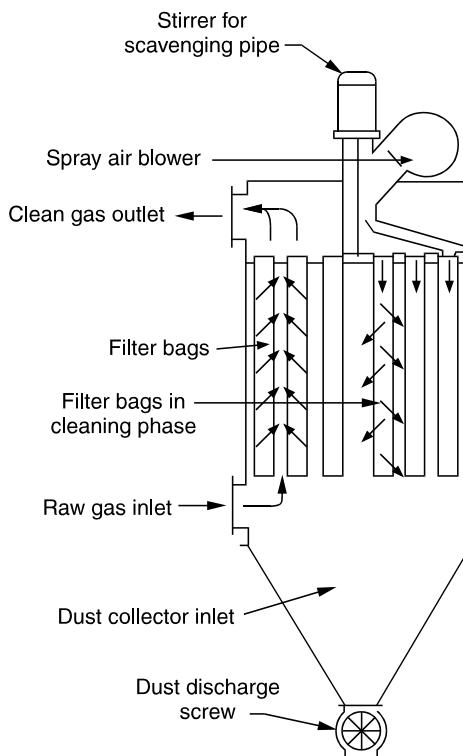


Fig. 8.12 Fabric filters.

- (d) *Electrostatic precipitator:* The most efficient and widely used device for controlling particulate emissions in power plants, cement and paper industry and oil refineries is the electrostatic precipitator. In this technique the particles present in gaseous exhaust are charged electrically and separated from the gas stream under the influence of electric field.

The electrostatic precipitator consists of a series of grounded thin plates which are charged to high voltages, alternately + and -. Particles approaching these plates (around 50,000 V) become charged and are attracted towards opposite plates. From these plates they fall into a collector (hopper) below (Fig. 8.13). The efficiency of electrostatic precipitator is 97.9% and it is

capable of cleaning 150,000 litres of gas per minute at a temperature of 600°C.

Electrostatic precipitators are the devices of choice and are widely used in power plants, paper and pulp industries, chemical industries such as sulphuric acid plants, iron and steel plants.

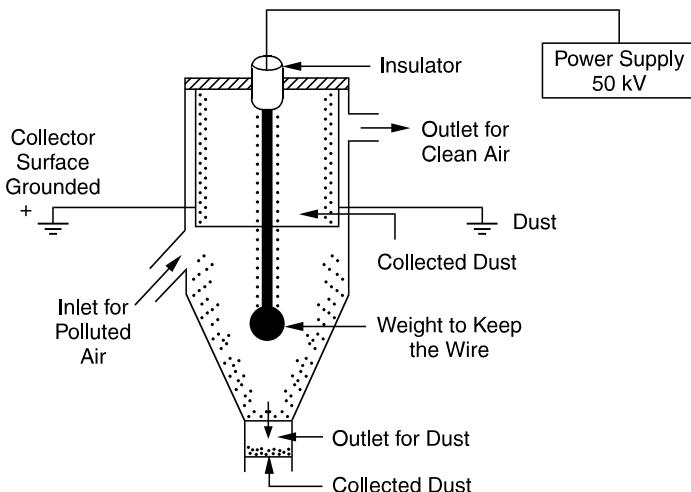


Fig. 8.13 Electrostatic Precipitator.

- (e) **Wet Scrubbers:** A natural cleansing mechanism is wet precipitation through which some pollutants are washed out of the atmosphere. The same concept is employed in wet scrubbers. The exhaust gases are passed through a fire spring of water so that the effective size of the particle is increased due to the formation of water particulate agglomerates. These are then separated from the gas stream by any of the collection mechanism.

However the collected waste water may become a source of water pollution.

- (ii) **Controlling Gaseous Pollutants:** Control of gaseous pollutants can be achieved through source correction methods Some of the methods adopted for control of gaseous pollutants are:

- (a) **Combustion:** When the pollutant contains gases or vapours, which are organic in nature, flame combustion is employed. Combustion converts them to water vapours and CO₂. Catalytic combustion is also employed where low operating temperatures are desired.
- (b) **Absorption/Adsorption:** Gaseous effluents are passed through scrubbers or absorbers. The technique can be dry or wet depending on the phase in which the main reactions occurs. Some of the solvents used for wet scrubbing are:

NaOH, Na₂SO₃ (for SO_x) and NH₄HCO₃, Ca(OH)₂ (for NO_x)

For dry scrubbing, activated carbon is used since it attracts thin layers of gases and vapours to its surface.

8.9 CARBON DIOXIDE SEQUESTRATION

'Over the last century, human activity had a profound impact on the environment. Fossil fuel consumption, deforestation, and other unsustainable land use practices have resulted in a dramatic increase of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions into the atmosphere. Most scientists believe the increase of CO_2 emissions has created the human-induced climate warming conditions that are currently affecting the globe. If this trend continues, climate change will be the inevitable result. The long-term effects of global temperature change are largely unknown; however, adverse effects can already be seen in certain parts of the world in the form of droughts, increased severity of storms, and flooding, particularly in the poorer regions of the globe.

The natural production and absorption of carbon dioxide (CO_2) is achieved through the earth's biosphere and oceans. However, mankind has altered the natural carbon cycle by burning coal, oil, natural gas, and wood and each of these activities has increased in scale and distribution. Carbon dioxide was the first greenhouse gas demonstrated to be increasing in atmospheric concentration.

Atmospheric levels of CO_2 have risen well over 30% from pre-industrial levels of 280 parts per million (ppm) to present levels of 375 ppm. Evidence suggests this observed rise in atmospheric CO_2 levels is due primarily to expanding use of fossil fuels for energy. Predictions of global energy use in the next century suggest a continued increase in carbon emissions and rising concentrations of CO_2 in the atmosphere unless major changes are made in the way we produce and use energy - in particular, how we manage carbon. One way to manage carbon is to use energy more efficiently to reduce our need for a major energy and carbon source - fossil fuel combustion. Another way is to increase our use of low-carbon and carbon-free fuels and technologies (nuclear power and renewable sources such as solar energy, wind power, and biomass fuels). The most recent alternative for managing carbon is sequestration.

Carbon sequestration refers to the provision of long-term storage of carbon in the terrestrial biosphere, underground, or oceans, to reduce the buildup of carbon dioxide (the principal green house gas) concentration in the atmosphere. This is accomplished by maintaining or enhancing natural processes, or the development of new techniques to dispose off carbon.

The main natural sinks are (i) Oceans which take up one third of anthropogenic emissions of CO_2 , (ii) plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass and release oxygen into the atmosphere, and (iii) soils which contain more organic carbon than is contained in vegetation and atmosphere together.

Enhancing Natural Sequestration

However, the natural CO_2 sequestration in the environment is not able to cope up with the increasing anthropogenic emissions, thus natural sequestration processes are enhanced. For instance, reforestation can increase the capacity of forests to act as sink. In the oceans, micrometer-sized iron particles in the form of hematite (iron oxide) or melanterite

(iron sulphate) are added to water to increase the carbon sequestration efficiency. The addition of iron particles stimulate the growth of phytoplankton, which in turn remove significant quantities of CO₂ from the atmosphere via photosynthesis. However, phytoplankton have a complex effect on cloud formation via the release of dimethyl sulfide (DMS) that is converted to sulfate aerosols in the atmosphere, providing cloud condensation nuclei (CCN). But the effect of small scale plankton blooms on overall production of DMS is still unknown. In soil, no-till farming, cover cropping and crop rotation methods are used to significantly enhance carbon sequestration. Conversion to pastureland with good management of grazing, can also increase carbon sequestration in soils.

Artificial Sequestration

For carbon to be sequestered artificially (i.e. not using the natural processes of the carbon cycle) it must first be captured, or it must be significantly delayed or prevented from being re-released in the atmosphere (by combustion decay, etc.) from an existing carbon-rich material, by being incorporated into an enduring usage (such as in construction). Thereafter it can be passively stored or remain productively utilized over time in a variety of ways.

In the oceans the carbon dioxide is directly pumped into the water at depth and is expected to form lakes of liquid CO₂ at the bottom. However, this method could have dangerous consequences. The CO₂ could react with water to form carbonic acid, although most (as much as 99%) remain as dissolved molecular CO₂.

The method of *geo-sequestration or geological storage* involves injecting carbon dioxide directly into underground geological formations. Declining oil fields, saline aquifers, and unminable coal seams have been suggested as storage sites. Caverns and old mines that are commonly used to store natural gas are not considered, because of a lack of storage safety.

Biosequestration of CO₂ involves plantation of biodiesel crops such as Jatropha curcas, switch grass and algal species etc.

According to Kyoto Protocol CO₂ should be brought down to 1990 level for the sustainable development. Thus CO₂ and other related green house gases are being considered for the carbon trading under *Clean Development Mechanism* (CDM) in the stock exchanges. CDM is an arrangement under Kyoto Protocol allowing industrialized countries with green house gas reduction commitment to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reduction in their own countries. An industrialised country that wishes to get credits from a CDM project must obtain the consent of the developing country hosting the project that it will contribute to sustainable development. The project is then submitted to CDM Executive Board for approval. Once the project is approved and registered, the CDM Executive board issues credits called *Certified Emission Reduction* (CERs) commonly known as *carbon credits* where each unit is equivalent to the reduction of one metric tonne of CO₂ or its equivalent to the project participants based on the monitored difference between baseline and actual emissions. (Carbon credits are discussed in the last unit in detail).

8.10 WATER POLLUTION

When toxic substances enter lakes, streams, rivers, oceans and other water bodies, they get dissolved or lie suspended in water. This results in the pollution of water whereby the quality of water deteriorates.

The word polluted water is defined as the deterioration of physical, chemical and biological properties of water brought about mainly by human activities and natural resources and which cause harmful effects on human and aquatic life.

Sources of Water Pollution: Water pollution is caused by natural as well as human activities.

- (i) Pollution from **natural sources** include the decomposed vegetable, animal and weathered products which are brought into main water resources.
- (ii) Pollution from **human activities** include domestic as well as industrial pollution.
 - (a) *Domestic:* The release of huge quantities of municipal and domestic wastes through drains into the rivers and canals is the major cause of pollution. The domestic waste water contain human faeces, kitchen wastes, organic water that provide nutrition to bacteria and fungi.
 - (b) *Industrial:* The industrial sources of water pollution include effluents from factories, refineries and a number of chemical industries. Water get polluted by acids, alkalies, detergents, copper, zinc, lead, mercury, pesticides etc. which are constantly added to water by industrial effluents, deteriorating the quality of water to such an extent that it becomes unsafe for human consumption.
 - (c) Apart from these two, the water is also polluted through **agricultural discharge** such as pesticides, insecticides plant, nutrients, fertilizers etc. Beside this, bacteria, algae, virus also cause water pollution.

8.11 CLASSIFICATION OF WATER POLLUTANTS

The problem of water pollution due to discharge of domestic and industrial water into water has already become a serious problem in the country. Nearly 75 to 80% of India's population is exposed, to unsafe drinking water as a result, enteric diseases often reach epidemic proportions.

To aid in a systematic discussion of water pollutants, they have been classified into nine categories as described below

1. Oxygen demanding wastes
2. Pathogens (Disease causing agents)
3. Synthetic organic compounds
4. Plant nutrients
5. Inorganic chemicals and minerals

6. Sediments
7. Radioactive substances
8. Thermal discharges
9. Oil

Water pollution is often caused by the combination of the above categories, increasing the severity of the problem. The categories are discussed briefly in the following sections:

1. Oxygen Demanding Wastes

Dissolved oxygen (DO) is essential for sustaining the plant and animal life in any aquatic system. Warm-water fish requires a minimum DO level of at least 5mg/L (5ppm). If DO level drops below the level necessary to sustain normal life, then water is classified as polluted.

The amount of DO in water is reduced because of oxygen demanding wastes. Oxygen demanding wastes are substances that oxidize in water, reducing the amount of DO. These substances include the organic substances which are formed due to death and decay of the algae and related species. Oxygen demanding wastes also include organic substances contained in municipal waste water or in effluents from certain industries, such as food processing and paper production. In addition, the oxidation of certain inorganic compounds may also contribute to the oxygen demand. Even naturally occurring organic matter, such as leaves and animal droppings, that find their way into surface water, add to the DO depletion.

The oxygen demanding wastes are oxidized by bacteria or micro organisms consuming dissolved oxygen in water to CO_2 and water. Thus DO levels drop. These substances produce undesirable odour, tastes and reduce the acceptability of water as a domestic supply.

There are several measures of oxygen demand commonly used.

- (a) Biological Oxygen Demand (BOD) BOD is the amount of oxygen required by microorganisms to biologically degrade the wastes. It is most important measure of the strength of organic pollution.
- (b) Chemical Oxygen demand (COD) COD is the amount of oxygen needed to chemically oxidize the waste.

2. Pathogens

Pathogens are disease causing organisms that grow and multiply within the host. Water is a potential carrier of pathogenic micro-organisms.. These pathogens are carried into the water bodies by sewage and wastes from farm and various industries, specially tanning and wheat packaging industries.

Contaminated water caused by poor sanitation can lead to both, water borne and water contact diseases.

Water borne diseases are those acquired by ingestion of pathogens not only in drinking water, but also from water that makes it into a person's mouth from washing food, utensils and hands.

Examples of pathogens associated with water borne diseases include bacteria, viruses and protozoa. A brief account of the diseases caused by these organisms given in table 8.7

Water-Contact diseases do not even require that individuals ingest the water. Just contact with contaminated water may cause disease. For example, Schistosomiasis (bilharzia) is the most common water-contact disease in the world, affecting approximately 200 million people, spread by free swimming larva in water, called cercaria. These larvae attach themselves to human skin, penetrate it and enter the blood stream.

According to WHO report approximately 80 percent of all sickness in the world is attributed to contaminated water.

Table 8.7: Diseases Commonly found in polluted water

Disease	Agent Type of organism	Symptoms
Cholera	Vibrio cholerae (Bacterium)	Severe diarrhea, vomiting fluid loss, cramps and coiiape.
Dysentery	Shigella dysenteriae (Bacterium)	Infection of the colon causes painful diarrhea with mucus and blood in the stools
Enteritis	Clostridium perfringens (Bacterium)	Inflammation of the small intestine cause general dicomfort loss of appetite abdominal cramps and diahrea
Typhoid	Salmonella typhi (Bacterium)	Early symptoms include headache, loss of energy, fever later a pink rash appears along with hemorrhage in the intestine
Infectious Hepatitis	Hepatitis virus A (Virus)	Inflammation of liver causes jaundice, fever, headache, nausea, vomiting sever loss of appetite;
Poliomyelitis	Poliovirus (Virus)	Early symptoms include sore throat, fever, diarrhea and aching in limbs Spreads to spinal cord, paralysis and atrophy of muscles.
Amoebic Dysentery	Entamoeba histolytica (Amoeba)	Infection of the colon causes painful stools; abdominal pain
Schistosomiasis	Schistosoma (Fluke)	Disorder of the liver and bladder, causes blood in urine, diarrhea, weakness, lack of energy, repeated abdominal pain.
Ancylostomiasis	Ancylostoma (Hookworm)	Severe anemia sometimes symptoms of bronchitis.

The coliform group of bacteria are considered reliable indicators of the hygienic quality of water. **Escherichia coli** (*E. coli*), belonging to the coliform group is harmless bacteria found in large number in human faeces. A large concentration of *E. Coli* in water indicates faecal contamination and evidence of the presence of pathogens.

3. Synthetic Organic Compounds

These include pesticides, synthetic organic chemicals and detergents. In contrast to organic wastes, these compounds are not biodegradable and persist for longer periods. Most of these are accumulative toxic poisons and ultimately reach objectionable levels in water. Out of various synthetic organic compounds, the pesticides and detergents have been subjected to intensive study because of their liberal use resulting in water pollution.

Pesticides The term pesticide is used to cover a range of chemicals that kill organisms that humans consider undesirable. Pesticides can be classified into three main classes of insecticides, herbicides and fungicides. Other types include rodenticides, molluscicides and acaricides.

Pesticides enter the water body from surface run off from agricultural lands, waste discharge by pesticide manufacturers and by other means. Because of their world-wide usage, nearly all the rivers and oceans of the world contain pesticide residues.

There are three main groups under which the pesticides can be categorized — chlorinated hydrocarbons, organophosphorus compounds and carbonate pesticides. The common pesticides and their effects are tabulated in table 8.8

Table 8.8

Pesticide	Effects
1. Chlorinated hydrocarbons – DDT (Dichloro diphenyl trichloro ethane) Chlordane Heptachlor Aldrin Dieldrin Kepone Chlorophenoxy compounds (2,4,5,T, 2 – 4 D)	<ul style="list-style-type: none"> Very persistent (last a long time in the environment) Soluble in lipids and hence can accumulate in fatty tissues Affect the calcium metabolism in predatory birds, resulting in birds, laying eggs with thin shells and consequent reproductive failure. Tends to become more concentrated from one trophic level to another due to the process of *biological magnification. Produce liver cancers Cause birth defects Severe neurological damage. Contains the impurity dioxin, one of the most potent toxins known.

* Biological magnification implies that successively higher trophic levels in food chain are consuming food that has successively higher concentration of pesticides. For example, the concentration of DDT increases as we move from water → plankton → Fresh water fish → Predatory birds.

Pesticide	Effects
2. Organophosphorus compounds Parathion Malathion Diazinon	<ul style="list-style-type: none"> Non-persistent but damage nervous system Acute exposure result in slurred speech, muscle twitching and convulsions.
3. Carbonate Pesticides Propoxur Carbaryl Aldicarb	<ul style="list-style-type: none"> Acute exposure results in nausea, vomiting, blurred vision and convulsions.

It may be emphasized that India is one of the few world's producers of DDT, which is banned in US in 1972 for environmental reasons.

Detergents: The term detergent means cleansing agent. The basic active ingredient in detergents is the surfactant or surface-active agent which contains hydrophobic (hydrocarbon) and hydrophilic (polar) groups.

Surfactants decrease the surface tension of water so that they can penetrate the surface and interstices of the object being cleaned. Although reducing the surface tension is an essential feature of cleaning agents, detergents usually contain 10 – 30 % surfactant. The remainder comprises of polysulphate salts (the builder) and a number of other ingredients. Both the surfactants and builders of detergents create serious pollution problems in water.

Surfactant concentrations as low as 1 ppm produce foam in rivers and in sewage treatment plants. Although these concentrations are non-toxic to humans, the presence of surfactants gives an off taste to drinking water. The presence of surfactants also reduce the rate of oxygen absorption in water and may lead to the symptoms similar to asphyxia in certain kind of fish (trout). Till the early 1960s the surfactants present in synthetic detergent was alkylbenzene sulphonate (ABS). ABS is non biodegradable and cause rivers and sewage treatment plants to become covered with huge amounts of foams. ABS have been now replaced by linear alkyl sulphonate (LAS) which is rapidly biodegradable.

The detergent builders pose greater problem to day. The polyphosphates builders are released into water and act as plant nutrients. The extensive growth of algae consumes most of dissolved oxygen from water.

Nitrilotriacetate (NTA) was considered a replacement but it proved to be hazardous to human health

4. Plant Nutrients (Sewage and agricultural runoff)

Nutrients are chemicals, such as nitrogen, phosphorus, carbon, sulphur, calcium, potassium, iron, manganese etc. that are essential to growth of living things. However, in terms of water, these nutrients are considered as pollutants, when their concentrations are sufficient to allow excessive growth of aquatic plants, particularly algae. When these algae die and decompose they add undesirable odour and objectionable taste to water. Further, the decaying organic matter oxidizes and leads to reduced DO levels.

The gradual accumulation of silt and organic matter in the lake is known as **eutrophication**. A eutrophic lake gets shallower and warmer with further growth and decay of algae and eventually lake turns into a marsh or bog.

The plant nutrients enter in the water through municipal waste water, industrial wastes and runoff from fertilized lands. The green slimy layer seen on the surface of some water bodies is an example of eutrophication of the lake. The slimy layer reduces light penetration and restricts atmospheric reoxygenation of water.

High concentration of nitrogen not only poses the problem of eutrophication but when found in drinking water, it is serious health hazard. Certain bacteria found in the intestine, reduce the nitrate in water to highly toxic nitrites (NO_2). Nitrites have a greater affinity for haemoglobin as compared to oxygen. Thus nitrite attaches to haemoglobin forming methaemoglobin. As a result, the oxygen carrying capacity of the blood is reduced producing a condition called methaemoglobin anemia commonly referred to *blue baby syndrome*. In young babies, it is extremely fatal. Further the nitrates can be converted into nitrosoamines in the body leading to gastric cancer.

5. Inorganic Chemicals and Minerals

This category of water pollutants includes inorganic salts, mineral acids, finely divided metals or metal compounds, trace elements, cyanides, organometallic compounds etc.

These pollutants are added to the water bodies through municipal and industrial waste waters and mine runoff. Most of these substances are toxic and are a health hazard to human life. Some of these pollutants are discussed below in brief.

Acid Mine Drainage: Mine drainage is an important source of increased acidity in natural water. Acid rain also adds to the acidity. The mining of sulphur bearing ores containing lead, zinc and copper lead to acid drainage. Coal mines discharge containing varying amounts of iron sulphide (pyrite) is also a major cause of acid mine drainage. These discharges release considerable quantities of sulphuric acid and ferric hydroxide, (which are formed as result of reactions between air, water and pyrite) into local streams through seepage. Acids cause corrosion of metals and concrete and is fatal to fish.

Soluble Salts: Water naturally accumulates variety of dissolved solids or salts as it passes through soils and rocks on its way to sea. These salts include cations such sodium, calcium, magnesium and potassium and anions such as chloride, sulphate and bicarbonate. The measure of salinity is to determine the concentration of total dissolved solids (TDS). Water with less than 500 mg/L TDS is considered safe for drinking purpose. For irrigation purposes, the TDS above 500 mg/L is also considered harmful.

Salts also cause 'hardness' of water leading to the formation of scale and sludges. High chloride concentration are fatal to fish. One way to approach salt problem is through desalination.

Heavy Metals: The term 'heavy metals' is less precisely defined. In chemical terms it refers to metals with specific gravity greater than about 4 or 5 metals. But more often, the term is simply used to denote metals that are toxic. The toxic properties of numerous metals have been known for years. The metals of particular concern in industrial waste waters are cadmium, chromium, lead, mercury, silver, arsenic, aluminium, copper, cobalt, manganese etc. Some of these, such as chromium and iron, are extremely toxic in higher doses.

Metals may be inhaled or may be digested. These have a range of adverse impacts on the body, including nervous system and kidney damage, creation of mutations and induction of tumours. The kidneys contain millions of excretory units called nephrons and the chemicals that are toxic to kidneys are called nephrotoxins. Cadmium, lead and mercury are examples of nephrotoxic metals.

Table 8.9 summarises the effects of some of the toxic metals.

Table 8.9: Effects of trace metals present in air and water

Pollutant	Source	Effect
Lead	Automobile emissions, paints, storage batteries, lead piping, effluents from printing and dyeing industries	<ul style="list-style-type: none"> Impairment of intellectual development and cognitive functioning Absorbed through gastrointestinal and respiratory tract and cause liver and kidney damage. Permissible limit in drinking water 0.05 mg/L
Cadmium	Effluents from textile, electro plating and chemical plants, Fertilizer industry cadmium nickel Satteries (Nicad)	<ul style="list-style-type: none"> Inhalation of vapours causes kidney damage, bronchitis Once absorbed by the organism remains resident for many years in the body. High dose has been linked to lung cancers. May produce bone defects. Permissible limits in drinking water is 0.01mg/L
Chromium	Metallurgical and chemical industries, pigments for paints cement, paper, ceramic and glass industry.	<ul style="list-style-type: none"> Low level exposure can irritate the skin and cause ulceration Accumulates in the body of fish and adds to the health effects of eating the fish exposed to high levels of chromium. Permissible limit in water 0.05mg/L

Pollutant	Source	Effect
Mercury	Various industrial effluents such as those from paint and paper manufacturing units. Highly prevalent in medical waste, lamps, thermometers, used in dentistry as amalgam for fillings.	<ul style="list-style-type: none"> Builds up in the tissues of fish and other creatures living in contaminated water and may be carried up the food chain to humans. It is proved to be the most toxic aquatic pollutant because of its rapid methylation in aquatic environment by some bacteria. Monomethyl mercury and dimethyl mercury and dimethyl mercury are highly toxic and cause neurotoxicological disorders.
Arsenic	Introduced as a by-product of fossil fuel combustion, irrigation water containing pesticides, chemical wastes	<ul style="list-style-type: none"> Carcinogenic Can cause mild bronchitis Attack — SH group of enzymes and can coagulate proteins.
Silver	Electroplating and photographic industries	<ul style="list-style-type: none"> Fish and lower organisms are susceptible to silver poisoning It is cumulative poison and chronic ingestion can cause permanent discolouration. Permissible limit in drinking water is 0.05 mg/L.

6. Sediments

Sediments include soil, sand and mineral particles washed into the aquatic environment by storms and flood waters. Sediments are the sources of organic and inorganic matter in the streams, fresh water, rivers, and other water bodies. Soil particles eroded by running water ultimately find their way into water reservoirs and such a process is called 'siltation'. Reservoirs and dams are filled with soil particles and other solid materials because of siltation. This reduces their storage capacity. Further presence of suspended solid particles present in the water bodies block the sunlight and hence decrease the process of photosynthesis for aquatic plants. As a result, evolution of oxygen is decreased and it is not enough as required by aquatic animals.

- Sediments increase the cost of water treatment used for culinary purposes.
- Sediments enter pumping equipment and power turbines and increase the turbidity.
- In suspension, the solids may cause thickening of fish gills which may lead to eventual asphyxiation of the fish.

7. Radioactive Substances

Radioactive pollutants enter into the aquatic system through a number of human activities involving the use of naturally occurring or artificially pro-

duced radioactive materials. The radioactive pollutants enter into the water system through a variety of sources such as

- Mining and processing of ores to produce radioactive ores, e.g, uranium and thorium.
- From nuclear power plants and from industrial use of radioactive materials
- Leakage from underground nuclear detonations
- Use of radio isotopes in medicine, industry, agriculture and research operations

The refining of uranium ore is an important source of radioactive waste, producing radionuclides of radium, bismuth etc. Radium is considered to be a hazard in drinking water. It causes various genetic disasters in human beings. Radioactive substances can enter humans with food and water and get accumulated in blood and certain vital organs like thyroid gland, the liver, bone and muscular tissues. These may cause cancers, leukaemia and eye cataract

8. Thermal Discharges

Industry and power plants use large quantities of water for cooling purposes. Used coolant water is usually discharged directly into water bodies. This results in increase in temperature of the water bodies which is called thermal pollution. Coal fired power plants, electric powers, steel and chemical industries as well as atomic energy plants discharge their heated effluents into nearby lakes or rivers leading to thermal pollution.

Rise in temperature of water decreases dissolved oxygen content of water which effects the aquatic life. At 32°F the DO content of water is 15 ppm which is decreased to 6.5 ppm at 64° F. Fishes are killed due to the action of heat on nervous system, inactivation of enzymes and coagulation of cell protoplasm.

An increase in temperature also increases the toxicity of some chemical pollutants.

9. Oil

Oil is an important commodity used in one way or the other. Oil and oil wastes are added to the water bodies from industries as effluents, oil refineries, storage tanks, automobile waste oil and petrochemical plants. Oil is insoluble in water and hence floats over it as a thin layer. This oil may penetrate the feathers of the birds and effect their insulation and buoyancy. Thus birds experience difficulty in floating and flying. The birds may ingest oil while they dive to feed. This ingestion may produce toxic effects.

Moreover the oil slick formed on the surface prevents the diffusion of oxygen into water resulting in decreased concentration of DO.

10. Volatile Organic Compounds

These are one of the most commonly found contaminants in water. Volatile organic compounds are often used as solvents in industrial processes.

They are volatile and hence their concentrations remain as low as few micrograms per litre in surface water. But in ground water their concentrations can be hundreds or thousands of times higher. Volatile organic compounds are toxic and their presence in drinking water is cause of great concern. The following VOCs are tabulated in table 8.10

Table 8.10: Volatile Organic Compounds

Vinyl Chloride	Production of polyvinyl chloride resins	Carcinogenic
Trichloroethylene	Used as a solvent, heat transfer medium, manufacture of CFCs.	Causes tumours in animals.
Trichloroethylene	Solvent, used to clean electronic parts	Carcinogenic
1,2 Dichloroethane	Metal degreaser, used in manufacture of vinyl chloride, varnish removers and soap compounds.	Cause injury to central nervous system liver and kidneys
Carbon tetrachloride	Common household cleaning agent, used in fire extinguisher, solvent	very toxic, only a few millilitres can result in to death

8.12 WASTE WATER TREATMENT

Until 1900's human wastes were simply dumped as raw sewage into the nearest stream or river. But later on when a number of diseases were linked to the waste waters, the treatment of waste water was taken up seriously.

The purpose of waste water treatment is to remove the contaminants from water so that the treated water can meet the acceptable quality standards. The quality standards usually depend upon whether water will be reused or discharged in to a receiving stream..

The waste water is often referred to as *sewage*. Sewage is the liquid water which includes human and domestic waste waters, industrial wastes, ground wastes and street washings. Sewage contains 99.9 percent water and rest being the organic, inorganic compounds in dissolved colloidal or suspended states. It is this small percentage of pollutants that brings about polluted conditions.

Constituents of Sewage

There are various types of chemicals founds in waste water, depending upon the source from where it is being discharged. Depending upon the nature of the sewage it can be grouped as

- (i) *Domestic sewage*: Domestic sewage includes human excreta as well as discharges from kitchens, baths, lavatories etc. from public and private buildings.

- (ii) *Industrial Sewage*: Industrial sewage or waste water may be regarded as the liquid waste water in which industrial effluents are present as main wastes
- (iii) *Storm water*: This is the rain water which flows as runoff from streets, open yards etc.
- (iv) *Combined Sewage*: Combined sewage is the combination of domestic sewage, industrial waste and storm water.

Characterisation of Waste Water (Strength of the Sewage)

The strength or impurity in a particular sewage is usually measured on the following categories.

1. Dissolved Oxygen

Oxygen is poorly soluble in water. The amount of oxygen in water depends on physical, chemical and biological activities taking place in water. The solubility of dissolved oxygen in water at saturation at any temperature and pressure is given by Henry's law.

For determination of dissolved oxygen refer to chapter 1.

Biochemical Oxygen Demand

When biodegradable organic matter is released into water, the micro organisms feed on the wastes and break it down into simpler organic or inorganic substances. If the decomposition takes place in the **presence of oxygen** i.e aerobically, **the non objectionable**, stable end products are formed.



On the other hand if **insufficient oxygen** is available, the decomposition takes place anaerobically. The micro organisms causing the decomposition of the organic matter without the presence of oxygen are entirely different from aerobic bacteria and produce **highly objectionable** end products including H_2S , NH_3 and CH_4 .



The amount of oxygen required by micro-organisms to oxidize organic wastes aerobically is called biochemical oxygen demand (BOD). The BOD of raw water will indicate the extent of organic matter present, thus indicating the extent of treatment required to make it safe for use. The BOD of treated water should be nil, so as to make it free from any organic matter. If BOD is high, the dissolved oxygen becomes low and this results in greater pollution.

Determination: Polluted waters will continue to absorb oxygen for many months, till the oxidation gets completed and hence it is not practical to determine this ultimate oxygen demand which would require an extended

period of time. As a result, it has become standard practice simply to measure the oxygen over a shorter period of 5 days. This is known as 5-day BOD test. **BOD₅ is the total amount of oxygen consumed by microorganisms during the first five days of biodegradation.**

In its simplest form BOD₅ would involve diluting a known volume of sample water with a known volume of pure water, whose oxygen content is already known. This is kept for 5 days at 20°C in a stoppered bottle, away from light. The dissolved oxygen is measured after the period of incubation. The difference between the original oxygen content and residual oxygen content will indicate the oxygen consumed by the water sample in five days in oxidizing the organic matter present in water sample. Thus BOD₅ is given by:

$$\text{BOD}_5 = \text{Loss of oxygen in mg/L} \times \text{Dilution factor}$$

Chemical Oxygen Demand

Although BOD test is applicable to organic wastes, there are many drawbacks. Certain organic materials are not biodegradable and hence can give wrong conclusions that less organic matter is present because BOD of such water samples will be low. In this case COD, Chemical Oxygen demand reveals the real organic content present. Here the oxidation of organic substances present in water is done chemically.

COD, is the amount of oxygen required by organic matter in a sample of water for its oxidation by a strong chemical oxidizing agent such as K₂Cr₂O₇.

Determination: A known amount of K₂Cr₂O₇ is added to a measured amount of the sample and the mixture is boiled with concentrated H₂SO₄. After boiling, the amount of unreacted K₂Cr₂O₇ is determined by titrating against a standard Mohr's salt solution using ferroin as indicator.

The difference between the dichromate originally present and the dichromate remaining unreacted gives the amount of dichromate used for oxidation of organic matter.

2. Dissolved CO₂

Varying amounts of CO₂ are present in water. CO₂ can be picked up from the atmosphere or it is generated at the bottom of the lake due to the decay of organic matter. Rivers receiving acid wastes may also show high CO₂ content.

Determination: CO₂ is determined by titrating the sample water with N/10 sodium carbonate solution using phenolphthalein as indicator. The end point is appearance of pink colour.

3. Free Chlorine

Chlorine determination is necessary in those samples of water that have been treated with chlorine or hypochlorites.

Determination: The estimation of free chlorine is based on oxidation of KI by free chlorine i.e by iodometric titration. (Refer to chapter 1 for details)

4. Dissolved Chlorides

The presence of chlorides in natural waters is due to the discharges of effluents from the industries, irrigation drainage, presence of marine sedimentary deposits etc.

Determination: Chlorides ions can be determined by titration of the water sample against a standard solution of AgNO_3 using potassium chromate as indicator. (Argentometric titration). (Refer to chapter 1 for details.)

5. Total Dissolved Solids (TDS)

Dissolved solids denote mainly the various kinds of minerals present in water. However, some organic substances present in water also contribute to the dissolved solids.

Determination: The amount of total solids in a water sample can be determined very easily as the residue left after evaporation of the filtered sample.

8.13 WASTE WATER TREATMENT PROCESSES

Available waste water treatment processes can be broadly classified as

- Physical processes
- Chemical processes
- Biological processes

These processes consists of a series of unit operations. These are applied in different combinations composition and specifications of the waste water.

Further, the waste waters treatment processes are generally grouped according to the water quality they are expected to produce. These processes are (physical, chemical and biological) grouped as

- (i) *Primary Treatment:* Removes suspended solids and floating matter
- (ii) *Secondary Treatment:* Involves biological process and organic matter is removed.
- (iii) *Tertiary or Advanced treatment:* Physical, chemical or biological processes depending upon the impurities to be removed.

We would be discussing these in detail in the following section.

1. Primary Treatment

Primary treatment plant utilizes physical processes such as screening or sedimentation to remove a portion of pollutants that will settle, float or that are too large to pass through simple screening devices.

Primary treatment comprises two steps, Pretreatment and Sedimentation.

- (a) *Pretreatment:* Pretreatment consists of screening and grit removal. Screening removes large floating objects such as rags, sticks, wood and other large floating and suspended solids. A typical screen consists of a parallel steel bars spaced anywhere from 2 to 7 cm apart.

This may be followed by a wire mesh screen. The material collected on the screens is disposed off. One way to dispose off the material is to use a device called comminuter, which grinds the coarse material in to small pieces which flow along with water and handled in sedimentation tank. After screening, the waste water passes into a grit chamber where the velocity of water is reduced or it is detained for a few minutes. Here sand, grit and other heavy materials settle down. The grit settling chambers are periodically disconnected from the main system to remove grit manually, for possible use in land-filling, road making and on sludge drying beds. Grit also is a food manure for growing crops.

- (b) *Sedimentation:* From the grit chamber, the sewage passes to a primary settling tank known as sedimentation basin. Here the velocity of the water is reduced considerably to allow most of the suspended solids to settle out by gravity. The most common equipment used include horizontal flow sedimentation tanks, similar to the one described under domestic water. The water is detained in the horizontal flow tanks for 2-3 hours resulting in removal of 50% of the suspended solid matter. An efficient sedimentation tank or clarifier removes about 80-90% of the suspended solids and 40% of organic matter. The solids that settle are called primary sludge or raw sludge.

Sedimentation aids: The removal of finely divided solids is difficult by simple sedimentation technique. In such cases, ,mechanical flocculation or chemical coagulation is employed.

In *mechanical flocculation*, the waste water is passed through a sedimentation tank which is fitted with rotating paddles which rotate slowly at a speed of 0.43 m/s. This slow mechanical stirring allows the finely divided solid particles to coalesce into larger particles and settle out.

In *chemical coagulation*, certain chemical substances, known as coagulants are added. Coagulation used for sewage treatment are similar to the ones used in water treatment. The coagulants react with colloidal matter in the sewage to form floc. The floc entraps the smaller particles and eventually settles down as sludge. Common coagulants used in sewage treatment are:

Alum $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$, Copperas $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, hydrated lime, ferric chloride, and chlorinated copperas, $\text{FeSO}_4 \cdot \text{Cl}$ (mixture of ferric sulphate and chloride).

Apart from using coagulants, coagulant aids are also used sometimes for efficient removal of finely divided particles. The commonly used coagulant aids are, activated silica polyelectrolytes (polymers of cynamide or methacrylic acids), and hydrolysed high molecular weight polymers. The coagulant aids draw a number of suspended particles together because of their long chain molecular structure. They also neutralize the charge on the particles by them bringing them closure to form large particles.

In *industrial waste water*, sometimes the primary treatment also includes equalization and neutralization

Equalization: Sometimes different types of wastes are produced by some industries. To apply uniform treatment, different effluents are held in big

tanks for certain periods and are mixed thoroughly to produce homogeneous equalized effluent.

Neutralization: Acidic wastes are neutralized with lime stone and alkaline wastes are neutralized by treatment with sulphuric acid or CO_2 or waste boiler flue gas. If both acid and alkaline wastes are produced in the nearby plants then mutual neutralization by mixing them is the cheapest method of neutralization.

2. Secondary Treatment

In primary treatment, only those materials are taken care of, which can be removed by simple physical or mechanical action. However, in waste water much of the organic material is dissolved or in colloidal form which is not removed by primary treatment. This organic material is oxygen demanding and must be removed further. Thus the main purpose of the secondary treatment is to remove the organic matter. This is achieved through biological processes which are quite similar in concept to the natural biodegradation of organic matter by aerobic bacteria. The various changes which are brought by secondary treatment include:

- Coagulation of the finely divided or colloidal matter.
- Oxidation of the organic matter to CO_2
- Conversion of nitrogenous organic matter to ammonia, which is eventually converted into nitrite and nitrate.
- Anoerobic digestion of the sludge so obtained.

There are three commonly used approaches, all of which take advantage of the biological processes. These processes are

- (i) Trickling filters.
- (ii) Activated Sludge Process
- (iii) Oxidation Ponds (Lagoons).

(i) Trickling Filters (Aerobic filtration)

A trickling filter consists of a rotating distribution arm that sprays the liquid over a circular bed of rocks or other coarse material (Fig. 8.14)

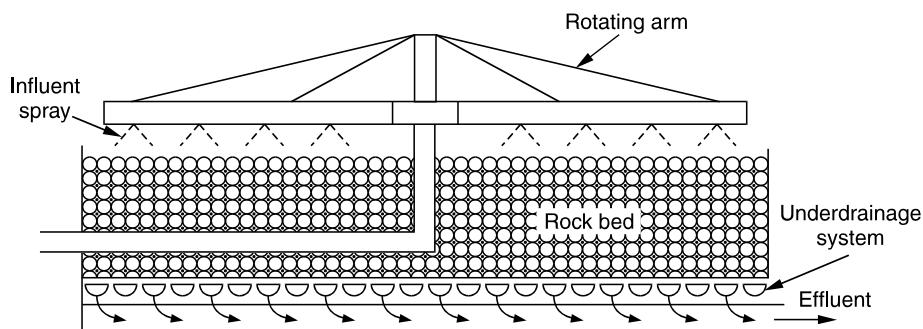


Fig. 8.14 Sketch of the cross section of a trickling filter.

The rock bed is 1 to 3 meters deep with enough open spaces between rocks to allow air to circulate easily. The individual rocks becomes coated with a layer of biological slime or a gelatinous film that absorbs and consumes the wastes trickling through the bed. The slime consists mainly of aerobic microorganisms (bacteria, algae, protozoa etc) which are collectively called **zoogaea** and thrive on the nutrients supplied by the waste water. The effluent (waste water) is sprinkled over this bed packing. As the liquid trickles over the packing, oxygen and the dissolved organic matter diffuses into the slimy layer and are oxidised by the microorganisms to form CO_2 , NO_3 , etc., which diffuse back out of film and appear in the filter effluent. As the microorganisms utilize the organic matter, the thickness of the slime layer increases and it gets detached from the surface of the rock and is carried away along with the effluent, which is referred to as *Humus*. The effluent along with detached slimy layer and treated water is collected at the bottom of the filter and passed on to settling tank, where the detached slimy layer settles down and is removed. The slimy layer (sludge) is then pumped to the sludge digestion unit.

More recently, plastic filters have been used for trickling filters. The plastic filters are light and can be stacked many times higher than the conventional bed rock which crumbles under its own weight if stacked high. These filters, made with the plastic media are sometimes referred to as 'biological towers'.

Advantages of the Process

- Trickling filters are simple to operate and can produce BOD removal to the extent of 65 to 85%
- Constant monitoring is not required.
- Effluents so produced are of better quality.

Limitations

- The microbial film formed is sensitive to temperature changes in winters.
- Efficiency of the filter is dependent upon the composition of waste, pH, size uniformity of the filtering medium and the supply of air.
- Cost of construction is high
- Trickling filters are used for treating industrial waste water from dairy, brewery, food processing, pulp and paper mills, pharmaceuticals, petrochemicals etc.

(ii) Activated Sludge Process

This is the most versatile biological oxidation method, employed for the treatment of waste water containing organic matter. It is a biological waste water treatment process in which a mixture of waste water and activated sludge is agitated and aerated. *The activated sludge is the sludge obtained by settling the sewage in presence of excess of oxygen.* The activated sludge is biologically active because it is heavily laden with microorganisms which are in active state of growth.

The activated sludge treatment process, the effluent after the primary treatment, is passed to an aeration tank where the activated sludge obtained from the previous process is present. The organic matter in the waste water is brought into intimate contact with the activated sludge in presence of adequate amount of oxygen or air. During this aeration process, oxidation of organic matter present in waste water takes place. The oxidation is carried out by microorganisms which are aggregated in masses about 0.1mm in diameter. To maintain aerobic conditions, the air or oxygen is pumped into the tank and the mixture is thoroughly agitated. After about 6-8 hours, the waste water, now referred to as 'mixed liquor' is made to flow through a settling tank where the solid, mostly bacterial masses are separated from the liquid. This settled mass, called the sludge, is partly reintroduced in the aeration tank to provide an effective microbial population for a fresh treatment cycle and is therefore termed as activated sludge. Rest of the sludge is digested in a sludge digester, along with the primary sludge obtained from primary treatment. Fig. 8.15.

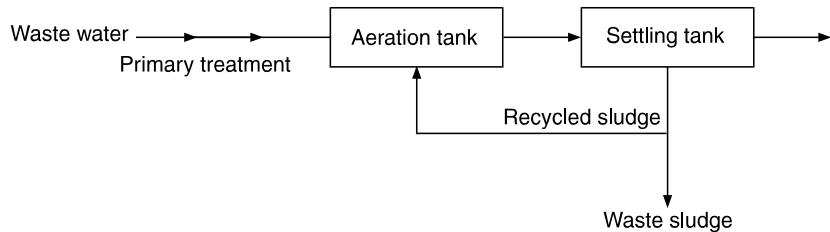


Fig. 8.15 Activated sludge process

Advantages

- The primary advantage of the activated sludge process is, good effluent quality. The effluent after going through activated sludge has little BOD (< 20mg/L)
- It takes less area as compared to trickling water filters.
- The activated sludge process equipment is less expensive.

Limitation

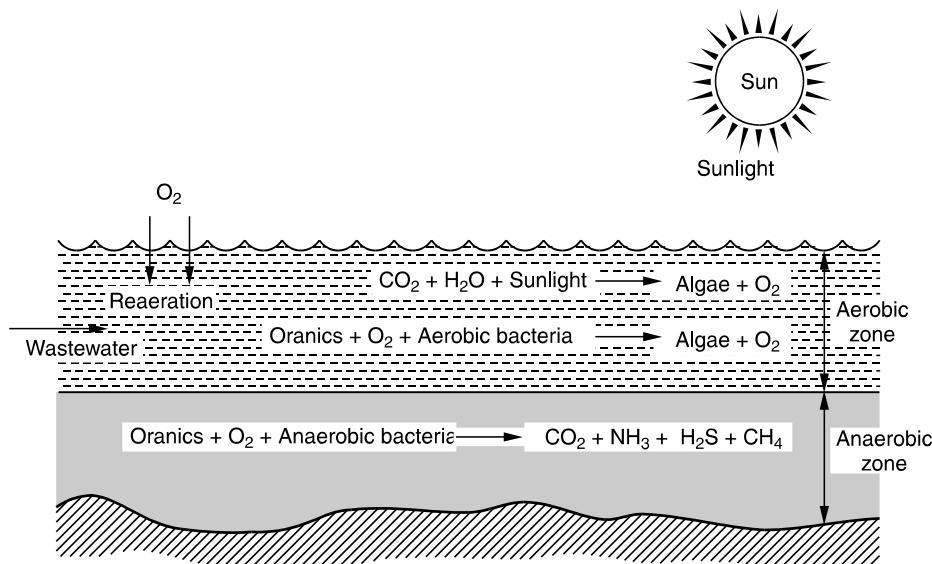
- For the process to be efficient, at least 0.5 ppm oxygen must be present all time.
- The optimum pH range 6.5 to 9.0 has to be maintained throughout.
- Low temperature slows down the rate of metabolism, while high temperature increases the metabolic activity to such an extent that the oxygen is consumed fast, leading to anaerobic conditions.
- The presence of detergents (which are not biodegradable) lead to the formation of foam, making the process difficult.
- The disadvantage of activated sludge process is the production of a huge amount of sludge, which should be digested and disposed off.
- Table 8.11 gives a comparison between trickling filters and activated sludge process for water treatment.

Table 8.11: Comparison of trickling filters with activated sludge systems

Trickling filters	Activated sludge systems
1. Bacterial growth is fixed on the media	1. Bacterial growth is suspended as a dispersed floc
2. All solids from the settler are wasted	2. Solids from the settler are partially recycled
3. Less sensitive to shock loading, more stable	3. More sensitive to shock loadings, required closer process control
4. Produce odours	4. Produce spray clouds
5. Less effective in removing disease-causing organisms	5. More effective in removing pathogens than trickling filters
6. Low operating costs	6. High operating costs

(iii) Oxidation Ponds

Oxidation ponds are large shallow ponds, typically 1-2 m deep, where the partially treated waste water is decomposed by microorganisms. The waste water enter the pond at one end of the treated waste water is collected at the other end. The organic matter is oxidized by the microorganisms present in the pond (such as pseudomonas, flavo bacterium etc). The decomposition of the organic matter near the surface is aerobic, whereas near the bottom, it is anaerobic. Such ponds having a mix of aerobic and anaerobic conditions are called facultative ponds. The oxygen required for aerobic decomposition comes from algal photosynthesis. However deeper ponds known as lagoons are mechanically aerated. Fig. 8.16

**Fig. 8.16** Schematic diagram of an oxidation pond.

Advantages

- The process is simple and cheap.
- Can be used for all types of waste waters
- Due to the light pH of waste water in the pond, the heavy metal ions present in waste water are precipitated as hydroxides which settle as sludge.

Limitations

- The oxidation ponds require larger space.
- Anaerobic conditions may lead to release of bad odours.

The main drawback of the above secondary treatment processes is the formation of sludge. The collection, processing and disposal of sludge can be the most costly and complex aspect of waste water treatment.

Sludge Treatment and Disposal

Sludge is the watery residue from the primary sedimentation tank and humus tank from secondary treatment. The quantity of sludge produced may be as high as 2 percent of the original volume of waste water, depending upon the treatment process used. One of the primary goals of sludge treatment is to separate as much of the water from the solids as possible. In addition to reducing the water content of the sludge, it may be stabilized so that its biological activity and tendency towards putrefaction is reduced.

The traditional method of sludge digestion is **anaerobic digestion**. It involves the microorganisms that thrive in absence of oxygen. The organic material in the sludge is digested by these microorganisms under anaerobic conditions to give carbon dioxide and methane gas. The components of the sewage which can be converted into gases are called volatile solids. Though the sludge digestion is complex, it can be summarized in two steps.

- First the complex organics such as fats, proteins, and carbohydrates are converted to organic fatty acids by acid forming bacteria.
- Then these acids are converted into methane, CO_2 etc by methane forming bacteria.

Most treatment plants use a sludge digester in which the sludge is maintained at 35° for 30 days at a pH of 7.0 to 8.0. CH_4 , CO_2 and NH_3 are liberated as the end products (Fig. 8.17)

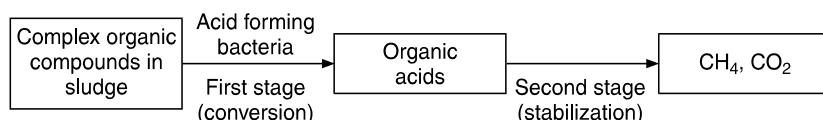


Fig. 8.17 Anaerobic digestion

Digested sludge is removed from the anaerobic digester. This sludge contains 90 to 93% water and is *dewatered*. Dewatering is accomplished by mechanical methods, the most common being centrifugation and filtration,

which includes pressure filtration and vacuum filtration. Drying beds are also commonly used. The dewatered sludge is sent for ultimate disposal. Wet sludge is sprayed on to crop land where it functions as fertilizer. Dried sludge may be used as a landfill or a soil conditioner.

Tertiary Treatment

Any treatment that follows primary and secondary treatment is considered tertiary treatment. Tertiary treatment improves the quality of the effluent further.

The effluent after secondary treatment plant still contains suspended solids (20-40mg/L) which may settle on the stream or river bed and inhibit certain forms of aquatic life. Some amount of BOD, significant amount of nutrients, dissolved solids, traces of organic chemicals and other contaminants are also present. The emphasis on recovery of valuables from industrial wastewaters have created the need for tertiary treatment.

The type of tertiary treatment depends upon the specific goal which include removal of

- suspended solids
- bacteria
- dissolved organic solids
- toxic substances
- nutrients (phosphorus and nitrogen)

Depending upon the required quality of final effluent a number of techniques can be used. Some of which are described in brief as follows:

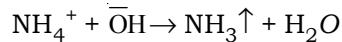
- (i) **Removal of suspended solids (Microstraining):** This can be achieved by **microstraining**. The filter media consists of finely woven stainless steel fabric. The treated waste is allowed to pass through it. The solids which are retained on the fabric are washed into a trough, which recycles the solids to the sedimentation tank.
- (ii) **Removal of dissolved solids:**
 - (a) *Adsorption:* Dissolved solids can be organics or inorganic. The soluble organics are removed by **adsorption** on activated carbon. Special adsorbents are commercially available for the removal of toxic heavy metals from industrial waste water.
 - (b) *Solvent Extraction:* It is sometimes used to recover phenolic materials from waste waters of refineries and coke plants. The waste water is intimately brought in contact with a solvent having high affinity for the solute. The layers (aqueous and the solvent layer containing solute).
 - (c) *Ion Exchange:* Ion exchange is extensively used to remove hardness and iron and manganese salts from drinking water. This technique has been extended to waste water treatment for the removal and recovery of waste during water treatment.

- (d) *Reverse Osmosis:* When waste water containing dissolved solids is allowed to pass through a semi-permeable membrane at a pressure, which is more than osmotic pressure, the water from the waste passes through the membrane. Hence a highly concentrated solution containing dissolved solids is left behind.
- (e) *Chemical precipitating:* The precipitating agents like lime etc remove heavy ions by precipitating these as hydroxides. Precipitating agents include FeSO_4 , alum and ferric chloride.

(iii) Removal of Nutrients

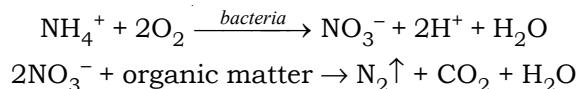
- (a) *Nitrogen Removal:* All forms of nitrogen in wastewater are harmful because plants can utilize the inorganic forms as nutrients, NH_3 can be utilized by bacteria resulting in reduced oxygen in water.

One of the method of nitrogen removal is **ammonia stripping**. Ammonia is present in natural water as ammonium in (NH_4^+) . This NH_4^+ is changed to ammonia gas by raising the pH (the OH^- concentration) of the waste water by adding quick lime.

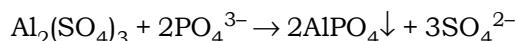


The ammonia gas is liberated

Another approach of nitrogen removal is nitrification i.e. to convert NH_4^+ to NO_3^- , followed by anaerobic stage in which microorganisms convert nitrates to nitrogen gas (N_2)



- (b) *Phosphorus Removal (Chemical precipitation):* Phosphorus is present in the form of orthophosphates (H_2PO_4^- , HPO_4^{2-} and PO_4^{3-}). Phosphates are removed by adding coagulants usually alum $[\text{Al}_2(\text{SO}_4)_3]$ or lime $[\text{Ca}(\text{OH})_2]$.



- (iv) **Removal of bacteria:** Bacteria are removed by retaining the effluents in maturation ponds or lagoons for specified period of times.

8.14 WASTE WATERS FROM SOME TYPICAL INDUSTRIES

1. Textile Industries

Introduction

The textile industry uses vegetable fibers such as cotton; animal fibers such as wool and silk; and a wide range of synthetic materials such as nylon, polyester, and acrylics.

The stages of textile production are fiber production, fiber processing and spinning, yarn preparation, fabric production, bleaching, dyeing and

printing, and finishing. Each stage generates wastes that require proper management.

Waste Characteristics

Taste production involves a number of wet processes that may use solvent.

- Emissions of volatile organic compounds (VOCs) mainly arise from textile finishing, drying processes, and solvent use.
- Process wastewater is a major source of pollutants. It is typically alkaline and has high BOD — from 700 to 2,000 milligrams per liter (mg/l) — and high chemical oxygen demand (COD) in the range 2 to 5 times BOD.
- Wastewater also contains solids, oil, and possibly toxic organics, including phenols from dyeing and finishing and halogenated organics from processes such as bleaching.
- Dye wastewaters are frequently highly coloured and may contain heavy metals such as copper and chromium.
- Wool processing may release bacteria and other pathogens.
- Pesticides are sometimes used for the preservation of natural fibers, and these are transferred to wastewater during washing operations.
- Pesticides are used for mothproofing, brominated flame retardants are used for synthetic fabrics, and isocyanates are used for lamination.
- Air emissions include dust, oil mists, acid vapours, odours, and boiler exhausts.
- Cleaning and production changes result in sludges from tanks and spent process chemicals, which may contain toxic organics and metals.

Treatment Technologies

- VOC abatement measures include using scrubbers, employing activated carbon adsorbers, and routing the vapors through a combustion system.
- A common approach to wastewater treatment consists of screening, flow equalization, and settling to remove suspended solids, followed by biological treatment.
- Physical-chemical treatment is also practiced: careful control of pH, followed by the addition of a coagulant such as alum before settling, can achieve good first-stage treatment. Further treatment to reduce BOD, if required, can be carried out using oxidation ponds or another aerobic process; up to 95% removal of BOD can be achieved.
- Anaerobic treatment systems are not widely used for textile wastes.
- Carbon adsorption is sometimes used to enhance removal. In some case, precipitation and filtration may also be required.

- Residues and sludges often contain toxic organic chemicals and metals. These should be properly managed, with final disposal in an approved, secure landfill.
- Sludges containing halogenated organics and other toxic organics should be effectively treated by, for example, incineration before disposal of the residue in a secure landfill.

2. Tanning and Leather Finishing Industries

Introduction

In the tanning process, animal hides and skins are treated to remove hair and nonstructured proteins and fats, leaving an essentially pure collagen matrix. The hides are then preserved by impregnation with tanning agents. Leather production usually involves three distinct phases: preparation (in the beamhouse); tanning (in the tanyard); and finishing, including dyeing and surface treatment. A wide range of processes and chemicals, including chrome salts, used in the tanning and finishing processes.

The tanning and finishing process generally consists of :

- Soaking and washing to remove salt, restore the moisture content of the hides, and remove any foreign material such as dirt and manure
- Liming to open up the collagen structure by removing interstitial material
- Fleshing to remove excess tissue from the interior of the hide
- Dehauling or dewooling to remove hair or wool by mechanical or chemical means
- Bating and pickling to delime the skins and condition the hides to receive the tanning agents.
- Tanning to stabilize the hide material and impart basic properties of the hides
- Retanning, dyeing, and fat-liquoring to impart special properties to the leather, increase penetration of tanning solution, replenish oils in the hides, and impart color to the leather
- Finishing to attain final product specifications.

Waste Characteristics

- Composite untreated wastewater, amounting to 20—80 cubic meters per metric ton (m^3/t) of hide or skin, is turbid, clouted, and foul smelling. It consists of acidic and alkaline liquors, with chromium levels of 100—400 milligrams per liter (mg/l) sulfide levels of 200—800mg/l – nitrogen levels of 200—1,000mg/l – biochemical oxygen demand (BOD) levels of 900—6,000mg/l, usually ranging from 160 to 24,000mg/l – chemical oxygen demand (COD) ranging from 2,400 to 14,000mg/l – chloride ranging from 27,000mg/l and high levels of fat. Suspended solids are usually half of chloride levels.
- Wastewater may also contain residues of pesticides used to preserve hides during transport, as well as significant levels of pathogens.

- Significant volumes of solid wastes are produced, including trimmings, degraded hide, and hair from the beamhouse processes.
- The solid wastes can represent up to 70% of the wet weight of the original hides. In addition, large quantities of sludges are generated.
- Decaying organic material produces strong odours. Hydrogen sulfide is released during dehairing, and ammonia is released in deliming.
- Air quality may be further degraded by release of solvent vapours from spray application, decreasing, and finishing (for example, dye application).

Treatment Technologies

- Treatment of tannery wastewaters is always required. Some streams, such as slaking liquor (which has high salinity), sulfide-right lime liquor, and chrome wastewaters should be segregated.
- Preliminary screening of wastewaters is required because of the large quantities of solids present.
- Recovery of hair from the dehairing and liming processes reduces the BOD of the process effluent.
- Physical-chemical treatment precipitates metals and removes a large portion of solids, BOD, and COD.
- Biological treatment is usually required to reduce the remaining organic loads to acceptable levels (0.3kg BOD, 2kg COD, and 0.004kg chromium per metric ton of raw hide).
- Good ventilation and minimization of solvent release can avoid the need to collect and treat vapours in carbon adsorption beds, VOC emissions from finishing are approximately 30kg/t if pollution prevention measures are not adopted.
- Maximum upstream pollutant reduction is essential for tanneries, but treatment is also required.

3. Electroplating Industries

Introduction

Electroplating involves the deposition of a thin protective layer (usually metallic) onto a prepared metal surface, using electrochemical processes. The process involves pretreatment (cleaning, degreasing, and other preparation steps), plating, rinsing, passivating, and drying. The cleaning and pretreatment stages involve a variety of solvents (often chlorinated hydrocarbons, whose use is discouraged) and surface stripping agents, including caustic soda and a range of strong acids, depending on the metal surface to be plated.

In the plating process, the object to be plated is usually used as the cathode in an electrolytic bath. Plating solutions are acid or alkaline and may contain complexion agents such as cyanides.

Waste Characteristics

- Any or all of the substances used in electroplating (such as acidic solutions, toxic metals, solvents, and cyanides) can be found in the wastewater, either via rinsing of the product or from spillage and dumping of process baths.
- The solvents and vapours from hot plating baths result in elevated levels of volatile metal compounds, which may contain chromates.
- The mixing of cyanide and acidic wastewaters can generate lethal hydrogen cyanide gas, and this must be avoided. The overall wastewater stream is usually high in heavy metals, including cadmium, chrome, lead copper, zinc, and nickel, and in cyanides, fluorides, and oil and grease., all of which are process dependent
- Air emissions may contain toxic organics such as trichloroethylene and trichloroethane.
- Cleaning or changing of process tanks and treatment of wastewaters can generate substantial quantities of wet sludges containing high levels of toxic organics or metals.

Treatment Technologies

- Segregation of waste streams is essential because of the dangerous reactions that can occur. Strong acid and caustic reactions can generate boiling and splashing of corrosive liquids; acids can react with cyanides and generate lethal hydrogen cyanide gas. In addition, segregated streams that are concentrated are easier to treat.
- Exhaust hoods and good ventilation systems protect the working environment, but the exhaust streams should be treated to reduce VOCs and heavy metals to acceptable levels before venting to the atmosphere.
- Acid mists and vapors should be scrubbed with water before venting. In some cases, VOC levels of the vapors are reduced by use of carbon filters, which allow the reuse of solvents, or by combustion (and energy recovery) after scrubbing, adsorption, or other treatment methods.
- Cyanide destruction, flow equalization and neutralization, and metals removal are required, as a minimum, for electroplating plants.
- Individual design is necessary to address the characteristics of the specific plant, but there are a number of common treatment steps.
- Cyanide destruction must be carried out upstream of the other treatment processes.
- If hexavalent chrome (Cr^{+6}) occurs in the wastewaters, the wastewater is usually pretreated to reduce the chromium to a trivalent form using reducing agent, such as a sulfide.
- The main treatment processes are equalization, pH adjustment for precipitation, flocculation, and sedimentation/ filtration.
- The optimum pH for metal precipitation is usually in the range 8.5-11, but this depends on the mixture of metals present.

- Flocculation agents are sometimes used to facilitate the filtration of suspended solids.
- Modern wastewater treatment systems use ion exchange, membrane filtration, and evaporation to reduce the release of toxins and the quantity of effluent that needs to be discharged.
- Treatment sludges contain high levels of metals, and these should normally be managed as hazardous waste or sent for metals recovery.
- Electrolytical methods may be used to recover metals. Sludges are usually thickened, dewatered, and stabilized using chemical agents (such as lime) before disposal, which must be in an approved and controlled landfill.

4. Pulp and Paper Industries

Introduction

Pulp and paper are manufactured from raw materials containing cellulose fibers, generally wood, recycled paper, and agricultural residues.

The main steps in pulp and paper manufacturing are raw material preparation, such as wood debarking and chip making; paper manufacturing; and fiber recycling. Pulp mills and paper mills may exist separately or as integrated operations. Manufactured pulp is used as a source of cellulose for fiber manufacture and for conversion into paper or cardboard.

Chemical pulps are made by cooking (digesting) the raw materials, using the kraft (sulfate) and sulfite processes. Kraft processes produce a variety of pulps used mainly for packaging and high-strength papers and board.

Mechanical pulp can be used without bleaching to make printing papers for applications in which low brightness is acceptable—primarily, newsprint. However, for most printing, for copying, and some packaging grades, the pulp has to be bleached.

The soluble organic substances removed from the pulp in bleaching stages that use chlorine or chlorine compounds, as well as the substances removed in the subsequent alkaline stages, are chlorinated. Some of these chlorinated organic substances are toxic; they include dioxins, chlorinated phenols, and many other chemicals.

The finished pulp may be dried for shipment (market pulp) or may be used to manufacture paper on site.

Waste Characteristics

- The significant environmental impacts of the manufacture of pulp and paper result from the pulping and bleaching processes.
- In some processes, sulfur compounds and nitrogen oxides are emitted to the air, and chlorinated and organic compounds, nutrients, and metals are chlorinated to the wastewaters.

- In the pulping process, emissions of reduced sulfur compounds, measured as total reduced sulfur (TRS) and including hydrogen sulfide, methyl mercaptan, demethyl sulfide, and dimethyl disulfide, are emitted, other pollutants are particulate matter, sulfur oxides, nitrogen oxides, and volatile organic compounds (VOCs),
- Wastewaters are discharged are high in biochemical oxygen demand (BOD), total suspended solids, chemical oxygen demand (COD), and chlorinated organic compounds, which may include dioxins, furans, and other adsorbable organic halides,
- Phosphorus and nitrogen are also released into wastewater. The main source of nutrients, nitrogen, and phosphorous compounds is raw material such as wood. The use of peroxide, ozone, and other chemicals in bleaching makes it necessary to use a complexing agent for heavy metals such as manganese.

Treatment Technologies

- Sulfur oxide emissions are scrubbed with slightly alkaline solutions. The reduced sulfur-compounds gases are collected using headers, hoods, and venting equipment. Condensates from the digester relief condenser and evaporation of black liquor are stripped of reduced sulfur compound. The stripper overhead and noncondensable are incinerated in a lime kiln or a dedicated combustion unit.
- Electrostatic precipitators are used to control the release of particulate matter into the atmosphere.
- Wastewater treatment typically includes (a) neutralization screening, sedimentation, and floatation/hydrocycloning to remove suspended solids and (b) biological/secondary treatment to reduce the organic content in wastewater and destroy toxic organics.
- Chemical precipitation is also used to remove certain cations. Fibers collected in primary treatment should be recovered and recycled.
- Biological treatment systems, such as activated sludge, aerated lagoons, and anaerobic fermentation, can reduce BOD by over 99%.
- Tertiary treatment may be performed to reduce toxicity, suspended solids, and color.
- Solid waste treatment steps include dewatering of sludge and combustion in an incinerator, bark boiler, or fossil-fuel-fired boiler.

5. Food Industries

- (i) **Dairy : Sources of Waste Waters :** Spillage, washing of cans, water from butter and cheese producing units.
Characteristics : High organic content, high BOD, Foul odour easily putrescible
Treatment : Equalization, Skimming, Grease removal, Biological treatment

(ii) **Distilleries :**

Sources of waste waters : Washings, Spillage

Characteristics : Low pH, High organic matter, very high COD High suspended ad dissolved organic matter.

Treatment : Equalization, Biological treatment

(iii) **Cane Sugar Industry :**

Sources : Cane wash water, effluents from evaporators, spray over-flow, molasses effluents

Characteristics : Coloured, disagreeable odour, contains oil and grease, high BOD, high carbonaceous matter

Treatment : Biological treatment methods are not effective due to high concentration of carbohydrates.

Lagooning, oxidation ponds have been found to be the most practical treatment which is proceeded by equalization and anaerobic digestion.

WEATHER

By absorbing infra-red (as well as by its contact with the hot ground), air heats up. As hot air expands, each cubic meter of it weighs less than before heating. Where the heating is most pronounced, the warm air is more buoyant than the cooler air surrounding it, and tends to float upwards; soaring birds and glider pilots seek such “thermal currents” and allow themselves to be carried upwards by them. This buoyancy is the basic process responsible for weather.

Rising air expands, and expansion of a gas cools it down, which is why mountain tops are cooler. Ultimately, a height is reached where not enough air remains on top to stop the IR radiation from escaping to space. The air then cools by radiation and stops rising, producing a relatively stable layer of the atmosphere known as the **stratosphere**. As one goes up in the stratosphere, air actually gets warmer from the absorption of ultra-violet light by ozone, and this extra heating keeps it even more stable.

Just below the boundary of the stratosphere (“tropopause”), air which has cooled is forced down again by warmer air rising from below. The result is a **circulation** of air, rising hot and returning cold, going around again and again, a motion known as **convection**. On a cold winter day such convection also occurs in homes: near poorly insulated windows the air cools and descends while further inside the room it rises again. The region between the ground and the stratosphere where convection and weather take place is known as the **troposphere**.

Sunlight also evaporates water-from the oceans, from lakes and rivers and from green plants. Energy is invested in turning liquid water into vapour, and therefore humid air has **more** energy stored in it than dry air.

The capacity of air to hold water vapour depends strongly on temperature, and is smaller in cold air (just as less sugar can dissolve in cold water). As warm humid air rises, it expands and cools, and

since it then cannot hold as much water as before, the excess is forced out: Initially into the tiny droplets of clouds, then if the cooling is more drastic, into raindrops.

The remaining air is drier and **warmer** - warmed by water vapor turning back to liquid and returning energy to its surroundings - and warmer air is better able to radiate its heat into space. That is how water, clouds and rain play a major role in the transport of solar heat from the ground back to space and help create the complex patterns of weather and climate.

EXERCISES

Short Answer Questions

1. What are hydrosphere, lithosphere and biosphere?
2. What are primary and secondary pollutants?
3. What are biodegradable and non-biodegradable pollutions?
4. What is the compound formed when CO combines with blood?
5. How are NO and NO_2 formed in the atmosphere?
6. What are the reactions involved in removing SO_2 from the atmosphere by passing it through a solution containing citrate ions?
7. What type of aromatic compounds are present as particulates in the air?
8. What is the composition of pure dry air? What do you mean by the term 'sink' with respect to pollution.
9. What are the main air pollutants? Write about the sources and harmful effects of any one of them.
10. How carbon monoxide acts as a poison for human beings?
11. What remedial steps should be taken to save a person suffering from CO poisoning?
12. What are sources and sinks of nitrogen oxides as air pollutant? What are their effects?
13. How can pollution due to nitrogen oxides be controlled?
14. What are sources and sinks of sulphur oxide pollution.
15. What are particulates? What are their sources?
16. What are the harmful effects of particulate pollutants? List atleast five of them.
17. Write a short note on carbon dioxide sequestration.
18. List the main points of difference between 'London smog' and 'Phytochemical smog'.
19. What is 'Acid Rain'? What are harmful effects?
20. Brief explain 'Electrostatic precipitation' method for controlling particulate pollution.
21. What is 'Greenhouse effect'? How does it affect the global climate?
22. What are the factors responsible for depletion of ozone layer? What are the chemical reactions involved?
23. How synthetic detergents present as water pollutant create problems?
24. What are oxygen-demanding wastes? Define ' BOD_5 '. How is it determined?

- 25.** How plant nutrient and pesticides act as water pollutants?

26. What are thermal pollutants? What are their sources? What damage is done by them?

27. (a) What are Primary and Secondary air pollutants?
(b) Explain in brief, the commonly used approaches for Secondary treatment of waste water.

Long Answer Questions



UNIT 9

Environmental Pollution – II

"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."

Robert Goddard

Objectives

- Solid Waste Pollution
- Treatment and Disposal Methods
- Soil Pollution
- Hazardous Wastes
- Hazardous Waste Treatment Technologies
- Marine Pollution

9.1 SOLID WASTE POLLUTION

Solid waste is that material which arises from various human activities and is normally discarded as useless or unwanted.

It consists of discarded materials from the urban community as well as accumulation of agriculture, industrial, and mining wastes. The quality of solid wastes generated in some major cities of India is very high (300 to 600 g per person per day). Thus crores of rupees are being spent on solid waste management. Moreover, in some cases such as cans, bottles, plastic containers, tyres etc. are considered cheaper to throw away than to reclaim. This has increased the generation of solid waste many folds.

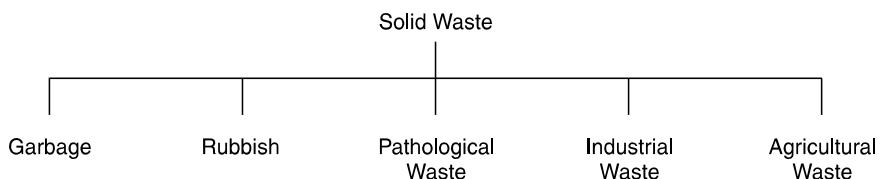
Classification

Solid wastes can be classified on the basis of content or on moisture basis or on the basis of heating value.

A typical classification is given in Fig. 9.1

- (i) *Garbage*: This is the solid waste produced during the preparation or storage of meat, fruit, vegetables etc. This putrescible waste have a moisture content of about 70% and a heating value of around 6×10^6 J/kg. It may contain valuable minerals and nutrients.
- (ii) *Rubbish*: Rubbish is non — putrescible solid waste. It can be either combustible (such as paper, wood, scrap, rubber etc) or non combustible (such as metals, glass, ceramics etc.) The water content of the waste is about 25% and the heating value of the waste is around 15×10^6 J/kg.

- (iii) *Pathological Waste:* Dead animals, humans etc constitute pathological waste. It has a moisture content of 85% and a heating value of around 2.5×10^6 J/kg. The waste may also include hospital waste which comprises of disposable syringes, swabs, bandages, body fluids etc. This kind of waste is highly infectious.
- (iv) *Industrial Waste:* The industrial waste include the waste from industries. The industrial wastes include waste from coal or ore mines, electroplating works, textile industries, paper industries, dairies, chemical industries, oil refineries etc. Industrial wastes contain inorganic or organic pollutants which may or may not be soluble.

**Fig. 9.1**

- (v) *Agricultural Wastes:* Agricultural wastes include animal manure, crop residues, Herbicides, fungicides, etc.
- (vi) *Ashes:* These are residues of the combustion of solid fuels.

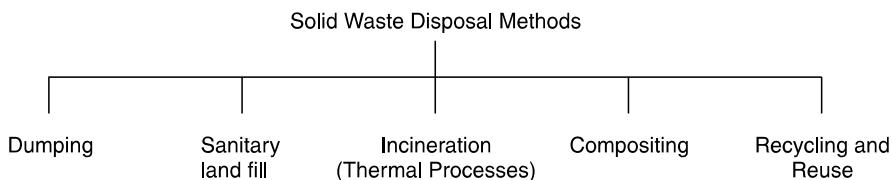
The principal sources of solid wastes are domestic, commercial, industrial and agricultural activities. Sometimes domestic and commercial wastes are considered together and called *urban wastes*. The composition of the urban wastes remain similar throughout the world but the amount generated, density and the ratio of the constituents vary widely from place to place. Urban wastes amount to between 0.3 to 0.5 kg per person per day.

On the other hand, agricultural wastes amount to around 2 kg per person per day in India. Waste is also referred to as trash, junk, debris, refuse.

9.2 TREATMENT AND DISPOSAL METHODS

The composition of solid waste is not the same everywhere, so the process of selection of the right solid waste disposal method is a complex one. In rural areas, agricultural waste forms the major portion of solid waste, whereas in urban areas, plastic, paper, glass, metal, chemical, food waste etc. are found in large quantities.

Several disposal methods are being used in various parts of the world and the most prominent of these are discussed below:

**Fig. 9.2**

1. Dumping

Open dumping of solid wastes is practized extensively in India because it requires no planning and is cheap. Open dumps refer to uncovered areas that are used to dump solid waste of all kinds. The waste is untreated, uncovered and not segregated. It is the breeding ground for flies, rats, and other insects that breed diseases. The rainwater run-off from these dumps contaminates nearby land and water thereby spreading disease. This system of open dumping is no more used in some countries.

2. Sanitary Landfills

Historically landfills have been the main method used to dispose off solid wastes because of their convenience and low maintenance costs

Landfills are generally located in urban areas where a large amount of waste is generated and has to be dumped in common place. Unlike an open dump, it is pit that is dug in the ground. The garbage is dumped and the pit is covered thus preventing the breeding of flies and rats. At the end of each day, a layer of soil is scattered on top of it and some mechanism is used to compress the garbage forming a layered structure which is usually called a *cell*. Thus every day, garbage is dumped and becomes a cell. After the landfill is full, the area is covered with a thick layer of mud and the site can thereafter be developed as a parking lot or a park.

Landfills have many problems. All types of waste is dumped in landfills and when water seeps through them, it gets contaminated and in turn pollutes the surrounding area. This contamination of groundwater and soil through landfills is known as leaching.

An alternative to landfills which will solve the problem of leaching to some extent is, a **sanitary landfill** which is more hygienic and built in methodical manner. These are lined with materials that are impermeable such as plastics and clay, and are also built over impermeable soil. The lining materials are called liners.

Daily collections of waste are spread evenly across the depression and are then covered by a layer of soil. Drainage systems are set up around and beneath the liner to collect liquids leaching from garbage and waste. Collected liquids are treated to make them more environmentally safe.

The landfill operation is essentially a biological method of waste treatment. The whole process takes place in five phases

- In the first phase aerobic bacteria deplete the available oxygen as a result of aerobic respiration.
- In the second phase anearobic conditions prevail and H_2 and CO_2 are evolved
- In phase three and four methane forming bacteria decompose the matter to methane and CO_2 . That is why escape vents for gases are provided in the landfills.
- In phase five the methanogenic activity decreases, representing the depletion of organic matter and ultimately the system returns to aerobic conditions within the land fill.

Constructing sanitary landfills is very costly as they have their own problems. Some authorities claim that often the plastic liner develops

cracks as it reacts with various chemical solvents present in the waste.

The rate of decomposition in sanitary landfills is also extremely variable. This can be due to the fact that less oxygen is available as the garbage is compressed very tightly. It has also been observed that some biodegradable materials do not decompose in landfill. Another major problem is the development of methane gas, which occurs when little oxygen is present, i.e. during anaerobic decomposition. In some countries, the methane being produced from sanitary landfills is tapped and sold as fuel.

Advantages of Landfill

- Infectious diseases are minimized because flies, rats and other pests are unable to breed in covered pits.
- No air pollution from burning
- Fire hazards are minimal.

3. Incineration

The process of burning waste in large furnaces is known as incineration. In these plants the recyclable material is segregated and the rest of the material is burnt. At the end of the process all that is left behind is ash. During the process some of the ash floats out with the hot air. This is called fly ash. Both the fly ash and the ash that is left in the furnace after burning have high concentration of dangerous toxins such as dioxins and heavy metals. Disposing of this ash is a problem. The ash that is buried at the landfills leaches the area and cause severe contamination.

Burning garbage is not a clean process as it produces tonnes of toxic ash and pollutes the air and water. A large amount of the waste that is burnt here can be recovered and recycled. In fact, at present, incineration is kept as the last resort and is used mainly for treating the infectious waste.

To make the process more effective, governments or private operators can implement properly equipped incinerators which can convert water into steam or generate electricity. Burning solid waste can generate energy, while reducing the amount of waste by up to 90 percent in volume and 75 percent in weight.

In addition to heat, the products of incineration include the normal primary products of combustion, (carbon dioxide and water) as well as oxides of sulfur and nitrogen the other gaseous pollutants. Non gaseous products are fly ash and unburnt solid residue.

A variety of pollution control technologies reduce the toxic materials emitted in combustion smoke. Among these are scrubbers (a device that uses a liquid spray to neutralize acid gases in smoke) — and filters, which remove tiny ash particles from the smoke. Burning waste at extremely high temperatures also destroys harmful chemical compounds and disease causing bacteria. Regular testing ensures that residual ash is nonhazardous before being landfilled.

Advantages

1. Useful material and energy can be recovered, if incineration is done in properly equipped incinerators.
2. Varying solid wastes loads are converted into small volumes of ash which can be handled.

4. Composting

Organic matter constitutes 35%–40% of the municipal solid waste generated in India. This waste can be recycled by the method of composting, one of the oldest forms of disposal. In contrast to a sanitary landfill, composting of waste is an *aerobic* method of decomposing. It is the natural process of decomposition of organic waste that yields manure or compost, which is very rich in nutrients. Composting is a biological process in which micro organisms, mainly fungi and bacteria, convert degradable organic waste into humus like substance.

Initially the process starts with oxidization of organic matter in the waste to produce CO and liberate heat. The temperature rises to 45°C and at this point, the thermophilic bacteria take over and continue decomposition. After about three weeks compost is stabilized. The compost should have an earthy smell and a dark brown colour. This finished product, which looks like soil, is high in carbon and nitrogen and is an excellent medium for growing plants.

For an optimum composting operation, the following conditions should be satisfied:

Temperature	40 to 50°C	Above this biological activity is reduced
pH	4.5 to 9.5	Above this N ₂ is lost as NH ₃
Moisture	40 – 70%	
Air	0.5 to 0.8 m ³ /day/kg of volatile compost	
Carbon: Nitrogen ratio	35 to 50: 1	
Carbon: Phosphorus ratio	100: 1	

Vermi-composting has become very popular in the last few years. In this method, worms are added to the compost. These help to break the waste and the added excreta of the worms makes the compost very rich in nutrients.

The composting process is generally carried out in three steps:

- (i) *Waste Preparation:* The solid waste is placed on slow moving conveyer belts. Materials like corrugated paper are hand picked and iron material is removed by magnetic separation. The waste is ground to the desired size. A nutrient source is mixed in it along with water to provide 50% moisture.
- (ii) *Digestion:* The mixture is subjected to digestion by microorganisms for 4/6 weeks.

- (iii) *Product Upgradation:* Sometimes the resulting compost is upgraded by operations such as curing, grinding etc. for better market prospects.

Advantages

1. The process of composting ensures the waste that is produced in the kitchens is not carelessly thrown and left to rot.
2. It recycles the nutrients and returns them to the soil as nutrients.
3. Apart from being clean, cheap and safe, composting can significantly reduce the amount of disposable garbage.
4. This organic fertilizer can be used instead of chemical fertilizers and is better specially when used for vegetables. It helps reduce the adverse effects of excessive alkalinity, acidity or the excessive use of chemical fertilizer.
5. It increases the soil's ability to hold water and makes the soil easier to cultivate. It helps the soil to retain more of the plant nutrient over a longer period.
6. It helps to keep soil cool in summer and warm in winter

5. Recycling and Reuse

Solid wastes contain significant amounts of valuable materials like steel, aluminium, copper and other metals which can be recovered or reused. This will reduce the volumes of the wastes to be collected and at the same time would yield significant resale value. Recycling involves the collection of used and discarded materials, *processing* these materials and *making them* into new products. It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air more fresh to breathe.

Surveys carried out by Government and non-government agencies in the country have all recognized the importance of recycling wastes. However, the methodology for safe recycling of waste has not been standardized. Studies have revealed that 7%-15% of the waste is recycled. If recycling is done in a proper manner, it will solve the problems of waste or garbage.

The steps involved in the process prior to recycling include:

- (a) Collection of waste from doorsteps, commercial places, etc.
- (b) Collection of waste from community dumps.
- (c) Collection/packing up of waste from final disposal sites.

The four 'R's to be followed for managing the problem of solid waste management are:

1. *Refuse:* Instead of buying new containers from the market, use the ones that are in the house. Refuse to buy new items.
2. *Reuse:* Do not throw away the soft drink cans or the bottles; cover them with homemade paper or paint on them and use them as pencil stands or small vases. Use shopping bags made of cloth or jute, which can be used over and over again.

3. *Recycle*: Segregate the waste to make sure that it is collected and taken for recycling.
4. *Reduce*: Reduce the generation of unnecessary waste, e.g. carry your own shopping bag when you go to the market and put all your purchases directly into it.

Some Items that Can be Recycled or Reused	
Paper	Old copies Old books Paper bags News paper Old greeting cards Cardboard box
Plastic	Containers Bottles Bags Sheets
Glass and ceramics	Bottles Plates Cup Bowls
Miscellaneous	Old cans Utensils Clothes Furniture

Most of the garbage generated in the household can be recycled and reused. Organic kitchen waste such as leftover foodstuff, vegetable peels, and spoilt or dried fruits and vegetables can be recycled by putting them in the compost pits.

The schematic diagram below depicts recycling of wastes.

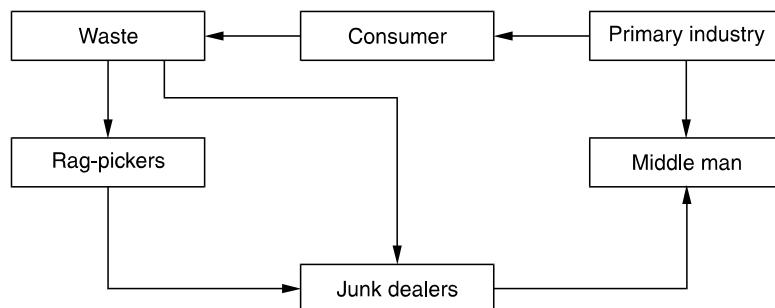


Fig. 9.3

Waste recycling has some significant advantages. It –

- leads to less utilization of raw materials.
- reduces environmental impacts arising from waste treatment and disposal.

- makes the surroundings cleaner and healthier.
- saves money.
- reduces the amount of energy required to manufacture new products.
- prevent the creation of waste at the source.

Segregation of Waste

Prior to recycling the waste should be segregated . Separating our waste is essential as the amount of waste being generated today causes immense problem. Certain items are not biodegradable but can be reused or recycled as is discussed above. In fact, it is believed that a larger portion can be recycled, a part of it can be converted to compost, and only a smaller portion of it is real waste that has no use and has to be discarded.

Waste can be segregated as

1. Biodegradable and
2. Nonbiodegradable.

Biodegradable waste: Include organic waste, e.g. kitchen waste vegetable, fruits, flowers, leaves from the garden, and paper.

Nonbiodegradable waste: Can be further segregated into

- (a) Recyclable waste – plastics, paper, glass, metal, etc.
- (b) Toxic waste – old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
- (c) Soiled – hospital waste such as cloth soiled with blood and other body fluids.

Toxic and soiled waste must be disposed of with utmost care.

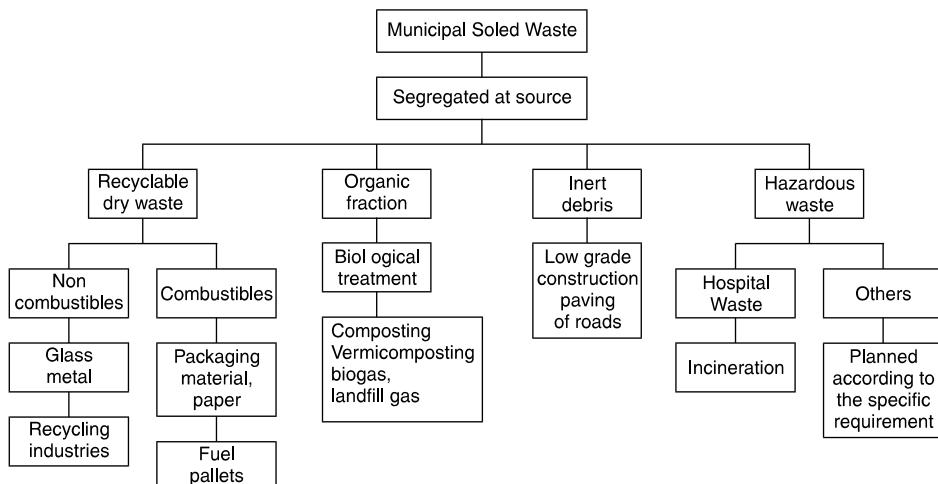


Fig 9.4 Schematic representation of segregation of solid waste

9.3 SOIL POLLUTION

Soil is the thin layer of organic and *inorganic* materials that covers the earth's rocky surface. It plays a vital role in the production of food for the

survival of life on earth. Soil can be defined as the weathered layer of the earth's crust.

Composition

Soil comprises of a mixture of organic and inorganic matter including water and gases in variable proportions. Depending upon the particle size it can be called:

Soil	Particle size (diameter in mm)
• Stone and gravel	2 and above
• Coarse sand	0.2 – 2.0
• Fine sand	0.02 – 0.2
• Silt	0.002 – 0.0
• Clay	less than 0.002

Inorganic matter: The inorganic portion is made up of rock fragments and was formed over thousands of year by physical and chemical weathering of rocks. The inorganic mineral constituents of soil include complex mixture of the following inorganic compounds.

- Silicates of Na, K, Ca, Al and Fe
- Oxides of Fe, Mn and Ti
- Carbonates of Ca and Mg

Primary minerals come from rocks such as quartz (SiO_2), feldspars and micas. Secondary formed from primary minerals by weathering. Clay are essentially hydrates, and silicates of aluminium and iron. The clay particles bind Na^+ , K^+ , Ca^{2+} , and Mg^{2+} which serve as plant nutrients.

Organic Matter: Organic matter constitute 50% of soil, which determines the productivity of soil. The organic matter consists of biologically active compounds such as polysaccharides, nucleotides, organosulphur compounds and humus. Partially decomposed organic matter present in a soil is referred to 'humus'. The process is called humification. Humus plays a vital role in maintaining the porosity of soil, its nutrient and water retaining capacity. The amount of organic matter affects soil fertility capacity and tilth (looseness of soil)

Living Organisms: Billions of tiny plants and animals such as bacteria, fungi, worms, insects and protozoa live in the soil and render the soil productive. A single gram of fertile topsoil may contain a trillion bacteria.

Apart from these water and air are also present in the soil.

Soil Water and Soil Air: Soil water and soil air fill up the space in between the soil particles. The quantity of the water present depends upon the pH of the soil water. Some space between soil particles is also occupied by the 'Soil air' which is very important for the oxidation of organic material in the soil. Absence of air in soil promotes anaerobic activity.

Soil nutrients are important for plant growth and development. Plants obtain carbon, hydrogen and oxygen from air and water but other nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulphur are

obtained from soil. Nitrogen, Phosphorus, Potassium, (N,P,K) are usually added to soil as fertilizers in the form of NH_4NO_3 , P_2O_5 and K_2O etc. Apart from fertilizers, pesticides, herbicides and insecticides are also added to the soil to kill unwanted organisms

Sources of Soil Pollution

Soil pollution is the contamination of soil by some chemical substances, whereby the productivity and fertility of soil decreases. It is the degradation of earth's land through human misuse. The human influences on soil include

- Industrial Waste
- Disposal of Soil Wastes in urban areas.
- Agricultural practices
- Biological Agents
- Soil Erosion

Industrial Wastes: Disposal of industrial waste is the main cause of soil pollution. These discharges are from pulp and paper mills, chemical, steel, coal and mining industries etc. The pollutants added affect and alter the chemical and biological properties of soil. Industrial sludges containing calcium salts and several toxic volatile elements such as arsenic, selenium, mercury etc pose a detrimental threat to environment. Moreover fallout of gaseous and particulate air pollutants from mining and smelting industry also add to soil pollution.

Soil pollution by urban wastes: Accumulation of lead particulates from automobile exhausts, garbage containing plastic, glasses, metallic cans, fibers, papers etc constitute soil pollution by urban wastes.

Agricultural Practices: Excessive use of fertilizers such as nitrates and phosphates may lead to excessive release of these nutrients in soils which may leach out nearby water body and may cause water pollution.

Use of fertilizers, pesticides, herbicides to increase crop yield may also pose soil pollution when used excessively. For example, soil becomes acidic, when $(\text{NH}_4)_2\text{SO}_4$ is used as a fertilizer excessively, because NH_4^+ is absorbed by the plants and SO_4^{2-} remains in the soil making it acidic. Similarly use of KNO_3 makes the soil alkaline as NO_3^- ions are used by plants and K^+ remains in the soil. This alkaline soil becomes unfit for crops.

Pesticides used to kill the unwanted species such as DDT, BHC, aldrin, heptachlor etc are absorbed by the soil particles and contaminate root crops grown in soil.

Animal wastes (cow dung etc.) contain several pathogenic bacteria and viruses which enter into plant metabolism and ultimately to man. Though cow dung is richest source of nitrogen still when dumped into heaps, it becomes the breeding ground for insects.

Biological Agents: Soil gets large quantities of human, animals and birds excreta which constitute the major source of land pollution by biological agents. In addition to these excreta, faulty sanitation, municipal garbage waste water also add to soil pollution.

Soil Erosion: Soil erosion is when the topsoil of the land is stripped of essential nutrients needed for plant and vegetative growth. When the soil erodes, the rich top layer called humus is removed. The result of soil erosion over a long period of time includes, the decaying of vegetation and negative microbial effects. This man-made disaster leaves large areas of land destroyed and unfit for regrowth for many years, and thus, thousands of acres of land are wasted each year.

Coal based Thermal plants: Disposal of large quantities of fly ash and bottom ash from coal based thermal plants also contribute to the soil pollution. It is estimated that two lakh tons of ash is being deposited per day by thermal plants in our country. This renders large areas of agriculture unfit for cultivation. Moreover the toxic metals also leach out of the soil and pollute ground waters.

Effects of Soil Pollution

Soil nutrients are essential for plant growth and development which inturn have a great impact on human life.

The prosperity of the nation depends upon the quality of its soil. However, soil pollution due to various sources listed above cause detrimental effects on environment and human life. Some of the effects of soil pollution are discussed below:

1. Soil pollution through industrial wastes adds a number of chemicals to the soil which are extremely toxic to living beings. This toxic metals are transferred to human beings in their food chain through plants and cause undesirable effects.
2. Metallic contaminants (Hg, Pb, Zn, As, Cr, K, Na, Cu, etc) destroy the beneficial microorganisms in the soil. These metals act as indestructible poisons to the soil and are highly fatal to living organisms in the soil.
3. Excessive use of fertilizers renders the soil alkaline or acidic, depending upon the fertilizer used. The acidic or alkaline soil is unfit for the growth of many crops. An estimate shows that soil fertility between 30 – 80% of world's irrigated land has been degraded due to increased salinity. Nitrates and phosphates added as fertilizers may be leached out of soil by run off waters and pollute the nearby surface water or ground water sources. High concentration of nitrates is objectionable in drinking water because they reduce to nitrites and cause a disease methemoglobinemia.
4. Use of pesticides contaminate the soil and are persistent pollutants. They enter the food chain and pose serious health hazards. The degradation products of these pesticides is more dangerous than their parent compounds and some of there are carcinogenic. These pesticides residues in food cause hazards to human health. Some arsenic pesticides if used indiscriminately, may render the soil permanently infertile. The most threatening pesticide DDT concentrates and accumulates in food chain. Polychlorinated biphenyls (PCBs) are more dangerous having half life of 25 years in

soil. PBCs when enter in human bodies cause deformities in foetus, nervous disorders, liver and stomach cancer in animals.

Control of Soil Pollution

Control measures of soil pollution include primarily the methods for the solid wastes to be reduced and to dispose it safely. Some of the control measures are

- (i) Proper dumping of solid waste: Dumping of solid waste in open dumps should be discouraged. Instead, land fill should be the possible way of disposal.
- (ii) Highly toxic and persistent synthetic chemical pesticides should be banned. Biopesticides should be used instead of toxic chemical pesticides.
- (iii) Proper awareness: Anti litter campaigns should be carried on to educate people. People should be trained regarding sanitary habits.
- (iv) Crop rotation should be encouraged to revive the depleted nutrients.
- (v) High concentration of lead and cadmium can be controlled by growing a special type of grass, the vetiver grass. The contaminants concentrates in its roots and reduce the concentration of lead and cadmium in soil by 38 - 60% and 35 - 40% respectively.
- (vi) Recycling of waste such as ferrous materials, metal, paper, glass, plastics is another method of reducing the amount of pollutants added to soil.
- (vii) Plantation of trees can help to check soil erosion. Deterrent measures against deforestation should be implemented.

9.4 HAZARDOUS WASTES

Although the legal definition of Hazardous Waste is complex, the term generally refers to the waste that could pose a threat to human health and the environment, if managed improperly. In other words, hazardous waste can be defined as *any waste which because of its quantity, concentration, or physical, chemical or infectious characteristics, may cause significant hazard to human health and environment when improperly treated, stored, transported or disposed off.*

Hazardous waste will significantly contribute to

- An increase in mortality
- An increase in serious, irreversible or incapacitating reversible illness
- Pose a substantial potential hazard to human health.

More specifically, a substance is defined as hazardous if it possesses any of the following characteristic attributes:

Reactivity: Any waste which is not stable at normal conditions and hence can cause explosive reactions or liberate toxic fumes, gases and vapours, reacts violently when mixed with water. Example of reactive waste include, sodium and potassium metal, dry picric acid, compounds that form explosive peroxides, cyanide plating operations etc.

Ignitability: Wastes which are easily ignited and burn vigorously at or below 60°C. Examples include volatile liquids, such as solvents (acetone, toluene, methanol, ethers), rubber, cement glue, paint thinners etc.)

Corrosivity: Wastes which include liquids with pH less than 2 or greater than 12.5, and those that are capable of corroding metal containers. These include H_2SO_4 , HCl, NaOH, OH, lime, battery acid, drain openers and other products that contain strong acids or bases.

Toxicity: Toxic substances are harmful or fatal when ingested or absorbed. The wastes which release toxic materials on leaching in excess of the permissible concentration pose a substantial hazard to human health and are termed as toxic. These are measured by Toxicity Characteristics Leaching Procedure (TCLP). Examples are, products that contain benzene (many petroleum based products), cadmium (nickel cadmium batteries), lead (lead batteries, paints) silver (spent photofixer, silver mercury), chromium, mercury (mercury batteries), rat poison and antifreeze etc.

Table 9.1 gives maximum concentration of contaminants for environment Protection Agency (EPA) test

Table 9.1 Maximum Concentration of Contaminants For EPA Toxicity Test

EPA hazardous waste number	Contaminant	Maximum concentration (mg/L)
D004	Arsenic	5.0
D005	Barium	100
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin	0.02
D013	Lindane	0.4
D014	Methoxychlor	10.0
D015	Toxaphene	0.5
D016	2, 4-D (2, 4-dichlorophenoxyacetic acid)	10.5
D017	2, 4, 5-TP Silver (2, 4, 5-trichlorophenoxypropionic acid)	1.0

Toxicity can be acute toxicity (one massive dose kills you) or chronic toxicity (long exposure to small dose resulting in chronic disease).

While the four characteristic attributes given above are sufficient to consider a substance to be hazardous, EPA has given a list of specific hazardous wastes. The hazardous wastes have been classified into three categories as given in the schematic representation (Fig. 9.5)

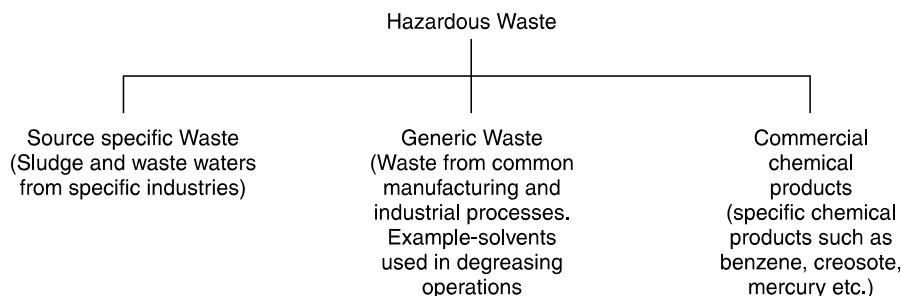


Fig. 9.5 Schematic representation of classification of hazardous waste by EPA

Hazardous Waste is generated through various industrial processes and can be named accordingly. The prominent among them include:

- (i) Radiochemical Wastes
- (ii) Biomedical Wastes
- (iii) Chemical Wastes

A brief description of these is given below:

1. Radiochemical Waste

Radioactivity arises naturally from the decay of particular forms of some elements, called isotopes. Some isotopes are radioactive, most are not, though in this discussion we concentrate on the former.

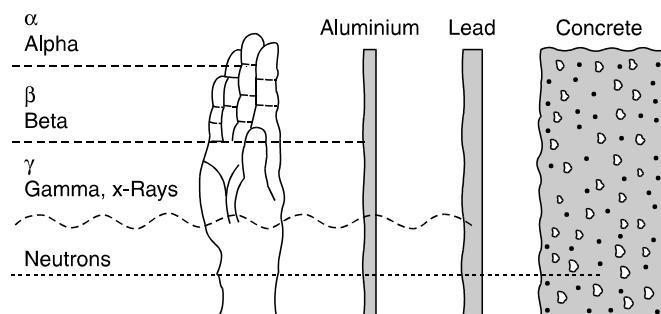


Fig. 9.6

There are three kinds of radiation to consider: **alpha, beta and gamma**. A fourth kind, neutron radiation, generally only occurs inside a nuclear reactor (9.6).

Different types of radiation require different forms of protection:

- Alpha radiation cannot penetrate the skin and can be blocked out by a sheet of paper, but is dangerous in the lung.
- Beta radiation can penetrate into the body but can be blocked out by a sheet of aluminium foil.
- Gamma radiation can penetrate into the body, aluminium foil, but can be blocked by lead.

All of these kinds of radiation are, at low levels, naturally part of our environment. Any of them may be present in any classification on waste.

Source: The radioactive waste is generated in

- (i) Discharges from nuclear reactions contain a number of radio-nuclides. These nuclides emit radiations harmful to living organisms.
- (ii) Use of radioactive materials in nuclear weapons
- (iii) Mining and processing of ores to produce radio isotopes.
- (iv) Radioactive fallout from nuclear bombs.
- (v) Emissions from industrial use of nuclear energy
- (vi) Leakage from underground nuclear detonations.
- (v) Use of radio isotopes in medicine, industry, agriculture and research operations.

Fortunately most of the radio-nuclides, which emit radiations are unstable and do not persist for long time in environment. But some radionuclides e.g., strontium-90 and iodine-137 are slow decaying and produce hazardous effect on human life.

Effects: Radiation damages the living organisms. The damage can be classified as somatic damage or genetic damage

Somatic damage: It is the damage to the organism itself, resulting in sickness and death. The effects may appear almost immediately if a massive dose of radiation is received. For smaller doses, damage, may appear years later, usually in the form of cancer.

Genetic Damage: It is the damage which passes from one generation to another. The radiations affect the chromosomes causing mutations in the genes.

Method of Disposal of Radioactive Wastes

The radioactive wastes must be disposed off in such a manner that they create no hazard to the living organism. The wastes can be disposed of in ground, air or ocean.

Disposal in ground: Soil absorbs the radioactive materials easily that is why disposal in ground is an easy method for disposal of radioactive wastes. The radioactive waste containing calcium and strontium is first separated and stored in the tanks, which are buried in ground. This is done to allow the radioactivity of the material to decay so that it is much easier to handle. The burial of the radioactive waste is around 500 metres deep. The wastes are kept buried for about 13 years and finally disposed off in the sea. Vacated coal mines can be used for disposal. Salt is a powerful absorber of radioactive radiations and hence the wastes is disposed off in salt heaps provided in mines. Before disposing the buried tanks in the sea, it must be ensured that radioactive waste should be below harmful levels. Further details of treatment technology are discussed in the next section.

2. Biomedical Waste

“Biomedical waste” means waste, that is generated by human or animal health care facilities, medical or veterinary and teaching establishments, health care teaching establishments, clinical testing or research laboratories or facilities involved in the production or testing of vaccines. Biomedical wastes include:

- (i) Human anatomical waste, that consists of tissues, organs or body parts, but does not include teeth, hair and nails.
- (ii) Animal waste, that consists of tissues, organs, body parts, fluid blood and blood products, items saturated or dripping with blood, body fluids contaminated with blood, and body fluids removed for diagnosis or removed during surgery.
- (iii) Microbiology laboratory waste, that consists of laboratory cultures, stocks for specimens of microorganisms, live or attenuated vaccines, human or animal cell cultures used in research
- (iv) Waste sharps, that are clinical and laboratory materials consisting of needles, syringes, blades or laboratory glass capable of causing punctures or cuts.

3. Chemical Wastes

Chemical wastes include the effluents from various industries, solvents, etc and have been discussed earlier.

9.5 HAZARDOUS WASTE TREATMENT TECHNOLOGIES

In the past the disposal of hazardous waste was most often on Land. But RCRA (Resource Conservation and Recovery Act) emphasize the development and use of alternative and innovative treatment technologies that result in permanent destruction of wastes or a reduction in toxicity.

The following treatment technologies are available for the treatment of hazardous wastes:

- Physical Processes
- Chemical Processes
- Biological Processes
- Incineration
- Land disposal

1. Physical Processes

Physical treatment processes include gravity separation, phase change systems, (air and steam coming out of volatiles from liquid wastes) and various filtering operations such as carbon adsorption, reverse osmosis etc.

Some of the methods have been discussed below:

- (i) **Sedimentation:** This is the simplest physical treatment system that separate solids from liquids. It involves gravity settling and natural floating. The solids in the hazardous wastes are made to settle in the specially designed sedimentation tanks, where they are collected as sludge. Some solids naturally float to the surface and are removed

by skimming device. The floatation is encouraged by introducing finely divided bubbles into the waste stream. When these bubble rise they collect the particles and the combination is skimmed out.

- (ii) *Adsorption:* Dissolved hazardous substances that would never settle out can be removed by this technique of adsorption. The chemicals are adsorbed onto the adsorbent. The most commonly used adsorbent is granular activated carbon (GAC), which has large surface area of about $1000\text{ m}^2/\text{g}$. A single handful of GAC has an internal surface area of about one acre.

The process consists of a series of large vessels partially filled with the adsorbent. Contaminated water enters the top of each vessel, trickles down the adsorbent and is released at the bottom. After sometime the GAC filter gets clogged by contaminants and is regenerated, which is quite expensive process. The regeneration is usually done by burning the contaminants from the surface of the adsorbent granules or using a solvent. Carbon filters which cannot be regenerated due to their contaminant composition must be disposed off.

- (iii) *Aeration:* This process typically use the process of aeration to drive the contaminants out of solution. The air or steam is used in the process. Contaminated wastes is sprayed downward through a packing material in a tower, through which air is blown upward carrying away the chemicals that are relatively volatile. This process can remove 95% of VOCs (volatile organic compounds) such as trichloro ethylene, tetrachloro ethylene, benzene, toluene etc. Sometimes the adsorption is combined with aeration and many volatile and nonvolatile compounds are removed from water to non detectable levels. First the waste waster is passed through the air stripper which removes volatile substances before the waste water is subjected to adsorption process. This extends the life of carbon because no clogging with volatile compounds take place.
- (iv) *Reverse Osmosis:* The contaminated water is forced against a semi-permeable membrane, which acts as a filter. The water passes through the pores, and hazardous chemical substances are left behind.
- (v) *Ion exchange process:* This is similar to the process, discussed under the chapter 'Water' for removing hardness causing ions. Special exchange resins are used to remove toxic substances from waste water.
- (vi) *Electrodialysis:* This technique which is also discussed in detail in chapter 'Water' for purifying brackish water, is also used to remove hazardous substances. Metal salts from electroplating rinses are removed this way.

2. Chemical Processes

In chemical treatment methods the hazardous waste is converted into less hazardous form and sometimes useful products are also formed. The various chemical techniques are:

- (i) **Neutralization:** As per the definition of hazardous material, one of the characteristic is that hazardous waste comprises of corrosive material having pH less than 2 or more than 12.5. Neutralization converts these materials to less hazardous by changing their pH.

Acidic waste waters are neutralized with $[Ca(OH)_2]$. The waste water is continuously stirred with $Ca(OH)_2$ in a chemical reactor. The rate of addition of lime is controlled with a feedback control system that monitors pH and adjust the feed.

Alkaline waste waters are neutralized by adding acid directly or by bubbling CO_2 . Simultaneous alkaline and acidic neutralization can be accomplished in the same vessel as shown in Fig. 9.7

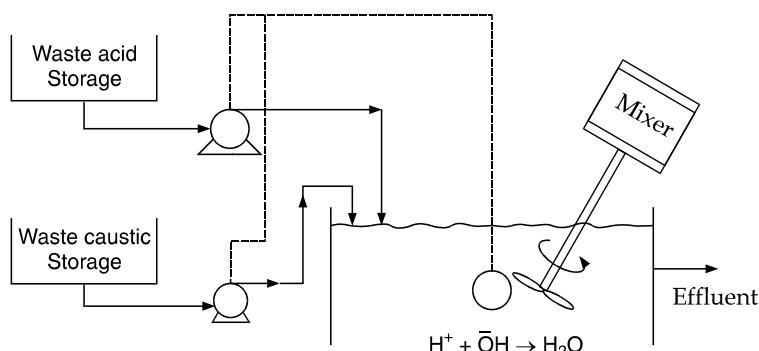


Fig. 9.7 Simultaneous neutralization of acid and base

- (ii) **Chemical Precipitation:** This is a common method for removing heavy metals from a liquid waste. This method is again pH dependent. The pH of waste waters is so adjusted that the solubility of toxic metals is decreased, leading to the formation of a precipitate that can be removed by settling and filtration. For example, the ion M^{2+} can be removed by converting it into its insoluble hydroxide, using lime

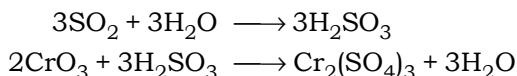


The metal hydroxides in general are relatively insoluble in basic solutions. Each metal has its own pH at which its solubility is minimum. If the waste contains several metals then it becomes difficult to control the precipitation of a mix of different metals in the same waste. In such cases more than one stage of precipitation is required to allow different values of pH to control the removal of different hazardous substances.

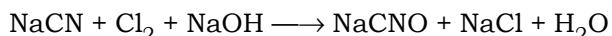
If the metals are present in very low concentrations in waste water then the metals are precipitated as sulphides. Metal sulphides have lower solubilities than metal hydroxides and hence can be precipitated out. The only disadvantage of precipitating metals as sulphides is the potential formation of toxic H_2S gas if alkalinity is not properly maintained. Some metals like Pb, Cd and Ni precipitate as carbonates.

- (iii) **Oxidation – Reduction Process:** Certain hazardous substances have variable oxidation states. All the oxidation states do not have the

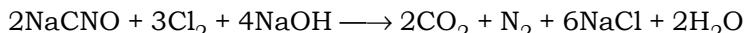
same toxicity. Therefore, the substances can be converted to the oxidation state which is less toxic by redox reactions. One of the most important redox treatment process is the reduction of hexavalent chromium (Cr^{6+}) to trivalent (Cr^{3+}). The trivalent chromium is less toxic and can be precipitated easily as compared to Cr^{6+} . In this process SO_2 is often used as reducing agent.



Similarly cyanide wastes are treated using redox process. These hazardous substances which are common in effluents from metal finishing industry, are converted to less toxic cyanate using alkaline chlorination.



If chlorination is continued further, the cyanate ion oxidizes to CO_2 and N_2 resulting in complete destruction of cyanide



The wastes that can be treated using redox *oxidation* include the waters which contain benzene, toluene, phenols, cyanide, arsenic ions, iron, and manganese. The wastes which can be treated using redox *reduction* include the ones containing chromium (IV), mercury, lead, silver, and chlorinated organics.

3. Biological Processes

Mostly the wastewater treatment plants rely on biological processes to decompose the organic water. As was discussed earlier in the chapter, the biological treatment systems use microorganisms (bacteria, fungi etc.) to oxidize organic matter to CO_2 and H_2O .

Now, living organisms survive on the nutrients such as nitrogen and phosphorus as well as a source of carbon and energy. The microorganisms get carbon and energy from the organics they consume. These living organisms are susceptible to toxic substances in hazardous wastes present in organics water and that the treatment of these hazardous wastes by these organisms seems unlikely.

But, surprisingly, most hazardous organics can be treated with these microorganisms. This is because, for a given organic hazardous substance, there may be one type of organisms which find it toxic whereas the other type may find the same substance to be an acceptable food, thus decomposing it. Moreover microorganisms are sensitive to concentration of these substances. These may flourish in one concentration and may die when concentration is increased beyond a critical level.

The following biological processes are common for the treatment of hazardous wastes. It may be emphasized here that *biological treatment stage utilizes processes already described for municipal waste water treatment plants*.

In situ biodegradation:

In, *in situ* biodegradation the bacteria are used to degrade organic compounds in the soil and groundwater on site itself. The advantage of in

situ biodegradation is that soil and groundwater do not have to be removed and hence there is less risk associated with hazardous waste transportation.

In situ biodegradation can be carried out by using two approaches:

- In one approach the population of already existing microorganisms is increased by supplying necessary nutrients such as ammonium sulphate, magnesium sulphate, sodium carbonate etc, to the contaminated waste. Oxygen can be supplied by injecting an oxidant such as H_2O_2 or by forcing air.
- In another approach, the underground population of microorganism is altered by seeding with new microorganisms, which have proven to be effective to decompose the hazardous wastes under consideration, based on laboratory studies.

In situ biodegradation have been used to treat wastes containing gasoline and diesel. It also can be used to treat chlorinated solvents such as trichloroethylene (TCE), tetrachloroethylene (PCE) and 1, 2 dichloroethylene (DCE) and heavy metals etc.

4. Incineration

Incineration was discussed in the section ‘sewage disposal’. The same technology is particularly effective with organic containing hazardous substances. Carcinogens (cancer causing), mutagens (causing mutation in genes), teratogens (causing birth defects) can all be completely detoxified in a properly operated incinerator. However, inorganic compounds are not destroyed in incinerators and are only concentrated in ash.

Incinerators however have a disadvantage that the substance which volatilize at temperatures below 2000°F are added in the air and cause air pollution. They are difficult to remove using conventional air pollution control equipment.

The measure of incinerator’s performance is known as the destruction and removal efficiency DRE.; A DRE of 99.99%, for example, means that one molecule of an organic compound is released to the air for every 10,000 molecules entering the incinerator.

A number of hazardous waste incinerators are there, but the two most commonly used are:

- liquid injection incinerator and
- rotary kiln incinerator.

Liquid injection Incinerator: In liquid injection incinerators the waste containing gases, liquids and slurries are pumped through an atomizing nozzle. The nozzle emits tiny droplets of waste that are mixed with air and fuel gas. The resulting mixture is burned at high temperature.

Rotary kiln Incinerator: In rotary kiln incinerator all sorts of wastes can be treated. Wastes and fuel gas are introduced in the rotary kiln from one end and combustion takes place while the cylinder slowly rotates. Rotation helps to increase turbulence which improves the combustion efficiency.

The emissions from these incinerators include unburned organic compounds, products of incomplete combustions, CO_2 , N_2 , SO_X , and

particulates. The unburned ash, which may contain hazardous substance, should be treated with care.

5. Land Disposal

The purpose of a hazardous waste landfill is to store the waste which are not yet recoverable. Land disposal techniques include landfills, surface impoundments, underground injection wells and waste piles.

Conventionally, land disposal methods were used to dispose off hazardous wastes because this was the convenient and inexpensive method. Unfortunately, the poorly monitored disposal sites have resulted in tragic incidences. Therefore RCRA (Resources Conservation and Recovery Act) has put ban on some of the hazardous substances from land disposal. A few of the restrictions are:

- Banning liquids from landfills
- Banning underground disposal of hazardous waste within 1/4 mile of a drinking water well.
- Requiring more stringent structural designs for landfills, impounds
- Requiring corrective action, if hazardous substance leaks from a facility
- Requiring disposable facilities to be constructed only in suitable hydrogeologic settings.

Some of the Land disposal Techniques used are:

(i) *Landfills:* The sanitary landfill has already been discussed in the section ‘sewage disposal’. The similar type of treatment is applicable to hazardous water treatment. However, for disposing off hazardous waste more stringent RCRA requirements are there. The hazardous waste landfill is designed as a modular series of three-dimensional control cells. The wastes are segregated, and only compatible wastes are disposed off together. After dumping the wastes in the appropriate cells, these cells are covered at the end of each working day with a layer of soil.

A double-liner system is placed beneath the hazardous wastes to stop the leakage of liquids from the waste. The leakage is often referred to as leachate. The leachate may enter the soil and groundwater beneath the site. The double-liner system prevents this. The upper liner of this double liner must be a flexible-membrane lining and is made of sheets of plastic or rubber. The plastics used are polyvinyl chloride (PVC), high density polyethylene (HDPE). The rubbers used for the purpose are chlorosulphonated polyethylene (CSPE) and ethylene propylene diene monomer (EPDM). The lower lining can be recompacted clay having a thickness of atleast 3 feet. Flexible plastic membranes can also be used in lower linings.

The leachate that collects over each double liner is collected in a series of perforated drainage pipes and pumped to the surface for further treatment. A low permeability cap is placed over completed

cell to minimize the leakage of leachate. The landfill must also include monitoring facilities to check the possibility of any contamination from the site (Fig. 9.8).

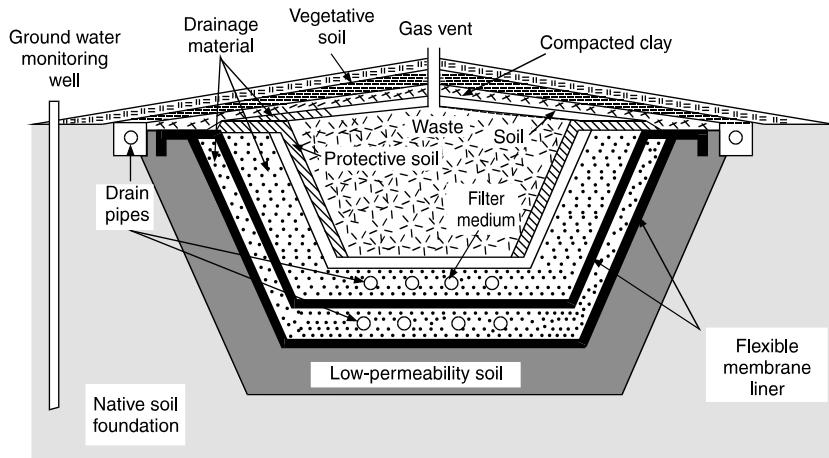


Fig. 9.8 Schematic diagram of a hazardous waste landfill.

- (ii) *Surface Impoundments:* Surface impoundments are excavated areas used to store liquid hazardous wastes. Usually storage is temporary unless the impoundment has been designed to eventually be closed as a landfill. In these impoundments the waste remains accessible for further treatment during storage. The treatments include neutralization, precipitation, settling and biodegradation. Conventional surface impoundments have typically been poorly constructed and monitored. More than half were located over thin or very permeable soils that would allow easy transport of leachate to groundwater. Recent regulations require new surface impoundments with two or more liners, leachate collection system and a monitoring system, similar to those required in landfills.
- (iii) *Underground Injections:* Underground injection is to force the waste underground through deep injection wells. This is the most popular way of disposing hazardous waste. Typical injection depths are more than 700m below the surface. However, the main concern with underground injection is the potential for contaminating underground drinking water supplies. Thus injection wells are required to extend below the lowest formation containing underground sources of drinking water.

6. Disposal of e waste:

“Electronic waste” or e waste may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets and refrigerators. This definition includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal.



Fig. 9.9 Electronic waste

Over the last decades the electronics industry has revolutionized the world: electrical and electronic products have become ubiquitous of today's life around the planet. Without these products, modern life would not be possible in (post-)industrialized and industrializing countries. These products serve in such areas as medicine, mobility, education, health, food supply, communication, security, environmental protection and culture. Such appliances include many domestic devices like refrigerators, washing machines, mobile phones, personal computers, printers, toys and TVs.

Growing and ever changing technology have resulted in a fast-growing surplus of electronic waste around the globe and loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable). An estimated 50 million tons of E-waste are produced each year. According to a report by UNEP, "Recycling - from E-Waste to Resources," the amount of e-waste being produced, including mobile phones and computers , could rise by as much as 500 percent over the next decade in some countries, such as India.

Modern electronics can contain up to 60 different elements; many are valuable, some are hazardous and some are both. The most complex mix of substances is usually present in the printed wiring boards (PWBs).

Some of the hazardous substances found in e-waste are:

- *CRT*: CRTs, may contain contaminants such as lead, cadmium, beryllium, or brominated flame retardants.
- *Mercury*: Found in fluorescent tubes (numerous applications), tilt switches (mechanical doorbells, thermostats and flat screen monitors). Health effects include sensory impairment, dermatitis, memory loss, and muscle weakness.
- *Sulphur*: Found in lead-acid batteries. Health effects include liver damage, kidney damage, heart damage, eye and throat irritation.
- *Cadmium*: Found in light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments, and nickel-cadmium batteries. The inhalation of cadmium can cause severe damage to the lungs and is also known to cause kidney damage. Cadmium is also

associated with deficits in cognition, learning, behavior, and neuromotor skills in children.

- **Lead:** Solder, CRT monitor glass, lead-acid batteries, some formulations of PVC. A typical 15-inch cathode ray tube may contain 1.5 pounds of lead.
- The substances contained in the devices can also have an impact on the environment.
- Cooling and freezing equipment for example, employ ozone depleting substances (ODS) in the refrigeration system. These substances, such as CFCs and HCFCs, have a huge global warming potential,

Recycling

Even in developed countries recycling and disposal of e-waste may involve significant risk to workers and communities and great care must be taken to avoid unsafe exposure in recycling operations and leaking of materials such as heavy metals from landfills and incinerator ashes. Uncontrolled discarding or inappropriate waste management/recycling generates significant hazardous emissions, with severe impacts on health and environment.

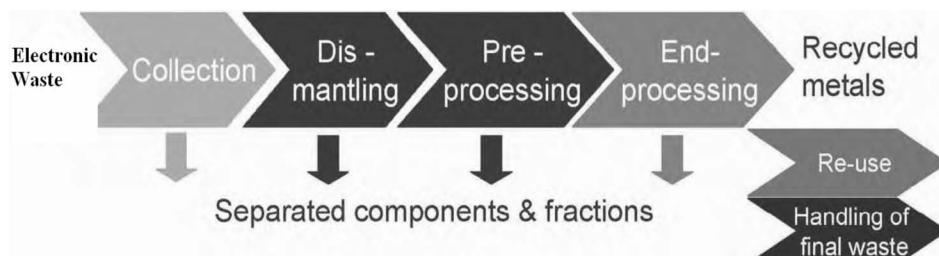
There are three levels of toxic emissions:

- Primary emissions: Hazardous substances that are contained in e-waste (e.g. lead 5, mercury, arsenic, polychlorinated biphenyls (PCBs), fluorinated cooling fluids etc.),
- Secondary emissions: Hazardous reaction products of e-waste substances as a result of improper treatment (e.g. dioxins or furans formed by incineration/inappropriate smelting of plastics with halogenated flame retardants),
- Tertiary emissions: Hazardous substances or reagents that are used during recycling (e.g. cyanide or other leaching agents, mercury for gold amalgamation) and that are released because of inappropriate handling and treatment.

Main steps in the recycling chain:

The recycling chain for e-waste consists of three main subsequent steps:

- (i) Collection,
- (ii) Sorting/dismantling and pre-processing (sorting, dismantling, mechanical treatment) and
- (iii) End-processing (refining and disposal).



Usually for each of these steps specialized operators/plants exist.

1. Collection: **Collection** of e-waste is of crucial importance as this determines the amount of material that is actually available for recovery. Improvement of collection rates depends more on social and societal factors than on collection methods as such, but should be considered when discussing innovative recycling technologies/systems.

2. Dismantling and pre processing: The aim of **dismantling and pre-processing** is to liberate the materials and direct them to adequate subsequent final treatment processes. Hazardous substances have to be removed and stored or treated safely while valuable components/materials need to be taken out for reuse or to be directed to efficient recovery processes. This includes removal of batteries, capacitors etc. prior to further (mechanical) pre-treatment.

- The batteries from the devices can be sent to dedicated facilities for the recovery of cobalt, nickel and copper.
- For devices containing ODS such as refrigerators and air-conditioners, the de-gassing step is crucial in the pre-processing stage as the refrigerants used (CFC or HCFC in older models) need to be removed carefully to avoid air-emissions.
- For CRT containing appliances (e.g. monitors and TVs) coatings in the panel glass are usually removed as well before end-processing.
- LCD monitors with mercury-containing backlights need special care too, as the backlights need to be carefully removed before further treatment.
- The circuit boards present in ICT equipment and televisions contain most of the precious and special metals as well as lead (solders) and flame retardant containing resins. They can be removed from the devices by manual dismantling, mechanical treatment (shredding and sorting) or a combination of both. Manual removal of the circuit boards from telecommunication and information technologies (IT) equipment prior to shredding will prevent losses of precious and special metals and offers advantages, especially in developing and transition countries with rather low labour costs.
- An intermediate approach to the removal of hazardous and valuable components can be a very coarse crushing to liberate the components (circuit boards, batteries etc.) as a whole followed by removal of the components by hand picking.

After removal of the hazardous and other special components, the remainder of the ICT, cooling or television devices can be further separated in the material output streams by manual dismantling or mechanical shredding and (automated) sorting techniques. Fractions are usually iron, aluminium, copper, plastic etc. It has to be noted that pre-processing of e-waste is not always necessary. Small, highly complex electronic devices such as mobile phones, MP3 players etc.

can (after removal of the battery) also be treated directly by an end-processor to recover the metals.

- 3. End processing:** The **final metals recovery** from output fractions after pre-treatment takes place at three main destinations. Ferrous fractions are directed to steel plants for recovery of iron, aluminium fractions to aluminium smelters, while copper/lead fractions, circuit boards and other precious metals containing fractions are to e.g. integrated metal smelters, which recover precious metals, copper and other non-ferrous metals, while isolating the hazardous substances.

Both ferrous and non-ferrous smelters need to have state-of-the-art off-gas treatment in place to deal with the organic components present in the scrap in the form of paint layers and plastic particles or resins containing flame retardants. During smelting formation of volatile organic compounds (VOCs), dioxins can appear and their formation and emission have to be prevented. Alternatively, painted scrap, such as painted aluminium can be delacquered prior to smelting using appropriate technologies with off-gas control equipment. For treatment of circuit boards, it is of utmost importance that the smelter is equipped.

9.6 MARINE POLLUTION

Marine Pollution is the direct or indirect introduction of substances or energy to the marine environment resulting in deleterious effect such as: hazards to human health, hindrance of marine activities, (including fishing) and impairment of the quality of sea water .

The ocean is ultimate sink for most of the waste we produce. It is commonly used to dispose off waste materials, and many of these substances are toxic to living creatures. These substances diffuse through large volumes of water, which makes them less concentrated and more dispersed. While the overall impact of pollution on the marine environment is unknown, contaminants introduced by rivers, coastal runoff, ocean dumping and various other activities are beginning to take their toll on the oceans.

Source and Effects

More than 80% of all marine pollution originates from land-based sources which are primarily industrial, agricultural and urban. The greatest volume of wastes entering coastal waters and estuaries is composed of organic material. Bacteria breaks down organic compounds to stable inorganic compounds such as carbon dioxide, water, and ammonia.

Some major types of marine pollutants that have been the focus of recent research are oil, sewage, garbage, chemicals, radioactive waste, thermal pollution, and eutrophication.

- 1. Oil:** Approximately 3.25 million metric tons of petroleum(oil) products enter the earth's oceans every year. The oil may enter through oil spills due to tanker accidents, conventional shipping and tank

cleaning at sea, waste disposal, runoff, and oil exploration. However; for the most part this pollution does not come from oil spills. Oil spills make up only about 10 percent of the oil input into the ocean and oil field blow outs account for another small proportion of oil pollution. Low level oil pollution on the other hand, accounts for more than half of the oil entering the ocean. Low level oil pollution comes from leaks at marine terminals, disposal of drilling muds from offshore operations, municipal and industrial wastes, urban runoff into rivers, and atmospheric fallout from the incomplete combustion of oil in motor vehicles.

Effects:

- Recovery time after an oil spill is 5-10 years, dependent on temperature and wave action; 80% of hydrocarbons are degraded bacterially or evaporated after 2 months in open sea spills, leaving heavy hydrocarbons (long chains) behind
- World-wide average contamination in the ppb (parts per billion) range is considered harmless because toxic effects occur in the ppm (parts per million) range; long-term exposure effects are unknown, though

2. Sewage: This type of pollution is discharged into the oceans all over the world. Sewage adds to the amount of small particles suspended in the water column and contributes large amounts of nutrients.

Effects:

- Release of organic matter, heavy metals, pesticides, detergents, oil, nutrients
- Pathogenic bacteria and viruses can be introduced by sewage (e.g. Cholera epidemics in India by bathing in the polluted Ganges River)
- Nutrients can cause algal blooms, among the harmful/toxic blooms, alter the phytoplankton species composition (food chain effects!); can also promote growth of benthic green algae and cyanobacteria, which overgrow and destroy natural communities
- Near sewage outflow areas in temperate waters of California, the benthic invertebrate communities have degraded, kelp beds have disappeared and diseased fish have become more prevalent.

3. Solid wastes: This type of pollution has a huge effect on ocean life. It consists of inert solid wastes with much of it composed of man-made plastics, including polythene containers, plastic sheeting, nylon ropes, nets, and other fishing gear. Size can range from nylon drift nets to millimeter-sized plastic pellets

Effects:

- Plastics are non biodegradable and remain in the oceans for many years .Birds and turtles mistake plastic for jellyfish and ingest them; 80% of shear-waters in a North Pacific survey had plastics in their stomachs .
- Fish, water birds and other marine life can be killed by mistakenly eating plastic materials floating in the water. Marine animals

such as turtles and whales can die because they mistake a discarded plastic bag for a jelly fish - something they like to eat. Seabirds, seals, turtles and fish can become entangled in plastic lines which trap and slowly strangle them.

- Finer particulate matter suspended in the water effect animal (clogging respiratory or feeding) and plant (light penetration).

4. Chemicals: These are toxic substances that are released by the industrialized nations and make their way into ocean systems. They are not visible like garbage and sewage and therefore can sneak their way into ocean systems undetected. Toxic chemicals often enter ocean systems through food chains and affect organisms at different times and places from where they were released.

Effects:

- Mostly sublethal effects. Heavy metals: mercury, copper, cadmium, lead; accumulate in food web and cause acute and chronic health effects.
- Chlorinated hydrocarbons: accumulate in tissue and are enriched along the food chain; reduced fertility, abnormalities growth, thin egg-shell in birds. DDT, DDE (both now banned in USA and Europe).
- Agricultural fertilizers (Nitrates and phosphates) are leached from arable land and carried by rivers to the sea. Fertilizers enhance phytoplankton production, sometimes to the extent that the accumulation of dead plant remains on the seabed produces anoxic conditions

5. Radioactive waste: The world's oceans have been a sink for radioactive waste from the production of nuclear weapons and electric power since 1944. Radioactive waste enters the ocean from nuclear weapon testing, the releasing or dumping of wastes from nuclear fuel cycle systems, and nuclear accidents. Dumping of high-level radioactive waste is no longer permitted in the ocean, but dumping of low-level wastes is still permitted.

6. Dissipating wastes:

- Heat comes principally from the cooling water from coastal power stations. Commonly, the discharge is at about 10°C above the temperature of the receiving water. Thermal pollution affects the ocean in a negative way. Increases in water temperature causes a change (lowering) of dissolved oxygen levels
- Acids and alkalis: Seawater has a large buffering capacity and the effect of such discharges is extremely localized.
- Cyanide. This comes principally from metallurgical industries. Cyanide rapidly dissociates in seawater and has little effect except in the immediate neighbourhoods .

7. Eutrophication: Eutrophication is a process where the nutrient levels are very high for the volume of water. It is caused due to release of

excess nutrients into coastal waters. Fertilizers used on land are washed into the ocean via rivers and streams.

Effects:

- High nutrient concentrations cause phytoplankton blooms such as, red tides, various yellow and green foams, slimes, and slicks.
- Oxygen consumption increases by bacterial degradation of organic matter and sedimented phytoplankton, causing hypoxia (anoxic conditions) and fish kills
- The toxicity of recent blooms are increasing, which can have a direct effect on the organisms that feed on them. Also, phytoplankton naturally contains DMS (dimethyl sulfide) which is released from dead phytoplankton into the atmosphere and can be changed to sulfuric acid to eventually contribute to acid rain.

Control

Waste disposal always has some impact on the environment and in dealing with the pollution problems in one environment (the sea), it is easy to suggest solutions that merely transfer the problem to a different environment. (ex. from sea to land or vice versa). What is required is the means of disposing of a waste that will cause the least environmental damage. This is known as the **Best Practicable Environmental Option**.

Some of the suggested measures are:

- Fostering industrial processes that produce little or no waste (**low waste** and **no waste technology**) and by withdrawing particularly damaging substances from use, it is possible to reduce marine pollution.
- It is necessary to establish principles for the disposal of wastes that result in the least environmental damage..
- When a substance is clearly identified as being unacceptably damaging, it may be possible to withdraw it from use altogether (ex. DDT)
- Waste discharges should be treated by the **best available technology** (BAT) to minimize the release of damaging substances.

A number of such approaches underlie attempts to bring pollution in the sea under control

Legal Control:

- In most developed countries waste discharge requires some kind of official consent or license
- When a new discharge is proposed, the discharger must provide a detailed **Environmental Impact Assessment** (EIA) or **Environmental Impact Statement** (EIS) which predicts the effect of the proposed discharge on the surrounding area.
- On the basis of this, a permit may be issued or denied, or modifications of the discharge are required

EXERCISES

- 1.** How are solid wastes classified?
- 2.** Why dumping is disadvantageous?
- 3.** What are advantages of Sanitary Landfills?
- 4.** What do you mean by incineration?
- 5.** What are the advantages of incineration?
- 6.** What do you understand by composting?
- 7.** Give an appraisal on recycling and reuse of solid wastes?
- 8.** Discuss different steps in composting operation.
- 9.** Discuss advantages and problems of sanitary landfill.
- 10.** What are the sources of soil pollution?
- 11.** How do industrial waste contribute to soil pollution?
- 12.** How soil pollution can be controlled?
- 13.** What is the effect of modern agriculture practices on soil pollution?
- 14.** What is the composition of soil?
- 15.** What are hazardous wastes and how are they classified?
- 16.** Discuss biological methods of treatment and disposal of hazardous wastes.
- 17.** What are the chemical processes of hazardous waste treatment.
- 18.** Write a short notes on
 - (i) biodegradation
 - (ii) landfill
- 19.** Which soil is considered as best soil for most of the crops? What is its composition?
- 20.** What do you mean by hazardous substance?
- 21.** What are the advantages of sanitary landfill?
- 22.** What is underground injection technique?
- 23.** What are the sources and effects of marine pollution.
- 24.** (a) What does the term incineration mean? What are its disadvantages?
(b) What are the advantages and problems of a sanitary landfill?
(c) How are hazardous wastes classified? What are their sources and biochemical effects?
(d) Write short notes on: Underground injection technique and surface impoundments.
(e) What are the sources and effects of marine pollution?



UNIT 10

Chemical Toxicology

"Science cannot solve the mystery of Nature. It is because in the analysis we ourselves are part of the mystery we are trying to solve"

— Max Plank

Objectives

- Introduction
- Terms Used in Reference to Toxicology: (Toxicology terminology)
- Dose-Response Relationships
- Routes of Entry of Toxicants into the body
- Chemical Interactions
- Damages Caused by the Toxic Materials
- Various Disciplines of Toxicology
- Toxic Chemicals in the Environment
- Impact of Toxic Chemicals on Enzymes
- Biochemical Effects of Heavy Metals
- Biochemical Effects of Pesticides

10.1 INTRODUCTION

Toxicology is essentially the science of poisons. Toxicology can be defined as, "*the study of the adverse effects of chemicals or physical agents on living organisms*". Harmful or *adverse* effects are those that are damaging to either the survivor or normal function of the individual.

These adverse effects may occur in many forms, ranging from immediate death to subtle changes not realized until months or years later.

Historical development of toxicology began with early cave dwellers who identified the poisonous plants and animals and used their extracts for hunting or in warfare. In those days hemlock, opium, arrow poisons, and certain metals were used to poison enemies or for state executions. Notable poisoning victims include Socrates, Cleopatra, and Claudius.

The studies of a Swiss doctor Paracelsus (~1500AD) and Orfila (~1800 AD) helped to understand the fundamental concepts of toxicology. Paracelsus is widely regarded as "the father" of toxicology.

All chemicals are potential toxicants. Paracelsus, summed up this concept by stating "*all substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy.*" Even a material such as water, which is normally considered non-toxic, can be toxic when ingested in large quantity.

Before discussing the toxicology in detail, it is worthwhile to discuss some of the terms used in toxicology.

10.2 TERMS USED IN REFERENCE TO TOXICOLOGY: (TOXICOLOGY TERMINOLOGY)

Terminology and definitions for materials that cause toxic effects are not always used consistently in the literature. Toxicant, toxin, and toxic are often used interchangeably in the literature; however, there are subtle differences as indicated below:

Toxic: This term relates to poisonous or deadly *effects* on the body by inhalation (breathing), ingestion (eating), or absorption, or by direct contact with a chemical.

Toxicant: A toxicant (toxic substance) is anything that can produce an adverse biological effect. It may be chemical, physical, or biological in form. For example cyanide (chemical), radiation (physical) and snake venom (biological) represent various forms of toxic substances.

Toxin: The term “**toxin**” usually is used when talking about toxic substances produced *naturally*. A toxin is any poisonous substance of microbial (bacteria or other tiny plants or animals), vegetable, or synthetic chemical origin that reacts with specific cellular components to kill cells, alter growth or development, or kill the organism. It causes injury to the health of a living thing on contact or absorption, typically by interacting with biological macromolecules such as enzymes and receptors. The term is usually reserved for naturally produced substances that kill rapidly in small quantities, such as the bacterial proteins that cause tetanus and botulism. The word “toxic” is used more loosely and often applied to non-biological materials, as in “toxic waste” and “toxicology”

Toxicity: The word “toxicity” describes the degree to which a substance is poisonous or can cause injury. In most cases the quantity of material is related to its toxicity.

The traditional way to test toxicity is to count how many laboratory organisms die or suffer impaired health when exposed to various concentrations of a substance. Toxicity is measured in terms of the amount of the particular material that is needed to kill half the organisms in the test, which is called the LD50 (*Lethal Dose 50%*).

Toxicity can be generally broken down into two categories:

- (a) *Acute toxicity* refers to the rapid development of symptoms/effects after the intake of relatively high doses of the toxicant. Acute toxicity refers to immediate harmful effects generated by sufficiently large doses.
- (b) *Chronic toxicity* refers to the harmful effects of long-term exposure to relatively *low doses* of toxicant. This would include traces of pesticides in foods, air pollution, etc. Chronic health effects are often irreversible. Examples: lead or mercury poisoning, cancer.

A single compound may generate both acute and chronic toxic effects depending on the dose and duration of exposure.

Toxic Effects: This term refers to the health effects that occur due to exposure to a toxic substance; also known as a poisonous effect on the body. Toxic effects can be :

Lethal : resulting in the death of individuals or

Sublethal: effects not directly resulting in death

Toxic effects can be of following types:

- An *acute effect* is characterized by sudden and severe exposure and rapid absorption of the substance. An acute exposure occurs over a very short period of time, usually 24 hours. Normally, a single large exposure is involved. Adverse health effects are often *reversible*. Examples: carbon monoxide or cyanide poisoning
- A *chronic effect* is characterized by prolonged or repeated exposures of a long duration. It occurs over long periods of time such as weeks, months, or years. Symptoms may not be immediately apparent. Chronic effects are often irreversible. Examples: lead or mercury poisoning.
- A *local effect* refers to an adverse health effect that takes place at the point or area of contact (skin, the respiratory tract, eyes, etc.). Absorption does not necessarily occur. Examples: strong acids or alkalis.
- A *systemic effect* refers to an adverse health effect that takes place at a location distant from the body's initial point of contact. Examples: arsenic affects the blood, nervous system, liver, kidneys and skin; benzene affects bone marrow.
- *Cumulative poisons* are characterized by materials that tend to build up in the body as a result of numerous chronic exposures. The effects are not seen until adverse health effect takes place. Example: heavy metals.
- *Synergistic effect*: When two or more hazardous materials are present at the same time, the resulting effect can be *greater* than the effect predicted based on the additive effect of the individual substances. This is also called a potentiating effect. Example: exposure to alcohol and chlorinated solvents; or smoking and asbestos.

Dose: The most important factor that influences the toxic effect of a specific chemical is the dose. The dose is the actual amount of a chemical that enters the body. The dose received may be due to either acute (short) or chronic (long-term) exposure. The amount of exposure and the type of toxin will determine the toxic effect. This is important because for each chemical, a certain dose produces certain biological effects in the individual organism.

Response: Any biological effect caused by the exposure is called the *response*. Typically, as the dose of a toxic substance goes up, increasing numbers of organisms die or show signs of impaired health.

Xenobiotic: Xenobiotic is the general term that is used for a *foreign* substance taken into the body. It is derived from the Greek term *xeno* which means “*foreigner*.” Hence, *xenobiotic* is a chemical which is found

in an organism but which is not normally produced or expected to be present in it. Xenobiotics may produce beneficial effects (*such as a pharmaceuticals*) or they may be toxic (*such as lead*)

Target organ: An organ that is damaged by the xenobiotic or its metabolism.

Selective toxicity refers to species differences in toxicity between two species simultaneously exposed. A compound can produce *selective toxicity*. “Selective toxicity” means that a chemical will produce injury to one kind of living matter without harming another form of life, even though the two may exist close together. This is the basis for the effectiveness of pesticides and drugs. Examples are:

- an insecticide is lethal to insects but relatively nontoxic to animals
- antibiotics are selectively toxic to microorganisms while virtually nontoxic to humans.

Sensitivity: People vary widely in their sensitivity to the effects of a chemical. Many things determine how an individual will react to a chemical. These include age, sex, inherited traits, diet, pregnancy, state of health and use of medication, drugs or alcohol. Depending on these characteristics, some people will experience the toxic effects of a chemical at a lower (or higher) dose than other people.

People may also become allergic to a chemical. These people have a different type of response than those who are not allergic. This response frequently occurs at a very low dose. Not all chemicals can cause allergic reactions. Substances that are known to cause allergies are called allergens, or sensitizers.

10.3 DOSE-RESPONSE RELATIONSHIPS

All chemicals, including essential substances such as oxygen and water, produce toxic effects when taken in large doses. As discussed above, “*all substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy*” (Paracelsus).

Dose is a very significant factor in toxicology. The statement “the dose makes the poison” aptly describes the role of the dose. Even chemicals naturally present in our food and drinks are toxic if consumed in sufficiently large quantities. For example,

- The caffeine in a normal human diet does not cause illness, but just 50 times this amount could kill you.
- The oxalic acid found in spinach is harmless in the amounts anyone would normally eat but could lead to kidney damage if 10 to 20 pounds were consumed at a single sitting.
- Vitamin D, for example, is an important nutrient that promotes good health when ingested at recommended dosages. However, vitamin D also is a highly toxic chemical, and taking too much can lead to serious health problems including kidney stones, high blood pressure, deafness, and even death.

10.3.1 Dose-response

Dose-response is a relationship between exposure and health effect, that can be established by measuring the response relative to an increasing dose. This simply relates the dose (quantity administered) of a substance to the response generated in a test organism. The dose-response relationship is based on observed data from experimental animal, human clinical, or cell studies

The measured dose (usually in milligrams, micrograms, or grams per kilogram of body-weight) is generally plotted on the X axis and the response is plotted on the Y axis. Commonly, it is the logarithm of the dose that is plotted on the X axis, and in such cases the curve is typically sigmoidal, with the steepest portion in the middle.

For most types of toxic responses, there is a dose, called a threshold, below which there are no adverse effects from exposure to the substance. The human body has defences against many toxic agents. Cells in human organs, especially in the liver and kidneys, break down chemicals into nontoxic substances that can be eliminated from the body in urine and faeces. In this way, the human body can take some toxic substance (at a dose that is below the threshold) and still remain healthy.

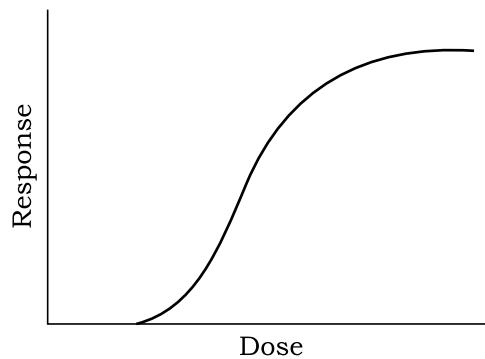


Fig. 10.1: Dose-response curve: response (percent of population affected) vs. Dose (mg/kg).

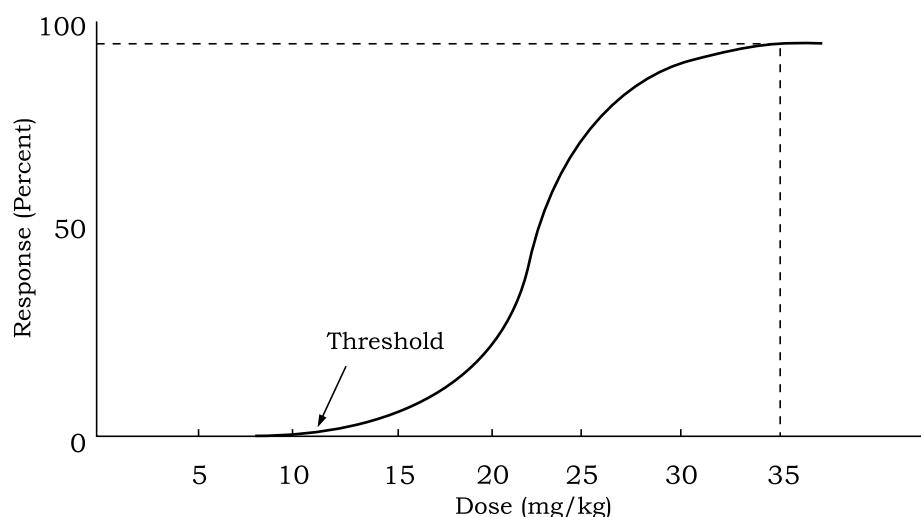


Fig. 10.2

For most effects, small doses are not toxic. From the threshold point at which toxicity first appears, the curve increases with higher dose levels. In the hypothetical curve in Fig 10.2, no toxicity occurs at 10 mg whereas at 35 mg 100% of the individuals experience toxic effects.

This simple model is useful to develop basic dose-response relationships however, more complex dose-response relationships are there for many toxicants depending on the target organ and the species exposed.

For all chemicals there is a dose response curve, or a range of doses that result in a graded effect between the extremes of no effect and 100% response (toxic effect). All chemical substances will exhibit a toxic effect given a large enough dose. If the dose is low enough even a highly toxic substance will cease to cause a harmful effect. The toxic potency* of a chemical is thus ultimately defined by the dose (the amount) of the chemical that will produce a specific response in a specific organism.

Dose-response curve and Toxic Effects

Dose-response curves are used to derive dose estimates of chemical substances. A common dose estimated for acute toxicity is the LD50 (*Lethal Dose 50%*). This is a statistically derived dose at which 50% of the individuals will be expected to die. Fig. 10.3 illustrates how an LD50 of 20 mg is derived.

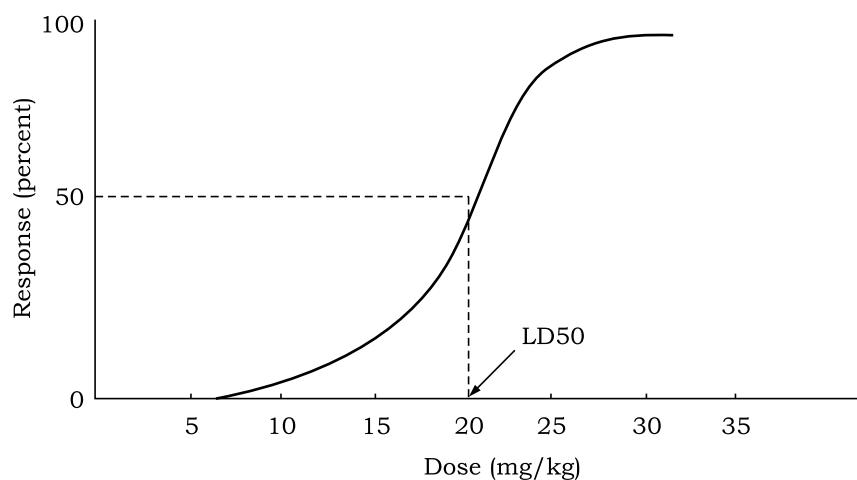


Fig. 10.3

Other dose estimates also may be used. LD0 represents the dose at which no individuals are expected to die. This is just below the threshold for lethality. LD10 refers to the dose at which 10% of the individuals will die.

For *inhalation* toxicity, air concentrations are used for exposure values. Thus, the LC50 is utilized which stands for Lethal Concentration 50%, the calculated concentration of a gas lethal to 50% of a group. Occasionally LC0 and LC10 are also used.

The term Lethal Concentration is also used to describe aquatic toxicity, where concentration refers to the concentration in water.

Effective Doses (EDs) are used to indicate the effectiveness of a substance. Normally, effective dose refers to a beneficial effect (*relief of pain*). It might

***Note:** The **potency** of a chemical is a measure of its strength as a poison compared with other chemicals. The more potent the chemical, the less it takes to kill.

also stand for a harmful effect (*paralysis*). Thus the specific endpoint must be indicated. The usual terms are:

ED0	effective for 0% of the population
ED10	effective for 10% of the population
ED50	effective for 50% of the population
ED90	effective for 90% of the population

Toxic Doses (TDs) are utilized to indicate doses that cause adverse toxic effects. The usual dose estimates are listed below:

TD0	toxic to 0% of the population
TD10	toxic to 10% of the population
TD50	toxic to 50% of the population
TD90	toxic to 90% of the population

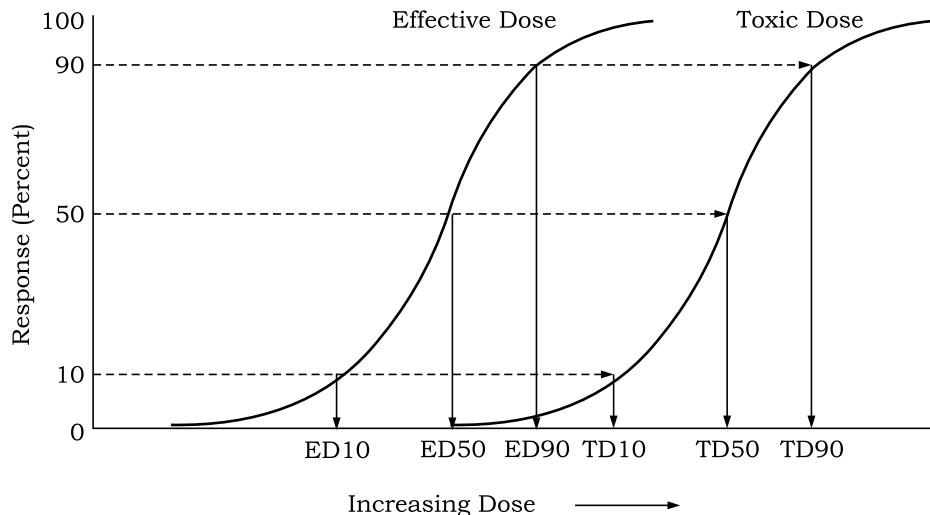


Fig. 10.4

To summarize,

- TD_{50} : (toxic dose) The dose required to elicit a defined toxic effect (e.g. fatty liver, fever, etc.) in 50% of the sample population . TD_{50} is used to indicate responses such as reduced enzyme activity, loss of hearing, nausea etc, whereas
- ED_{50} : (Effective Dose)Generally used for drugs - the dose required to have a therapeutic or other effect in 50% of sample population. ED_{50} of paracetamol would be the dose that relieves high temperature of the body in 50% of the people.

- LD₅₀: (lethal dose) The dose required for lethality in 50% of the sample population. LD₉₅ is used for insecticides and pesticides so that 95% of the insect population dies. For human health, chemicals having LD₀ are used so that no one dies

10.3.2 NOAEL and LOAEL

Two terms often encountered are No Observed Adverse Effect Level (NOAEL) and Low Observed Adverse Effect Level (LOAEL). They are the actual data points from human clinical or experimental animal studies.

NOAEL	Highest data point at which there was not an observed toxic or adverse effect
LOAEL	Lowest data point at which there was an observed toxic or adverse effect

Some examples that illustrate these concepts are:

Substance	Non-Toxic or Beneficial Dose	Toxic Dose	Lethal Dose
Alcohol <i>Ethanol Blood Levels</i>	0.05%	0.1%	0.5%
Carbon Monoxide <i>%Hemoglobin Bound</i>	<10%	20–30%	>60%
Secobarital (sleep aid) <i>Blood Levels</i>	0.1 mg/dL	0.7 mg/dL	> 1 mg/dL
Aspirin	0.65 gm (2 tablets)	9.75 gm (30 tablets)	34 gm (105 tablets)
Ibuprofin <i>E.G., Advil & Motrin</i>	400 mg (2 tablets)	1,400 mg (7 tablets)	12,000 mg (60 tablets)

Principles of Clinical Toxicology (T.Gossel and J. Bricker, eds)

10.4 ROUTES OF ENTRY OF TOXICANTS INTO THE BODY

The human body has three protective barriers against outside environmental contaminants.

- The skin, which protects the body from contaminants outside the body;
- The gastrointestinal (GI) tract, which protects the inner body from contaminants (toxins) that have been ingested,
- The membranes within the lungs, which protect the inner body from contaminants that have been inhaled

Before toxicity can develop, a substance must come into contact with a body surface such as skin, mucosa of the digestive or respiratory tract.

We are exposed to a number of chemicals in our home, at work, and in the general environment. Route of exposure describes the way the chemical enters the body. Chemicals may have serious effects by one route, and minimal effects by another. Hazardous chemicals may enter the body by:

- Absorption through the respiratory tract via inhalation
- Absorption through the skin via dermal contact.
- Absorption through the digestive tract via ingestion. (Ingestion can occur through eating or smoking with contaminated hands or in contaminated work areas.)
- Injection: Introducing the material directly into the bloodstream. (Injection may occur through mechanical injury from “sharps”.)

In general, substances are absorbed into the body most efficiently through the lungs so that inhalation is often the most serious route of exposure.

10.5 CHEMICAL INTERACTIONS

The effect that one chemical has on the toxic effect of another chemical is known as an **interaction**. Humans are normally exposed to several chemicals at one time rather than to an individual chemical. Medical treatment and environment exposure generally consists of multiple exposures. Examples are:

- drinking water may contain small amounts of pesticides, heavy metals, solvents, and other organic chemicals
- air often contains mixtures of hundreds of chemicals such as automobile exhaust and cigarette smoke
- home influenza treatment consists of aspirin, antihistamines, and cough syrup taken simultaneously
- gasoline vapor at service stations is a mixture of 40-50 chemicals

Xenobiotics administered or received simultaneously may act independently of each other. However, in many cases, the presence of one chemical may drastically affect the response to another chemical. The toxicity of a combination of chemicals may be less or it may be more than would be predicted from the known effects of each individual chemical

10.5.1 Types of Interactions

There are four basic types of interactions. Each is based on the expected effects caused by the individual chemicals. The types of interactions are:

additivity	a combination of two or more chemicals is the sum of the expected individual responses
antagonism	exposure to one chemical results in a reduction in the effect of the other chemical
potentiation	exposure to one chemical results in the other chemical producing an effect greater than if given alone
synergism	exposure to one chemical causes a dramatic increase in the effect of another chemical

Examples:

Additivity :Two central nervous system (CNS) depressants taken at the same time, a tranquilizer and alcohol, often cause depression equal to the sum of that caused by each drug.

Antagonism is often a desirable effect in toxicology and is the basis for most antidotes. Examples include, swallowed poison is absorbed by introducing charcoal in the stomach.

Potentiation occurs when a chemical that does not have a specific toxic effect makes another chemical more toxic. Examples are: The hepatotoxicity of carbon tetrachloride is greatly enhanced by the presence of isopropanol. Such exposure may occur in the workplace.

Synergism can have serious health effects. With synergism, exposure to a chemical may drastically increase the effect of another chemical. Examples are: Exposure to both cigarette smoke and radon results in a significantly greater risk for lung cancer than the sum of the risks of each.

10.6 DAMAGES CAUSED BY THE TOXIC MATERIALS

Toxicity is complex with many influencing factors; dosage is the most important. Xenobiotics cause many types of toxicity by a variety of mechanisms. Some chemicals are themselves toxic. Others must be metabolized (*chemically changed within the body*) before they cause toxicity.

Many xenobiotics distribute in the body and often affect only specific **target organs**. Others, however, can damage any cell or tissue that they contact. The target organs that are affected may vary depending on dosage and route of exposure. For example, the target for a chemical after acute exposure may be the nervous system, but after the chronic exposure to the liver.

Toxicity can result from adverse cellular, biochemical, or macromolecular changes. Examples are:

- cell replacement, such as fibrosis
- damage to an enzyme system
- disruption of protein synthesis
- production of reactive chemicals in cells
- DNA damage

Based on the above factors ,there are four basic types of damage caused by toxic materials:

Physiological damage: reversible/irreversible damage to the health of the organism

Carcinogenesis: induction of cancer

Mutagenesis: induction of genetic damage / mutation(s)

Teratogenesis: induction of birth defects

Physiological Classification of Toxic Responses:

Toxic substances can be classified according to the physiological effects they have on the human body. This classification scheme separates toxic substances into the following categories: (Table 10.1)

Table 10.1: Physiological Classification of Toxic Responses

Class	Effect
Irritant:	Causes inflammation of the skin and mucous membranes (skin, eyes, nose, or respiratory system).
Corrosive:	A material that can destroy human tissue. Includes both acids and bases and may be a solid liquid or gas. Most common toxic material encountered in the laboratory.
Asphyxiant:	A material that deprives tissue of oxygen and causes suffocation by displacing oxygen or interfering chemically with oxygen absorption, transport or utilization. e.g., CO and NO _x inhalation.
Anesthetic:	Depresses the central nervous system Example: alcohols, halogenated hydrocarbons
Hepatotoxin:	causes liver damage. Example: carbon tetrachloride
Nephrotoxin:	causes kidney damage. Example: chloroform, mercury, dimethyl sulfate
Neurotoxin:	affects the nervous system. Example: mercury, lead, carbon disulfide
Hematopoietic toxin:	affects the cellular components of blood or its ability to function Example: benzene, xylene, CO, cyanides
Pulmonary toxin:	irritates or damages the lungs. Example: asbestos, silica ozone, chromium
Reproductive toxins:	causes impotence or sterility in men and women. Example: lead, dibromodichloropropane
Carcinogen:	A material which can cause cancer. Example: asbestos, Bis-chloromethyl ether, benzene, acrylonitrile, Poly Aromatic Hydrocarbons (PAH).
Mutagen:	Anything which causes a change in the genetic material of a living cell. Many mutagens are also carcinogens.
Teratogen:	A material which interferes with the developing embryo when a pregnant female is exposed to that substance. Example: lead, thalidomide

10.7 VARIOUS DISCIPLINES OF TOXICOLOGY

The field of toxicology can be further divided into many sub-disciplines :

- (a) **Environmental Toxicology** is concerned with the study of chemicals that contaminate food, water, soil, or the atmosphere. It also deals with toxic substances that enter bodies of waters such as lakes, streams, rivers, and oceans. Environmental Toxicology deals with the question of how various plants, animals, and humans are affected by exposure to toxic substances.

- (b) Occupational (Industrial):** Toxicology is concerned with health effects from exposure to chemicals in the workplace. This field grew out of a need to protect workers from toxic substances and to make their work environment safe. Occupational diseases caused by industrial chemicals account for an estimated 50,000 to 70,000 deaths, and 350,000 new cases of illness each year in the United States.
- (c) Food Toxicology:** It is involved in delivering a safe and edible supply of food to the consumer. During processing, a number of substances may be added to food to make it look, taste, or smell better. Fats, oils, sugars, starches and other substances may be added to change the texture and taste of food. All of these additives are studied to determine if and at what amount, they may produce adverse effects. A second area of interest includes food allergies.
- (d) Forensic Toxicology:** It is used to help establish cause and effect relationships between exposure to a drug or chemical and the toxic or lethal effects that result from that exposure.

However in this chapter, we will confine our discussion to Environmental Toxicology

10.8 TOXIC CHEMICALS IN THE ENVIRONMENT

Environment toxicology is concerned with the biological effects of the chemicals that are encountered by man either incidentally because they are in the environment or by contact during occupational or recreational activities, or by ingestion of food additives. The introduction of chemicals in the environment may occur in every sector, from major industrial plant to small shops to individual homes.

Toxicant may affect the human health by different mechanism. They may be systemic toxicants or organ toxicants.

A systemic toxicant is one that affects the entire body or many organs rather than a specific site. For example, potassium cyanide is a systemic toxicant in that it affects virtually every cell and organ in the body by interfering with cells' ability to utilize oxygen.

Toxicants may also affect only specific tissues or organs while not producing damage to the body as a whole and hence is called **organ toxicant**. These specific sites are known as the target organs or target tissues.

- Benzene is a specific organ toxin in that it is primarily toxic to the blood-forming tissues.
- Lead is also a specific organ toxin; however, it has three target organs: the (central nervous system, the kidney, and the hematopoietic system).

A toxicant may affect a specific type of tissue (for example, connective tissue) that is present in several organs. The toxic site is then referred to as the target tissue.

The list of toxic chemicals in the environment is very long. Most of the toxic chemicals have already been discussed in the Unit III under different

heads. In this chapter we will discuss the effects of different types of toxicants in detail, including metals, pesticides, and other chemicals.

1. Outdoor Air Pollutants:

Outdoor pollutants, which may pose a health hazard from exposure are : carbon monoxide, sulfur oxides, ozone, nitrogen oxides, and particulates. Chemicals other than these also have the potential to be toxic, however above chemicals are considered mainly because they are produced in the largest amount and have the greatest chance of producing a toxic effect. The outdoor air pollutants are already discussed in *Unit 3* under section: Some Common Air Pollutants.

2. Heavy Metals

The last 50 years have seen the introduction of many new chemicals. Some metals, the essential minerals, such as zinc (Zn), iron (Fe), copper (Cu), manganese (Mn) and magnesium (Mg), we need to ingest since they are required for normal growth and survival, while other metals such as cadmium (Cd), lead (Pb) and mercury (Hg) are only harmful to living systems.

Heavy metals are everywhere in nature as components of the earth's crust. Plants can absorb and accumulate metals, which may be toxic. Industrial development has resulted in exposure to heavy metals in people because of increased production of by-products such as cadmium, mercury, chromium, and zinc.

There are 72 metals in the periodic table. Those which are toxic to man are:

- Arsenic (As)
- Cadmium (Cd)
- Lead (Pb)
- Chromium (Cr)
- Mercury (Hg)
- Iron (Fe)
- Aluminium (Al)
- Thallium (Th)
- Plutonium (Pu)

These metals are all toxic if excessive amounts of them are ingested. However, many metals are always toxic if they are ingested, for example arsenic, cadmium, lead, mercury and tin. The effect of heavy metals on human health are discussed in detail in next section.

3. Radiation and Radioactive Materials

Radiation is the release and propagation of energy in space or through a material medium in the form of waves, the transfer of heat or light by waves of energy, or the stream of particles from a nuclear reactor. The two major classes of radiation are ionizing radiation and non-ionizing radiation.

- Ionizing radiation affects the bone marrow, resulting in a decrease in red blood cell production, reddening of the skin, gastrointestinal and reproductive effects, cataracts, birth defects, and respiratory illness.
- Non-ionizing radiation is associated with mutagenic and carcinogenic effects, primarily by UV radiation, which can alter the repair mechanisms for DNA and potentially lead to skin cancer.

4. Polychlorinated Biphenyls (PCBs):

Polychlorinated Biphenyls (PCBs) are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl. The chemical formula for all PCBs is $C_{12}H_{10-x}Cl_x$.

PCBs are another major contaminant of concern .They were used in plasticizers, adhesives, and as dielectric fluids in capacitors. In humans, they accumulate in fat tissue and milk, which is a major route of excretion.

PCBs cause liver cancer in rats and mice and is classified as a probable carcinogen in humans. PCBs are persistent in the environment and bioaccumulate upward in the food chain. A non-occupational source of PCBs is in fish from contaminated water. Cultures where subsistence fishing is a primary source of food would subsequently represent populations of concern regarding PCB-contaminated fish .

High-level exposure to PCBs may cause a classic dermatological condition called chloracne. Developmental and fetotoxic effects may also be observed in humans. Occupational exposures to PCBs primarily occurs in the production of electrical equipment. PCBs have been banned from further production as a material for the production of electrical equipment and chronic workplace exposure is now uncommon.

5. Pesticides

The word “pesticide” is a broad term that refers to any device, method, or chemical that kills plants or animals that destroy our food supply or are otherwise undesirable. In simple terms, it is an agent that kills pests. Several classes of pesticides cause adverse human health effects. The major classes of pesticides include:

- Bactericides for the control of bacteria
- Fungicides for the control of fungi
- Herbicides for the control of weeds
- Insecticides for the control of insects
- Molluscicides for the control of slugs and snails
- Nematicides for the control of nematodes
- Rodenticides for the control of rodents
- Virucides for the control of viruses

Pesticides include the organochlorides, organophosphates, and the carbamates. All these classes of pesticides are discussed in detail under the heading “section 10.11” at the end of chapter.

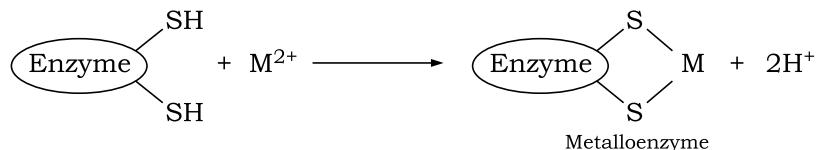
10.9 IMPACT OF TOXIC METALS ON ENZYMES

An enzyme is typically a large protein molecule that contains one or more active sites where interaction with the substrate takes place. Toxic chemicals generally produce their toxicity

- By forming complexes with the active sites on the enzymes. The modified enzymes loose their ability to function properly, which leads to the malfunction or death of the affected cells. Metals commonly bind to biological compounds containing oxygen, sulphur and nitrogen, which may inactivate certain enzyme systems or affect protein structure.
- In addition to this, light toxic metals may compete with or replace similar metals, for example lithium competes with the similar metal sodium.
- In acute poisoning, large excesses of metal ions can cause disruption of membrane and mitochondrial function in the cells and the generation of free radicals.

These steps can be illustrated by taking the example of heavy metals as toxic substance:

- Heavy metals are electrophilic and react with nucleophilic groups on proteins (enzymes) in the body. These nucleophilic groups are:
– SH, – NH₂, – CONH, – PO₄



- As a result of binding to these groups on proteins, the heavy metal may compete with endogenous metals, e.g. Ca²⁺ or Zn²⁺ which also rely on binding to these proteins via the same groups.
- Heavy metal binding may lead to disruption of enzyme function e.g. Pb interferes with haem biosynthesis by inhibition of 8 aminolevulinic acid dehydratase (ALAD). This results in a reduction in plasma ALAD activity and an increase in plasma aminolevulinic acid

10.10 BIOCHEMICAL EFFECTS OF HEAVY METALS

Five of the most toxic heavy metals: arsenic, cadmium, lead, chromium and mercury are discussed in the following sections:

1. ARSENIC

Arsenic, one of the most toxic metals, is produced at a rate of about 60,000 tons per year. Arsenic exists in three common valence states: As(0) (metalloid arsenic, 0 oxidation state), As(III) (trivalent state, such as arsenites), and As(V) (pentavalent state, such as arsenates). The pentavalent form is not as toxic as the trivalent form due to greater cellular

uptake. Metalloid arsenic is generally regarded as nonpoisonous due to its insolubility in water and body fluids. Moreover, inorganic arsenic is generally more toxic than organic arsenic.

The order of decreasing toxicity (most to least) for arsenic is: arsines, inorganic arsenites, organic arsenoxides, inorganic arsenates, arsenorganics with As valence of +5, and metallic As.

Sources: Environmental sources of arsenic exposure include food, water, soil, and air.

- Natural sources : Arsenic is found naturally on earth in small concentrations.
- Commercial products: Wood treated with arsenate wood preservatives is an important source of arsenic exposure, insecticides, herbicides (weed killers and defoliants), fungicides, cotton desiccants, cattle and sheep dips, paints and pigments, antifouling paints, leaded gasoline, and fire salts , all are sources of arsenic.
- Industrial processes: In industry, arsenic is a by-product of the smelting process for many metal ores such as lead, gold, zinc, cobalt, and nickel. Other industrial processes include; purifying industrial gases (removal of sulfur), burning fossil fuels, burning wood treated with arsenic preservatives.
- In electronic industry: Arsine gas (AsH_3), used commercially in the microelectronics industry and encountered accidentally in metallurgical and mining processes, produces a clinical syndrome which is very different from syndromes produced by other arsenic compounds, and is the most toxic arsenic.
- Gallium arsenide (GaAs) is used in integral components of discrete microwave devices, lasers, light-emitting diodes, photoelectric chemical cells, and semiconductor devices.
- Pesticides in food: wine (grapes sprayed with arsenic-containing pesticides), tobacco (plants sprayed with arsenic-containing pesticides) seafood (especially bivalves, certain cold water and bottom-feeding finfish, and seaweed). Fish absorb arsenic from the water they live in.
- Volcanoes release about 3000 tonnes per year and microorganisms release volatile methylarsines to the extent of 20.000 tonnes per year,

Although it is a deadly poison, arsenic is an essential trace element for some animals, and maybe even for humans, although the necessary intake may be as low as 0.01 mg/day.

Exposure Pathways

The primary routes of exposure to arsenic are ingestion and inhalation. In humans, soluble forms of ingested arsenic are well absorbed (60% to 90% absorption) from the gastrointestinal tract. Airborne arsenic in the workplace is generally in the form of arsenic trioxide

Health Effects

Acute exposure to arsenic may result in death, fever, anorexia, and liver enlargement . A lethal dose of arsenic oxide is generally regarded as 100 mg.

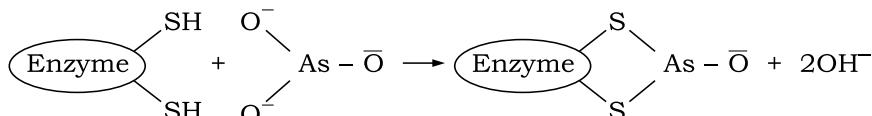
Some of the health effects of arsenic toxicity are:

- *Neurologic Effects:* Chronic exposure may result in poisoning of the nervous system,liver damage, and peripheral vascular disease, which could result in gangrene of the lower limbs. This condition is more commonly known as “black foot disease” and was a phenomenon that occurred in Taiwan from arsenic contamination of the drinking water supply.
- *Skin and Lung Cancer:* In addition, skin cancer and lung cancer may result from chronic arsenic exposure. Chronic arsenic exposure has also been associated with leukemia, kidney, and bladder cancers, dermatitis, hyper pigmentation, and keratosis (or arsenical keratosis).
- *Renal Effects:* Arsenic is capable of causing acute renal failure, as well as chronic renal insufficiency.
- *Cardiovascular Effects:* Acute arsenic poisoning may cause both diffuse capillary leak and cardiomyopathy, resulting in shock.
- *Respiratory Effects:* Inhalation of high concentrations of arsenic compounds produces irritation of the respiratory mucosa.
- *Reproductive Effects:* A very high exposure to inorganic arsenic can cause infertility and miscarriages with women.
- *Gastrointestinal:* The gastrointestinal (GI) effects of arsenic generally result from exposure via ingestion; however, GI effects may also occur after heavy exposure by other routes. Exposure to inorganic arsenic can cause various health effects, such as irritation of the stomach and intestines.

Biochemical Effects Of Arsenic:

Arsenic is a general protoplasmic poison and it affects all systems in the body. The major biochemical affects of Arsenic that impair tissue respiration are :

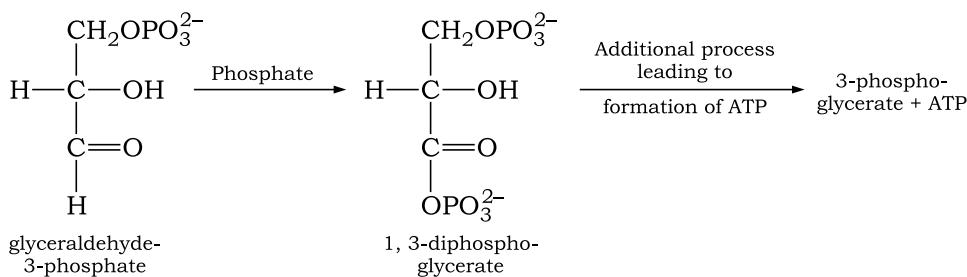
- (i) **Complexation with coenzyme/enzyme :** Arsenic readily combines with sulphhydryl (-SH) groups. Arsenic binds with sulphhydryl groups and disrupts sulphhydryl-containing enzymes; As(III) is particularly potent in this regard.



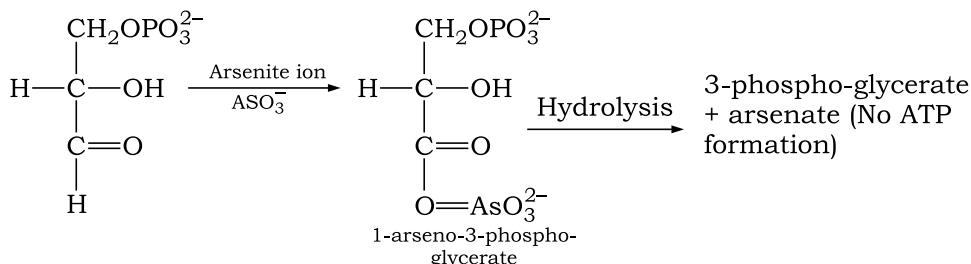
As a result of critical enzyme effects, there is inhibition of the pyruvate and succinate oxidation pathways and the tricarboxylic acid cycle (all are essential metabolic activities of cell respiration). The inhibitory action is based on inactivation of pyruvate

dehydrogenase by complexation with As ions. Thus the formation of adenosine triphosphate (ATP), which is an important energy source is inhibited.

(ii) Uncoupling of Phosphorylation: Another mechanism involves substitution of As(V) for phosphorus in many biochemical reactions by virtue of its chemical similarity to phosphorus. Replacing the stable phosphorus anion in phosphate with the less stable As(V) anion leads to rapid hydrolysis of high-energy bonds in compounds such as ATP. That leads to loss of high-energy phosphate bonds and effectively “uncouples” oxidative phosphorylation. Example:



However in presence of arsenic, arsenolysis takes place as follows:



(iii) Coagulation of Proteins:

Arsine (III) compounds of high concentrations coagulate proteins by attacking the sulphur bonds responsible for primary and secondary structures of proteins.

(iv) Arsine gas poisoning results in a considerably different syndrome from that caused by other forms of arsenic. After inhalation, arsine rapidly fixes to red blood cells, producing irreversible cell-membrane damage. At low levels, arsine is a potent hemolysin, causing dose-dependent intravascular haemolysis. At high levels, arsine produces direct multisystem cytotoxicity.

2. MERCURY

Mercury is the third most toxic substance in the environment. Throughout the centuries, several incidents of mercury toxicity have been reported. It was during the 1800s that the phrase “mad as a hatter” was coined because of the chronic mercury exposure that the felters faced because mercury was used in hat making. Mercury occurs naturally in the environment and exists in several forms. These forms can be organized under three headings: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury.

Sources: Several forms of mercury occur naturally in the environment. The most common natural forms of mercury found in the environment are metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury

The main source of mercury exposure is from industry that puts it to various uses:

- *Electronics and electrical industry:* Approximately half of all mercury is used to produce vapor lamps, fluorescent tubes, thermometers, and electrical products. Spills of metallic mercury from broken thermometers or damaged electrical switches in the home may result in exposure to mercury vapors in indoor air. You must be careful when you handle and dispose off all items in the home that contain metallic mercury.
- *In medicine:* In dental amalgams for filling teeth and various antiseptic agents
- *Chemical industry:* In determining Nitrogen by Kjeldahl method, for Millon's reagent; manufacture of vinyl chloride. As cathode in electrolysis, electro analysis.
- Mercury may be released into the air when coal, oil, or wood are burned as fuel or when mercury-containing wastes are incinerated. Air borne mercury is highly toxic when inhaled. Metallic mercury slowly evaporates when exposed to the air. The air in a room can reach contamination levels just from the mercury in a broken thermometer.
- Inorganic salts of mercury, including ammoniated mercuric chloride and mercuric iodide, have been used in skin-lightening creams.
- Mercury in the air can fall to the ground with rain and snow, landing on soil or in bodies of water, causing contamination. Lakes and rivers are also contaminated when there is a direct discharge of mercury-laden industrial or municipal waste into the water.
- When mercury enters bodies of water, biological processes transform it to methylmercury, a highly toxic and bioaccumulative form. Fish can absorb methylmercury from their food and directly from water as it passes over their gill

Some of the more recent occurrences include exposures in Minamata Bay in Japan (1960); mercury contaminated fish in Canada; methyl-mercury-treated grain in Iraq (1960, 1970); and, in the United States (1996), a beauty cream product from Mexico called "Crème de Belleza-Manning."

MeHg has an unfortunate history. An industrial discharge of MeHg into Minamata Bay in Japan led to the poisoning of local fishermen and their families in the 1950's. A similar incident occurred in Iraq in 1972 when MeHg-fungicide treated grain was released for human consumption. This led to neurological damage to several thousand people and death to several hundred. The study of cases of MeHg poisoning has led to much of our current understanding of mercury toxicity.

Exposure Pathways:

Mercury in any form is toxic. The difference lies in how it is absorbed, the clinical signs and symptoms, and the response to treatment modalities. Mercury poisoning can result from vapor inhalation, ingestion, injection, or absorption through the skin.

Health Effects:

- It exists in a number of forms, which may affect different parts of the body.
- Organic mercury primarily affects the brain. Methyl mercury is the most toxicological form of the element and, by its accumulation in the central nervous system (CNS), may result in neurotoxic effects in adults and toxicity in the fetuses of mothers exposed to methyl mercury during pregnancy.
- Metallic mercury is slowly absorbed by the gastrointestinal system and is not as toxic as methyl mercury .
- Inorganic mercury (mercury salts) primarily affects the kidneys. Exposure to mercuric salts may lead to abdominal cramps and bloody diarrhea.

Biochemical Effects Of Mercury

Mercury has a strong affinity for sulfur, and mercury's primary mode of toxic action in living organisms is thought to be the interference of enzyme function and protein synthesis by binding to sulfohydryl or thiol groups. The mercury atom or molecule will tend to bind with any molecule present that has sulfur or a sulfur-hydrogen combination in its structure. This process of combining with a metal to form a complex in which the metallic ion is sequestered and firmly bound is called *chelation*.

The primary sulfur-containing protein amino acids in the body are *cystine*, *cysteine*, *methionine*, and *taurine*. There is also a sulfur-containing *tripeptide* (having three amino acids) called *glutathione* that is composed of glutamic acid, cysteine, and glycine. Sulfur exists in a *reduced* form (-SH) in cysteine and in an *oxidized* form (-S-S) as the double molecule in cystine. Whenever mercury binds to one of these sulfur-containing molecules, it reduces the molecule's availability for normal metabolic functions.

The biochemical toxicology of mercury depends on the chemical form and entrance route into the body.

- (i) **Elemental mercury** (Hg) is found in liquid form, which easily vaporizes at room temperature and is well absorbed (80%) through inhalation. From the lungs it dissolves in blood plasma, and from there it has access to diffuse into any cell in the body. Once inside a cell, mercury vapor, itself unreactive, is oxidized to the highly toxic mercury (+2) ion. This is also known as divalent mercury. This oxidation process is mediated by the enzyme *catalase*. This keeps most inhaled mercury vapor from ever reaching the brain. However, some elemental mercury vapor does reach the brain, and

there it is also oxidized to divalent mercury. This divalent mercury in the brain leads to strange symptoms, including *erethism* (mad hatter's disease). However, the process by which this happens is still not known. It is believed that divalent mercury attaches to receptors in the brain. Elemental mercury, Hg(0), the form released from broken thermometers, causes tremors, gingivitis, and excitability when vapors are inhaled over a long period of time.

Elemental mercury is not well absorbed by the GI tract and, therefore, when ingested (eg, thermometers), is only mildly toxic.

(ii) **Inorganic mercury**, found mostly in the mercuric salt form (eg, batteries), is highly toxic and corrosive. It gains access to the body orally or dermally and accumulates mostly in the kidney, causing significant renal damage. Organic or inorganic mercury can both precipitate protein in a local reaction. In the GI tract, acute poisoning produces a sloughing away of the mucosa to an extent where pieces of the intestinal mucosa can be found in the stools. This produces a large loss of fluids and electrolytes. Mercury also breaks down barriers in the capillaries. This results in edema throughout the body. A range of neurological toxicities are also common. These include lethargy (at low doses), excitement, hyper-reflexia, and tremor.

(iii) **Organic mercury** is highly lipophilic (high affinity for fat tissues). Organic mercurials are absorbed more completely from the gastro intestinal (GI) tract than inorganic salts .Once absorbed, the aryl and long chain alkyl compounds are converted to their inorganic forms and possess similar toxic properties to inorganic mercury. Alkyl organic mercury is distributed uniformly throughout the body, accumulating in the brain, kidney, liver, hair, and skin. Organic mercurials also cross the blood brain barrier and placenta and penetrate erythrocytes, attributing to neurological symptoms, teratogenic effects, and high blood to plasma ratio, respectively.

Monomethyl mercury is an estimated 100-1000 times more toxic than elemental mercury to humans. *Methyl mercury* can react directly with important receptors in the nervous system, such as the acetylcholine receptors in the peripheral nerves. The effects of mercury on the nervous system range from irritability, excitability and parasthesia (numbing of the extremities) at low levels of exposure, to tremors, violent muscle spasms and death in the extreme.

3. CADMIUM

Cadmium has no essential biological function and is extremely toxic to humans.Cadmium is an element that occurs naturally in the earth's crust. Cadmium is most often present in nature as complex oxides, sulfides, and carbonates in zinc, lead, and copper ores. Cadmium is a byproduct of the mining and smelting of lead and zinc. The potential for cadmium to harm our health depends upon the form of cadmium present, the amount taken into the body, and whether the cadmium is ingested or inhaled.

Sources

The main routes of exposure to cadmium is through the following:

- It is estimated that about 25,000 to 30,000 tons of cadmium are released to the environment each year, about half from the weathering of rocks into river water and then to the oceans.
- Cadmium can enter the air from the burning of fossil fuels (e.g., coal fired electrical plants) and from the burning of household waste. Cadmium compounds are often found in or attached to small particles present in air.
- Fertilizers often contain some cadmium that will enter the soil when fertilizers are applied to crops. Cadmium can gather and concentrate in plants. Lowest levels are in fruits and beverages, and highest levels are in leafy vegetables.
- Cadmium is also found in tobacco, each cigarette has approximately 1-2 µg of cadmium. Food and cigarette smoke are the biggest sources of cadmium exposure for people in the general population
- Cadmium is also a constituent of alloys, pigments, batteries, metal coatings for example protective coatings on steel, plastics.

Routes of Exposure:

Humans have a daily intake of cadmium from ingestion and inhalation which is around 20 to 40 µg per day, but only 5 to 10% of this is absorbed. After absorption, cadmium is transported in the blood bound to albumin. It is taken up by the liver, and, due to its similarity to zinc, causes this organ to induce the synthesis of the protein metallothionein to which it binds and prevents it to reach the target molecules.

Health Effects

- Cadmium is more efficiently absorbed in the lungs (25-60% absorbed) than the gastrointestinal tract (5-10 % absorbed). It is estimated that on average, adults absorb 1.4-8 mg of cadmium per day by oral exposure.
- The organs most affected by cadmium exposure are the kidneys and the lungs. Inhaling cadmium-laden dust quickly leads to *respiratory* tract and kidney problems which can be fatal (often from renal failure).
- Cadmium is also known to be carcinogenic, and in studies has been linked with cancers in the lungs and prostate .
- In prolonged cadmium exposure, disorders of calcium metabolism occur, causing osteomalacia (The bones become soft) This leads to painful fractures, hence the name given to the chronic exposure disease in Japan: Itai-itai disease (literally “ouch!-ouch!” disease) .

Biochemical Effects of Cadmium

The toxic effects of cadmium are due to its inhibition of various enzyme systems. Like similar heavy metals, it is able to inactivate enzymes containing sulphhydryl groups and it can also produce uncoupling of oxidative phosphorylation in mitochondria.

The kidney is the critical organ of intoxication after long-term exposure to cadmium. One of the initial signs of renal dysfunction is an increased urinary excretion of proteins. Cadmium-induced proteinuria is generally considered to be characterized by the excretion of low molecular weight proteins.

Metallothionein, a protein plays an important role in the metabolism and toxicity of cadmium. Metallothionein is largely involved in the binding of cadmium, which is generally thought to reduce the toxicity of cadmium. In the liver, its production is sufficient to bind all cadmium accumulated. The metallothionein-bound cadmium is released from the liver into the blood where it is cleared by glomerular filtration in the kidney and taken up by the renal tubules. In renal tubules, metallothionein is cleaved and cadmium is released. Cadmium is selectively accumulated in the kidney.

A lethal dose of cadmium for ingestion is estimated to be between 350 and 8900 milligrams

Itai-Itai Disease is a multi-system disorder characterized by:

- severe osteomalacia, osteoporosis and bone fragility
- disruption of calcium metabolism (increased excretion)
- nephropathy
- Affects primarily post-menopausal, multiparous women
- Occurs with high chronic cadmium exposure
- Nutritional deficiencies (Vit. D, Ca)

4. LEAD

Lead is a heavy, low melting, bluish-grey metal that occurs naturally in the Earth's crust. However, it is rarely found naturally as a metal. It is usually found combined with two or more other elements to form lead compounds. It is the most widespread toxic metal on earth.

Sources:

- Sources of lead may be natural, as it is found in the earth's crust and thus enters the food and water supply
- Lead industries, mining, and smelting: Lead is used in the manufacture of batteries, plastics, china, ceramic glass, and paint products.
- Petrol: Previously, tetraethyl lead was an additive in petrol and lead was used in plumbing. The use of leaded petrol is being phased out these days.
- Paint: Due to lead's unique properties, it has been used as a pigment and drying agent in primers, paints and enamels, inks, oils, resins and other surface coatings for centuries.
- *Drinking Water:* Lead is unusual among drinking water contaminants in that it seldom occurs naturally in water supplies like rivers and lakes. Lead enters drinking water primarily as a result of the corrosion, or wearing away, of materials containing lead in the water distribution system and household or building plumbing. Lead piping in households

is gradually being replaced, due to health concerns. (Small amounts of lead from lead pipe or solder may be released into water when the water is acidic or “soft”. Lead may remain stuck to soil particles or sediment in water for many years)

- Imported food in cans that are sealed with lead solder

Routes of Exposure:

The primary route of lead exposure is ingestion and inhalation. This could occur through eating lead-based paint flakes and chips (e.g., pica-like behavior), breathing contaminated dust, drinking contaminated water, and absorbing lead from lead-contaminated glaze in pottery. Children are particularly at risk. Total intake is about 225 μ g/day out of which 200 μ g/day is excreted through urine while rest is stored in bones.

Health Effects:

- In children, symptoms of lead poisoning can include headaches, irritability, abdominal pain, vomiting, anemia, weight loss, poor attention span, noticeable learning difficulty, slowed speech development, and hyperactivity.
- Other factors include lowered IQ, neurological deficits, behaviour problems, mental retardation, kidney disease, heart disease, stroke, and death
- In adults, symptoms of lead poisoning can include pain, numbness or tingling of the extremities, muscular weakness, headache, abdominal pain, memory loss, unsteady gait, pale skin, weight loss, vomiting, irritability, and anemia.
- Lead at high concentrations (80 ug/dl or above) can cause convulsions, coma, and death.
- The effects of lead exposure on unborn and young children can be severe. Children are more vulnerable to lead exposure than adults since lead is more easily absorbed into growing bodies, and the tissues of small children are more sensitive to the damaging effects of lead.

Lead and fall of Roman Empire

During Greco-Roman and Medieval times, a sweet lead acetate syrup, was added to both wines and food. This resulted in widespread lead intoxication among the affluent and has been suggested as a probable reason for the fall of the Roman Empire.

Biochemical Effects of Lead

Lead poisoning results from the interaction of the metal with biological electron-donor groups, such as the sulphydryl groups, which interferes with a multitude of enzymatic processes.

Lead also interacts with essential cations, particularly calcium, iron, and zinc; it interferes with the sodium-potassium-adenosine triphosphate (Na^+/K^+ -ATP) pump; and it alters cellular and mitochondrial membranes, thereby increasing cellular fragility. Additionally, lead inhibits pyrimidine-5'-nucleotidase and alters other nucleotide functions.

Lead interferes with many enzyme systems of the body, thereby affecting the function of virtually every organ. The major health effects of lead are manifest in three organ systems;

- (i) the haematological system,
- (ii) the central nervous system (CNS) and
- (iii) the renal system.

Haematological System

Perhaps the best-known and best-studied toxic effect of lead is the effect lead has on heme synthesis (the oxygen carrying component of haemoglobin). Lead perturbs multiple enzyme systems. As in most heavy metals, any ligand with sulphhydryl groups is vulnerable to lead. Lead is absorbed into blood plasma, where it equilibrates rapidly with extracellular fluid, crosses membranes such as the blood-brain barrier and the placenta, and accumulates in soft and hard tissues. In the blood, around 95 to 99% of lead is sequestered in red cells, where it is bound to hemoglobin and other components. The anaemia that lead poisoning causes is due to the impairment of the synthesis of haem and an increased rate of destruction of red blood cells.

Neurologic Effects

Lead affects the central nervous system by multiple mechanisms, most of which are unexplored. In the brain, lead is known to alter the function of cellular calcium and inactivate the blood-brain barrier. These alterations result in leakage of proteinaceous fluid and brain edema, which affects all parts of the CNS, predominantly the cerebellum and the occipital lobes. Lead-induced cerebral edema is manifested initially by headaches, clumsiness, vertigo, and ataxia, followed by seizures, coma, mortality, or recovery with permanent neurologic loss.

Renal Effects

Lead nephropathy develops because of the inhibitory effects of lead on cellular respiration. Lead causes a generalized dysfunction of proximal, tubular, energy-dependent functions, manifesting as aminoaciduria, glycosuria, and phosphaturia.

Table 10.2 summarizes the various effects in these systems which have been attributed to lead in environmentally exposed populations.

Table 10.2: Major health effects attributed to lead in environmentally exposed population

<i>Organ affected</i>	<i>Range of effects reported</i>
Haematological system	Inhibition of ALA-D (d-aminolevulinic acid dehydratase) and haem synthetase and corresponding accumulation of ALA and FEP (free erythrocyte protoporphyrin). At higher levels of exposure, reduced haem synthesis and anaemia.
Nervous system	CNS impairment at moderate exposure in children, reflected by inattention, cognitive difficulties, fine motor dysfunction and altered EEG patterns. Under heavy exposure, encephalopathy may arise.
Renal system	Functional impairment of the tubular region characterized by mild aminoaciduria, glucosuria and hyperphosphaturia. Morphological effects include mitochondrial damage and intranuclear inclusion bodies. Long-term heavy exposure may result in irreversible nephropathy.

Other Effects

Lead has negative effects on the reproductive system, causing low sperm count and abnormal sperm morphology in men and infertility, menstrual irregularity, spontaneous abortion, and stillbirths in women.

In children, lead impairs the release of human growth hormone and insulin growth factor and interferes with skeletal calcium and cyclic adenosine monophosphate (cAMP) functions, resulting in abnormalities of bone growth.

5. CHROMIUM

Chromium is present in the environment in several different forms. The most common forms are chromium(0), trivalent (or chromium(III)), and hexavalent (or chromium(VI)). Chromium(III) occurs naturally in the environment and is an essential nutrient required by the human body to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Chromium VI (hexavalent chromium) is very toxic. Chromium(VI) and chromium(0) are generally produced by industrial processes

Sources:

- Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases.
- The metal chromium, which is the chromium(0) form, is used mainly for making steel and other alloys.
- The naturally occurring mineral chromite in the chromium(III) form is used as brick lining for high-temperature industrial furnaces, for making metals and alloys (mixtures of metals), and chemical compounds.

- Smaller amounts are used in drilling muds, rust and corrosion inhibitors, textiles, and toner for copying machines.
- Waste streams from electroplating can discharge chromium(VI). The levels of both chromium(III) and chromium(VI) in soil increase mainly from disposal of commercial products containing chromium, chromium waste from industry, and coal ash from electric utilities.
- In air, chromium compounds are present mostly as fine dust particles

Routes Of Exposure:

- For the general population, eating foods that contain chromium is the most likely route of chromium(III) exposure. Chromium(III) occurs naturally in many fresh vegetables, fruits, meat, yeast, and grain.
- You can be exposed to chromium by breathing air, drinking water, or eating food containing chromium or through skin contact with chromium or chromium compounds
- Acidic foods in contact with stainless steel cans or cooking utensils might contain higher levels of chromium because of leaching from stainless steel.

Health Effects:

- Chromium(III) is an essential nutrient that helps the body use sugar, protein, and fat. An intake of 50–200 µg of chromium(III) per day is recommended for adults.
- Without chromium(III) in the diet, the body loses its ability to use sugars, proteins, and fat properly, which may result in weight loss or decreased growth, improper function of the nervous system, and a diabetic-like condition. Therefore, chromium(III) compounds have been used as dietary supplements and are beneficial if taken in recommended dosages.

The health hazards associated with exposure to chromium are dependent on its oxidation state. Some of the harmful effects of Chromium are:

- In general, chromium(VI) is more toxic than chromium(III). Breathing in high levels (greater than 2 µg/m³) of chromium(VI), such as in a compound known as chromic acid or chromium(VI) trioxide, can cause irritation to the nose, such as runny nose, sneezing, itching, nosebleeds, ulcers, and holes in the nasal septum.
- High doses of chromium III may cause skin irritation.
- Chromium VI exposure: if the exposure is short-term at a high level, then irritation and ulcers develop at the site of contact. It also has adverse effects on the kidneys and liver. Long term exposure by inhalation causes nasal irritation or mild lung effects
- Hexavalent chromium is a likely carcinogen, particularly of the lungs.

Biochemical Effects

Chromium is an essential trace mineral. Chromium is known to enhance the action of insulin, a hormone critical to the metabolism and storage of carbohydrate, fat, and protein in the body.

In general, chromium(VI) is absorbed by the body more easily than chromium(III), but once inside the body, chromium(VI) is changed to chromium(III). Chromium is distributed to various tissues of the body, but appears to be most concentrated in the kidney, muscle, and liver.

The principal carrier protein for chromium is transferrin, which also plays a critical role in the movement of chromium from blood to low-molecular weight (MW) chromium (LMWCr)-binding substance, which is composed of glycine, cysteine, glutamic acid, and aspartic acid. It is proposed that LMWCr then participates in insulin metabolism.

Chromium will then pass through the kidneys and be eliminated in the urine in a few days.

10.11 BIOCHEMICAL EFFECTS OF PESTICIDES

A brief account of the pesticides was given under the heading 'Environmental pollutants'. In this section we will discuss the biochemical effects of pesticides. Based on their chemical composition, pesticides can be broadly grouped under the following headings:

- (i) Organochlorides,
- (ii) Organophosphates
- (iii) Carbamates
- (iii) Pyrethroids

Both the beneficial and harmful effects of pesticides are determined by pesticide-organism interactions or how pesticides and organisms react to each other. The manner in which the pesticide affects the vital function is called its *mode of action*. *Pesticides are sometimes classified on the basis of the biological system affected by the pesticide*. This method is most preferred among scientists. Most pesticides affect one of five biological systems in insects. These include:

1. the nervous system,
2. production of energy,
3. production of cuticle,
4. the endocrine system, and
5. water balance.

Different classes of pesticides and their mode of action is discussed below:

1. Pesticides that Affect the Nervous System

Most traditional insecticides fit into this category. Organochlorides, organophosphorus, carbamate and pyrethroid pesticides all adversely affect the nervous system

- (i) Organochlorides:** They are mostly pesticides with a very wide range of actions, they can be divided into three main groups:
- DDT and related compounds including rhothane (DDD) and methoxychlor

- chlorinated cyclodiene insecticides such as aldrin, dieldrin and heptachlor.
- hexachlorocyclohexanes (HCHs), such as lindane.

Organochlorine pesticides are very stable solids with: limited vapour pressure, very low water solubility and high lipophilicity. They tend to be stored in body fats and are particularly hazardous because they are so stable and tend to accumulate in successive organisms in the food chain. DDT and the HCHs are regarded as only moderately toxic to mammals while the chlorinated cyclodienes are highly toxic.

Action: Organochlorides *pesticides* are nerve poisons . These disrupt function of nervous system, mainly the brain..Organochloride *pesticides* affect the peripheral nervous system (PNS) through dermal absorption, inhalation, and ingestion. Organochloride compounds also decrease antibody production, placing a person at risk for infection. DDT is an organochloride insecticide that persists and bioaccumulates in the environment, which is why it is no longer manufactured as a pesticide. DDT acts on the sodium channels in the nervous system so that the passage of an 'action potential' along the nerve is disrupted. It causes uncontrolled repetitive spontaneous discharges along the nerve. Uncoordinated muscle tremors and twitches are characteristic symptoms.

- (ii) *Organophosphate*: Organophosphates *pesticides* are synaptic poisons. The synapse is a junction between two nerves or a nerve connection point (hence the name synaptic poison). Specifically, organophosphorus *pesticides* bind to an enzyme found in the synapse called acetylcholinesterase. This enzyme is designed to stop a nerve impulse after it has crossed the synapse. Organophosphorus *pesticides* bind to enzyme found in synapse and prevent the enzyme from working. Therefore, poisoned synapses cannot stop the nerve impulse. Consequently, continued stimulation of the nerve occurs. Poisoned insects exhibit tremors and uncoordinated movement.

Organophosphorous exposure may result in headache, anxiety, chest tightness, seizures, loss of consciousness, abnormal heart beat, and liver dysfunction. In addition, Organophosphorous pesticides, like malathion, seem to enhance the immune response in some circumstances.

- (iii) *Carbamate Pesticides*: Carbamate pesticides are derived from carbamic acid and kill insects in a similar fashion as organophosphate insecticides. They are widely used in homes, gardens and agriculture. Like the organophosphates, their mode of action is inhibition of cholinesterase enzymes, affecting nerve impulse transmission. Unlike organophosphate poisoning, carbamate poisonings tend to be of shorter duration because the inhibition of nervous tissue acetylcholinesterase is reversible. Muscle weakness, dizziness, sweating and slight body discomfort are commonly reported as early symptoms. Headache, salivation, nausea, vomiting, abdominal pain and diarrhea are often prominent at higher levels of exposure. Some of the examples of carbamate pesticides are Aldicarb, Carbofuran and Carbaryl.

(iv) *Pyrethroids*: Pyrethroids are synthetic chemicals whose structures mimic the natural insecticide pyrethrin. These insecticides have a unique ability to knock down insects quickly. Pyrethroids are axonic poisons (they poison the nerve fiber). They bind to a protein in nerves called the voltage-gated sodium channel. Normally, this protein opens causing stimulation of the nerve and closes to terminate the nerve signal. Pyrethroids bind to this gate and prevent it from closing normally which results in continuous nerve stimulation as observed with organophosphorus and carbamates. Again, poisoned insects exhibit tremors and uncoordinated movement.

2. Insecticides that Inhibit Energy Production

Only a handful of chemicals that inhibit the production of energy are currently in use as insecticides. The most pervasive and well-known energy inhibiting insecticide is hydramethylnon. This chemical binds to a protein called a cytochrome in the electron transport system of the mitochondrion. This binding blocks the production of ATP. Insects killed by these chemicals die on their feet. They essentially “run out of gas.”

Another insecticide currently available that inhibits energy production is sulfluramid. Chemicals in the class pyrrole, thiourea, and quinazoline are showing great promise as pesticides that inhibit energy production.

3. Insecticides that Affect the Insect Endocrine System

These chemicals are typically referred to as insect growth regulators or IGRs. IGRs act on the endocrine or hormone system of insects. These insecticides are specific for insects, have very low mammalian toxicity, are nonpersistent in the environment, and cause death slowly. Most of the currently registered IGRs mimic the juvenile hormone produced in the insect brain. Juvenile hormone tells the insect to remain in the immature state. When sufficient growth has occurred, the juvenile hormone production ceases triggering the molt to the adult stage. IGR chemicals, such as hydroprene, methoprene, pyriproxyfen, and fenoxy carb, mimic the action of juvenile hormone and keep the insect in the immature state. Insects treated with these chemicals are unable to molt successfully to the adult stage, and cannot reproduce normally.

4. Insecticides that Inhibit Cuticle Production

These chemicals are known as chitin synthesis inhibitors or CSIs. They are often grouped with the IGRs. These chemicals inhibit the production of chitin. Chitin is a major component of the insect exoskeleton. Insects poisoned with CSIs are unable to synthesize new cuticle, thereby preventing them from molting successfully to the next stage.

The most notable chemical being used as a CSI is the benzoylphenyl ureas. This class of insecticides includes lufenuron (Program®) which is a systemic insecticide used for flea control (fed to your pet), diflubenzuron (Dimilin®) used against fly larvae in manure, and hexaflumuron (Sentricon®) used in a termite bait station.

5. Insecticides Affecting Water Balance

Insecticides with this mode of action include boric acid, diatomaceous earth, and sorptive dusts. Insects have a thin covering of wax on their body that helps to prevent water loss from the cuticular surface. Silica aerogels (sorptive dusts) and diatomaceous earth are very effective at absorbing oils. Therefore, when an insect contacts one of these chemicals it absorbs the protective waxy covering on the insect resulting in rapid water loss from the cuticle and eventually death from dessication.

Borate containing insecticides also disrupt water balance in insects. The exact mode of action (more specifically the target site) of borate containing insecticides is not currently known.

Table 10.3. Examples of commonly used insecticides and their mode of action.

Insecticide Class	Common Name	Example (Trade Name)	Primary Site Affected
Pyrethroid	Permethrin	Flee	Nervous System
Carbamate	Propoxur	Baygon	Nervous System
Organophosphorus	Chlorpyrifos	Dursban	Nervous System
Avermectins	Abamectin	Avert	Nervous System
Chloronicotinyl	Imidacloprid	Advantage	Nervous System
Cyclodiene	Aldrin	*	Nervous System
Amidinohydrazone	Hydramethylnon	Amdro	Energy Production
Sulphonamide	Sulfluramid	Raid Max	Energy Production
Fumigant (Inorganic)	Sulfluryl Fluoride	Vikane	Energy Production
Juvenile Hormone Analog	Hydroprene	Gencor	Endocrine System
Juvenile Hormone Analog	Methoprene	Pharoid	Endocrine System
Juvenile Hormone Mimic	Fenoxy carb	Logic	Endocrine System
Juvenile Hormone Mimic	Pyriproxyfen	Archer	Endocrine System
Benzoylphenyl Urea	Diflubenzuron	Dimilin	Chitin Production
Benzoylphenyl Urea	Lufenuron	Program	Chitin Production
Benzoylphenyl Urea	Hexaflumuron	Sentricon	Chitin Production
Inorganic	Borates	Roach Prufe	Water Balance
Inorganic	Silica Aerogels	Dri-Die	Water Balance
Inorganic	Diatomaceous Earth	Shell Shock	Water Balance

EXERCISES

1. Define toxicology.
2. All chemicals are potential toxicants .Comment.
3. Define the terms: Toxic, toxicity, toxicant.
4. Distinguish between acute and chronic toxicity.
5. What do you mean by a dose and dose response relationship?
6. "Dose makes the poison". Comment.
7. What do you understand by the term xenobiotic?
8. What are the different routes of exposure to the toxic substance?
9. In toxicology what do the following stand for: LD,TD , and ED?
10. What do you mean by the term LD50?
11. Define the terms: Additivity, antagonism, potentiation and synergism.
12. What are the most common toxic chemicals in the environment?
13. How toxic chemicals affect the working of the enzymes?
14. Arsenic is the most toxic substance .Comment.
15. What are the factors responsible for lead poisoning?
16. What types of damages are generally caused by toxic materials?
17. Write a short note on toxic chemicals in the environment.
18. How polychlorinated biphenyls PCBs cause damage to the human health?
19. Explain the effect of toxic chemicals on enzymes.
20. Write a note on biochemical effects of pesticides.
21. What are the harmful effects of inhalation of mercury vapours?
22. Discuss the biochemical effect of arsenic, mercury, and cadmium.
23. What happens if mercury is inhaled and it reaches the brain?
24. What are the health effects of exposure to lead?
25. How lead poisoning affects the hematological system?
26. Discuss biochemical effects of chromium.
27. (a) What are the common forms of chromium present in the environment?
Which of these is most toxic?
(b) Explain the terms TD₅₀, ED₅₀ and LD₅₀ in toxicology.
(c) Write short note on: Biochemical effects of pesticides.
(d) Enumerate the various forms of mercury and describe their sources and biochemical effects.



UNIT III

Disaster Management

"We cannot stop natural disasters but we can arm ourselves with knowledge: so many lives wouldn't have to be lost if there was enough disaster preparedness.".

—Petra Nemcova

Objectives

- Introduction
- Types of Disasters

11.1 INTRODUCTION

Disaster management (or **emergency management**) is the discipline of avoiding and fighting both natural and man-made disasters. Preparedness, response and recovery plans are made to decrease the impact of these disasters. In India the responsibility of emergency management lies with National Disaster Management Authority which is a government agency under the Ministry of Home Affairs. In recent years there has been a shift in responsibility from government-centre approach to decentralized community participation and also more emphasis is given to risk management and reduction of disaster rather than recovery after the disaster. The Ministry of Science and Technology also facilitates research by bringing the academic knowledge and expertise of earth scientists to emergency management.

11.2 TYPES OF DISASTERS

There is no country on earth which can claim that it is free from any type of disaster although the vulnerability for disasters vary depending on the preparedness of any country. The four main types of disasters are:

- (i) **Natural disasters:** These disasters include floods, hurricanes, earthquakes and volcanic eruptions. These disasters can cause both immediate impacts on human health, as well as secondary impacts causing further death and suffering from floods causing landslides, earthquakes resulting in fires etc.
- (ii) **Environmental emergencies:** These accidents include technological and industrial emergencies using hazardous

materials (Bhopal Gas Leak Disaster 1984) large forest fires (man made) are also included in this category.

(iii) **Complex emergencies:** These emergencies involve a break-down of authority, looting and attacks on strategic installations and war.

(iv) **Pandemic emergencies:** These emergencies arise due to a sudden onset of a contagious disease that not only affects the health sector but social and economic sector also.

Since disasters have a long-lasting impact on people even after the mitigation of the effect hence improper planning of the measures taken can have a significant negative impact not only on the disaster victims but also on the entire structure. Therefore a well established programme has to be chalked out for the execution of activities which includes prevention, preparedness relief and recovery. Some major types of disasters are described in details below

11.2.1 Floods

Floods refer to huge amount of water reaching land in a short span of time, causing land surface to be submerged under water which is otherwise dry. They are caused by heavy rainfall, snowmelts, severe winds over water, unusual high tides, or failure of structures like dams that retain the water. As per National Flood Commission report India is one of the highly flood prone countries in the world where approximately 40 million hectares of land is prone to floods.

Types Of Floods

- **Flash Floods:** In areas with steep slopes during heavy rainfall, first the rain water is collected on the slopes and then it flows downhill gathering speed.. The water level rises fast on the river bed. The water flows over the river banks and floods the area.
- **Coastal flood:** The cause of such types of floods is severe storm in coastal areas The storm wind pushes the water up and creates high waves when the coast is flooded by the sea. The characteristic of a coastal flood is that the water level drops and rises with the tide. At high tide the water may flow in and at low tide it may recede again. This generates the build-up of force by the sea and then the sea floods the coast.
- **Urban flooding:** This type of floods is specific in the urban areas where there is a lack of drainage. Heavy rainfall can cause flooding when the city sewage system and draining canals do not drain away the amounts of rain that are falling. Water may even enter the sewage system in one place and then get deposited somewhere else in the city on the streets.
- **Fluvial floods:** Rainfall over an extended period and an extended area can cause major rivers to overflow their banks covering large areas. Downstream areas which do not receive any rain may be affected in such cases. When a dam breaks and a lot of water is released suddenly with high speed. As a larger area gets covered the speed of water reduces flowing to the lower lying areas before slowly rising.. The strength of

the water may carry cars, trees and even houses away and cause loss of life

- **Pluvial floods:** This type of floods affects relatively flat areas. When more rainwater enters a water system than can be stored, or can leave the system, flooding occurs. In this case, rain is the source of the flood.. The layer of water in this case is decimeters high and causes no immediate threat to people's life.

Mitigation Strategy of Flood:

The mitigation strategy was designed by Carla R Mcmillan in 1998 and is given in Table 11.1

Table 11.1 Flood Mitigation (before, during and after the disaster)

Before the Disaster	During the Disaster	After the Disaster
<ul style="list-style-type: none"> • Learn warning signs and community alert systems • Emergency building materials should be collected • Sewer drains should have check valves in sewer traps to prevent flood waters from collecting • Evacuation route should be chalked out. • An emergency communication plan in case of separation should be made. 	<ul style="list-style-type: none"> • During a flood, turn on battery operated radio to get latest emergency information • Get pre-assembled emergency supplies • In case of emergency leave, the place immediately. • If outdoors: Climb to high ground and stay there. • If advised to evacuate, do so immediately to avoid flooded roads, being sure to follow recommended evacuation routes and listen to radio for evacuation instructions 	<ul style="list-style-type: none"> • Don't return home until told by authorities • Use extreme caution when entering buildings and check for cracks or other damage to make sure that the building is not in danger of collapsing • Watch out for animals, especially poisonous snakes, which may have come into your home with flood water.

11.2.2 Earthquakes

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves It is always natural and can never be man made like nuclear tests etc. An earthquake is caused by a sudden slip on a fault. Stresses in the earth's outer layer push the sides of the fault together. Stress builds up and the rocks slips suddenly, releasing energy in waves that travel through the earth's crust and cause the shaking that we feel during an earthquake. The place of initial rupture of earthquake is called hypocenter and the ground directly above the hypocenter is called epicentre.

Classification of Earthquakes

The impact of an earthquake is characterized by two primary characteristics which are:

- **Intensity:** This measures the effect of the earthquake at different places having the same epicentre thus having a qualitative value. Intensities are assigned values based on the interviews of the observer of that particular affected area. The two scales widely used are MMI (Modified Mercalli Intensity) and MSK (Medvedev-Spoonheuer-Karnik) Scale.
- **Magnitude:** It is the amount of energy released of a particular earthquake. The most common scale used for measuring an earthquake is Richter scale, which is a logarithmic scale. The category with magnitude is given in Table 11.2

Table 11.2 Classification of earthquake on the basis of magnitude

Category	Magnitude on Richter Scale
Slight	Upto 4.9
Moderate	5.0 to 6.9
Great	7.0 to 7.9
Very Great	8.0 and more

Source: www.imd.gov.in

- **Epicenter:** The epicenter is the point on the Earth's surface that is directly above the focus, the point where an earthquake originates.

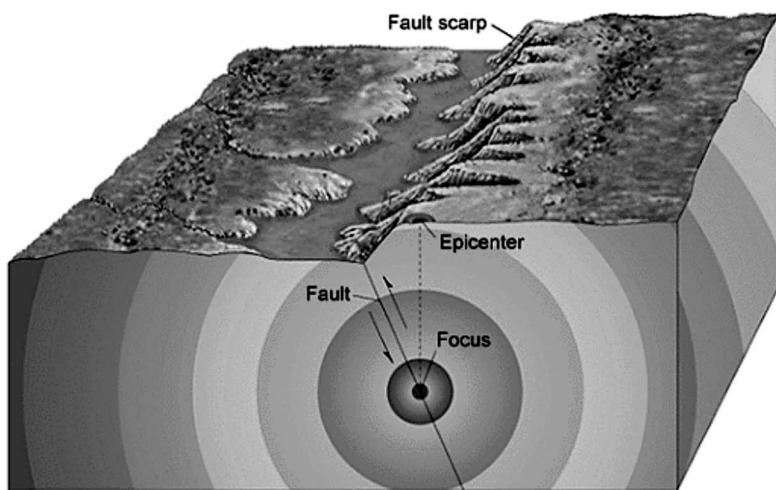


Fig. 11.1 Hypocenter and Epicenter of The Earthquake

Seismic Zones of India

The seismic zoning maps indicate broadly the seismic coefficient that could generally be adopted for design of buildings in different parts of the country. The current map is an ad-hoc revision of 1970 zone map. These maps are based on subjective estimates of intensity from available information on earthquake occurrence, geology and tectonics of the country.

Earthquake Hazard and Risk

- **Earthquake Hazards:** Earthquake hazard is anything associated with an earthquake that may affect the normal activities of people.
- **Earthquake Risk:** Earthquake risk is the probable building damage, and number of people that are expected to be hurt or killed if a likely earthquake . Earthquake risk and earthquake hazard are occasionally incorrectly used interchangeably.

Isoseismal Line or Isoseismal Map

An isoseismal is a contour or line on a map joining places of equal intensity for a particular earthquake. Such maps help to identify earthquake epicenters, particularly where no instrumental records exist, such as for historical earthquakes. They also contain important information on ground conditions at particular locations, such as the geological condition, radiation pattern of the seismic waves and the response of different types of buildings to such seismic disturbances.

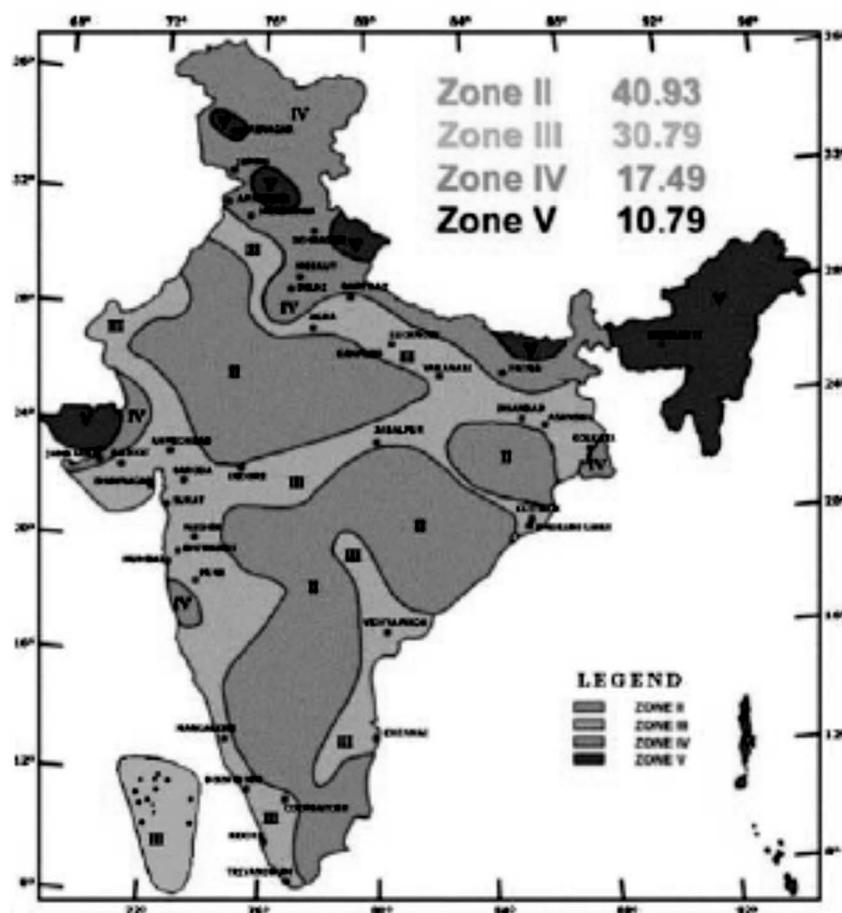
Seismic Zonation of India

The seismic zoning maps indicate broadly the seismic coefficient that could generally be adopted for design of buildings in different parts of the country. The current map is an ad-hoc revision of 1970 zone map. These maps are based on subjective estimates of intensity from available information on earthquake occurrence, geology and tectonics of the country. The current seismic Zonation map of India is shown in Fig. 11.2.

Surface movements due to natural disasters like earthquake are affecting throughout the world with increasing frequency, and are producing intense damage. These incidences have been of serious concern to the society due to loss of life and also pose problem for future urban development. Regardless of the location of a natural disaster in India, a program of disaster preparedness, mitigation, management, and prevention must be followed.

Disaster Preparedness and Mitigation

- **Disaster preparedness** includes all the activities which should be carried out before the event in order to facilitate the use of available resources, relief, and rehabilitation in the best possible way.

Seismic Zone Map of India: 2002

About 59 percent of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area Liable to shaking intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone intensity VII
Zone II	Low Risk Zone VI (and lower)

Source: www.civil.iitb.ac.in

Fig. 11.2 Present Seismic Zonation map of India (IS 1893-2002)

- On the other hand **Disaster mitigation** is the ongoing effort to lessen the impact disasters have on people and property.. Because of the varying degree of each natural disaster, there are different mitigation strategies for each.
- Disaster management** is the process of addressing an event that has the potential to seriously disrupt the social structure of the community. Disaster management is similar to disaster mitigation; however it

implies a whole-of-government approach to using community resources to fight the effects of an event and assumes the community will be self-sufficient for periods of time until the situation can be stabilized.

- **Disaster prevention** is concerned with policies and programs to prevent the recurrence of natural disasters and covers the long-term aspect of such disasters.

Natural disaster mitigation strategies due to earthquake have been given in table 11.3.

Table 11.3 Natural Earthquake Disaster Mitigation Strategies

Before the Disaster	During the Disaster	After the Disaster
<ul style="list-style-type: none"> • Check for hazards in the home • Identify safe places in each room • Locate safe places outdoors • Ensure all family members know how to respond after an earthquake • Teach children when and how to call 9-1-1 • Have disaster supplies on • Develop an emergency communications plan in case of separation during the earthquake • Ask an out-of-state relative or friend to serve as the family contact 	<ul style="list-style-type: none"> • If indoors: Take cover under a piece of heavy furniture or against an inside wall and stay inside • If outdoors: Move into the open, away from buildings, street lights, and utility wires and remain there until shaking stops • If in a moving vehicle: Stop quickly, stay in vehicle, move to a clear area away from buildings, trees, overpasses, or utility wires 	<ul style="list-style-type: none"> • Be prepared for aftershocks • Help injured or trapped persons and give first aid where appropriate • Listen to a battery operated radio for emergency information • Stay out of damaged buildings and return home only when authorities say it is safe

Source: www.csa.com

National Guidelines on Earthquake Risk Management in India

National Disaster Management Authority has released a national guidelines in May 2007 in which it is mentioned that from June 2007 onwards all new constructions in the earthquake prone area must adopt earthquake resistant measures. The critical factors responsible for the high seismic risk in India have categorized six sets of critical interventions. These are:

- (a) Ensure the incorporation of earthquake-resistant design features for the construction of new structures.

- (b) Facilitate selective strengthening and seismic retrofitting of existing priority and lifeline structures in earthquake-prone areas.
- (c) Improve the compliance regime through appropriate regulation and enforcement.
- (d) Improve the awareness and preparedness of all stakeholders.
- (e) Introduce appropriate capacity development interventions for effective earthquake management (including education training, R&D, and documentation).
- (f) Strengthen the emergency response capability in earthquake-prone areas.

11.2.3 Cyclones

Cyclone is a whirl in the atmosphere with very strong winds circulating around it in anti-clockwise direction in the Northern Hemisphere and clockwise in the Southern Hemisphere. The term Tropical Cyclones is used in the Indian Ocean, Bay of Bengal and Australian waters with wind speeds of over 118 km per hour. The same storms are called hurricanes in the Caribbean, Gulf of Mexico and the Atlantic Ocean, and in the North-West Pacific in the vicinity of the Philippines and Japan they are known as typhoons. The cyclone preparedness and mitigation strategies is given in Table 11.4.

Table 11.4 Cyclone Mitigation Strategies

When a cyclone warning is issued	On warning of local evacuation	After a Cyclone
<ul style="list-style-type: none"> • When requested by local authorities, collect children from school. • Put wooden or plastic outdoor furniture with other loose items. • Pack an evacuation kit of warm clothes, essential medications, valuables, important documents. Large/heavy valuables could be protected in a strong cupboard. • Remain indoors (with your pets). Stay tuned to your local radio/TV for further information. 	<ul style="list-style-type: none"> • Wear strong shoes and tough clothing for protection. • Lock doors; turn off power, gas, and water. • If evacuating outside the town, take pets and leave early to avoid heavy traffic, flooding and wind hazards. • If going to a public shelter, take bedding needs and emergency kit (medicine etc.). • Leave pets protected and with food and water. 	<ul style="list-style-type: none"> • Don't go outside until officially advised it is safe. • Check for gas leaks. Don't use electric appliances if wet. • Listen to local radio and remain indoors until advised. • Beware of damaged power lines, bridges, buildings, trees, and don't enter floodwaters. • Don't make unnecessary telephone calls.

11.2.4 Landslides

Landslides is a geological phenomenon caused by the mass movement of rock, debris or earth down a slope, where a broad range of motions like

falling, sliding and flowing under the influence of gravity takes place . They often take place in conjunction with earthquakes, floods and volcanoes and can occur in offshore, coastal and onshore environments. In the hilly terrain of India including the Himalayas, landslides have been a major and widely spread natural disaster the often strike life and property and occupy position of major concern

The two regions most vulnerable to landslides are the Himalayas and the Western Ghats. The landslides of Himalayas are huge and massive as the Himalayas mountain belt is tectonically and geologically unstable making it vulnerable to severe seismic activity whereas the Western Ghats and nilgiris are geologically stable but have uplifted plateau margins influenced by neo-tectonic activity. The intensities of landslides in different regions of India is given in Table 11.5.

Table 11.5 Intensities of Landslides in India

Major Mountain Ranges	Intensities of Landslides
Himalayas	High to very high
North-eastern Hills	High
Western Ghats and the Nilgiris	Modern to high
Vindhayachal	Low

The main causes of the Landslides are given in the following table 11.6.

Table 11.6 Main causes of landslides

Geological causes	Morphological causes	Anthropogenic causes	Physical causes	Man made Causes
<ul style="list-style-type: none"> • Weak or sensitive materials • Sheared , jointed, or fissured materials • Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth) • Contrast in permeability and/or stiffness of materials 	<ul style="list-style-type: none"> • Tectonic or volcanic uplift·Fluvial, wave, or glacial erosion of slope toe or lateral margins • Subterranean erosion (solution, piping) • Deposition loading slope or its crest·Vegetation removal (by fire, drought) • Thawing·Freeze-and-thaw weathering • Shrink-and-swell weathering 	<ul style="list-style-type: none"> • Excavation of slope or its toe • Loading of slope or its crest·Draw-down (of reservoirs) • Deforestation • Irrigation • Mining • Artificial vibration • Water leakage from utilities 	<ul style="list-style-type: none"> • Prolonged precipitation • Rapid draw-down·Earthquake • Volcanic eruption·Thawing • Shrink and swell 	<ul style="list-style-type: none"> • Excavation (particularly at the toe of slope • Loading of slope crest • Draw -down (of reservoir) • Deforestation • Irrigation • Mining • Artificial vibrations • Water impoundment and leakage from utilities

11.2.5 Nuclear Accidents and Holocaust

A nuclear and radiation accident is defined by the International Atomic Energy Agency as “an event that has led to significant consequences to people, the environment or the facility.” It can have adverse affects both on mankind and the environment. In the case a “major nuclear accident” the reactor core gets damaged and significant amounts of radioactivity are released, such as Chernobyl Disaster of 1986. Although Nuclear power is a useful alternative to fossil fuels, three major environmental problems that is the generation of radioactive waste, thermal waste and nuclear accidents. Caused by generating nuclear power are extremely dangerous. The release of radioactive waste, to the biosphere can harm the mankind for generations (Bhopal Gas Disaster of 1984). Thermal discharges are a major concern since the thermal pollution from these enormous plants directly into the atmosphere can have negative effects on national and global meteorology, causing unfavorable conditions from dangerous fogs and icing to global warming. Thus the solid, liquid or gaseous waste from nuclear plants should be disposed so that there is no risk to humans and plants. Radioactive materials severely damage living cells that are exposed to it. Although some technical measures have been adopted to minimize the amount of radioactivity released to the atmosphere and the risk of nuclear accidents there have been many accidents with varying impacts. Some serious and more well-known nuclear accidents that haven disastrous impact include the Three Mile Island accident in 1979, the Chernobyl accident in 1986 and the Fukushima accident in 2011. For instance, in the Fukushima accident, 19,126 people were dead or missing and decontamination work is estimated to be last for at least one decade.

CASE STUDY

Japan earthquake, tsunami and Fukushima nuclear disaster in 2011

Fukushima in northeast **Japan** is a quiet rural region renowned for its green mountains, hot springs and cool beaches. **Japan was rattled by the powerful March 11 earthquake and tsunami** which claimed close to 20,000 lives across swathes of the eastern coast.

Fukushima Daiichi nuclear power plant, 150 miles northeast of Tokyo, was severely damaged by the earthquake and tsunami with its crucial cooling systems knocked out, resulting in a series of explosions and meltdowns and the world’s worst nuclear accident in 25 years. As a result, today more than 80,000 residents remain evacuated across the country, with no immediate prospect of being able to return to their abandoned homes and businesses. The impact on the local economy has been no less harsh, with local industries, farm produce and tourism all strongly affected by associations of the name Fukushima with “nuclear contamination”. Faced with a litany of

problems, challenges and delays, Tokyo Electric Power Co, operators of the nuclear plant, have spent months working to bring it into a state of **cold shutdown** and claim to have at last succeeded. In addition to the physical clean up of the area – which will involve painstaking industrial cleansing of all buildings and removal of topsoil – there are continued concerns in relation to food safety across the country.

EXERCISES

1. How do you define disaster? List and describe phases of disasters.
2. What are the types of disaster? Describe them.
3. Why do trends of disasters increase over time?
4. What are earthquakes? List out the causes of an earthquake.
5. Differentiate between magnitude and intensity of an earthquake. How are they measured ?
6. Identify three major mitigation measures to reduce earthquake risk
7. Explain the characteristics of a cyclone.
8. Identify risk reduction measures for cyclones.
9. Define Flood. List out some of the causes and adverse effects of floods.
10. What are different types of floods? How are they caused?
11. Explain in detail the possible risk reduction measures for floods.
12. What are landslides ? List out five major causes of landslides in India.
13. Identify major type of landslides. What are their causes?
14. Suggest risk reduction measures for landslide mitigation.
15. Giving examples (from your own country) state situations where Disaster Management could have been better implemented.
16. In the case of a natural disaster, both government and individuals are responsible for how citizens are affected. List 3 actions/activities/methods each for both government and individuals, which can be carried out to mitigate the effects of a known natural disaster.
17. What is disaster preparedness?
18. What are the impacts of most damaging hazards occurring in the country, on communities, infrastructure, environment etc.
19. Should there be communities to organise themselves to monitor potential disasters?
20. What are the different levels of awareness of disaster risk factors in the community?
21. Should there be any disaster awareness and public information projects or programmes undertaken in the country?



UNIT 12

Social Issues, Human Population and the Environment

“Overpopulation in various countries has become a serious threat to the health of people and a grave obstacle to any attempt to organize peace on this planet.”

—Albert Einstein

Objectives

- Sustainable Development
- Climate Change
- Environmental Ethics: Issues and Possible Solutions
- Consumerism and Waste Products
- Wasteland Reclamation
- Population Growth
- Problems of Urbanisation

12.1 SUSTAINABLE DEVELOPMENT

Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It implies economic growth together with the protection of the environmental quality, each reinforcing the other. The essence of this form of development is a stable relationship between human activities and the natural world, which does not diminish the prospects for future generations to enjoy a quality of life at least as good as our own. The guiding rules are that people share with each other and care for the earth. Humanity must take no more from nature than nature can replenish. This in turn means adopting lifestyles and development paths that respect and work within nature's limits. It can be done without rejecting the many benefits that modern technology has brought provided that technology also works within those limits.

Environmental sustainability applies at many levels including individual, community, regional, national and global levels.

Environmental sustainability is based on the following ideas:

- We must consider the effects of our actions on the health and well-being of the natural environment, including all living things.

- Earth's resources are not present in infinite supply. We must live within limits and let renewable resources such as fresh water regenerate for future needs.
- We must understand *all* the costs of products we consume to the environment and to society.
- We must each share in the responsibility for environmental sustainability.

Many experts in environmental problems think human society is not operating sustainably because of the following human behaviours:

- We are using non-renewable resources such as fossil fuels as if they were present in unlimited supplies.
- We are using renewable resources such as fresh water and forests faster than they are replenished naturally.
- We are polluting the environment with toxins as if the capacity of the environment to absorb them is limitless.
- Our numbers continue to grow despite Earth's finite ability to feed and sustain us and absorb our wastes.

If left unchecked, these activities may reach the point of environmental catastrophe, threatening the life-support systems of Earth to such a degree that recovery is impossible.

In general the researchers say that degradation of self governing resources has occurred in the past and is occurring today also. As one goes from local to regional to global levels, the challenges of sustainably managing resources become more complex. No individual, jurisdiction, or country owns the resources and they are susceptible to over use. Although exploitation may benefit only a few, everyone on Earth must pay for the environmental cost of exploitation.

The world needs effective legal and economic policies to prevent the short-term degradation of our global resources and ensure their long-term well-being. There are no short cuts because solutions to global-environmental problems are not as simple as are solutions to local problems. The degradation of environment is due to the following persistent problems-

- Poverty.
- Over population.
- Social injustice.

These are the problems beyond the ability of a single nation to resolve. Everybody on this Earth must have a shared responsibility for the sustainable care of this planet, cooperation and commitment at the International level are essential if we are to alleviate poverty, stabilize the human population and preserve our environment and its resources for future generations.

12.2 CLIMATE CHANGE

Climate is the average weather of an area. It is the general weather conditions, seasonal variations and extremes of weather in a region. Such

conditions which average over a long period, at least thirty years is called climate.

Factors that influence the climate include interactive, *internal components* (oceans, the atmosphere, snow cover, sea ice, etc.) and *external factors* (solar radiation, the Earth's rotation, slow changes in our planet's orbit, and the gaseous makeup of the atmosphere). Radiative forcing is the influence a particular factor has on the energy balance of the atmosphere-ocean-land system. The factors can be *positive*, leading to *warming*, or *negative*, leading to *cooling*, as they affect the energy balance. If the factors change over time, they can lead to a change in the climate.

On the global scale, water vapour, CO₂ and other gases in the atmosphere are called greenhouse gases (GHGs). Our global climate depends on Earth's concentrations of GHS. If these concentrations increase or decrease significantly, their influence as positive forcing agents will change, and the climate will change accordingly.

Earth's atmosphere is also subject to negative forcing factors. Sunlight reflected due to cloud covers, known as Planetary albedo, contributes to overall cooling by preventing a certain amount of warming in the first place. Snow and ice also reflect sunlight contributing to the planetary albedo. Recent studies, however, suggest that this effect is greatly reduced by the soot released from anthropogenic sources. The settled root on snow and ice promotes absorption of radiant energy than reflection. Volcanic activity can also lead to planetary cooling. When Mount Pinatubo in Phillipines erupted in 1991, almost twenty million tons of particles and aerosols entered the atmosphere and contributed to a major drop in the regional temperature as radiation reflected and scattered away. This cooling effect lasted for several years, until the volcanic aerosols were removed from the atmosphere by chemical change and deposition.

Researchers have found that sulphate aerosols formed due to sulphur-dioxide emission from anthropogenic sources, also play a significant role in counteracting some of the warming from GHGs. Climatologists have estimated that the cooling effect of these pollutant has counteracted about 20-30% of the global warming in recent years.

Thus, global atmospheric temperature are a balance between the positive and negative forcing from natural causes (volcanoes, clouds, natural GHGs, solar irradiance) and anthropogenic causes (sulfate aerosols, soot, ozone depletion, increase in GHGs levels)

Global warming, ozone layer depletion and acid rain formation has been covered at length in Chapter 8 (Environmental Pollution).

12.3 ENVIRONMENTAL ETHICS: ISSUES AND POSSIBLE SOLUTIONS

Ethics is about the good values and virtues we should encourage and our moral duties. In simple words, it tells us what is right and what we ought to do. It has four components—

- **Cases.** These refer to specific acts and ask whether a particular act is morally justified. The answer must be based on moral rules.

- **Moral rules.** These are general guidelines that can be applied to various areas of concern, such as the rules that govern how we should treat endangered species.
- **Moral principles.** Moral rules are based on more general principles, which are the broadest ethical concepts; They are considered to be valid in all cases. An example is the principle of distributive justice, which states that all persons should be treated equitably.
- **Bases.** Ethical principles are justified by reference to some philosophical or theological basis. This is the foundation for an ethical system.

Environmental ethics refer to the issues, principles and guidelines relating to human interaction with the environment. Every person on the earth has the responsibility towards the environment. Thus environmental ethics are to be developed in each person, so that the actions and decision taken by him on different aspects of the environment do not harm the local, national and international community. These ethics sharpen the judgement of a person, not to jeopardize the health and security of the other humans for the sake of material gains. For example, the testing of new drugs on low income layers of society spurs ethical questions. Similarly disposal of dangerous e-waste and nuclear waste in the countries or markets where proper regulations have not been implemented. These human decisions are to be guided by environmental ethics. These ethics provided us the guidelines for putting our beliefs into action and help us decide what to do when faced with crucial situations. Some important guidelines known as Environmental ethics are given below:

- We should love and honour the earth since it has given us life and governs our survival.
- We should keep each day sacred to earth and celebrate turning of its seasons.
- We should not overexploit the earth's resources and judiciously use them.
- We should be grateful to the plants and animals which nourish us by giving us food.
- All the species on this earth have an intrinsic right to exist and we have no right to drive them to extinction.
- We should not conceal from others the effects on earth caused by our activities.
- We should not run after gains at the cost of nature, rather, we should strive to restore its damaged majesty.

Our ancient vedic literature also describes ecological and environmental values. The upanishads emphasised the values in a stanza which says, "This whole universe together with its creatures belong to the lord (Nature). Let no one species encroach over the rights and privileges of other species. One can enjoy nature by giving up greed". Our vedas have glorified each and every component of nature as Gods and Goddesses so that people have a feeling of reverence for them. This is our duty to follow the environmental ethics and become true earth citizens.

12.4 CONSUMERISM AND WASTE PRODUCTS

Consumerism refers to the consumption of resources by the people at a higher rate. The early human societies consumed very less resources, due to a much simpler life with fewer needs. There has been an exponential rise in consumerism with the dawn of industrial era, which is related to both increase in population size as well as increase in our demands due to change in life-style. Modern society has made mankind the largest consumer of resources. The economy is judged by the production and selling of goods. The growth rate of the economy is directly related to the goods produced and consumed by the society. The prosperity of the nation is judged by the per capita income of individuals residing in it and the economy of the nation is judged by the purchasing power of the people. Today the person's standard of living is valued by his or her material possessions.

The positive consumerism effects are:

- More industrial production
- More employment opportunities
- High growth rate economy
- More goods and services available
- Comfortable and better life style.

Consumerism leads to material prosperity but has many negative effects on the people and society. The negative effects are:

- Craving for goods is high. The wants and desires of the people increase. The better their income, the better their purchasing power. But in case, they are not able to do so, they feel dissatisfied.
- One is in a rat race to earn more and is forced to cope up with stress and other work related tensions.
- Material wealth is the deciding factor about whether a society is highly developed or not. Spiritual values are underplayed.
- Crime rate also increases as wants to possess expensive gadgets increase. Thefts become common and daylight robberies take place.
- Personal relationships also get affected as people are busy trying to earn more to maintain their standard of living.
- Consumerism has also resulted in ecological imbalances. The natural habitat is being destroyed to create more goods and build more buildings affecting the environment and Global climate.
- Consumerism is also depleting the natural resources around the globe.

Apart from these negative effects, consumerism results in production of large quantities of solid, liquid and gaseous waste like mineral refuse, e-waste, biomedical waste, agricultural waste due to fertilizer and pesticide overuse, dead animals, human and animal excreta, industrial waste etc.

The wastes generated from industrial operations and anthropogenic activities are mainly non-biodegradable in nature, leading to increased landfills and dumping in rivers and oceans. The waste disposal thus poses a serious threat to the environment.

Careful and judicious utilization of resources and recovery of used material by recycling of waste are essential today. The generation of waste at source must be minimized by improving the process efficiency with minimal use of resource. Reduce, reuse, recycle-the three Rs principle must be adopted by everyone to make a low waste or zero waste society.

12.5 WASTELAND RECLAMATION

Waste lands have been defined as those lands which are ecologically unstable, whose top soil has been lost and which have developed toxicity in root zones for growth of most plants. The National Waste Land Development Board (NWDB) of the ministry of environment and forests, has defined “degraded land which can be brought under vegetative cover with reasonable effort and which is currently under utilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes”.

Almost half of our country's land (about 175 million ha) is estimated to be wasteland with Rajasthan having the maximum area (about 36 million ha) followed by Madhya Pradesh, Andhra Pradesh and Haryana.

The NWDB has identified wasteland in following categories:

1. Gullies and/or ravines
2. Upland with a without scrub
3. Waterlogged and marshy land
4. Land affected by salinity/alkalinity in coastal and inland areas
5. Land under shifting cultivation
6. Under utilized/degraded notified forest land
7. Degraded pasture/grazing land
8. Degraded land under plantation crops
9. Shifting sands-inland/coastal
10. Mining/industrial wastelands
11. Barren rocky/stony waste/sheet rock areas
12. Steep sloping area
13. Snow covered and/or glacial area.

The wastelands can be broadly classified into two types:

- 1. Culturable Wastelands:** These include ravinous and gullied lands, water logged and marsh lands, saline lands, lands with lateritic soils, shifting cultivation areas, degraded forest lands, mine spoils and industrial wastelands.
- 2. Unculturable Wastelands:** These include baren rocky areas, steep slopes, snow capped hills and glaciers.

Wastelands are formed by natural processes and anthropogenic activities. The major anthropogenic activities leading to wasteland formation are deforestation, overgrazing, mining and wrong agricultural practices.

Causes of Land Degradation

Various causes of land degradation have also been extensively discussed in Chapter 4.

- (a) **Over cultivation:** The proportion of landless and marginal farmers in India is high. Because of scarcity of land, farming of ecologically vulnerable areas is taken up resulting in erosion and associated land degradation problems.
- (b) **Deforestation:** Trees are among the most effective preservers of land; however, at present, trees are being cut for various reasons:
 - *Fuel wood:* Deforestation for fire wood is estimated at around 5000 hectares annually; the actual figure in fact, could be much higher.
 - *Shifting cultivation:* Prevalent in north eastern states and Orissa. The result is poor crop yield necessitating the shifting cultivators to go in for fresh clearing of forests causing extensive land degradation.
 - *Commercial timber exploitation:* Timber exploitation to meet the ever increasing need of industries and urban areas has been a major cause of extensive deforestation.
 - *Clearing for permanent non forestry purpose:* Activities such as cultivation, human settlement, setting up of industries etc. often bares the soil to ravages of rain and wind, with all the subsequent dangers of flooding, silting and drought when rainfall is markedly seasonal, especially in inappropriate methods of arming are used on erosion sensitive soils.
- (c) **Over grazing:** Over grazing is as destructive as deforestation but its effects are not immediately noticeable. According to an FAO estimate, one buffalo eats seven tones of leaves (by fresh weight) per year, and a cow two and a half tones—all these leafy material coming from forests adjoining the villages. The uncontrolled grazing has contributed to destruction of forests and grasslands thereby exposing the soil to wind and water erosion and consequent land degradation.
- (d) **Improper Irrigation:** The farmer is totally oblivious of the cost that improper irrigation, viz, over use of water and non-provision of adequate drainage, imposes on others. In most cases, especially in large plains, the water table, and capillary arising from the higher ground water level increases accumulation of salts both in ground water and the soil near the surface thus subsequently lowering soil productivity, and in extreme cases, making it unfit for crop production.

Reclamation Practices of Wastelands.

- **Leaching:** Reclamation of salt affected soil can be achieved by leaching, i.e., applying excess amount of water to wash down the salts.
- **Drainage:** Water logged soils are reclaimed by removing excess of water by **artificial drainage**. This can be done by two methods
 - (i) **Surface drainage:** It is done by making 30–45 m deep ditches lying parallel to each other at 20–60 m distance to remove water stands from the field after heavy rains

- (ii) **Sub-surface drainage:** In this method a horizontal sub-surface drainage system consisting of a network of perforated PVC pipes is laid down 2–3 m below the land surface to flush out excess of water and salts.
- **Proper Irrigation Practice:** The irrigation practices such as thin and frequent irrigation with good quality of water on levelled land prevent water logging and salinity.
 - **Sowing of Tolerant Crops:** Salt tolerant crops can be grown on saline soils, Barley sugar beet and date palm are highly tolerant crops, while wheat, sorghum pearl millet soyabean, mustard and coconut come in the category of salt tolerant crops. Rice, millets, maize, pulses, sunflower, sugarcane and vegetables like brinjal, gourd, etc., are semi-tolerant crops.
 - **Addition of Gypsum:** Excess of sodium can be removed by the addition of gypsum. Gypsum contains calcium which replaces sodium from the soil.
 - **Use of Green Manures, Organic Manures and Biofertilizers:** Saline soils can be improved by the application of organic manures and biofertilizers. Use of green manure helps in improving salt affected soils. Blue green algae are being used as biofertilizers for improving salt-affected soils.
 - **Afforestation programmes:** Plantation of trees on degraded forest lands, river and canal sides, road and railway track sides helps in reclamation of wastelands.

CASE STUDY

Jatropha curcas Cultivation:

Biodiesel from Wastelands: Plantation of *Jatropha curcas* is a unique case of wasteland reclamation for study and adoption. *Jatropha curcas* which produces oil-rich seeds is known to survive in eroded land and requires limited amount of water, nutrients and capital inputs. The *Jatropha curcas* trees not only grow in uncultivable wastelands but also yield vegetable oil suitable for conversion into biodiesel. The concept of substituting biodiesel produced from plantations from eroded soils for conventional diesel fuel has gained widespread attention in India. The Government of India as well as many state governments have agreed to use marginal lands unsuitable for food production to be used, for plantation of *Jatropha* trees.

National Bank for Agriculture and Rural Development (NABARD), an apex body of planning, policy and operation on agriculture and rural finance is extensively involved in extending credit support for renewable energy development in the rural areas. *Jatropha curcas* trees can be planted through joint forest management. It is hard in

nature, has a short gestation period, high rate of recovery and high quality of oil. The average production cost is Rs. 25,826 per hectare. Besides the use of *Jatropha curcas* trees as substitute of diesel, the following are some of the other uses of the Jatropha tree:

- To make soap, lubricants and candles.
- It is a raw material for plastic and synthetic fibres.
- It is raw material for medicines.

12.6 POPULATION GROWTH

The world population is estimated to be more than 7 billion and is expected to reach 11 billion by 2045 as per the world bank estimates.

Six of Earth's seven continents are permanently inhabited on a large scale. Asia is the most populous continent, with its 4.3 billion inhabitants accounting for 60.31% of the world population. The world's two most-populated countries alone, China and India, together constitute about 37% of the world's population. Africa is the second-most-populated continent, with around 1 billion people, or 15% of the world's population. Europe's 733 million people make up 11% of the world's population, while the Latin American and Caribbean regions are home to around 600 million (9%). Northern America, primarily consisting of the United States and Canada, has a population of around 352 million (5%), and Oceania, the least-populated region, has about 35 million inhabitants (0.5%). Though it is not permanently inhabited by any fixed population, Antarctica has a small, fluctuating international population, based mainly in polar science stations. This population tends to rise in the summer months and decrease significantly in winter, as visiting researchers return to their home countries.

Four factors determine population growth for a given geographical area - births (B), deaths (D), immigration rate (I), and emigration rate (E):

$$\text{growth rate of population} = (B - D) + (I - E)$$

In other words, the population growth of a period can be calculated in two parts, natural growth of population ($B - D$) and mechanical growth of population ($I - E$), in which mechanical growth of population is mainly affected by social factors, e.g. advanced economies may grow faster while backward economies grow slowly or even experience negative growth.

In demographics and ecology, the "population growth rate" is the rate at which the number of individuals in a population increases in a given time period as a fraction of the initial population. Specifically, population growth rate refers to the change in population over a unit time period, often expressed as a percentage of the number of individuals in the population at the beginning of that period.

$$\text{Population growth rate} = \frac{P(t_2) - P(t_1)}{P(t_1)}$$

Population growth is usually expressed as percentage.

$$\% \text{ growth} = \text{Population growth rate} \times 100$$

A positive growth rate indicates that the population is increasing, while a negative growth rate indicates the population is decreasing. A growth rate of zero indicates that there were the same number of people at the two times—net difference between births, deaths a growth rate may be zero even when there are significant changes in the birth rates, death rates, immigration rates, and age distribution between the two times.

According to United Nations population statistics, the world population grew by 30%, or 1.6 billion people, between 1990 and 2010. In number of people the increase was highest in India 350 million and China 196 million. Population growth was among highest in the United Arab Emirates (315%) and Qatar (271%).

Consequences of Population Growth

The growth in human population around the world affects all people through its impacts on the economy, social and environment sectors. Rapid human population growth has a variety of consequences, such as environmental threats, poverty, scarcities of food and fresh water and international security threat.

Environmental Threats: Rapid population growth would lead to the expansion of human activity, causing the destruction of forest and the loss of biological diversity which may lead to instability of ecological systems and reducing ability of the ecosystem to combat global warming. As reality, the population growth would lead to more water pollution, erosion of hillsides and silting of rivers, increasing of greenhouse gases, rising sea levels, growing weather severity, disruption of agriculture, and increase in the energy and resources consumption.

Poverty: Rapid population growth aggravates poverty in developing countries by producing a high ratio of dependent children for each working adult. Only about 20 percent of the current world's population has a generally adequate standard of living. The other 80 percent live in conditions ranging from mild deprivation to severe deficiency. This imbalance is likely to get worse, as more than 90 percent of future population growth is projected for the less developed countries.

Scarcity of Food and Fresh Water: The Green Revolution of the 1970s enabled some developing countries to become net exporters of food. Yet, global population growth during and since the Green Revolution is continuing to consume more and more of the expanding food base, leading to a decline in per capita availability of cereal grains on a global basis over the last 15 years.

The world's agricultural systems rely substantially on increasing use of fertilizers. But now, the world's farmers are witnessing signs of a declining response curve, where the use of additional fertilizer yields little additional food product. At the same time, fertilizers and intensive cropping lower the quality of soil. These factors would limit the possibilities of raising food

production substantially and would boost relative food prices and resulting hunger for many. At the same time, shortages of water are at a crisis point in many countries. At least 400 million people live in regions with severe water shortages. By the year 2050, it is projected to be approximately two billion. Water tables on every continent are falling, as water is pumped out at far greater rates than rainwater can replenish in order to provide irrigation for agriculture. "India, for example, is pumping out its underground aquifers at twice the rate of natural replenishment." Humans are already using half of the globe's products of photosynthesis and over half of all accessible fresh water.

Threats to International Security: Population growth is a major contributor to economic stagnation through its depressing effect on capital formation. With growing numbers of young people attempting to enter the labor force, many developing countries have extraordinarily high levels of unemployment. Often high rates of unemployment give rise to severe political instability, which ultimately threatens national and international security. Moreover, the combination of poverty and violence is adding rapidly to the number of refugees seeking to move into more stable and prosperous areas. Growth of refugee and migrant populations are contributing to political instability and economic dislocation in many countries.

12.7 PROBLEMS OF URBANISATION

It is now a universally recognized fact that the progress of man depends upon social planning, upon a perfect harmony between man and his total environment. Till recently, men lived in village communities and their culture, mode of living, food and social organization were adjusted to their surroundings. Modern urbanized life has produced a new environment, creating new problems of adaptation.

Urbanization is a problem which has assumed gigantic dimensions in some of the technically and industrially advanced countries of the world. It means the concentration of population in the economically developed and industrialized centres and other big cities. This leads to much congestion and many social and economic problems.

The most noticeable evil associated with over-urbanization is the marked deterioration in the environment of the city and the appearance of slums. Modern cities have grown in a haphazard and unplanned manner due to fast industrialization. Cities in developing countries become over-populated and over-crowded partly as a result of the increase in population over the decades and partly as a result of migration of persons from the countryside to the big industrialized cities in search of employment, or in search of a higher standard of living and better living conditions. As decent habitation is not possible for them to afford, the poor are driven by necessity to living on foot paths or in slums under most intolerable conditions of incredible squalor, dirt and disease, in fact, they are unfit for habitation, a disgrace to the community. Being devoid of hygienic and sanitary considerations, they breed all kinds of epidemics. They become the nerve centres of all the worst vices and crimes, for all kinds of persons earning their livelihood

by dubious means—beggars, thief's, pickpockets, prostitutes, chromic drunkers, vagabonds, gamblers and drug pedlars and the like come to live in slums.

Urbanization has created another vital problem, that of pollution of the environment. According to a biologist, the price of pollution could be the death of man. Pollution is the direct outcome of the application of science and technology to human problems. The invention, preparation and experiments of nuclear weapons, the increasing use of science and technology in industry and agriculture, the carbon and smoke emitted by chimneys and motor-cars, and chemical wastes and poisonous exhausts—this has been causing disastrous environmental pollution in big industrial cities.

Another serious problem is that of housing the ever-growing and migrating population in big cities. Due to the paucity of houses to accommodate the people, the once beautiful cities are being reduced to slums. This pressure of population has led to the construction of vertically rising sky-scrappers to accommodate the maximum number within the minimum space. But they have themselves given birth to many problems such as fire hazard, in sanitary conditions, lack of civic amenities like parks, playgrounds and parking space, congestion, traffic jams.

EXERCISES

1. Discuss the concept of sustainable development. Explain the equitable use of resources for sustainable life style.
2. What do you understand by the term Environmental Ethics? What are the issues and possible solutions?
3. Explain how consumerism has affected the present society?
4. Write a note on different environmental movements for conservation of environmental resources.
5. Discuss the advantages from wasteland reclamation.
6. Write a note on consumerism and waste products.
7. Discuss the factors which determine population growth for a given geographical area.
8. What are the consequences due to population growth in a country?
9. What are the problems associated with urbanisation.
10. Write short notes on (i) Climate change (ii) global warming.



UNIT 13

Environmental Management Systems

“When the last tree is cut, the last river poisoned and the last fish dead, we will discover the we can’t eat money.”.

— Greenpeace, India

Objectives

- Introduction
- Objectives of Environment Management System
- Components of EMS
- Environment Impact Assessment
- Some Important Environmental Laws
- Green Bench
- Carbon Credits
- Environmental Management System standards ISO 14000 Series
- International Standards in the ISO 14000

13.1 INTRODUCTION

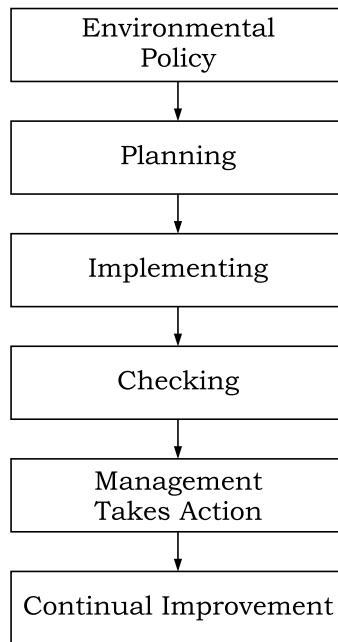
Organizations of all kinds are having an increasing concern for achieving sound environmental performance. This can be achieved by controlling the impacts of these activities, products and services on the environment. Thus an Environment Management System (EMS) is a tool for managing the impacts of an organisation's activities on the environment by providing a structured approach to planning and implementing environment protection measures.

EMS Model

The EMS Model is based on PDCA [Plan– Do, Check –Act] cycle. The cycle can be described as:

- *Plan:* The objectives and processes necessary to deliver results in accordance to the organizations environmental policy is established.
- *Do:* Implementation of the Process.
- *Check:* Monitoring the established objectives and processes and subsequently reporting the results.
- *Act:* Action is taken for the continual improvement.

PDCA cycle



13.2 OBJECTIVES OF ENVIRONMENT MANAGEMENT SYSTEM

An environmental objective is a specific environmental goal. An organization's, environmental objectives must be consistent with its environmental policy. Whenever possible the objectives should be quantified so that the performance (environmental) of the organization can be evaluated and measurements of progress towards meeting the organization's environmental targets can be made.

13.3 COMPONENTS OF EMS

To develop an EMS, an organization has to set the targets for reducing the impacts on the environment and to device methods to achieve the targets. Hence while the most important component is the commitment from the lowest rank to the top management in the organization, the other components are:

1. *Environmental Policy:* This is a statement of what an organization wants to achieve from EMS in compliance with its environmental activities.
2. *Environmental Impact Identification:* The organization's operations having impacts on the environment has to be identified and documented. This is achieved by conducting environmental audits.
3. *Objectives & Targets:* An environmental audit is the basis of determination of an organization's objectives and targets. An organization should adopt more stringent larger term objectives and review these regularly for the improvement of the performance.

4. *Consultation:* The staff and community consultation should be undertaken before, during and after the establishment of EMS. The involvement of the community helps in increasing the public perception of the company which is one of the benefits of EMS implementation.
5. *Operational & Emergency Procedures:* All procedures should be reviewed before documentation and the procedures should be compatible with the organization's objectives & targets.
6. *Environmental Management Plan:* This is a detailed method of procedures of an organization, for meeting its objectives.
7. *Documentation:* All the objectives, policies, responsibilities, procedures, formats should be properly documented. Documentation is a useful tool for verification of the performance.
8. *Responsibilities & Reporting Structures:* The responsibility to each member of the organization is to be allocated and documented for the effective implementation of EMS.
9. *Training:* Proper training should be imparted to all the staff members to make them aware of their respective responsibilities.
10. *Review Audits and Monitoring Compliance:* Review audits should be taken regularly (for instance once in every six months) to ensure the proper implementation of EMS. The report of these audits should be submitted to the management review committee for proper action.
11. *Continual improvement:* This component is very important. The audit report should be reviewed and the actions should be taken on the 'non-compliances' of the system. In case the organization meets with all the objectives of the existing system, new targets should be set for continual improvement.

13.4 ENVIRONMENT IMPACT ASSESSMENT

Manufacturing and processing facilities not only provide the city with the essential commodity inputs but also provide the means to earn livelihood to the people. But the adhoc decisions to set up industries also have adverse effects on the local environment. The degradation of the environment caused due to industrial development outweigh their benefits. Thus in view of the deteriorating environmental conditions in and around the townships, it has become essential for the industries to have environmental accountability before they are set up. **Environmental Impact Assessment** (EIA) may be defined as a formal process used to predict the environmental consequences of any developmental project. EIA ensures that the potential problems are foreseen and taken care of at an early stage in projects planning and design.

Impact Analysis of the Projects

Before starting a major project, it is essential to assess the present environment without the project and the likely impact of the project on environment after its completion. For analysis of the impacts experts from various discipline should be involved. The EIA should have the following objectives.

1. Predict environmental impacts of project after its completion.
2. Find ways and means to reduce the negative impacts.
3. Shape the project to make it conducive to the local environments.
4. Present the predictions and viable options to policy-makers.

Before any developmental project is taken up, there should be an analysis of the project by comparing its positive and negative impacts.

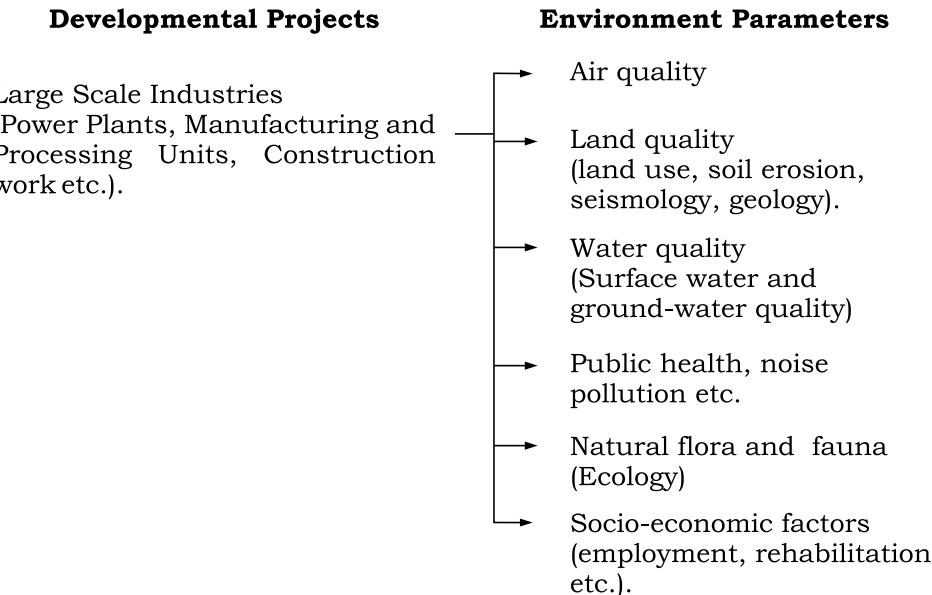
Positive Impacts of Developing New Projects are:

1. Increase in the small scale industries.
2. Increase in employment to the local people.
3. Improved standards of living because of improved infrastructures.

Negative impacts of developing new projects are:

1. Deterioration in the quality of local environment (air, water and soil).
2. Deforestation which may subsequently lead to soil erosion.
3. Natural flora and fauna is disturbed which disturbs the ecosystem.
4. May lead to increased level of noise pollution.

For assessment of the large scale projects it is useful to list the environmental parameters which are likely to be affected. Some of the parameters are listed below:



Thus the EIA statement should cover brief description of the positive and negative aspects of any developmental project, the **mitigation** and protection measure, consideration of alternatives, and its summary with conclusions.

CASE STUDY

The Karnataka Govt. had proposed to build a seventh dam on the Kali river near Dandeli in Uttara Kannada district of Karnataka in the year 2000 for generating 18 MW of electricities. This would have resulted in submergence of an additional 210 hectares of forest along the Kali river and disturbing the Dandeli wildlife Sanctuary and a 8 km long free flowing stretch of the river would have been lost for ever. The work was awarded to Murudeshwar Power corporations limited (MPCL). The EIA study was first carried out by the International, Consulting firm M/s Ernst and Young which was nothing but a plagiarized copy of the rapid EIA prepared by the institute for Catchment Studies and Environmental management, Bangalore. The 2nd EIA carried out by TERI did not comply with the laid down norms of EIA. Both the EIA studies were rejected on the ground that the proposed dam would be a violation of the Govt. of Karnataka's order dt. 19 May 1987 stating that no further projects involving diversion of forest land for other uses will be undertaken on kali river or its tributaries. The supreme court also upheld this order.

13.5 SOME IMPORTANT ENVIRONMENTAL LAWS

To protect the environment from degradation by human activities, it is necessary to enforce environmental laws. The legal control for the protection of Environment was incorporated by the 42nd amendment Act 1976 into the constitution. The amendment act incorporated two new articles, Article 48A, and Article 51A(g). Article 48A says that the state would protect and improve the quality of the environment where as Article 51A(g) says that it is the fundamental duty of every citizen to protect the environment including, lakes, rivers, wild life etc. The three important environmental laws. i.e. Water Act (1974), The Air Act (1981) and the Environmental Protection Act (EPA Act. 1986) are described below:

The Water (Prevention and Control of Pollution) Act, 1974

This act was enacted by the parliament in 1974 for preventing and abating water pollution. Under this act, the Central Pollution Control Board (CPCB) was constituted to promote cleanliness of streams and wells in different areas of the States. The CPCB was authorised to discharge the following functions.

- advise the Central Govt. on any matter pertaining to prevention and control of water pollution.
- co-ordinate the activities of the State Pollution Control Boards and resolve disputes among them.
- carry out and sponsor investigations and research relating to prevention/causes of water pollution.

- plan and organise training of persons to be engaged in programs for the prevention, control and abatement of water pollution
- organise comprehensive program through mass media regarding prevention and control of water pollution
- collect, compile and publish technical and statistical data relating to water pollution and the measures devised for its effective prevention and control
- prepare manuals, codes or guides relating to treatment and disposal of sewage and trade effluents.
- lay down, modify or annual the standards for stream or well for the quality of water,
- establish or recognise a laboratory for analysis of samples of water or sewage.

Under this act, the **State Pollution Control Boards** have the following function:

- to plan a comprehensive program for the prevention, control or abatement of pollution of streams and wells in the state
- advise the State Govt. on the matter concerning the above.
- to collaborate with CPCB for training of personnel
- to inspect sewage or trade effluents, works and plants for the treatment of sewage or trade effluents
- to review plans, specifications or other data relating to setting up of sewage treatment plants, water treatment plants etc.
- to lay down standards for sewage and trade effluents and for the quality of waters form the discharge of effluents.
- to evolve economical and reliable methods of treatment of sewage and trade effluents
- to evolve methods of utilisation of sewage and suitable trade effluents in agriculture
- to evolve efficient methods of disposal of sewage and trade effluents on land.

Air (Prevention and Control of Pollution) Act, 1981

The Air (prevention and control of pollution) Act was enacted by the parliament in 1981 for the prevention, control and abatement of air pollution. It entrusts the power of enforcing this act to the Central as well as the State Pollution Control Boards.

Functions of the Central Pollution Control Board (CPCB)

The Central Pollution Control Board performs, the following functions.

1. Advise the central Govt. on matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution.
2. Plan the programme which is to be executed as a nationwide program for the prevention, control or abatement of air pollution.
3. Co-ordinate the activities of the state and resolve the disputes among them.

4. Provide technical assistance and guidance to the State Boards. Carry out and sponsor investigation and research relating to problems of air pollution.
5. Lay down the standards for the quality of air.
6. Collect, compile and publish technical and statistical data relating to air pollution and provide methods for its effective prevention, control or abatement – and prepare manuals, codes or guides relating to it.

Function of a State Pollution Control Board (SPCB)

The State Pollution Control Board performs, the following functions.

1. To plan a comprehensive program for the prevention, control or abatement of air pollution.
2. To advise the State Govt. on any matter concerning it.
3. To inspect any control equipment, industrial plant or manufacturing process and to give, by order, directions to such persons as it may consider necessary for prevention, control or abatement of air pollution.
4. To inspect air pollution, control areas for assessing the quality of air and take steps for prevention, control or abatement of air pollution.
5. To lay down, in consultation with the Central Board, standards of emission of air pollutants into the atmosphere from industrial plants and automobiles.

The Air (prevention control of pollution) **Amendment Act** was enacted in 1987 empowering the central and State Pollution Control Boards to meet with grave emergencies of air pollution.

The Environment Protection Act. 1986

This was enacted by the parliament in 1986 to protect and improve the environmental quality, control and reduce pollution from all sources and prohibit or restrict the setting and/or operation of any industrial facility on environmental grounds.

Power of the Central Govt. to take measures to protect and improve environment are mentioned as under:

- coordination of actions by the State Govt.
- planning and execution of nation wide program for prevention, control and abatement of environmental pollution.
- laying down standards for the quality of environment in its various aspects
- laying down standards for emission or discharge of environmental pollutants from various sources.
- restriction of area in which industries, operations or processes can not be carried out without adequate safeguards.
- laying down procedures and safeguards for the prevention of accidents which may cause environmental pollution and provide remedial measures for such accidents.

- laying down procedures and safeguards for handling of hazardous substances.
- examination of such manufacturing processes, materials and substances that are likely to cause environmental pollution.
- inspection of any premises, plant equipment, machinery, manufacturing or other processes, material and substances and take necessary restrictive measures.
- establishment or recognition of environmental laboratories.
- collection and dissemination of information relating to environmental pollution.
- preparation of manuals, codes or guides relating to the prevention, control and abatement of environmental pollution.

Some of the important aspect of this act as given below:

- persons carrying on industry, operation of process can not discharge any environmental pollutants in excess of prescribed standards.
- persons handling hazardous substances shall have to comply with the safeguards prescribed under the following rules.
 - (i) Hazardous wastes (management and Handling) Rules, 1986
 - (ii) Manufacture, storage and usage of Hazardous Chemicals Rules, 1989
 - (iii) Rules for manufacture, use, import, export, and storage of Hazardous Micro-organisms, genetically required organisms or cells.

Wildlife (Protection) Act, 1972

It is an act to Provide for the protection of wild animals, birds and plants and for matters connected therewith. It extends to the whole of India except the State of Jammu and Kashmir. The major activities and provisions in the act can be summed up as follows:

1. It provides for the appointment of wildlife advisory board.
2. Protection of some endangered species.
3. The Chief Wild Life Warden may permit any person to hunt such animal, if any wild animal has become dangerous to human life or is so disabled or diseased as to be beyond recovery in writing and stating the reasons and any wild animal killed or wounded in defense of any person shall be Government property.
4. Chief Wild Life Warden may grant a permit to any person in writing stating the reasons on payment of such fee that is prescribed for the purpose, of eduction, scientific research, scientific management, collection of specimens, collection or preparation of snake-venom for the manufacture of life saving drugs.
5. No person shall willfully pick, uproot, damage, destroy, acquire or collect any specified plant from any forest land and any area specified or notification by Central Government.

6. No person shall cultivate a specified plant except under and in accordance with a license granted by the Chief Wild Life warden or any other officer authorized by the State Government in this behalf.
7. Every licence granted under this section shall specify the area in which and the conditions, if any, subject to which the licensee shall cultivate a specified plant.
8. The act of provides the declaration os sanctuary and National Parks.
9. There is restriction on entry in sanctuary. The Chief Wild Life Warden may, one application, grant to any person a permit to enter or reside in a sanctuary for all or any of the following purposes, namely investigation or study of wild life, photography, scientific research, tourism and transaction of lawful business with any person residing in the sanctuary.
10. It provides for legal power to officers and punishment to offenders. Any person who contravenes any provision of this act or any rule or order or who commits a breach of any of the conditions of any license or permit granted under this act, shall be guilty of an offence against this Act, and shall, on conviction, be punishable with imprisonment for a term which shall not be less than one year but which may extend to seven years and also with fine which shall not be less than five thousand.
11. This act gives the power of Central Government and State Government to make rules.

Forest (Conservation) Act, 1980

This is an act to provide for the conservation of forests and for matters connected therewith or ancillary or incidental thereto. It extends to the whole of India except the State of Jammu and Kashmir.

Under Section 2: Restriction on the Dereservation of Forests of Use of Forest Land for Non-forest Purpose.

Notwithstanding anything contained in any other law for the time being in force in a state, no State Government or other authority shall make, except with the prior approval of the Central Government, any order directing—

- (i) that any reserved forest (within the meaning of the expression “reserved forest” in any law for the time being in force in that state) or any portion thereof, shall cease to be reserved;
- (ii) that any forest land or any portion thereof may be used for any non-forest purpose;
- (iii) that any forest land or any portion thereof may be assigned by way of lease or otherwise to any private person or to any authority, corporation, agency or any other organization not owned, managed or controlled by Government;
- (iv) that any forest land or any portion thereof may be cleared of trees which have grown naturally in that land or portion, for the purpose or using it for reafforestation.

“Non-forest purpose” means the breaking up or clearing of any forest land or portion thereof for—

- (a) the cultivation of tea, coffee, spice, rubber, palms, oil-bearing plants, horticultural crops or medicinal plants;
- (b) any purpose other than reafforestation.

But does not include any work relating or ancillary to conservation, development and management of forests and wildlife, namely, the establishment of check-posts, fire lines, wireless communications and construction of fencing, bridges and culverts, dams, waterholes, trench marks, boundary marks, pipelines or other like purposes.

Under Section 3: Constitution of Advisory Committee

The Central Government may constitute a committee consisting of such number of persons as he may deem fit to advise that government with regard to—

- (i) The grant of approval, under Section 2; and
- (ii) any other matter connected with the conservation of forests which may be referred to by the Central Government.

Under Section 3A; Penalty for Contravention of the Provisions of the Act

Whoever contravenes or abets the contravention of any of the provisions of Section 2, shall be punishable with simple imprisonment for a period which may extend to fifteen days.

Under Section 3B: Offences by the Authorities and Government Departments

1. Where any offence under this act has been committed:
 - (a) by any department of government, the head of the department; or
 - (b) by any authority, every person who, at the time the offence was committed, was directly in charge of, and was responsible to, the authority for the conduct of the business of the authority as well as the authority. Shall be deemed to be guilty of the offence and shall be liable to be punished accordingly.

Under Section 4: Power to make Rules

1. The Central Government may, by notification in the Official Gazette, make rules for carrying out the provisions of this act.

Under Section 5: Repeal and Saving

1. The Forest (Conservation) Ordinance, 1980 is hereby replaced.
2. Notwithstanding such repeal, anything done or any action taken under the provisions of the said Ordinance shall be deemed to have been done or taken under the corresponding provisions of this act.

Some amendments are made in forest Act in 1992:

- Cultivation of tea, coffee, rubber are included under non-forestry activity.
- Exploration and survey of National Park and wildlife sanctuaries are totally prohibited.

CASE STUDY

(EPA)

Dahanu Taluka (located in the Thane District, about 120 km from Mumbai) is known for its horticulture and fisheries. The local industrialists and politicians have always created trouble to disturb its ecology so therefore the government issued a notification in 1991, declaring it ecologically fragile, to which the local industrialists, did not pay any attention. The supreme court then constituted DTEPA [Dahanu Taluka Environment Protection Authority] by the order issued by it on 31st October 1996. Today the region is faced with enormous problem of environmental degradation. The Maharashtra Pollution control Board (MPCB) issued order to a coal fired thermal power plant to set up a Fuel Gas Desulfurization (FGD) plant after it received 1400 letters from the local farmers.

The MPCB issued a five year consent for the plant whereas the DTEPA reduced it to one year. The DTEPA also asked BSES to install a FGD plant, but nothing has been done so far.

The MoEF mean-while filed an application in the supreme court in January 2002 to abolish DTEPA. It said that the function of DTEPA was to finalize the developmental plans for Dahanu and now it had become obsolete. It is believed that the MoEF is acting in this peculiar manner because it is pressurized by Reliance Energy (which took over BSES) and it wants to expand the plants operation from 500 MW. to 2000 MW. The DTEPA in this case is an excellent example of how the Environment Protection Act can be used to give decentralized power to the expert committee.

But all such decentralized working authorities will have to fight with the powerful industrial lobbies which have a greater say over the ministries like MoEF which are meant to strengthen entities like the DTEPA rather than abolishing them.

Water Act.

Damanganga River which flows through Vapi-Daman region merging in the Arabian Sea, is highly polluted due to heavy industrialization in that region. The two major sources of pollution are the discharge from Vapi CETP and distilleries at Daman. The pollution of the river resulted in the killing of fish occasionally. Matter was discussed with the concerned official after which assessment exercise was carried out covering surprise inspections of 34 industries of Vapi, 9 pharmaceuticals units at Daman. Directions were issued under section 18(1) (b) of Water/ Air act for further directions to the industrial units at fault and also to the M/s vapi water and management Company Ltd. (CETP), Vapi under section 5 of E(P) Act.

13.6 GREEN BENCH

Environmental Pollution has become a global problem. Hence every country developed/developing are putting emphasis on ways to minimize the environmental degradation. Laws are made in many countries for the protection of the environment. The Supreme Court (Apex court) of India also felt the need to establishing the Green Benches in different High courts in various states of India to deal with the environmental issues within the state. The first Green Bench was established in the Kolkata high court and started functioning in 1996. Till 2000 A.D. there are about 900 cases reported to the Green Bench.

The cases reported to Green Bench are related to various kinds of environment related issues such as:

- (a) Industries especially the small scale industries which do not have adequate pollution control system and hence cause violations to the existing norms.
- (b) Illegal filling of water bodies/lakes and direct effluent discharge into the rivers etc.
- (c) Cutting/felling of trees
- (d) Automobile emissions causing tremendous air pollution
- (e) Hazardous wastes (from hospitals etc.) which are not segregated and directly mixed with the Municipal solid waste
- (f) Ineffective waste collection system by the municipalities of various state (garbage is dumped on the streets directly).
- (g) Construction of dams (famous Narmada dam) for development and in turn causing environmental degradation and may others.

On 23rd July 2007, the centre had asked bluntly the 'Supreme Court' to wind up its Green Bench because it felt that the Bench had outlived its utility. In a special case concerning the preservation of forests the Centre felt that the hearings in the apex court clearly favoured the people who were experts in law and not in forestry. Hence it had asked the court to wind up the "Forest Bench" and dispose of the writ petitions seeking a direction to the Centre and States and to take more adequate and effective steps to conserve and increase the forest cover of the country.

13.7 CARBON CREDITS

One of the environmental threats our planet is facing today are the long term changes in the earth's temperature and climatic pattern. This is known as **Global Climate Change**. Scientists are estimating that as a result of global climatic changes, the Earth's temperature could increase by as much as six and a half degree (6.5°) Fahrenheit by the year 2100. This increase in temperature could result in the melting of glaciers, increase in the rise of sea levels to more than three feet and many other changes in the natural and human systems. To prevent this sort of disruption, on our planet efforts should be made to control global climatic changes. An important step in this process was made in 1997 when over 2500 scientists from the world agreed that emissions of the six green house

gases (Carbon dioxide, Methane, Nitrous Oxide, Hydrofluoro carbons (HCFs), Perflouro carbons (PFCs), Sulfur Hexaflouride (SF_6)) from human activities have influenced the global climate. Thus on 16th February 2005, the 'Kyoto Protocol' finally came into force. This protocol aimed to solve the problem of global warming by setting target levels for nations to reduce the green house gas emissions to 5.2 per cent below 1990 level by the year 2012.

The Kyoto Mechanism

The Kyoto Protocol has three innovative mechanisms for reducing the green house gas emissions. They are:

(i) Joint Implementation (JI)

It is a project based mechanism in which the developed countries (Annexure 1 countries) can reduce their emission targets through joint projects with other Annexure 1 developed countries. Here the investors could be Government companies, Private sectors etc. which will participate in the project activities of the host country to generate **Emission Reduction Units (ERUs)** to use them for compliance with targets under the Kyoto Protocol.

(ii) Clean Development Mechanism (CDM):

This mechanism is established by Article 12 of the Kyoto Protocol for project based emissions reduction activities in the **developing country**. The main objective of the mechanism is to meet the sustainable development needs of the host country which is a developing country. This would also help in reducing the emissions level of green house gases of the developed country which has invested in the projects in the host country.

(iii) International Emission Trading (IET):

In this mechanism, a country may allocate permits to individual companies for the emission of a certain quantity of green house gases allotted by the Kyoto commitments. If a country is incapable of meeting its target, it could buy permits from other countries. Similarly companies within a country that can reduce their emissions limits to a level lower than the allowed limit can 'sell' or 'trade' their excess **carbon credits** to other polluting countries.

As discussed in Unit-8, Carbon credits, as defined by the Kyoto Protocol are one metric ton of carbon dioxide emitted. The current prices of credits range from 25 Euros to 29 Euros. e.g. DMRC (Delhi Metro Rail Corporation) earned 4.2 crores of carbon credits by selling 82,000 CER's in 2008, for using regenerative braking system that reduces 30% electricity consumption.

Carbon Credits for Indian Scenario

India being a developing country is exempted from the requirement of adhering to the Kyoto Protocol. However it can sell the carbon credits to the

developed countries. The sectors which can generate the carbon credits are projects in wind mills, Bio-diesel, Co-generation, Bio-gas, afforestation etc.

The protocol is designed not only to reduce the climatic ill effects of the industrialization but identify the economic beneficiaries (i.e. the developing countries) and make them more accountable in the damage control.

Carbon Trading and Carbon Credits

Carbon trading is part of the large emission trading which is a method to control pollution by using economic incentives. In emission trading a central authority such as a government or an international body like the European Union sets a limit on the amount of the emitted pollutants. The allowance to emit pollution is called 'credit' and if the pollutant emitted is carbon dioxide, it is called carbon credit. If an industry or a company exceeds its emission level it will have to buy the extra allowance or credits from the countries which pollute less.

Merits of Carbon Credits

The following are the advantages of carbon credits:

- This allows the total quantum of emissions to be controlled without having to micromanage emissions by each firm.
- This concept penalizes the party polluting the environment by making it pay for the credit while the seller is rewarded monetarily.

Demerits of Carbon Credits

- Instead of policies that reduce emission, strict regulations, and penalties for polluters, this trading provides elaborate get out clauses for the biggest polluters.
- Carbon trading is a new form of colonialism where the developed countries would continue to pollute the atmosphere by buying the credits from the developing countries.
- Licences and credits will have no value without effective enforcement as the industries or companies may find it far less expensive to corrupt inspectors than to purchase emission licenses.

Markets Set up for the Trading

Different markets have been set up for different emissions. For carbon trading, the European Union is the largest multinational trading centre where all the 27 members of the union are involved. The programs covered under this, caps the amount of carbondioxide that can be emitted from large installations such as the power plants. The markets to reduce the acid rain is in the US where trading of nitrous oxide takes place. Markets for other pollutants tend to be smaller and more localised.

CASE STUDY

The first IT park to win carbon credits for India is in Kolkata. This park which is located in the posh ‘salt lake’ area of Kolkata would earn 8,500 carbon credits a year for next ten years. This will be sold in the International Market at the rate of 10 Euro each and would fetch to developers Rs 70 lakhs every year.

13.8 ENVIRONMENTAL MANAGEMENT SYSTEM STANDARDS ISO 14000 SERIES

The ISO: 14000 Series, currently being developed by the **International Organisation for Standardization (ISO)** is a collection of standards and guidance documents to help organizations address environmental issues.

In Sept. 1996, the International Organization of standardization published the first edition of ISO: 14001, i.e. the Environmental Management System standard. ISO: 14001 is a specification standard to which an organization may receive certification or registration and is known to be the foundation document of the entire series. A second edition of ISO: 14001 was published in 2004. This International Standard contains only those requirements that can be objectively audited.

Those organizations which require more general guidance on a broad range of environmental management system issues are referred to ISO: 14004.

Requirements of ISO: 14001 : 2004 Standard

The following are the 17 requirements of ISO: 14001 : 2004 standards.

- *Environmental Policy:* Development of a statement committed to the environment.
- *Environmental Aspects and Impacts:* Identification of the activities, products and services of the organization affecting the environment.
- *Legal and other Requirement:* Identify and ensure access to relevant laws and regulations.
- *Objectives and Targets and Environmental Management Program:* Setting of Short Term and Long Term goals and plan actions to achieve them.
- *Structure and Responsibility:* Assigning roles and responsibilities to all the members of the organization.
- *Training, Awareness and Competence:* Providing training about the programme to the employees so that they become competent to implement it.
- *Communication:* Development of processes for internal and external communication of environmental management issues.
- *EMS Documents:* Maintaining written evidences of objectives, procedures, responsibilities etc.
- *Document Control:* Ensure effective management of procedure and other documents.

- *Operational Control:* Identification, planning and management of the organization's operation and activities.
- *Emergency Preparedness and Response:* Development of procedures for preventing and responding to potential emergencies.
- *Monitoring and Measuring:* Monitoring the key activities to keep a track of performance.
- *Evaluation of compliance:* Develop the procedure to periodically evaluate compliance with legal and other requirements.
- *Non-conformance & corrective and Preventive Action:* Identify and correct problems so that the recurrence of the non-compliance is avoided.
- *Records:* Keep adequate records of EMS performance.
- *EMS audits:* Periodic verification of the system for achievements of objectives and targets.
- *Management Review:* A review of the audit to find if the system is effective or not.

Benefits of ISO: 14000 Certification

The manufacturers or production houses, who obtain ISO: 14000 certification generally reap the following benefits:

- Reduction in cost of manufacture/production
- Optimization of management efficiency
- Scrap, solid and hazardous waste reduction
- Improved energy efficiencies
- Streamlining of documentation process
- Minimize environmental liabilities
- Demonstrate a good corporate image
- Generate awareness for environmental concerns

13.9 INTERNATIONAL STANDARDS IN THE ISO 14000

The relevant International standards in the ISO 14000 Family are given below:

- ISO 14001 — Environmental Management System – Specification with guidance for use.
- ISO 14004 — Environmental Management Systems – General Guidelines on Principles, Systems and Supporting Techniques.
- ISO 14010 — Guidelines for Environmental Auditing – General Principles on Environmental Auditing.
- ISO 14011 — Guidelines for Environmental Auditing – Audit Procedures – Auditing of Environmental management Systems.
- ISO 14012 — Guidelines for Environmental Auditing – Qualification criteria for Environmental Auditors.
- ISO 14020 — Goals and Principles of All Environmental Labeling.
- ISO 14021 — Environmental Labels and Declaration – Self Declaration Environmental Claims – Terms and Definitions
- ISO 14024 — Environmental Labels and Declaration – Type 1-Guiding Principles and Procedures

- ISO 14025 — Type 3 Eco-Profile labelling Technical Report.
- ISO 14031 — Environmental Management – Environmental performance Evaluation – Guidelines
- ISO 14032 — Environmental Management – Environmental Performance Evaluation – case studies Illustrating the use of ISO: 14031 Technical Report.
- ISO 14040 — Environmental Management – Life Cycle Assessment – Principles and Framework.
- ISO 14041 — Environmental Management – Life Cycle Assessment – Goal and Scope definition
- ISO 14042 — Environmental management – Life Cycle Assessment – Impact Assessment.
- ISO 14043 — Environmental Management – Life Cycle Assessment – Interpretation
- ISO 14048 — Environmental Management – Life cycle Assessment – Life cycle assessment data documentation format]
- ISO 14049 — Environmental Management – Life cycle assessment – Examples of Application of ISO: 14041 to Goals and scope. Definition of Inventory Analysis Technical Report.
- ISO 14050 — Terms and Definitions – Guide on the Principle for Terminology work.
- ISO 14061 — Information to Assist Forestry Organizations in the use of Environmental Management System Standards ISO 14001 and ISO: 14004 Technical Report.

EXERCISES

- 1.** What are the various components of Environmental management systems?
- 2.** What is meant by EIA? Why is it necessary to have EIA before the development of any project?
- 3.** What are the various objectives of EIA?
- 4.** List some positive and negative impacts of developing a project in an area?
- 5.** Illustrate few important Environmental laws of India?
- 6.** Why was Green Bench established? List a few demerits of it.
- 7.** What do you understand by carbon credits?
- 8.** What are the merits and demerits of carbon credits?
- 9.** Why are the ISO: 14000 standards revised on a 5-year cycle?
- 10.** What is ISO: 14000 and ISO: 14001.
- 11.** How many requirements are there for ISO: 14001 : 2004 standards? List them.
- 12.** Does ISO: 14001 set limitations for discharge limits of emission?
- 13.** What kind of organisation can obtain ISO: 14001?
- 14.** What is KYOTO PROTOCOL? What was its objective?



EXPERIMENTS

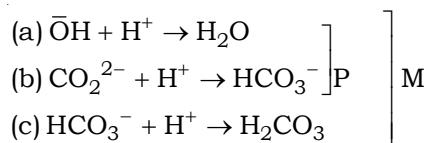
EXPERIMENT NO. 1

AIM To determine the alkalinity of a given water sample.

APPARATUS Burette, pipette, conical flask, beakers.

CHEMICALS N/106 HCl, phenolphthalein and methyl orange.

THEORY Determination of alkalinity due to different ions is based on the titration of the water sample against a standard acid making selective use of indicators. The indicators used are—phenolphthalein and methyl orange*. The reactions taking place may be represented by the following equations:



- The volume of the acid used upto phenolphthalein end point corresponds to the reaction (a) and (b) i.e. complete neutralization of $\bar{\text{O}}\text{H}$ ions and neutralization of CO_3^{2-} ions upto HCO_3^- stage (half neutralization of CO_3^{2-} ions).
- The volume of the acid used upto methyl orange end point corresponds to the reaction (a), (b), (c) i.e. complete neutralization of $\bar{\text{O}}\text{H}$, CO_3^{2-} and HCO_3^- ions.

Thus from the respective volume of the acid used, the respective strengths of various ions can be determined.

A known volume of the sample is titrated against a standard acid using phenolphthalein as indicator and alkalinity is found out in terms of CaCO_3 equivalents by using normality equation. This alkalinity is called *phenolphthalein alkalinity (P)*. Similarly the sample is titrated against a standard acid using methyl orange as indicator and alkalinity is calculated in terms of CaCO_3 equivalents. This alkalinity is called *methyl orange alkalinity (M)* or total alkalinity of water sample.

From the measurement of phenolphthalein alkalinity and methyl orange alkalinity, it is possible to calculate the magnitude of various forms of alkalinity present in water sample,

- Alkalinity due to HCO_3^- only
- Alkalinity due to CO_3^{2-} only
- Alkalinity due to CO_3^{2-} and HCO_3^-
- Alkalinity due to CO_3^{2-} and $\bar{\text{O}}\text{H}$
- Alkalinity due to $\bar{\text{O}}\text{H}$ only.

Discussion.

Case (i) When phenolphthalein alkalinity = 0, this implies that volume of the acid used till phenolphthalein end point is 0. This can only happen if CO_3^{2-} and OH^- both are absent. Whatever alkalinity is present is due to HCO_3^- ions and can be detected using methyl orange as indicator.

Case (ii): When $P = \frac{1}{2} \text{ M}$, this implies that only CO_3^{2-} ions are present. Neutralization using phenolphthalein as indicator reaches upto HCO_3^- stage. Same amount of acid will be further used when methyl orange is used as indicator to neutralize HCO_3^- to H_2O and CO_2 as represented in fig: 1-1 (a) The strength of CO_3^{2-} will be given by M or 2P

Case (iii) When $P < \frac{1}{2} \text{ M}$, this implies that besides CO_3^{2-} ions, HCO_3^- ions are also present. The acid used until phenolphthalein end point corresponds to half neutralization of CO_3^{2-} ions. Further titration using methyl orange as indicator corresponds to neutralization of HCO_3^- obtained from CO_3^{2-} ions and HCO_3^- originally present in the reaction mixture as shown in Fig. 1.1(b)

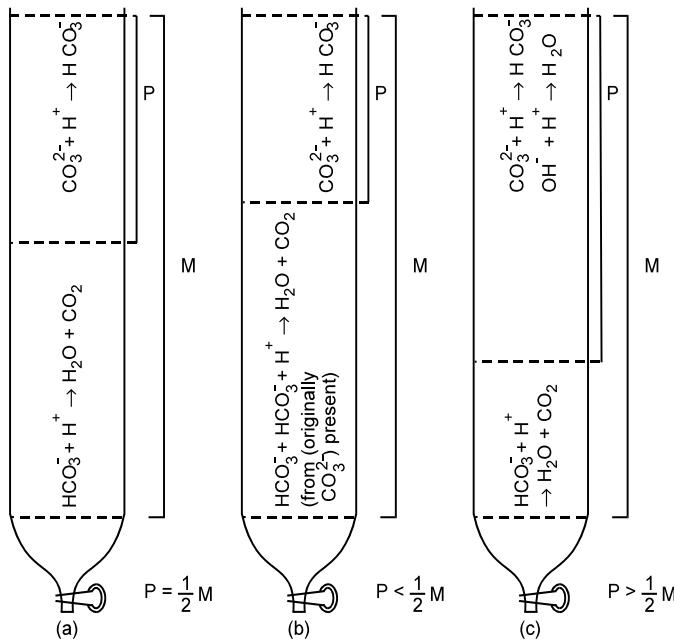


Fig. 1.1 Relative amounts of acid used, using phenolphthalein and methyl orange as indicator

Alkalinity due to $\text{CO}_3^{2-} = 2P$

Alkalinity due to $\text{HCO}_3^- = (M - 2P)$

Case (iv) When $P > \frac{1}{2} M$. This implies that besides CO_3^{2-} ions, OH^- ions are also present. OH^- will be completely neutralized by the acid whereas CO_3^{2-} will be neutralized upto the HCO_3^- stage using phenolphthalein as indicator. On further titration with the acid using methyl orange as indicator, the neutralization of HCO_3^- takes place as shown in Fig. 2.1(c)

Alkalinity due to $\text{CO}_3^{2-} = 2(M - P)$.

Alkalinity due to $\text{OH}^- = M - 2(M - P) = (2P - M)$

Case (v): When $P = M$ implies that only OH^- ions are present. Alkalinity due to $\text{OH}^- = P = M$.

Thus, on the basis of the analysis of water with respect to phenolphthalein alkalinity and methyl orange alkalinity, the alkalinity due to different ions can be calculated. The results are summarized in the following table.

Table 1 Computing the alkalinity due to different ions

Alkalinity	$\text{OH}^- (\text{ppm})$	$\text{CO}_3^{2-} (\text{ppm})$	$\text{HCO}_3^- (\text{ppm})$
$P = 0$	NIL	NIL	M
$P = \frac{1}{2} M$	NIL	$2P$	NIL
$P < \frac{1}{2} M$	NIL	$2P$	$(M - 2P)$
$P > \frac{1}{2} M$	$(2P - M)$	$2(M - P)$	NIL
$P = M$	$P = M$	NIL	NIL

INDICATORS Phenolphthalein and Methyl orange

END POINT Pink to colourless (Phenolphthalein), Yellow to red (Methyl orange)

PROCEDURE

1. Pipette out 20 ml of water sample into a conical flask. Add 1 – 2 drops of phenolphthalein.
2. Rinse and fill the burette with N/10 HCl.
3. Titrate the water sample in conical flask with N/10 HCl till the pink colour just disappears.

4. Note down the reading and repeat to get three concordant readings.
5. Again take 20ml of the water sample in conical flask and add methyl orange indicator to it.
6. Titrate it using N/10 HCl till a red colour is obtained.
7. Record the observation and repeat to get three concordant readings.

Observations

(a) Using Phenolphthalein

Normality of the acid used = N/10

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

Volume of the acid used = Vml

(b) Using Methyl Orange

Normality of the acid used = N/10

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) ml
		Initial Reading	Final Reading	
1.				
2.				
3.				

CALCULATIONS

Phenolphthalein Alkalinity in terms of CaCO_3 equivalents:

(Acid) (Water sample)

$$\text{N}_1\text{V}_1 = \text{N}_2\text{V}_2$$

Notes 1. If no colour develops on addition of phenolphthalein to the water sample, it means that phenolphthalein alkalinity is zero and hence do not titrate the sample for phenolphthalein alkalinity.

2. Methyl orange can also be added to the solution in which phenolphthalein was added, after the phenolphthalein end point is reached. In that case the total volume of the acid used to methyl orange end point would be, the volume of acid used upto phenolphthalein end point plus the volume of acid used upto methyl orange end point.

$$\frac{1}{10} \times V_1 = N_2 \times 20$$

$$N_2 = \frac{1}{10} \times \frac{V_1}{20} = \frac{V_1}{200}$$

Strength in terms of CaCO_3 equiv. = $N_2 \times \text{Eq.wt of } \text{CaCO}_3$

$$= \left(\frac{V_1}{200} \right) \times 50 \text{ g/L} = x \text{ g/L}$$

\therefore Phenolphthalein alkalinity (P) = $x \times 1000 \text{ mg/L} = x \times 1000 \text{ ppm.}$

(II) Methyl orange Alkalinity in terms of CaCO_3 equivalents:

Acid water sample

$$N'_1 V'_1 = N'_2 V'_2$$

$$\frac{1}{10} \times V'_1 = N'_2 \times 20$$

$$N'_2 = \frac{1}{200} \times V'_1$$

Strength in terms of CaCO_3 equiv. = $N'_2 \times 50 \text{ g/L}$

$$= \left(\frac{V'_1}{200} \times 50 \right) \text{ g/L} = y \text{ g/L}$$

Methyl orange alkalinity or total alkalinity of water sample = $y \times 1000 \text{ mg/L}$

$$= y \times 1000 \text{ ppm}$$

RESULT

Phenolphthalein alkalinity = ... ppm of CaCO_3

Methyl orange alkalinity = ... ppm of CaCO_3 .

To find out the alkalinity in terms of individual ions, we find out to which case the values of P and M falls and from table 1, we calculate the amount of individual ions.

Examples

1. If P = 0, the alkalinity is due to bicarbonate ions.

\therefore Bicarbonate Alkalinity in terms of CaCO_3 eq. = M.

$$\text{Bicarbonate ion concentration} = \frac{M \times 61}{50} \text{ mg/L.}$$

(The equiv. weight of HCO_3^- is 61 and of CaCO_3 is 50)

2. If $P = \frac{1}{2} M$, then alkalinity is only due to CO_3^{2-} . Carbonate alkalinity in terms of CaCO_3 equiv = 2P or M

$$\text{Carbonate ion concentration} = 2P \times \frac{30}{50} \text{ mg/L}$$

(The equiv. weight of CO_3^{2-} = 30)

3. If $P < \frac{1}{2} M$, then the alkalinity is due to CO_3^{2-} and HCO_3^-

Carbonate alkalinity in terms of CaCO_3 equiv = $2P$

$$\text{Carbonate ion concentration} = 2P \times \frac{30}{50} \text{ mg/L}$$

Bicarbonate alkalinity in terms of CaCO_3 equiv = $(M - 2P)$

$$\text{Bicarbonate concentration} = (M - 2P) \times \frac{61}{50} \text{ mg/L}$$

4. $P > \frac{1}{2} M$, then the alkalinity is due to OH^- and CO_3^{2-}

Hydroxide alkalinity in terms of CaCO_3 equiv = $(2P - M)$

$$\text{Hydroxide concentration} = (2P - M) \times \frac{17}{50} \text{ mg/L}$$

(Equiv. weight of OH^- = 17)

CO_3^{2-} alkalinity in terms of CaCO_3 equiv. = $2(M - P)$

$$\text{CO}_3^{2-} \text{ concentration} = 2(M - P) \times \frac{30}{50} \text{ mg/L}$$

5. If $P = M$, the alkalinity is due to hydroxide ions

\therefore Hydroxide alkalinity in terms of CaCO_3 eq. = P or M

$$\text{Hydroxide ion concentration} = P \times \frac{17}{50} \text{ mg/L}$$

EXERCISE

- Alkalinity of water cannot be due to the simultaneous presence of OH^- , CO_3^{2-} and HCO_3^- . Explain.
- Write the structural formula of phenolphthalein. In what forms does it exist in acidic and alkaline medium.
- What is the source of alkalinity in water.
- A 200 ml of a water sample required 20 ml. of N/50 H_2SO_4 using methyl orange as indicator but did not give any colouration with phenolphthalein. What type of alkalinity is present. Express in mg/L.

Note. P and M values in the above calculations are taken in mg/L.

EXPERIMENT NO. 2

DISSOLVED OXYGEN AND OXYGEN DEMAND

One of the most important water quality parameters is the amount of dissolved oxygen (DO) present. Oxygen is poorly soluble in water. The amount of oxygen in water depends on physical, chemical and biochemical activities taking place in water. The solubility of dissolved oxygen in water at saturation at any temperature and pressure is given by Henry's law. The saturation value of DO in water is of the order of 8 to 15 mg/L, depending upon temperature. Minimum amounts required for aquatic life or for a healthy fish population is 5-8 mg/L.

Significance of the determination of DO

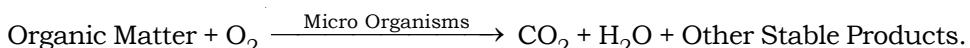
- In aquatic life, as DO drops, fish and other species are threatened and may get killed.
- Fall in DO levels causes undesirable odours, tastes and reduce the acceptability of water for domestic use.
- In steam generation, DO is one of the most important factors causing corrosion of the boiler material.

There are several measures of oxygen demand commonly used. Two of these are:

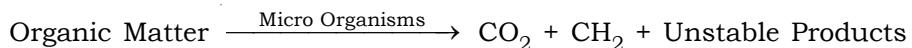
- (i) Biochemical oxygen demand (BOD)
- (ii) Chemical oxygen demand (COD)

BIOCHEMICAL OXYGEN DEMAND

When biodegradable organic matter is released into water, the micro organisms feed on the wastes and break it down into simpler organic or inorganic substances. If the decomposition takes place in the presence of oxygen i.e *aerobically* the non objectionable, stable end products are formed.

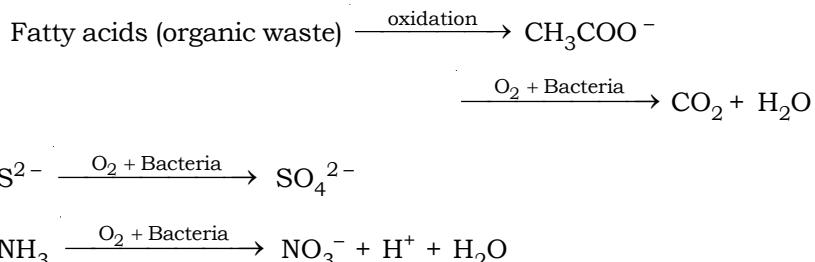


On the other hand if insufficient oxygen is available, the decomposition takes place *anaerobically*. The micro organisms causing the decomposition of the organic matter without the presence of oxygen are entirely different from aerobic bacteria and produce highly objectionable end products including H_2S , NH_3 and CH_4 .

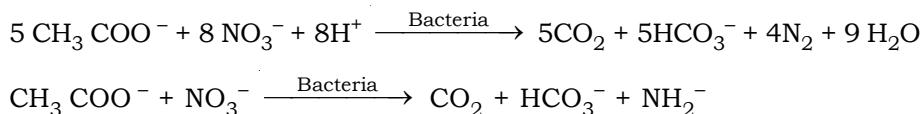


The amount of oxygen required by micro-organisms to oxidize organic wastes aerobically is called biochemical oxygen demand (BOD).

Actually, when sufficient oxygen is present, that is in aerobic systems, oxygen is the oxidizing agent to convert organic waste into CO_2 and H_2O . Similarly inorganic materials are also oxidized. The products obtained are not harmful.



However, if sufficient oxygen is not present (anaerobic conditions), organic matter is oxidized by nitrate to form undesirable products.



The products in this case like NH_2^- etc give bad odour to water. Example NH_2^- give smell of rotten fish. Similarly under anaerobic conditions, SO_4^{2-} , PO_4^{2-} , CO_2 are reduced to H_2S , HS^- , phosphine, methane etc. giving rotten egg smell or suffocating smell.

Therefore oxygen demanding wastes are termed as water pollutants because they deplete water from its dissolved oxygen. Thus sufficient oxygen may be present or supplied to maintain aerobic conditions and hence prevent bad odour, taste and colour.

CHEMICAL OXYGEN DEMAND

Although BOD test is applicable to organic wastes, there are many drawbacks. Certain organic materials are not biodegradable and hence can give wrong conclusions that less organic matter is present because BOD of such water samples will be low. In this case COD, Chemical Oxygen Demand reveals the real organic content present. Here the oxidation of organic substances present in water is done chemically.

COD, is the amount of oxygen required by organic matter in a sample of water for its oxidation by a strong chemical oxidizing agent such as $\text{K}_2\text{Cr}_2\text{O}_7$

Since in COD determination, the organic matter, both biologically oxidizable (glucose) and biologically inert (cellulose) is completely oxidized to CO_2 and H_2O , COD values are greater than BOD values.

AIM

Determination of dissolved oxygen in the given sample of water.

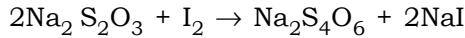
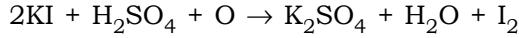
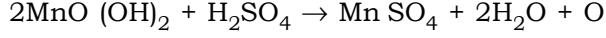
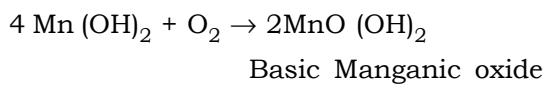
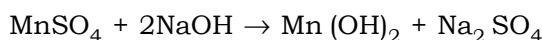
APPARATUS Burette, pipette, conical flask, beakers etc.

CHEMICALS $\text{Na}_2\text{S}_2\text{O}_3$ (N/40), Mn SO_4 solution, KI, starch, conc. H_2SO_4 .

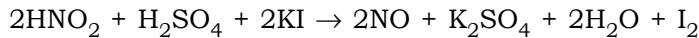
THEORY Oxygen itself is not a pollutant in water but its deficiency is an indicator of several types of pollution in water.

Dissolved oxygen (DO) is determined by Winkler's method or iodometric titration. The dissolved oxygen in water oxidizes KI and an equivalent amount of iodine is liberated. This iodine is titrated against a standard hypo solution. However since dissolved oxygen in water is in molecular state and is not capable of reacting with KI, therefore an oxygen carrier such as manganese hydroxide is used.

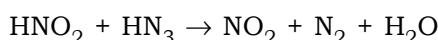
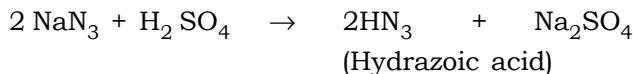
The method involves introducing a conc. solution of Mn SO_4 , NaOH and potassium iodide, azide reagent, into the water sample. The white precipitate of $\text{Mn}(\text{OH})_2$ which is formed, is oxidized by oxygen in water sample to give a brown precipitate of basic manganic oxide $\text{MnO}(\text{OH})_2$. This $\text{MnO}(\text{OH})_2$, in acidic medium dissolves and liberates free iodine from the added KI in a equivalent amount of dissolved oxygen in water sample. This liberated I_2 is then titrated against $\text{Na}_2\text{S}_2\text{O}_3$ solution using starch as indicator. The reactions involved are:



The nitrites present in water, interfere with the titration as these can also liberate I_2 from KI



Thus to destroy nitrite, sodium azide is used.



PROCEDURE

1. A known amount of sample water (say 250 ml) is taken in a stoppered bottle avoiding contact with air.
2. Add 0.2 ml of MnSO_4 solution to it by means of a pipette, dipping the end well below the surface of water. Also add 2 ml of alkaline iodide–azide solution to it.
3. Stopper the bottle and shake thoroughly. Allow the brown precipitates of MnO(OH)_2 formed, to settle down
4. When some portion of the liquid below the stopper is clear, add 2 ml of conc. H_2SO_4 with the help of pipette. Stopper and mix till the precipitate is completely dissolved. The characteristic brown colour of iodine is produced.
5. Transfer 100 ml of the above solution in a 250 ml flask with a pipette. Titrate the liberated I_2 with standardized sodium thiosulphate solution until the sample solution becomes pale yellow.
6. Add 2 ml of starch solution, the solution will turn blue.
7. Continue titration till the blue colour disappears.
8. Repeat to get another reading.

OBSERVATIONS

Volume of the water sample taken for titration = 100 ml

Observation Table:

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

CALCULATIONS

Hypo O_2 in water

$$\text{N}_1\text{V}_1 = \text{N}_2\text{V}_2$$

$$\frac{1}{100} \times \text{V}_1 = \text{N}_2 \times 100$$

$$\text{N}_2 = \frac{\text{V}_1}{10000}$$

Strength of dissolved oxygen = $N_2 \times \text{Eq. wt}$

$$\begin{aligned} &= \frac{V_1}{10000} \times 8 \text{ g/L} \\ &= \frac{V_1}{10000} \times 8 \times 1000 \text{ mg/L} \\ &= 0.8 V_1 \text{ ppm.} \end{aligned}$$

RESULT The amount of dissolved oxygen in water = . . . ppm.

PRECAUTIONS

1. The water should be taken in the stoppered bottle very carefully without trapping air bubbles which could raise oxygen level by aerating the sample.
2. MnSO_4 and alkaline iodine -azide solutions are added to the water sample just below the surface of water.
3. Whole of the precipitate of MnO(OH)_2 should be dissolved in H_2SO_4 .

Instructions For the Lab Assistant:

1. MnSO_4 sulphate: Dissolve 50 g of MnSO_4 in distilled water and make up the volume to 1L.
2. Alkaline potassium iodide azide reagent: Dissolve 40 g of NaOH, 20 g of KI in distilled water, add 0.5 g of reagent grade sodium azide to the cooled solution and make up the volume to 100 ml.
3. N/40 $\text{Na}_2\text{S}_2\text{O}_3$ solution: Dissolve 6.20 g of $\text{Na}_2\text{S}_2\text{O}_3$ solution in water and make up this volume to 1L. Standardize with N/40 $\text{K}_2\text{Cr}_2\text{O}_7$ solution.
4. Starch solution.

EXERCISE

1. Why MnSO_4 is used in the above determination?

Ans. Since oxygen in water is in molecular form and is not capable of reacting with KI, therefore an oxygen carrier such as manganese hydroxide is used. This in turn is prepared by Mn SO_4 and NaOH.

2. Why azide is added to the reaction mixture?
3. What is the significance of the above determination?

Ans. Measurement of D.O is necessary because

- It causes corrosion in boiler feed waters.
- Conc. of dissolved oxygen is a good indicator for polluted waters.
- DO is necessary for life of fish and other aquatic organisms.

Note. Sodium azide is poisonous. It may also explode if exposed to heat.

EXPERIMENT NO. 3

AIM To determine Biological Oxygen Demand (BOD) of a given sample of water.

APPARATUS Burette, pipette, conical flasks, beakers

CHEMICALS MgSO₄ solution (22.5 g/L) CaCl₂ solution (27.5 g/L) Fe Cl₃ solution (0.25 g/L), phosphate buffer solution, BOD bottles, Na₂S₂O₃.

THEORY The BOD in a water sample is directly related to the extent of pollution by sewage or other oxygen demanding waste. If the oxygen in water is *less than* Biological Oxygen Demand, the decomposition of microorganisms takes place anaerobically (in absence of oxygen) and hence produce highly objectionable end products including H₂S, NH₃ and CH₄.

Therefore sufficient oxygen must be present or supplied externally to maintain aerobic conditions so that organic matter decomposes into acceptable products. To know the amount of oxygen required by the given sample, the determination of BOD is necessary.

Polluted waters will continue to absorb oxygen for many months, till the oxidation gets completed and hence it is not practical to determine this ultimate oxygen demand which would require an extended period of time. As a result, it has become standard practice to simply measure the oxygen over a shorter period of 5 days. This is known as 5-day BOD test. **BOD₅ is the total amount of oxygen consumed by micro organisms during the first five days of biodegradation.**

In its simplest form BOD₅ would involve diluting a known volume of sample water with a known volume of pure water, whose oxygen content is already known. Let it be D₁. This is kept for 5 days at 20°C in a stoppered bottle, away from light. The dissolved oxygen is measured after the period of incubation. Let it be D₂. The difference between the original oxygen content and residual oxygen content will indicate the oxygen consumed by the water sample in five days in oxidizing the organic matter present in water sample. Thus BOD₅ is given by:

$$\text{BOD}_5 = D_1 - D_2 \times \frac{\text{Volume of sample after dilution}}{\text{Volume of sample before dilution}}$$

where D₁ = D.O of the sample in mg/L at the start of the experiment

 D₂ = D.O of the sample in mg/L after 5 days.

 = Loss of oxygen in mg/L × Dilution Factor.

The dilution of the waste water sample with pure water is necessary because waste water contains more of oxygen demanding material and hence the dissolved oxygen may not be sufficient to decompose it aerobically.

PROCEDURE

Preparation of dilution water:

1. Take 1000 ml of distilled water in a bottle. Add 1 ml each of phosphate buffer (pH = 7.2), CaCl_2 (27.5g/L), MgSO_4 (22.5g/L) and FeCl_3 (0.25g/L)
2. Water is aerated by passing compressed air through a diffusion tube until it is completely saturated.

Determination.

3. Take about 5ml of the sample and dilute it to 300 ml with dilution water prepared above. (or any appropriate dilution)
4. The diluted sample is taken in two bottles filled upto the neck.
5. The dissolved oxygen in one bottle is determined immediately and in the other bottle after five days of incubation. The procedure for determining the DO is the same as given in experiment number: 5.

OBSERVATION

(i) Determination of DO in bottle No - 1

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

(ii) Determination of DO in bottle No-2 (after incubation for 5 days)

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

Volume of sample taken for each titration = 100 ml

Normality of $\text{Na}_2\text{S}_2\text{O}_3$ used = N/100

CALCULATIONS

Volume of the sample before dilution = 5 ml.

Volume of the sample after dilution = 300 ml.

* (i) D.O in bottle no.- 1.

(Hypo) (O_2 in sample)

$$N_1 V_1 = N_2 V_2$$

$$\frac{1}{100} \times V_1 = N_2 \times 100$$

$$N_2 = \frac{V_1}{10000}$$

Strength of dissolved oxygen = $N_2 \times$ Eq. wt

$$(D_1) = \frac{V_1}{10,000} \times 0.8 \text{ g/L} = 0.8 V_1 \text{ ppm.}$$

** (ii) D.O in bottle- 2.

Similarly find D.O in bottle-No-2

Let it be D_2

$$(iii) \text{BOD} = D_1 - D_2 \times \frac{\text{Volume of sample after dilution}}{\text{Volume of sample before dilution}} \text{ mg/L}$$

RESULT BOD of the given water sample = ...ppm

Instructions For The Lab Assistant.

Prepare the solutions as in the case of determination of dissolved oxygen in Experiment No.: 2.

EXERCISE

1. What do you means by B.O.D?
2. What is BOD_5 test?
3. What is the significance of B.O.D. determination?
4. Why bad odour is developed in water if insufficient dissolved oxygen is present in water?
6. How is dilution water prepared?

Ans. It is prepared from distilled water by seeding with a small amount of domestic waste water to provide a mixed population of bacteria or it can be prepared as given in the experiment.

7. Why, while preparing dilution water is added, one ml each of phosphate, $FeCl_3$, $CaCl_2$, $MgSO_4$ etc.?

Ans. Phosphate is added to maintain a pH of 7 and it also serves as a nutrient. Salt like $FeCl_3$ is added to supply nutrients to bacteria and Ca^{2+} Mg^{2+} is added to serve as trace elements needed for growth of bacteria.

Note. The dilution depends upon the nature of the sample. For example. 1 – 1% for industrial wastes, 1 – 5% for raw and settled sewage, 25 – 100% for polluted water, 2 – 5% for domestic waste water)

EXPERIMENT NO. 4

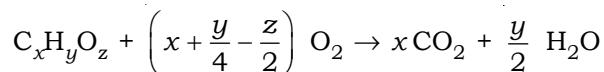
AIM To find the chemical oxygen demand (COD) of a waste water sample using $K_2Cr_2O_7$.

APPARATUS Burette, pipette, conical flask, beakers, round bottomed flask, condenser, water bath.

CHEMICALS N/4 $K_2Cr_2O_7$, N/4 Mohr's salt solution, ferroin indicator, sample solution, $HgSO_4$, silver sulphate reagent.

THEORY The chemical oxygen demand is defined as the amount of oxygen used while oxidizing the organic matter content of a sample with a strong chemical oxidant under acidic conditions.

A known amount of $K_2Cr_2O_7$ is added to the measured amount of the sample and mixture is boiled with conc. H_2SO_4 . The organic matter gets completely oxidized to produce CO_2 and H_2O



The excess of $K_2Cr_2O_7$ remained after the reaction is titrated against standard Mohr's salt solution using ferroin as indicator. The dichromate consumed is calculated which gives the oxygen required for the oxidation of organic matter.

INDICATOR Ferroin

END POINT Blue to wine red or (colourless to red)

PROCEDURE

- Take 50 ml of the sample in a round bottomed flask and add 1 g of $HgSO_4$ and some broken porcelain pieces.
- Immerse the flask in cold water and slowly add 75 ml silver sulphate reagents with continuous shaking. (As this is an exothermic process that is why the flask is immersed in cold water)
- Now add 25ml of $K_2Cr_2O_7$ (0.25N) to this solution and mix the contents of the flask.

-
- Notes**
- $HgSO_4$ is used to remove the chloride ions which may interfere because of their oxidation under the experimental conditions.
 - Ag_2SO_4 is used as a catalyst to achieve the oxidation of straight-chain aliphatic hydrocarbons and low molecular weight fatty acids.

4. Attach the reflux condenser and reflux for 2 hours.
5. Wash the condenser with distilled water into the flask. Cool and dilute to about 300ml by distilled water.
6. Add 2-3 drops of ferroin as indicator and titrate against 0.25N Mohr's salt solution till the end point *i.e. from blue to wine red*.
7. Record the volume of Mohr's salt solution used. Let it be X ml.
8. Perform a blank titration using distilled water in place of sample solution. For this, take 50ml of distilled water in a round bottomed flask, add the same amounts of reagents and reflux for two hours. Titrate it the same way as is done with the sample water.
9. Record the volume of Mohr's salt solution used. Let it be Y ml.

OBSERVATIONS

Volume of the sample taken = 50 ml.

Observation Table

(a) For sample solution

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

For distilled water (blank titration)

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

Volume of Mohr's salt solution used in case of sample solution = X ml (say)

Volume of Mohr's salt solution used in case of distilled water = Y ml (say)

$$\left[\begin{array}{l} \text{Volume of } K_2Cr_2O_7 \text{ used} \\ \text{to oxidize the organic} \\ \text{matter present in water sample} \end{array} \right] = \left[\begin{array}{l} \text{Volume of Mohr's salt} \\ \text{solution equivalent to} \\ K_2Cr_2O_7 \text{ used} \end{array} \right] = [Y - X] \text{ ml}$$

$$N_1 V_1 = N_2 V_2 \\ (\text{sample}) \quad (\text{Mohr's salt solution})$$

$$N_1 \times 50 = \frac{1}{4} (Y - X)$$

$$N_1 = \frac{1}{4 \times 50} (Y - X)$$

Therefore COD = $N_1 \times$ Eq.wt of oxygen = $N_1 \times 8$ g/L

RESULT The COD of the given sample is = $N_1 \times 8 \times 1000$ mg/L

PRECAUTIONS

1. The addition of $\text{Ag}_2\text{SO}_4 - \text{H}_2\text{SO}_4$ to the sample should be done slowly with shaking and cooling during mixing.
2. It should always be added through the open end of the condenser.
3. Smaller volume of the sample should be taken.

Instructions to the Lab Assistant

Provide the following:

1. $\frac{N}{4}$ $\text{K}_2\text{Cr}_2\text{O}_7$ solution: Dissolve 12.25g of $\text{K}_2\text{Cr}_2\text{O}_7$ in distilled water and make up the volume to 1000 ml.
2. $\frac{N}{4}$ Ferrous ammonium sulphate (Mohr's salt solution): Weigh 98 g of Mohr's salt and transfer in a flask having a few drops of conc. H_2SO_4 . Add distilled water to dissolve it. Make up the volume to 1000 ml.
3. Ferroin indicator: It can be purchased from the market as such or can be prepared in the lab. Dissolve 3.7125 g of O-phenanthroline monohydrate with 1.6375 g of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in distilled water and make up the volume to 250 ml
4. Hg SO_4 (solid)
5. Silver sulphate reagent: Dissolve 5g of Ag_2SO_4 in 500 ml of conc. H_2SO_4 .

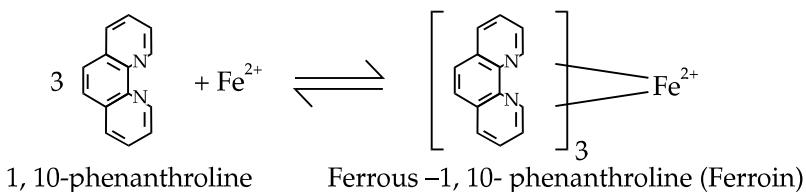
EXERCISE

1. Define COD?
2. What is the significance of COD determination?

Ans. The COD is widely used for measuring the polluting properties of domestic and industrial wastes.

- (3) What is the structure of ferroin indicator?

Ans. Ferroin is a ferrous complex of the organic compound 1, 10-phenanthroline



4. What is the colour of oxidized and reduced form of the indicator?

Ans.	$(phen)_3 Fe^{3+} + e^-$ pale blue (Appears colourless sometimes)	\rightarrow	$(phen)_3 Fe^{2+}$ Red (Reduced form)
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5. Why is HgSO_4 added to the sample water?

Ans. The chloride ions if present, may interfere because of their oxidation under the experimental conditions. Thus $HgSO_4$ i.e. added to eliminate chloride ions by forming complexes.

6. What is the use of adding silver sulphate in the sample to be refluxed?

Ans. The straight-chain aliphatic compounds, aromatic compounds are oxidized more effectively if Ag_2SO_4 is used as a catalyst.

EXPERIMENT NO. 5

AIM Determination of pH, conductivity and turbidity in some drinking water samples and preparation of report.

EXPERIMENT: 5(A)

AIM Determination of pH in some drinking water samples.

APPARATUS pH meter or potentiometer, glass electrode, thermometer, beaker, stirrer.

THEORY One of the frequently used test in water chemistry is to determine the pH of water. The water supplied for drinking purposes has to undergo many processes such as neutralization, precipitation, coagulation etc. All these processes are pH dependent. pH of natural water lies in the range of 4.4 to 8.5.

For determining the pH of a solution different methods are employed. The most widely used method is by using pH meter. The value of pH, the logarithm of the reciprocal of the hydrogen ion concentration in solution, is determined by measuring the difference in potential between two electrodes immersed in a sample solution.

The method is based on the determination of the potential difference between an electrode pair consisting of a glass electrode sensitive to the difference in the hydrogen ion activity in the sample solution and the internal filling solution, and a reference electrode, which is supposed to have a constant potential independent of the immersing solution. These days, **combined electrodes** are used in which the reference electrode is combined with the glass electrode. The measured potential difference is compared with the potential obtained when both electrodes are immersed in a solution or buffer with known pH or hydrogen ion concentration. The pH is defined by the formula:

$$pH_{(sample)} = pH_{(reference)} + (E_{(sample)} - E_{(reference)}) F / RT \ln 10$$

where E are the electrode potentials, R is the universal gas constant, T the absolute temperature and F is the Faraday constant.

PROCEDURE

1. Calibration Calibrate the electrode as per the following procedure:

- (a) Connect the pH meter to the power supply. Switch on the instrument.
- (b) Take a standard buffer solution of pH 7 in 100 mL beaker. Note the temperature of the buffer solution.
- (c) Set the temperature control of the pH meter to the temperature of the buffer solution.
- (d) Remove the combination electrode from the storage solution, wash it with distilled water and blot dry with soft tissue paper.
- (e) Connect the combination electrode to the input socket and dip the electrode in 7pH buffer solution.
- (f) Set the Function Selector Switch to pH position and adjust with ‘Calibrate’ control till the digital display shows the pH 7.
- (g) Now move the function switch to ‘Stand by’ position.
- (h) Remove the electrode from the buffer solution and wash it with distilled water. Dry with tissue paper.
- (i) Dip the electrode in the buffer solution having pH 4.
- (j) Set the “temperature” to the temperature of the solution.
- (k) Set the Function Selector Switch to pH position and adjust with ‘Slope correction’ control till the digital display shows the pH 4.

2. pH measurements:

- (a) Connect the combination electrode to the input socket after washing it with distilled water.
- (b) Dip the combined electrode in the solution under test.
- (c) Set the Temperature knob to the temperature of the solution.
- (d) Set the ‘Function Selector Switch’ to pH position.
- (e) Note the pH of the solution.
- (f) Repeat the same procedure for other water samples

OBSERVATION Drinking water samples:

	Sample	pH
1		
2		
3		
4		

RESULT The pH of the given water samples are:

SIGNIFICANCE

1. Knowing ‘pH’ value is very important parameter for analysis of water/waste water treatment, its suitability for domestic use and for irrigation. Certain chemicals and biological processes work

only at a particular pH of 6.5 to 8.5 has no direct adverse effect on health. However lower value will produce sour taste and higher value above 8.5 a bitter taste. Higher value of pH encourages the scale formation of trihalomethanes which are causing cancer in human beings. The water for domestic consumption should have pH between 6.5 to 8.5.

2. Corrosion of water mains is the main problem associated with acidic waters. Acidic/alkaline waters cannot be used for construction purposes also. If pH is less, algae will die, fish cannot reproduce and it causes acidity, corrosion, irritation of mucous membrane, tuberculosis and other health problems in humans.

PRECAUTIONS

1. Immediately after testing, the electrodes should be washed off with a gentle stream of distilled H_2O .
2. For storage, after cleaning, the electrodes are suspended in distilled water and the system is protected against evaporation. The drying out of the electrodes should be avoided.

EXPERIMENT: 5(B)

AIM Determination of conductivity of some drinking water samples.

THEORY Conductivity is a useful test in raw and finished water for a quick determination of minerals. In drinking water total dissolved solids are made up of primary inorganic salts, with small concentration of organic matter. Contributing ions are mainly CO_3^{2-} , HCO_3^{2-} , Cl^- , SO_4^{2-} , NO_2^- , K^+ , Na^+ , Ca^{2+} , Mg^{2+} . These ions are added to the water mainly through its contact with rocks and soil with minor contributions from pollution including urban runoff from industries.

Raw and potable water normally register specific conductance from 50 to $500\mu\Omega/cm$ whereas mineralized water register values over 500 and even over $1000\mu\Omega/cm$.

PROCEDURE

1. Wash the conductivity cell thoroughly with distilled water.
2. Rinse the conductivity cell repeatedly with KCl solution.
3. Take the sufficient volume of KCl solution in a beaker and note down its temperature.
4. Connect the instrument to the mains and switch on the instrument using the power switch. Connect the electrode leads in the input sockets at the rear of the instrument.
5. Set the 'Function' switch to 'check' position and adjust the display to 1.000 with CAL control at the back panel.
6. Dip the conductivity cell in KCl solution and adjust the temperature knob of the conductivity bridge at the temperature of the KCl solution.

7. Move the 'Function' switch to 'conductance' position and range position to appropriate range.
8. Adjust the cell constant knob so that the display reads the known value of the KCl solution at that temperature.
9. Bring the 'Function switch' to 'cell constant' position and read the value of the cell constant from the display window.
10. Take 100 ml of the water sample and note its conductivity.
11. Similarly note the conductivity of all the samples.

OBSERVATIONS

S.No	Sample	Conductivity
1	I	
2	II	
3	III	
4	IV	

RESULT The conductivities of drinking water samples are:

EXPERIMENT: 5(C)

AIM Determination of turbidity in the given water sample.

APPARTUS Laboratory Nephelometer, sample cells.

THEORY Turbidity in water is caused by suspended and colloidal matter such as clay, silt finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. Correlation of turbidity with the weight or particle number concentration of suspended matter is difficult because the size, shape, and refractive index of the particles affect the light-scattering properties of the suspension. When present in significant concentrations, particles consisting of light-absorbing materials such as activated carbon cause a negative interference. In low concentrations these particles tend to have a positive influence because they contribute to turbidity. The presence of dissolved, color-causing substances that absorb light may cause a negative interference. Some commercial instruments may have the capability of either correcting for a slight color interference or optically blanking out the color effect.

PRINCIPLE The nephelometric method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension

under the same conditions. The higher the intensity of scattered light, the higher the turbidity. Formazin polymer is used as the primary standard reference suspension. The turbidity of a specified concentration of formazin suspension is defined as 4000 NTU.

INTERFERENCE Turbidity can be determined for any water sample that is free of debris and rapidly setting coarse sediment. Dirty glassware and the presence of air bubbles give false results. "True color," i.e., water color due to dissolved substances that absorb light, causes measured turbidities to be low. The effect usually is not significant in treated water.

Unit of measurement: The nephelometric measurements are reported as nephelometric turbidity units (NTU).

PROCEDURE (a) *Preparation of stock primary standard formazin suspension:*

1. *Solution I:* Dissolve 1.000 g hydrazine sulfate, $(\text{NH}_2)_2\text{H}_2\text{SO}_4$, in distilled water and dilute to 100 mL in a volumetric flask.

CAUTION Hydrazine sulfate is a carcinogen; avoid inhalation, ingestion, and skin contact. Formazin suspensions can contain residual hydrazine sulfate.

2. *Solution II:* Dissolve 10.00 g hexamethylenetetramine, $(\text{CH}_2)_6\text{N}_4$, in distilled water and dilute to 100 mL in a volumetric flask.

3. In a flask, mix 5.0 mL Solution I and 5.0 mL Solution II. Let stand for 24 h at $25 \pm 3^\circ\text{C}$. This results in a 4000-NTU suspension. Transfer stock suspension to an amber glass or other UV-light-blocking bottle for storage. Make dilutions from this stock suspension. The stock suspension is stable for up to 1 year when properly stored.

(b) *Nephelometer calibration:* Follow the manufacturer's operating instructions. Run at least one standard in each instrument range to be used. Make certain the nephelometer gives stable readings in all sensitivity ranges used.

(c) *Measurement of turbidity:* Gently agitate sample. Wait until air bubbles disappear and pour sample into cell. Read turbidity directly from instrument display.

RESULT The turbidity of given water sample is ____ NTU.

EXPERIMENT NO. 6

RESIDUAL CHLORINE

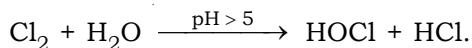
It has been known that contaminated water is responsible for the spread of many contagious diseases, number of epidemics such as typhoid or cholera are water born. Water borne diseases are those acquired by

ingestion of pathogens (disease causing bacteria) not only in drinking water, but also from water that makes it into persons mouth through washing food, utensils and hands.

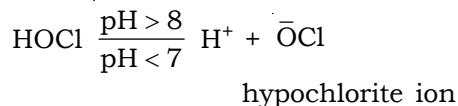
The process of destroying these pathogenic bacteria and micro organisms is known as sterilization or disinfection. The chemicals used for the above purpose are called disinfectants. The various methods used for disinfection of water include, boiling, addition of bleaching powder, chlorine, U.V radiations etc. However chlorination of water is widely used for disinfecting water supply since chlorine is a powerful oxidizing agent and is cheaply available.

Chlorine is applied to water in its elemental form or as hypochlorite (bleaching powder)

Disinfecting Action of Chlorine. Cl_2 reacts with H_2O to form hypochlorous acid or hypochlorite ions which have immediate disastrous effect on microrganisms

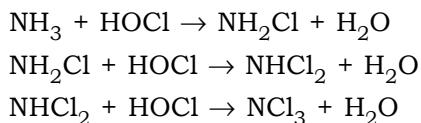


The hypochlorous acid is unstable and may dissociate as



All the three forms viz HOCl , $\bar{\text{OCl}}$, Cl_2 existing in sample water are termed as *free chlorine*.

When HOCl react with NH_3 likely to be present in water, it forms chloramines.



These chloramines also have disinfecting properties and act as chlorine reserves. The chlorine in this form is called *combined chlorine*.

The chlorine is added to water upto the break point. The break point chlorination of water is defined as chlorination to such an extent that micro-organisms as well as bad tastes and odours present in water are also destroyed.

However excess of free chlorine in drinking water is undesirable. An overdose of chlorine imparts an unpleasant taste to water and is also injurious to health.

Hence chlorine determination is necessary in those samples of water that have been treated with chlorine or hypochlorites (bleaching powder) so that necessary adjustments in dose rate can be made accordingly

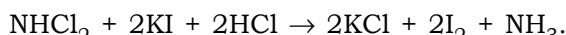
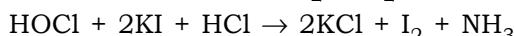
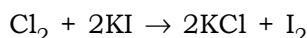
AIM Determination of total residual chlorine in water

APPARATUS Burette, pipette, conical flask and beakers.

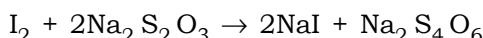
CHEMICALS N/50 $\text{Na}_2\text{S}_2\text{O}_3$, Glacial acetic acid, KI, conc. HCl.

THEORY The estimation of residual chlorine is based on oxidation of KI by residual chlorine i.e by iodometric titration*.

When the water sample containing residual chlorine is treated with KI, residual chlorine (both free and combined) oxidizes KI and liberate I_2 in equivalent amount.



The liberated I_2 is titrated against hypo solution, using starch as indicator



The end point is disappearance of blue colour.

PROCEDURE

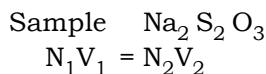
1. Pipette out 100 ml of the given water sample in conical flask and add 2g of KI solution and about 3ml of glacial acetic acid to maintain pH upto 3-4.
2. Cover the flask and shake it well to mix the solution.
3. Using a wash bottle rinse the sides of the flask.
4. Titrate it with N/50 $\text{Na}_2\text{S}_2\text{O}_3$ solution from the burette till the solution becomes straw yellow.
5. Add 2ml of the starch solution. The solution will turn blue.
6. Continue titration with $\text{Na}_2\text{S}_2\text{O}_3$ till the blue colour disappears.
7. Note the final reading and repeat to get three concordant readings.

OBSERVATIONS

Normality of the $\text{Na}_2\text{S}_2\text{O}_3$ solution = N/50

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

CALCULATIONS



$$N_1 \times 100 = \frac{1}{50} \times V_2$$

$$N_1 = \frac{V_2}{5000}$$

$$\begin{aligned} \text{Total chlorine residuals} &= N_1 \times \text{Eq. wt} = N_1 \times 35.5 \text{g/L} \\ &= N_1 \times 35.5 \times 1000 \text{ mg/L} \end{aligned}$$

RESULT Amount of total residual chlorine in given water sample =mg/L

PRECAUTIONS

- Chlorine vapours are harmful so the solution should not be sucked into the pipette with mouth.
- The titration should be completed rapidly in order to avoid atmospheric oxidation of iodide.
- First disappearance of blue colour may be taken as end point

Instructions to the Lab Assistant

Provide the following

- N/50 Na₂S₂O₃ solution. Dissolve 4.96 g of Na₂S₂O₃ in distilled water and make up the volume to 1L. Standardize with N/50 K₂Cr₂O₇
- Glacial acetic acid
- KI (solid)
- Starch solution.

EXERCISE

- Why chlorine is added to water?
- What are the disadvantages of excess of chlorine present in water?
- What is the action of chlorine on pathogens?
- Why and how pH is adjusted between 3 and 4.

Ans. pH is adjusted between 3-4 using acetic acid. At neutral pH, some combined chlorine residuals do not liberate I₂ by reacting with KI.

EXPERIMENT NO. 7a

AIM Determination of pH of some soil samples.

APPARATUS pH meter or potentiometer, glass electrode, thermometer, beaker, stirrer.

THEORY Soil acts as an electrolyte and hence its pH can be measured. The pH is measured to determine the degree of acidity or alkalinity in the soil sample. The pH of soil is an important Physico-chemical characteristic because it influences:

- The suitability of a soil for crop production.
- The availability of nutrients in the soil.
- The microbial activity in the soil.
- The lime and the gypsum requirement.
- The soil's physical properties like structure, permeability etc.

For determining the pH of a solution different methods are employed. The most widely used method is by using pH meter. The value of pH, the logarithm of the reciprocal of the hydrogen ion concentration in solution, is determined by measuring the difference in potential between two electrodes immersed in a sample solution.

The method is based on the determination of the potential difference between an electrode pair consisting of a glass electrode sensitive to the difference in the hydrogen ion activity in the sample solution and the internal filling solution, and a reference electrode, which is supposed to have a constant potential independent of the immersing solution. These days, *combined electrodes* are used in which the reference electrode is combined with the glass electrode. The measured potential difference is compared with the potential obtained when both electrodes are immersed in a solution or buffer with known pH or hydrogen ion concentration. The pH is defined by the formula:

$$pH_{(sample)} = pH_{(reference)} + (E_{(sample)} - E_{(reference)}) F / RT \ln 10$$

where E are the electrode potentials, R is the universal gas constant, T the absolute temperature and F is the Faraday constant

pH interpretation:

S.No.	pH	Interpretation
1.	Below 6.5	Acidic – requires liming
2.	6.5 – 8.7	Normal – No treatment, optimum for most of the crops
3.	Above 8.7	Alkaline – Requires reclamation with gypsum and by growing the salt tolerance crops.

PROCEDURE

1. **Soil Sample:**

- (a) Take the soil sample with the help of clean spatula and crush it if the lumps are there.
- (b) Take around 50 gm of the sample in a beaker and add 100 mL of distilled water. Stir at least four times over a 30 minutes period or continuous shaking for 10 min on mechanical shaker. This time is allowed for the soil and water to reach equilibrium
- (c) Shake the soil suspension and filter it.

2. **Calibration:** Calibrate the electrode as per the following procedure:

- (a) Connect the pH meter to the power supply. Switch on the instrument.
- (b) Take a standard buffer solution of pH 7 in 100 mL beaker. Note the temperature of the buffer solution.
- (c) Set the temperature control of the pH meter to the temperature of the buffer solution.
- (d) Remove the combination electrode from the storage solution, wash it with distilled water and blot dry with soft tissue paper.
- (e) Connect the combination electrode to the input socket and dip the electrode in 7pH buffer solution.
- (f) Set the Function Selector Switch to pH position and adjust with ‘Calibrate’ control till the digital display shows the pH 7.
- (g) Now move the function switch to ‘Stand by’ position.
- (h) Remove the electrode from the buffer solution and wash it with distilled water. Dry with tissue paper.
- (i) Dip the electrode in the buffer solution having pH 4.
- (j) Set the “temperature” to the temperature of the solution.
- (k) Set the Function Selector Switch to pH position and adjust with ‘Slope correction’ control till the digital display shows the pH 4.

3. **pH measurements:**

- (a) Connect the combination electrode to the input socket after washing it with distilled water.
- (b) Dip the combined electrode in the soil solution under test.
- (c) Set the Temperature knob to the temperature of the solution.
- (d) Set the ‘Function Selector Switch’ to pH position.
- (e) Note the pH of the solution.
- (f) Repeat the same procedure for other soil samples

OBSERVATIONS Soil Samples:

	<i>Sample</i>	<i>pH</i>
1		
2		
3		
4		

RESULT The pH of the given soil samples are:

PRECAUTIONS

1. Immediately after testing, the electrodes should be washed off with a gentle stream of distilled H₂O.
2. For storage, after cleaning, the electrodes are suspended in distilled water and the system is protected against evaporation. The drying out of the electrodes should be avoided.

EXPERIMENT NO. 7b**AIM To determine the conductivity of the given soil sample.****APPARATUS** Beaker, magnetic stirrer/glass rod, conductivity meter

THEORY Electrical conductivity (EC) is the reciprocal of resistance of a conductor, 1 cm long and 1 cm² in cross sectional area and is expressed in mhos/cm. In the case of soils, the electrical conductivity of a water extract is proportional to its salt concentration. Therefore the electrical conductivity measurements are used in soil-testing to estimate soil salinity. Since most soil solutions have a conductivity much less than unity, the measurements are expressed in terms of milli mhos / cm (EC × 10³) (the unit for expressing the conductivity of irrigation waters is micromhos / cm = EC × 10⁶)

The conductivity of a saturation extract is generally recommended for appraising soil salinity in relation to plant growth. In the range of Electrical conductivity, suitable for plant growth, the following equations describe the relationship between the osmotic pressure (O.P.) and the total soluble salts of soil solutions and conductivity measurements.

$$OP = 0.36 \times EC \times 10^3 \quad \dots (1)$$

$$\begin{aligned} \text{Percentage of soluble salts in soil} \\ = 0.064 \times EC \times 10^3 \times SP / 100 \end{aligned} \quad \dots (2)$$

However the difficulty of obtaining saturation extracts to find out saturation percentage (SP) of the soil sample makes the latter prohibitive for routine use.

The salinity estimation is based on the conductivity of dilute extracts of suspensions which are more convenient for rapid determinations. *For the soil sample, soil:water ratios of 1:2 is used for better result.*

Soils generally differ in their salt content, which affects their ability to grow crops. The soils containing an excess of soluble salts are called saline. Excess salts interfere with water and nutrient uptake, and in saline soils all crops may not grow successfully. Various crops differ in their tolerance to the presence of salts in the soils. The electrical conductivity of the soil is measured with a conductivity meter known as 'salt bridge'.

PROCEDURE

1. Weigh 50 gm of soil and add to it 100 ml of distilled water.
2. Stir the suspension continuously stirring for 20 min.
3. Filter the solution using Whatmann Filter paper.
4. Connect the instrument and calibrate the cell constant of the cell and with 0.01 M KCl. Put the temperature probe also in the KCl solution.
5. After calibration, dip the conductivity cell in the filtered solution.
6. Turn the knob towards the manual read and note the conductivity of the solution.

Interpretation: The following approximate values can be used as a guide when using a 1:2 soil water extract for conductivity measurement.

Table 7.1 Guidelines for the use of soil water extract conductivity

S.No.	Conductivity $mhos/cm^{-1}$	Relative level of salts	Plant response
1.	0.0 – 0.2	Low	No injury to any plants. May indicate lack of nutrients.
2.	0.2 – 0.8	Medium	Optimum level for most plants. Usually indicates well fertilized soils. Very sensitive plants may be injured.
3.	0.8 – 1.5	High	Injury to salt sensitive plants Germination seeds or seedlings likely to be injured.
4.	1.0 – 5.0	Excessive	Definitely injurious to most plants of any age.

RESULT The conductivity of the given soil sample is _____

PRECAUTIONS

1. Immediately after testing, the electrodes should be washed off with a gentle stream of distilled H₂O.
2. For storage, after cleaning, the electrodes are suspended in distilled water and the system is protected against evaporation. The drying out of the electrodes should be avoided.

EXPERIMENT NO. 8

AIM To estimate the soil moisture content in the given soil sample.

APPARATUS Watch glass, Drying oven, Spatula, Dessicator

THEORY Water plays a very significant role in soil growth relationship. It forms major part of plant itself, essential for physiological activities, acts as a solvent and nutrient carrier and maintains turgidity of the plants. Infact water is a regulator of physical, chemical and biological activities in the soil.

Water in a soil may be measured in a number of ways: Gravimetric, Volumetric method, Neutron scattering, Soil moisture tension and Electrical conductivity. However gravimetric method is the simplest and the most widely used method. In this the weighed soil sample is placed in an oven at 105°C and it is dried to constant weight. The weight difference is considered to be water present in soil sample.

$$\text{Percent moisture} = (\text{Loss in weight} / \text{weight of soil}) \times 100$$

PROCEDURE

1. Weigh the empty watch glass.
2. Put 10gms soil sample on the watch glass and weigh immediately to avoid loss in moisture content.
3. Place the watch glass in a preheated oven at 105°C for one hour.
4. Keep the watch glass in a Dessicator for cooling for atleast half an hour.

Now weigh the watch glass along with the oven dry soil.

OBSERVATIONS

$$\text{Weight of empty watch glass} = (x)$$

$$\text{Wt. of watch glass + moist soil} = (y)$$

$$\text{Wt. of watch glass + oven dry soil} = (z)$$

CALCULATIONS

$$\text{Moisture content in soil} = (y - z)$$

$$\text{Weight of moist soil} = (y - x)$$

$$\text{Percentage moisture in soil} = (y - z)/(y - x) \times 100.$$

RESULT The amount of moisture present in soil sample is%.

EXPERIMENT NO. 9

AIM Determination of Total dissolved solids in water/effluent sample.

THEORY Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) content of drinking water varies between 20-1000 mg/l, and it comprises mainly of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter and dissolved gases.

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing.

Table 1 Total Dissolved Solids (TDS) in some water samples.

Water Type	TDS (mg/l)
Sea water	35,000
Recommended for potable water	< 1000
Irrigation water	< 500 no restriction on use, 500-2000 moderate restriction on use, > 2000 severe restriction on use.

PROCEDURE

1. Take the empty weight of evaporating dish/crucible.
2. Measure accurately 100ml of well mixed water/effluent sample and filter the sample through the whatman filter paper.
3. Transfer filtrate to a preweighed evaporating dish/crucible and evaporate to dryness on a hot plate.
4. Dry for at least 1h in oven at 180°C.
5. Cool in a desiccator and take the final weight. Calculate the total dissolved solids (TDS) using the given equation.

CALCULATION

mg of total dissolved solids/L = (A-B) x 1000 / Sample volume, ml

where, A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

RESULT The amount of total dissolved solids in a given water sample is.....mg/l.

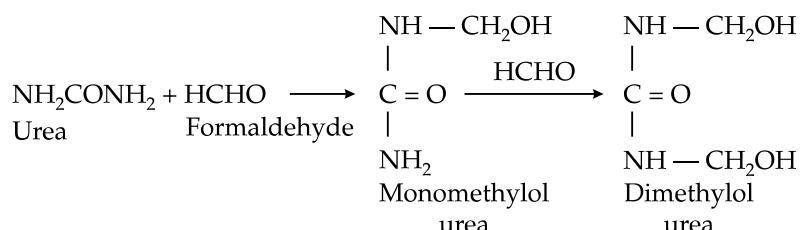
SIGNIFICANCE An elevated TDS indicates the following:

1. The concentration of the dissolved ions may cause the water to be corrosive, salty or brackish taste, result in scale formation, and interfere and decrease efficiency of hot water heaters; and
2. Many contain elevated levels of ions that are above the Primary or Secondary Drinking Water Standards, such as: an elevated level of nitrate, arsenic, aluminum, copper, lead, etc.

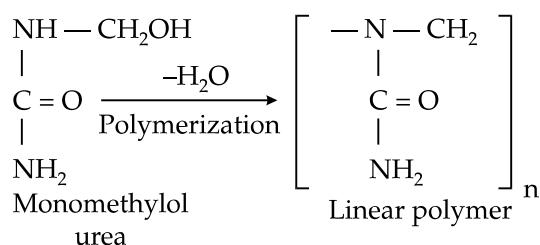
EXPERIMENT NO. 10

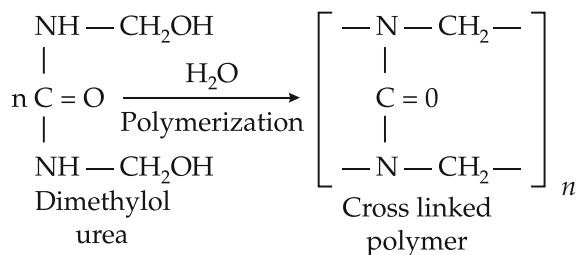
AIM Preparation of urea formaldehyde resin.

THEORY *Urea formaldehyde resin* is prepared by the condensation reaction between urea and formaldehyde in neutral or alkaline conditions. The first products formed during the formation of resin are monomethylol and dimethylol ureas.



Polymerization can take place from mono or dimethylol urea, or possibly through both, with the formation of long chains.





APPARATUS Beakers, glass rod, funnel, filter paper

CHEMICALS Formaldehyde (40%), urea, conc. H_2SO_4 , distilled water.

PROCEDURE

1. Place about 20 ml of 40% formaldehyde solution in 100 ml beaker.
2. Add about 10 g of urea with constant stirring till saturated solution is obtained.
3. Add a few drops of conc. H_2SO_4 with constant stirring.
4. A voluminous white solid mass appears in the beaker.
5. Wash the white solid with water and dry it in the folds of filter paper.
6. Calculate the yield of the product.

RESULT The yield of urea formaldehyde resin is

PRECAUTIONS

1. While adding conc. H_2SO_4 , it is better to stay little away from the beaker since the reaction sometimes becomes vigorous.
2. The reaction mixture should be stirred continuously.

PROPERTIES

1. The urea formaldehyde resins are light in colour and enable the production of light or pastel coloured objects.
2. Their heat and moisture resistance are lower than those of phenolic resins.
3. They have good electrical insulating properties.
4. They are resistant to oxidation to oil, grease and weak acids.
5. They are hard, resist abrasion and scratching.
6. They have good adhesive properties.

USES

1. Urea-formaldehyde resins are widely used to make moulded articles like vacuum flask cups, jugs, buttons, bottle caps etc. where the darker colour of phenolics may be objectionable.

2. They are also used for adhesive applications for the production of plywood and laminating.
3. They are used for the manufacture of coated abrasive paper and binder for foundry cores.
4. They are used for the manufacture of cation exchange resins.
5. These also find use in the manufacture of electrical switches, plugs and insulating foams.
6. Their applications also include the treatment of textile fibers for improving their shrink and crease resistance.

EXPERIMENT NO. 11

AIM Determination of Ammonia in Water

THEORY Ammonia is found as ammonium hydroxide in solution and reacts with sulfuric acid according to the following equation.



REAGENT Standard solution of H_2SO_4

METHOD

1. Rinse and fill the burette with N/50 H_2SO_4
2. Pipette out 25mL of the water solution in titration flask.
3. Add 2 drops of methyl red indicator and mix well.
4. Run the acid solution into the flask till the colour changes from yellow to red.
5. Repeat to get three concordant readings.

OBSERVATIONS

Normality of the acid solution = N/50

Volume of mixture taken for each titration = 25mL

Insert the table from page 39 practical book

CALCULATIONS

Acid = Water solution

$$\text{N}_1\text{V}_1 = \text{N}_2\text{V}_2$$

$$1/50 \times \text{V}_1 = \text{N}_2 25$$

$$\text{N}_2 = 1/50 \times \text{V}_1/25$$

$$\text{Strength} = \text{N}_2 \times 17\text{g/L}$$

RESULT The strength of ammonia in water sample is

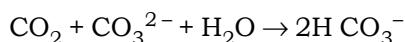
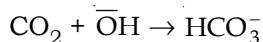
EXPERIMENT NO. 12

AIM Determination of free CO₂ in given sample of water.

APPARATUS Burette, pipette, conical flask, beakers etc.

CHEMICALS N/50 Na₂CO₃ (or N/50 NaOH), phenolphthalein

THEORY Free CO₂ is determined by titrating the sample water with N/10 NaOH or N/10 Na₂CO₃ solution using phenolphthalein as indicator. The CO₂ reacts with NaOH or Na₂CO₃ to form HCO₃⁻.



The end point is appearance of pink colour.

PROCEDURE

1. Rinse and fill the burette with N/50 Na₂CO₃ solution
2. Pipette out 100 ml of water sample in a conical flask (there should be no air bubbles) Add a few drops of phenolphthalein.
3. Titrate the solution with N/50 Na₂CO₃ from the burette, till the pink colour persists for atleast 30 seconds.
4. Note the reading and repeat to get three concordant readings

OBSERVATIONS

Volume of water sample taken for each titration = 100 ml.

Normality of Na₂CO₃ used = N/50.

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

CALCULATIONS

Water sample (Na₂CO₃)

$$N_1 V_1 = N_2 V_2$$

$$N_1 \times 100 = \frac{1}{50} \times V_2$$

$$N_1 = \frac{1}{5000} \times V_2$$

Strength of CO₂ = N₁ × Eq. wt

$$\text{Strength of CO}_2 = \frac{V_2}{5000} \times 22 \text{ g/L}$$

$$= \frac{V_2}{5000} \times 22 \times 1000 \text{ mg/L} = \frac{22}{5} V_2 \text{ mg/L.}$$

RESULT The amount of free CO₂ present in water sample = ...ppm.

PRECAUTIONS

1. The reaction mixture should be stirred very gently during titration.
2. Same amount of indicator should be added while taking different readings.

Instructions to the Lab Assistant

Provide the following

1. N/50 Na₂CO₃ solution: Dissolve 1.06 g of Na₂CO₃ in distilled water and make up the volume to 1 litre.
2. Phenolphthalein.

EXERCISE

1. What is the source of acidity in water?
2. How the acidity of water is determined?
3. What are the disadvantages of acidic water?
4. What are the disadvantages of dissolved CO₂ present in water.
5. How can you determine the amount of dissolved CO₂ in water.

EXPERIMENT NO. 13

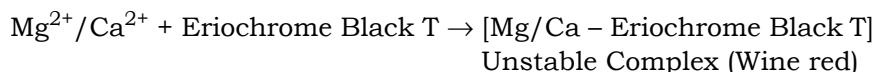
AIM Determination of total hardness by Complexometric titration method.

CHEMICALS 0.1 M EDTA, Eriochrome Black T, water sample, buffer solution.

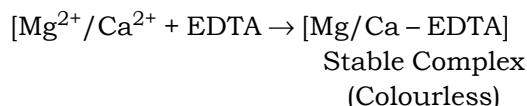
THEORY The hardness of water can be determined by *complexometric titration. EDTA is used as complexing reagent. The Ca^{2+} and Mg^{2+} present in water are titrated with EDTA using Eriochrome Black T as indicator.

Estimation of hardness by EDTA method is based on the following principle

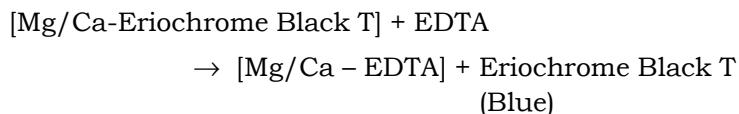
- (i) First, the indicator Eriochrome Black-T, which is a blue coloured dye, forms an unstable complex with calcium or magnesium ions in hard water at a pH of 9 to 10. The complex is wine red in colour.



- (ii) As this solution is titrated against EDTA, the free Ca^{2+} and Mg^{2+} ions in water form stable metal-ion EDTA, complex



Once the free metal ions are complexed, the EDTA replaces Ca and Mg ions from the unstable indicator complex also, to form a stable complex, with the result, the indicator is set free. Since the free indicator is blue in colour at the above mentioned pH, the endpoint is the appearance of blue colour.



Thus the amount of EDTA used corresponds to the hardness of water.

The temporary hardness is removed by boiling and after the removal of precipitate by filtration, the permanent hardness in the filtrate is determined by titration with EDTA as above.

Temporary hardness will be given by the difference of total hardness and permanent hardness. Hardness in water is generally expressed in CaCO_3 equivalent.

PROCEDURE

1. Rinse and fill the burette with EDTA solution
2. Pipette out 25 ml of hard water into volumetric flask and add 20 ml of distilled water and 10 ml of buffer solution.
3. Add 2-3 drops of indicator Eriochrome Black T.
4. Titrate against 0.1 M EDTA solution till the colour of the solution changes from wine red to blue.
5. Note the final reading and repeat to get three concordant readings.

OBSERVATIONS

Volume of hard water taken for each titration = 25 ml

Volume of 0.01 M EDTA used (from titration) = V_1 ml

Observation table

S. No.	Volume of the solution taken in the titration flask (ml)	Burette Readings		Volume of the titrant used (Final-Initial reading) (ml)
		Initial Reading	Final Reading	
1.				
2.				
3.				

CALCULATIONS

EDTA forms 1 : 1 complex with Ca^{2+} and Mg^{2+} ,

\therefore 1000 ml of 1M EDTA = 1 Mole of CaCO_3 = 100 gm of CaCO_3

$$1 \text{ ml of } 0.01 \text{ M EDTA} = 100 \times \frac{1}{1000} \times \frac{1}{100} \text{ gm of } \text{CaCO}_3 = 1 \text{ mg of } \text{Ca CO}_3$$

$$V \text{ ml of } 0.01 \text{ M EDTA} = 1.00 \times V \text{ mg of } \text{CaCO}_3 = x \text{ mg of } \text{CaCO}_3.$$

$$25 \text{ ml of hard water contains} = x \text{ mg of } \text{CaCO}_3$$

$$1000 \text{ ml of hard water contains} = \frac{x}{25} \times 1000 \text{ mg of } \text{CaCO}_3 = y \text{ mg/L}$$

Note. For determining permanent hardness of water, take 50 ml of water and boil it for about 15- 20 minutes. Temporary hardness will precipitate out. Filter and make up the volume of the filtrate to 50ml and titrate it, as described above. Calculate the permanent hardness in the similar way as total hardness is calculated. Subtract permanent hardness from total hardness to get temporary hardness.

RESULT The total hardness of water = y mg/L

PRECAUTIONS

Same as in experiment no. 1.12 in complexometric titrations, chapter-1.

Instructions for the Lab Assistant

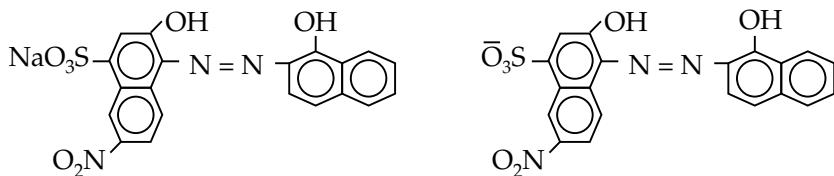
Provide the following

1. **0.1 M EDTA solution.** Dissolve 37.225 g of EDTA (Disodium salt) in distilled water and make up the volume to 1L.
2. **Indicator solution:** Dissolve 0.5g of the dye in 100 ml of methanol.
3. **Buffer solution:** Dissolve 70g of NH_4Cl in 570 ml of conc. NH_3 and dilute the solution to one litre with distilled water.

EXERCISE

1. Define hardness of water?
2. What do you mean by temporary and permanent hardness?
3. What is the principle of EDTA titration?
4. Why is it necessary to add buffer solution to the water sample in determination of hardness by EDTA method.
5. What is the structure of Eriochrome black T?

Ans.



(a) Black (unionized form)

(b) Wine red (ionized form
in aqueous medium)

*Eriochrome Black T (sodium 1-(1-hydroxy-2-naphthylazo)
6-nitro-2-naphthol-4-sulphonate)*

6. How would you find out permanent hardness of water?
7. What are the disadvantages of hard water.
8. If hard water sample does not contain Mg^{2+} , what will be the effect on the end point with EBT as indicator.

Ans. The colour change from wine red to blue is not sharp if only Ca^{2+} ions are present. Therefore, Mg^{2+} ions have to be present to produce a sharp end point. For this a small amount of MgCl_2 is added to the EDTA solution before it is standardized.

EXPERIMENT NO. 14

AIM To determine the molecular weight of a polymer (polystyrene) by using viscometric method.

THEORY When a very small amount of a polymer is added to a solvent of low viscosity, the viscosity of the resulting solution increases sharply. This increase in viscosity depends upon the molecular weight of the polymer, concentration, size and shape of the solute molecules.

* The relative viscosity (η_r) of the polymer solution will be given by

$$\eta_r = \frac{\eta_s}{\eta_0} \quad \dots(i)$$

where η_s is the coefficient of viscosity of the polymer solution.

η_0 is the coefficient of viscosity of pure solvent at the same temperature.

$$\text{Now } \frac{\eta_s}{\eta_0} = \frac{P_s t_s}{P_0 t_0} \quad \dots(ii)$$

where P_s and P_0 are the densities of polymer solution and the pure solvent, and t_s and t_0 are the corresponding time of flow of specified volume through the capillary in viscometer.

For a dilute solution, it can be assumed that $P_s = P_0$, hence equation (ii) becomes

$$\eta_r = \frac{t_s}{t_0} \quad \dots(iii)$$

Further, the specific viscosity (η_{sp}) of the polymer solution is obtained by:

$$\eta_{sp} = \frac{\eta_s - \eta_0}{\eta_0} \quad \dots(iv)$$

where $\eta_s - \eta_0$ is the increase in viscosity of the solvent due to the presence of a solute.

$$\text{or } \eta_{sp} = \frac{\eta_s}{\eta_0} - 1 \quad \dots(v)$$

$$= \eta_r - 1 = \frac{t_s}{t_0} - 1 \quad \dots(vi)$$

The ratio of specific viscosity of the solution to its concentration C (expressed in g/100ml) is known as *Viscosity Number* or *Reduced viscosity* η_{red} .

$$\eta_{red} = \frac{\eta_{sp}}{C} \quad \dots(\text{vii})$$

The plot of η_{red} versus concentration is a straight line (Fig. 14.1). It is given by the equation,

$$\eta_{red} = \frac{\eta_{sp}}{C} = mC + \text{constant} \quad \dots(\text{viii})$$

where m represents the slope of the line.

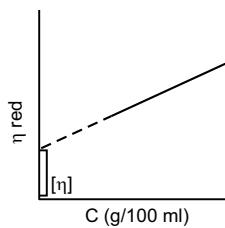


Fig. 14.1 Plot of η_{red} versus concentration.

The value of constant in equation (viii) is given by the intercept on the ordinate, which is obtained by extrapolating the graph to zero concentration or infinite dilution. This is termed as *limiting Viscosity* or *Intrinsic Viscosity* $[\eta]$. Actually, intrinsic viscosity is the limiting value of reduced viscosity

$$\text{Thus, } [\eta] = \lim_{C \rightarrow 0} \left(\frac{\eta_{sp}}{C} \right) = \lim_{C \rightarrow 0} \frac{\eta_s - \eta_0}{\eta_0 \times C} \quad \dots(\text{x})$$

For linear polymers, the intrinsic viscosity $[\eta]$ is related to the molecular weight of the polymer by *Mark-Kuhn-Houwink equation*:

$$[\eta] = KM^a \quad \dots(\text{x})$$

where M is the average molecular weight of the polymer; K and a are constants for a given polymer-solvent system.

Thus molecular weight of the polymer can be determined from viscometric measurements using equation (x). For most systems 'a' lies between 0.6 to 0.8.

APPARATUS Ostwald's viscometer, stop watch.

CHEMICALS Polystyrene, toluene or benzene.

PROCEDURE

1. Weigh accurately 0.5 g of polystyrene and transfer it in a 100 ml measuring flask.
2. Add about 90-95 ml of the solvent (benzene or toluene) and dissolve polystyrene by shaking it. Make up the volume to 100 ml to prepare 0.5% of the solution.
3. Similarly prepare the solutions of different concentrations (0.1%, 0.2%, 0.3% and 0.4%) by diluting the above solution.
4. Wash the Ostwald's viscometer with chromic acid, distilled water and dry in an oven. Pipette out 20 ml of the pure solvent (benzene or toluene) in the bulb B of the viscometer which is clamped vertically in a stand, placed in thermostat at 25°C or 30°C Fig. 14.2.

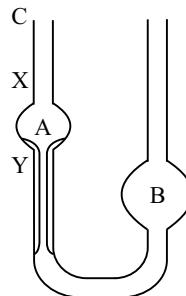


Fig. 14.2 Ostwald's Viscometer

5. Through a rubber tube attached to upper arm of bulb A, suck up the solvent until it rises above the mark X.
6. Allow the solvent to fall freely through a capillary upto the mark X. Start the stop watch and note the time t_1 for the flow of liquid from mark X to mark Y.
7. Repeat to get five readings and take the mean as the flow time t_0 .
8. Remove the solvent clean the viscometer and dry it.
9. Pipette out 20 ml of one of the solutions prepared above (say 0.5%) and determine the flow time as above. Repeat to get three readings and take their mean.
10. Similarly, determine the flow times for solutions of different concentrations after proper cleaning and drying of the viscometer after each set of readings.

OBSERVATIONS.

Temperature of the experiment =

Solvent used =

Value of the constant 'K' for styrene/solvent at the above temperature (from the Table 14.1) =

Value of constant 'a' (from the Table 14.1) =

Observation Table.

	Conc. of polymer solution	Flow time (Mean of three readings)	Relative viscosity $\eta_r = \frac{\eta_s}{\eta_0} = \frac{t_s}{t_0}$	specific viscosity $\eta_{sp} = \eta_r - 1$	Reduced viscosity $\eta_{red} = \eta_{sp}/C$
1.	Pure solvent	t_0			
2.					
3.					
4.					

CALCULATIONS

- Plot a graph between η_{red} and concentration and extrapolate the graph to zero concentration.
- Find out the value of intrinsic velocity $[\eta]$ from the graph.

$[\eta]$ = Intercept

- Now, we know, $[\eta] = KM^a$

Substitute the values of $[\eta]$, K, and a and calculate M, the molecular weight of the polymer.

Using logarithm,

$$\log [\eta] = \log K + a \log M$$

$$\log M = \frac{\log [\eta] - \log K}{a}$$

$$M = \text{Antilog } \frac{[\log [\eta] - \log K]}{a}$$

RESULT The molecular weight of the given polymer (polystyrene) is . . .

PRECAUTIONS

- All measurements should be made using a constant volume of the liquid
- Viscometer should be kept perfectly vertical.
- Mouth suction should not be done.
- There should not be any air bubbles in the viscometer.

Table 14.1 Values of constants 'K' and 'a'

Polymer	Solvent	Temperature	'K × 10 ⁴ '	'a'
Polystyrene	Benzene	25	1.02	0.74
		30	1.10	0.735
Polystyrene	Toluene	25	1.1	0.72
		30	1.1	0.725

EXERCISE

1. What is the significance of determination of molecular weight of a polymer?

Ans. Many of the important properties (mechanical strength, softening temperature, melt viscosity etc.) depend on the molecular weight.

2. How are the values of K and a in equation determined?

Ans. Log form of equation

$$\log [\eta] = \log K + a \log M$$

Thus, a plot of $\log [\eta]$ versus $\log M$ will be a straight line where.

$$\text{Slope} = a$$

$$\text{Intercept} = \log K$$

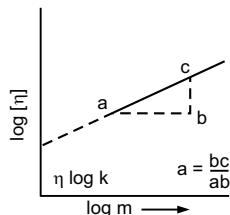


Fig. 14.3 Plot of $\log [\eta]$ versus $\log M$

Thus the values of constants K and a can be determined by working with samples of the polymer of known molecular weights in the same solvent.

3. What is intrinsic viscosity? How is it obtained?
4. Define relative viscosity, specific viscosity and reduced viscosity.

Note. For accurate measurement of viscosity another type of viscometer known as ubbelholder viscometer is employed Fig. 14.4. It is an improvement over Ostwald's viscometer. It is less affected by incorrect alignment. Moreover as the bottom of the capillary is above the level of the liquid so the pressure head is independent of the volume of the liquid present in the reservoir.

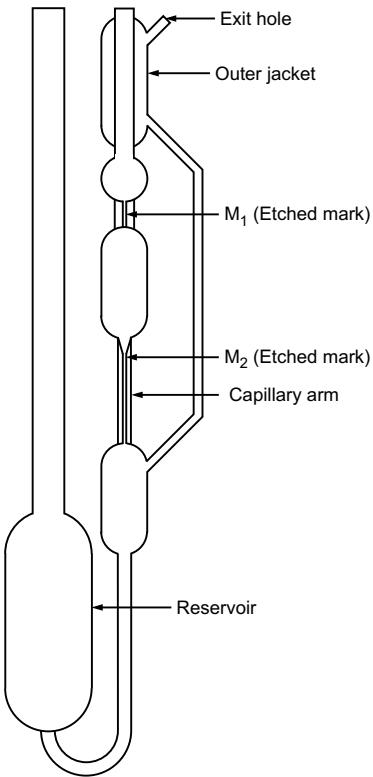


Fig. 14.4 Viscometer ubbelohde

EXPERIMENT NO. 15

ULTRAVIOLET AND VISIBLE SPECTROMETRY

Spectroscopy is the branch of science dealing with the study of interaction of electromagnetic radiation with matter. It is the most powerful tool available in the analysis of wide range of samples.

Spectroscopic methods of analysis are based on measurements of the electromagnetic radiation emitted or absorbed by the solutes. When an electromagnetic radiation is passed through a sample (solid, liquid or gas), certain characteristic wavelengths are absorbed by the sample. (The extent of absorption depends upon the wavelength of the radiation, thickness to the medium and also on the concentration of the sample). Thus there is a decrease in the intensity of transmitted radiation. By measuring the decrease in intensity of radiation we can qualitatively and quantitatively analyze a given substance. The technique is known as *photometry*.

A group of methods by which the *concentration* of substance is determined by measuring the interaction of electromagnetic radiation

with the sample is called *Photometric analytical methods*. The most common of these are:

- (1) Colorimetry (2) Spectrophotometry.

Colorimetry Colorimetry is concerned with the determination of concentration of a substance by measurement of the relative absorption of light with respect to a known concentration of a substance. The absorption employed is generally in the *visible region*. Any coloured substance can be analyzed by this method. In otherwords, the variation of the colour of a system with a change in concentration of a component, forms the basis of colorimetric analysis. The instrument used in this technique is called a colorimeter.

Spectrophotometry Spectrophotometry is a method of chemical analysis through measurements of radiations after these are allowed to pass through a sample. It deals with ultraviolet (185 – 400 nm) visible (400 – 760 nm) and infrared (0.76– 15 μm) region of spectrum. It employs a much narrower band of wavelengths as provided by a monochromator operating in UV, visible and infrared region. The instrument used in this method is called spectrophotometer.

The absorption of light by a substance is governed by certain laws. These are:

(i) Lambert's law. When a monochromatic radiation is passed through a solution, the decrease in intensity of radiation with the thickness of the solution is directly proportional to the intensity of the incident radiation. Let,

$$\text{Intensity of incident radiation} = I$$

\therefore Rate of decrease in intensity of incident radiation with thickness dx of the

$$\text{medium} = \frac{-dI}{dx}$$

$$\text{thus } \frac{-dI}{dx} \propto I \quad \dots(i)$$

$$\text{or } \frac{-dI}{dx} = kI \quad \dots(ii)$$

where k is the proportionality constant.

$$\text{Further } \frac{-dI}{I} = k dx \quad \dots(iii)$$

On integrating equation (iii) between limits $I = I_0$ at $x = 0$ and $I = I$ at $x = l$, we get

$$\ln \frac{I}{I_0} = -k l \quad \dots(iv)$$

$$2.303 \log \frac{I}{I_0} = -kl \quad \dots(v)$$

$$\log I/I_0 = \frac{-k}{2.303} l \quad \dots(vi)$$

$$\text{or } \log I_0/I = \frac{k}{2.303} l \quad \dots(vii)$$

where $\log I_0/I$ is called '**Absorbance**' and is represented as 'A'

and $\frac{k}{2.303} = E$ is '**Absorption coefficient**'

$$\therefore A = El \quad \dots(viii)$$

(2) Beer's Law. Beer's law takes into consideration the concentration of solution along with thickness of the solution. The law states that when a monochromatic light is passed through a solution, the decrease in intensity of radiation with the thickness of the solution is directly proportional to the incident light as well as concentration of the solution. Let a monochromatic light of intensity I pass through a solution of concentration C molar and thickness dx , then rate of decrease of intensity of radiation is given by,

$$\frac{-dI}{dx} \propto CI \quad \dots(ix)$$

$$\frac{-dI}{dx} = k'CI$$

$$\frac{dI}{I} = k'C dx \quad \dots(x)$$

On integrating the equation (x) between the limits

$I = I_0$ at $x = 0$ and $I = I$ at $x = l$ we get

$$\int_{I_0}^I \frac{dI}{I} = -k'C \int_0^l dx$$

$$\ln \frac{I}{I_0} = -k'C l$$

$$2.303 \log \frac{I}{I_0} = k'C l$$

$$\log I_0/I = \frac{k}{2.303} Cl$$

$$A = \epsilon Cl \quad \dots(xi)$$

Where C is the concentration of solute expressed in mole/litre, l = length of the cell containing the sample and ϵ is **molar extinction coefficient**.

$$\text{Also transmittance } T = \frac{I}{I_0},$$

$$\text{or } -\log T = \log \frac{I_0}{I} = A$$

thus, from equation (xi)

$$A = -\log T = \epsilon Cl \quad \dots(\text{xii})$$

From equation (xi) it is seen that the absorbance, which is also called optical density (OD), of a solution in a container of fixed path length is directly proportional to the concentration of a solution. A plot between absorbance and concentration is expected to be linear.

INSTRUMENTATION. Absorption measurements are carried out with various instruments such as colorimeter, spectrometer. All of these have the following features in common:-

1. Source of electromagnetic radiation. The incident light of required wave length is provided by using appropriate source. The source of visible radiation is *incandescent tungsten filament*, whereas the source of UV radiation is *hydrogen discharge lamp*.

2. Filter or Monochromator. In colorimeter filters are used whereas in spectrophotometers, filters are replaced by *monochromators. The filters or monochromators convert polychromatic radiation from source into narrow bands i.e these are used to eliminate the radiant energy of certain wavelengths and radiation in only selected region is allowed to pass. The monochromators are capable of isolating a much narrower band of wavelength.

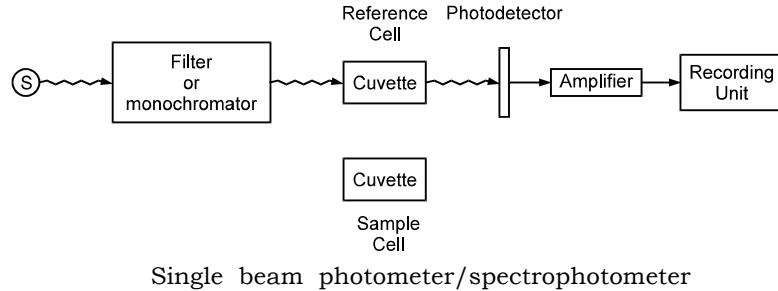
3. Sample Holder: The sample is placed in the sample container which are known as cuvettes or cells. For visible or Ultraviolet radiations, the cuvettes made of quartz are used.

4. Photodetectors: The main function of any detector is to absorb the energy of photons and convert it into measurable quantity such as electric current. Detectors generate an electrical signal, which activate meter or recorder. In UV-visible spectrophotometers photocells are used as detectors.

5. Amplification and Recording unit: The main function of amplifier is to amplify a signal so that it can be measured. It takes an input signal from circuit through electronic operations and produce an output signal which is several order of magnitude than input . The signal is recorded on a graph.

* Monochromator may be regarded as an assembly consisting of a dispersing element, such as prism, diffraction grating together with two narrow slits.

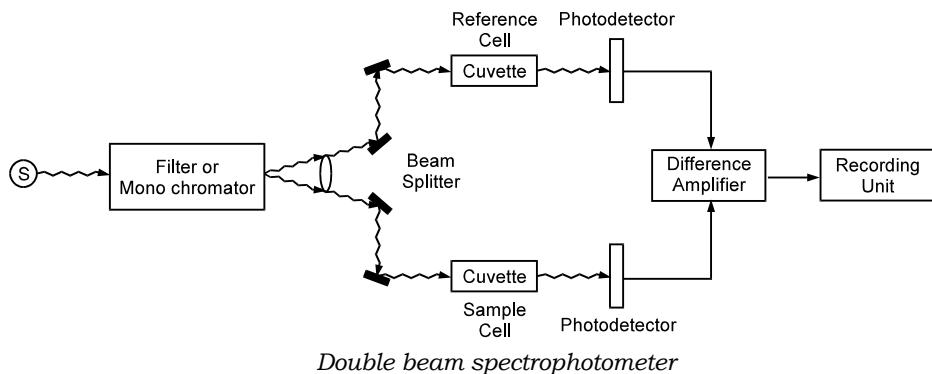
Most spectrophotometers record wavelength versus absorbance. A schematic diagram of the instrument design is given in figure.



Generally two types of spectrophotometers/photometers are used.

- (a) Single beam spectrophotometers
- (b) Double beam spectrophotometers.

Single beam is described above whereas in double-beam spectrophotometers, a beam of light is split into two identical beams known as sample beam and reference beam respectively. Sample beam passes through the sample and the reference beam is directed through an cuvette (Cell) which contains only the solvent. The function of a double beam operation is to measure the difference in intensities of the two beams at each wavelength. A schematic layout of double beam spectrophotometer is given in figure.



- AIM**
- (a) To determine λ_{\max} (wave length of maximum absorption) of solution of $KMnO_4$ using a spectrophotometer
 - (b) Verify Beer's law and apply it to find the concentration of the given unknown solution.

APPARATUS UV-visible spectrophotometer, beaker.

CHEMICALS Distilled water, standard solution of $KMnO_4$, tissue paper

THEORY When an electromagnetic radiation is passed through a sample, certain characteristic wavelengths are absorbed by the sample. As a result the intensity of the transmitted light is decreased. The measurement of the decrease in intensity of radiation is the basis of spectrophotometry. Thus the spectro-photometer compares the intensity of the transmitted light with that of incident light.

The absorption of light by a substance is governed by certain laws (discussed in detail in the preceding section page 323)

According to the Beer Lambert's law the intensity of the incident light is proportional to the length of thickness of the absorbing medium and the concentration of the solution,

$$\log \frac{I_0}{I} = A = \epsilon Cl \quad \dots(i)$$

where I_0 = Intensity of incident light
 I = Intensity of transmitted light
 A = Absorbance
 l = Thickness of the medium
 C = Concentration in mol L⁻¹
 ϵ = Molar absorption coefficient

The molar absorption coefficient is the absorbance of a solution having unit concentration ($C = 1$ M) placed in a cell of unit thickness ($l = 1$ cm). Absorbance is also called Optical Density (OD)

From equation (xii), it is seen that the absorbance (OD) of a solution in a container of fixed path length is directly proportional to the concentration of a solution. i.e.

$$A = \epsilon Cl$$

A plot between absorbance and concentration is expected to be linear. Such a straight line plot, passing through the origin, shows that Beer-Lambert's law is obeyed. This plot, known as calibration curve can also be employed in finding the concentration of a given solution.

Spectrophotometer. A spectrophotometer is a device which detects the percentage transmittance of light radiation when light of certain intensity and frequency range is passed through the sample. Thus the instrument compares the intensity of the transmitted light with that of the incident light

There are many spectrophotometers available for the visible range extending from 3800 – 7800 Å°.

PROCEDURE

Setting of the instrument

1. Spectrophotometer should initially read zero on transmittance scale (T). If it does not read zero, set it mechanically with adjusting knob.
2. Connect the instrument to the mains and put on the power switch.
3. Adjust the wavelength knob to the required wavelength region on scale (approximately)
4. Choose the position of wavelength switch correspondingly either to 340 – 400 nm or 400-960 nm.
5. Adjust the meter needle on zero on Transmittance scale and 100 on O.D scale

Working

6. Open the lid of the cell compartment and insert a cuvette containing the blank solvent (distilled water). Close the lid.
7. Adjust the needle to 100% transmittance or zero optical density
8. Remove the cuvette and close the lid tightly again. Empty the cuvette and rinse it with the standard solution of KMnO_4 (0.01 M). Fill it with standard solution.
9. Now place the cuvette containing the standard solution in the cell compartment. Note the O.D and Transmittance.

Determination of λ_{max}

10. Now change the wavelength by 20 nm and note absorbance (OD) and transmittance for each wavelength.
Imp. Transmittance through the pure solvent (blank) is always adjusted to 100% before each wavelength measurement. (For this repeat step 5 to 9). This is because the extinction coefficient of the blank also changes with the wavelength.
11. Plot a graph between wavelength on the x axis and Absorbance (OD) on the y axis

Verification of Beer's Law

12. Fix the wavelength at λ_{max} position.
13. Prepare KMnO_4 solutions with concentrations 0.2%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% etc. (20 ml each)
14. Note down the absorbance (OD) of series of solution of KMnO_4 prepared above by the method described above.
15. Plot a graph between O.D against concentration. (If a straight line is obtained Beer's law is verified)
16. Now find out the OD of the unknown solution of the KMnO_4 . Find out the concentration of this solution from the graph.

OBSERVATIONS

- (i) *Determination of λ_{max}*

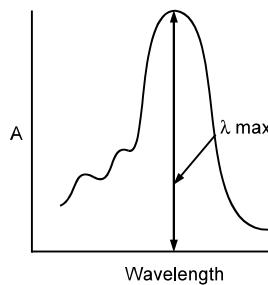
Wavelength (nm)	Absorbance (OD)

- (ii) *Verification of Beer's Law*

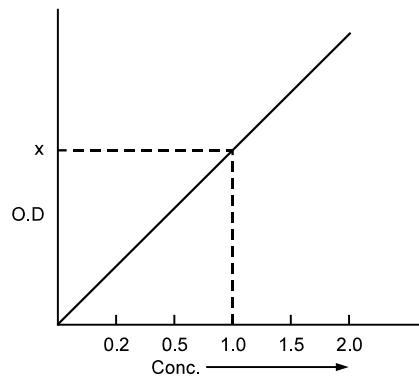
S.No.	Concentration (C) (moles/L)	Absorbance (OD)

Calculations.

- (i) A curve is plotted between wavelength and absorbance (OD)
From the graph, the maximum value of A gives λ_{max} .



- (ii) A curve is plotted between O.D and concentration and if a straight line is obtained as shown by equation (i), Beer's law is verified



(iii) From the graph of O.D Versus concentration, the concentration of the unknown solution can be found out. For example, in the Fig. 6.5 if x is the O.D of unknown solution then its concentration will be 1.0 %.

RESULTS

- (i) λ_{max} for $\text{KMnO}_4 = \dots \text{nm}$
- (ii) KMnO_4 solution obeys Beer's law
- (iii) Concentration of the unknown solution = ...mg/L

PRECAUTIONS.

1. Always use dilute solutions for getting calibration curve.
2. Cuvette should be cleaned properly and must be wiped with tissue paper.
3. Do not leave any finger marks on the cuvette.

AIM To determine the concentration of ferrous ions in a given sample spectrophotometrically by O-phenanthroline method.**APPARATUS** Spectrophotometer,

CHEMICALS Conc. HCl, Hydroxylamine hydrochloride (10%), Ammonium acetate buffer solution, Phenanthroline solution (0.25%), stock iron solution, standard iron solution, Sodium acetate solution.

THEORY Similar to experiment No. 11 for discussion on spectrophotometry in general.

Fe^{3+} ions in the sample are reduced to Fe^{2+} ions by boiling with HCl and hydroxyl amine hydrochloride. Fe^{2+} ions react with O-phenanthroline and give an orange red complex having the structure $[(\text{C}_{12}\text{H}_8\text{N}_2)_3 \text{Fe}]^{2+}$. The colour is stable for a long period at a pH ranging from 3-9. The intensity of the colour is independent of this pH range. Iron phenanthroline complex is then measured spectrophotometrically.

PROCEDURE

1. Prepare 1% stock solution of ferrous ions by weighing 0.3511g of Mohr's salt in 100 ml standard flask and add 5 ml of dilute H_2SO_4 .
2. Prepare 5 solutions of different known concentrations by diluting the above stock solution in 5 different flasks.
3. Transfer 1ml of solution from first flask in a 50 ml standard flask. Now add 5 ml each of 10% hydroxylamine solution, sodium acetate solution and O-phenanthroline solution. Dilute the solution to 50 ml

4. Repeat the same process with the solutions of other concentrations prepared above and also with the unknown sample.
Also prepare the blank solution by dissolving the specified amounts of each reagent except the standard iron solution.
5. Keep all these coloured solutions at rest for five minutes.
6. Note down the absorbance of these six solutions with spectrophotometer against blank solution, selecting λ_{max} at 515 nm. (as discussed in experiment 6.1)
7. Prepare a calibration curve by plotting absorbance against concentration.
8. From this, the concentration of the unknown solution corresponding to its absorbance can be found out.

OBSERVATIONS.

S.no.	Conc.	Absorbance
1		
2		
3		
4		
5		
6	Unknown	

RESULT The conc. of ferrous ions in a given sample solution is .. mg/l

Instruction to the lab assistant

Prepare the following

1. Ammonium acetate buffer (pH 5.0)- Dissolve 250g of ammonium acetate in 150 ml of distilled water and add 700 ml of glacial acetic acid.
2. Hydroxylamine hydrochloride - 100g of the compound is dissolved in 100 ml of distilled water and 2 drops of conc. HCl are added to it.
3. Phenanthroline solution : 100g of it is dissolved in 100 ml of distilled water.
4. Sodium acetate. Dissolve 2g of it in 1L of distilled water.

EXPERIMENT NO. 16

AIM Determination of nitrate ions in water using spectrophotometer.

APPARATUS UV- visible spectrophotometer.

CHEMICALS

Nitrate-free water: Use redistilled or distilled, deionized water of highest purity to prepare all solutions and dilutions.

Stock nitrate solution: Dry potassium nitrate (KNO_3) in an oven at 105°C for 24 h. Dissolve 0.7218 g in water and dilute to 1000 mL;

Intermediate nitrate solution: Dilute 100 mL stock nitrate solution to 1000 mL with water.

THEORY For general discussion or spectrophotometry refer to Experiment no. 15.

Measurement of UV absorption at 220 nm enables rapid determination of NO_3^- . Because dissolved organic matter also may absorb at 220 nm and NO_3^- does not absorb at 275 nm, a second measurement made at 275 nm may be used to correct the NO_3^- value.

PROCEDURE

Setting of the instrument

1. Spectrophotometer should initially read zero on transmittance scale (T). If it does not read zero, set it mechanically with adjusting knob.
2. Connect the instrument to the mains and put on the power switch.
3. Adjust the wavelength knob to the required wavelength region on scale (approximately)
4. Choose the position of wavelength switch correspondingly either to 200 –400 nm or 400-960 nm.
5. Adjust the meter needle on zero on Transmittance scale and 100 on O.D scale

Working

6. Open the lid of the cell compartment and insert a cuvette containing the blank solvent (distilled water). Close the lid.
7. Adjust the needle to 100% transmittance or zero optical density
8. Remove the cuvette and close the lid tightly again. Empty the cuvette and rinse it with the standard solution of KNO_3
9. Now place the cuvette containing the standard solution in the cell compartment. Note the O.D and Transmittance.
10. Now change the wavelength by 20 nm and note absorbance (OD) and transmittance for each wavelength.

Imp. Transmittance through the pure solvent (blank) is always adjusted to 100% before each wavelength measurement. (For this repeat step 5 to 9). This is because the extinction coefficient of the blank also changes with the wavelength.

11. Plot a graph between wavelength on the x axis and Absorbance (OD) on the y -axis
12. Fix the wavelength at 1 max position.
13. Prepare calibration standards in the range of 0 to 7 mg NO_3^- -N/L by diluting to 50 mL the following volumes of intermediate nitrate solution: 0, 1.00, 2.00, 4.00, 7.00... 35.0 mL. Treat NO_3^- standards in same manner as samples. (20 ml each)
14. Note down the absorbance (OD) of series of solution of KNO_3 prepared above by the method described above.
15. Plot a graph between O.D against concentration.
16. Now find out the OD of the unknown solution of the KNO_3 . Find out the concentration of this solution from the graph.

OBSERVATIONS.

S.no.	Conc.	Absorbance
1		
2		
3		
4		
5		
6	Unknown	

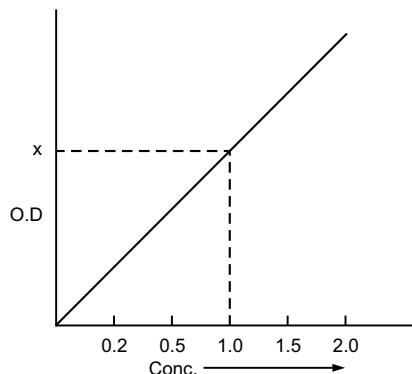


Fig. 16.1

From the graph of O.D Versus concentration, the concentration of the unknown solution can be found out.

RESULTS

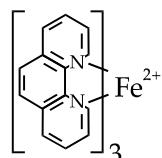
Concentration of the NO_3^- = ...mg/L

PRECAUTIONS

1. Always use dilute solutions for getting calibration curve.
2. Cuvette should be cleaned properly and must be wiped with tissue paper.
3. Do not leave any finger marks on the cuvette.

EXERCISE

1. What is spectrophotometry?
2. Discuss Lambert's and Beer's law of absorbance.
3. What is colorimetry?
4. What is absorbance, transmittance, extinction coefficient.
5. How you can verify Beer's law?
6. How you can find out the conc. of the given unknown solution spectrophotometrically?
7. What is monochromatic light ?
8. What is the significance of spectrophotometry.
9. What is the structure of orthophenanthroline complex with iron (II).

Ans.

This complex, which is sometimes called 'ferroin' is formulated as $(\text{phen})_3\text{Fe}^{2+}$.

EXPERIMENT NO. 17**AIM Determination of Calorific value of fuels using Bomb calorimeter.**

APPARATUS Determination of Calorific Value of Solid and Non volatile Liquid Fuels

CHEMICALS The calorific value of solids and non volatile liquid fuels is determined by **bomb calorimeter**.

THEORY A known amount of the fuel is burnt in excess of oxygen and the heat liberated is transferred to a known amount of water. The calorific value of the fuel is then determined by applying the principle of calorimetry i.e.

$$\text{Heat gained} = \text{Heat lost}$$

Construction: A simple sketch of bomb calorimeter is shown in Fig. 17.1. It consists of the following parts.

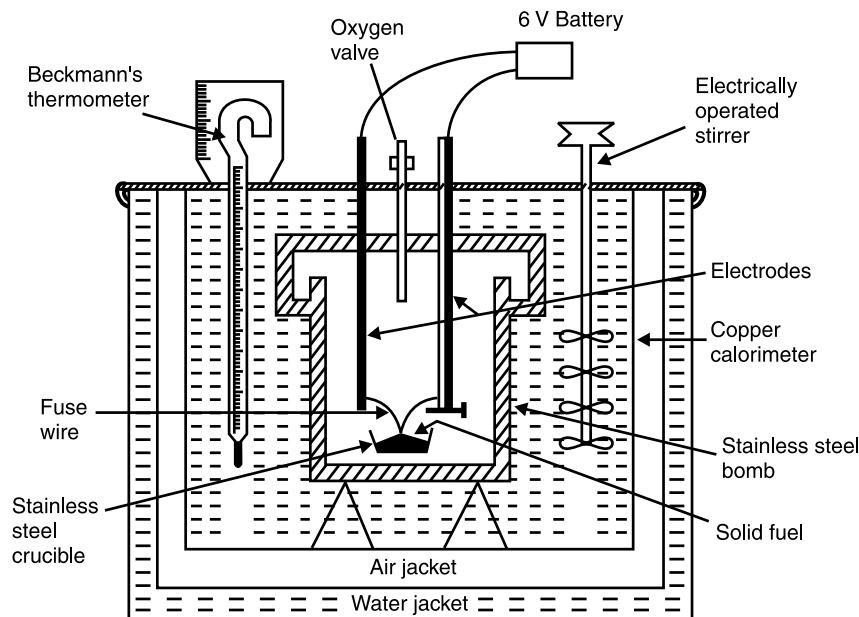


Fig. 17.1 Bomb calorimeter

- (i) *Steel bomb:* Steel bomb consists of a strong cylindrical container made up of stainless steel which is capable of withstanding pressure of atleast 50 atmospheres. The bomb is generally provided with a gas-tight screw cap or lid. The lid in turn is provided with two holes for electrodes and one oxygen inlet valve. A small ring is fitted to one of the electrodes which act as a support for silica crucible.
- (ii) The bomb is placed in a *copper calorimeter* containing a known amount of water. The calorimeter is provided with an electrical stirrer and a Beckmann thermometer.
- (iii) The copper calorimeter is surrounded by the *air jacket* and *water jacket* to prevent any loss of heat due to radiation.
- (iv) A *crucible* made up of nickel, or fused silica which contains the fuel. The crucible is placed inside the ring attached to one of the electrodes.

Working: A known amount of the given fuel (about .5 to 1g) is taken in the silica crucible supported over the ring. A piece of fine magnesium wire is tightly stretched across the electrodes, touching the fuel sample. The lid of the bomb is tightly screwed and bomb filled with oxygen at 25 atmospheric pressure. The bomb is placed inside the copper calorimeter which contains a known amount of water. After thorough stirring, initial temperature of water is noted with the help of Beckmann thermometer, which can read accurately, temperature difference upto 1/100th of a

degree. The electrodes are then connected to 6-volt battery and the circuit is completed. The fuel in the crucible burns with the evolution of heat. The heat produced by burning of a fuel is transferred to water, which is stirred throughout the experiment by the electric stirrer. Maximum temperature shown by thermometer is recorded. Time taken to cool the water in the calorimeter from maximum temperature to room temperature is also noted. The calorific value of the fuel is calculated as below:

Calculations

Let

$$\text{Weight of the fuel sample taken} = x \text{ g}$$

$$\text{Weight of water in the calorimeter} = W \text{ g}$$

$$^*\text{Water equivalent of the calorimeter, stirrer, bomb, thermometer} = w \text{ g}$$

$$\text{Initial temperature of water} = t_1 \text{ }^\circ\text{C}$$

$$\text{Final temperature of water} = t_2 \text{ }^\circ\text{C}$$

$$\text{Higher or gross calorific value} = C \text{ cal/g}$$

$$\begin{aligned}\text{Heat gained by water} &= W \times \Delta t \times \text{specific heat of water} \\ &= W(t_2 - t_1) \times 1 \text{ cal.}\end{aligned}$$

$$\text{Heat gained by Calorimeter} = w(t_2 - t_1) \text{ cal}$$

$$\text{Heat liberated by the fuel} = x C \text{ cal}$$

$$\text{Heat liberated by the fuel} = \text{Heat gained by water and calorimeter}$$

$$x C = (W + w)(t_2 - t_1) \text{ cal}$$

$$C = \frac{(W + w)(t_2 - t_1)}{x} \text{ cal/g}$$

* Water equivalent of a calorimeter is defined as the number of calories required to heat the calorimeter by 1°C . If M is the mass of the calorimeter and S be its specific heat, then

$$\text{Water equivalent } w = MS$$

If the calorimeter is made of different parts having different specific heats S_1, S_2, S_3 etc. and different masses, M_1, M_2, M_3 etc. then

$$\text{Water equivalent} = M_1S_1 + M_2S_2 + \dots$$

The water equivalent of the calorimeter is also determined by burning a fuel of known calorific value and using the equation.

$$\text{GCV} = \frac{(W + w)(t_2 - t_1)}{x};$$

The rise in temperature is determined. As all other values, except w are known in the above formula hence w can be easily calculated. The common fuels used for the purpose of determining water equivalent of the calorimeter are :

Substance	Calorific Value
Benzoic acid	6,325 kcal/kg
Naphthalene	9,688 kcal/kg
Camphor	9,292 kcal/kg

Net Calorific Value

Let percentage of hydrogen in the fuel = H

$$\text{Weight of water produced from 1 gm of the fuel} = \frac{9H}{100} \text{ gm}$$

(\because 1 gm of hydrogen produces 9 gm of H_2O)

Heat liberated during condensation of steam = $0.09H \times 587 \text{ cal}$

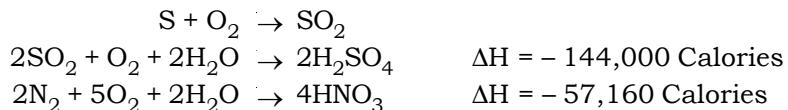
$$\begin{aligned} \text{Net (Lower) calorific value} &= \text{GCV} - \text{Latent heat of} \\ &\quad \text{water formed} \end{aligned}$$

$$= C - 0.09H \times 587 \text{ cal/g}$$

Corrections: For obtaining the accurate results the following corrections are also incorporated:

(a) Fuse wire correction: As Mg wire is used for ignition, the heat generated by burning of Mg wire is also included in the gross calorific value as measured above. Hence this amount of heat has to be subtracted from the total value.

(b) Acid Correction: During combustion, sulphur and nitrogen present in the fuel are oxidized to their corresponding acids under high pressure and temperature.



The above reactions are exothermic in nature but the heat liberated is not obtained in practical use of coal, because SO_2 and N_2 pass into the atmosphere. Thus corrections must be made for the heat liberated in the bomb by the formation of H_2SO_4 and HNO_3 . The amount of H_2SO_4 and HNO_3 is analyzed by washings of the calorimeter.

- For each ml of N/10 H_2SO_4 formed, 3.6 calories should be subtracted.
- H_2SO_4 can also be determined by precipitation as $BaSO_4$ using $BaCl_2$. The correction for 1mg of S formed is 2.25 calories.
- For each ml of N/10 HNO_3 formed, 1.43 calories must be subtracted.

(c) Cooling Correction: Heating and cooling are simultaneous processes. As the temperature rises above the room temperature, the loss of heat does occur due to radiation, and the highest temperature recorded will be slightly less than that obtained, if no loss of heat took place. A temperature correction (cooling correction) is therefore necessary to get the correct rise in temperature.

If the time taken for the water in the calorimeter to cool down from the maximum temperature attained, to the room temperature is x minutes and the rate of cooling is dt/minute , then the cooling correction = $x \times dt$. This should be added to the observed rise in temperature.

\therefore Gross Calorific Value,

$$C = \frac{(W + w)(t_2 - t_1 + \text{Cooling correction}) - [\text{Acid} + \text{fuse corrections}]}{\text{Mass of the fuel}}$$

EXPERIMENT NO. 18

AIM To determine moisture, volatile, fixed carbon and ash contents in a given coal sample by proximate analysis.

APPARATUS Electrical or Analytical balance, electric oven, dessiccator, silica crucible with lid, tong.

Materials. Given coal sample (powdered).

(i) **Moisture Content:**

Owing to its nature and origin, coal is always associated with moisture. When wet coal is exposed to atmosphere, the external moisture evaporates but the apparently dry coal still contains some moisture. This moisture is referred to as air dried moisture.

Significance.

- Excess of moisture is undesirable in coal.
- Moisture lowers the heating value of coal and takes away appreciable amount of the liberated heat in the form of latent heat of vapourisation. For every percent of moisture present .1% of heat is lost.
- Moisture also increases the transport costs.
- Excessive surface moisture may cause difficulty in handling the coal.
- Presence of excessive moisture quenches fire in the furnace.
- Hence lesser the moisture content, better is the quality of coal as a fuel. However presence of about 5-10% moisture is desirable as it produces a uniform fuel bed and less of "fly ash".

(ii) **Volatile Matter:**

The volatile matter in coal consists of a complex mixture of gaseous and liquid products resulting from the thermal decomposition of the coal. Volatile matter does not include moisture of coal. It consists mainly of combustible gases such as H_2 , CO , CH_4 and other hydrocarbons.

Significance.

- A high percent of volatile matter indicates that a large proportion of fuel is burnt as a gas or vapour or may escape unburnt.
- The high volatile matter content give long flames, high smoke and relatively low heating values.

- For efficient use of fuel, the outgoing combustible gases (volatile matter) have to be burnt by supplying secondary air. This requires a larger combustion space. A furnace with a small combustion volume or of short flame is not suitable for burning high volatile coals, since a large proportion of volatile matter will escape unburnt.
- The high volatile coals do not cake well whereas medium-volatile coals containing 20-30% of volatile matter are capable of forming hard and strong coke on carbonization.
- Coals containing less than 14% of volatile matter do not cake at all and are thus not suitable for manufacturing coke.
- However, high volatile matter content is desirable in coal gas manufacture because volatile matter in a coal denotes the proportion of the coal which will be converted into gas and tar products by heat.

(iii) **Ash.**

Coal contains inorganic mineral substances which are converted into ash by chemical reactions during the combustion of coal. Ash usually consists of silica, alumina, iron oxide and small quantities of lime, magnesia etc.

Ash can be classified as intrinsic ash and extrinsic ash. The mineral matter originally present in vegetable matter from which the coal was formed is called **intrinsic ash**. It consists of oxides of Na, K, Mg, Ca and Si. On the other hand the mineral matter, like clay, gypsum, dirt which gets mixed up during mining and handling of coal constitute the **extrinsic ash** which remains as a residue after the combustion. The extrinsic ash may consist of anhydrous CaSO_4 , CaCO_3 , Fe_2O_3 etc.

The minerals responsible for the formation of intrinsic ash cannot be removed by any mechanical means. Fortunately, this mineral matter content is low (about 2 to 3 percent) whereas the extrinsic ash content is relatively higher.

Significance.

- The high percentage of ash is undesirable.
- The ash does not contribute to the calorific value of coal. On the contrary it reduces the calorific value and creates many difficulties in efficient utilization of coal.
- In furnace grate, the ash may restrict the passage of air and lower the rate of combustion.
- High ash leads to large heat losses and cause problems of clinkering (forming of ash lumps).
- It has been estimated that one percent rise in coal ash is equivalent to 0.3 to 4 percent decrease in boiler efficiency.

- The composition of ash and fusion range also influences the efficiency of coal. Its composition is of considerable importance in metallurgical operations as it affects the slag and metal composition. When coal is used in boiler, the fusion temperature of ash is very significant. Generally fusion temperature lies in the range of 1000°-1700° C. Ash having fusion temperature below 1200°C is called *fusible ash* and above 1430°C is called *refractory ash*. If ash fuses at working temperature it leads to clinker formation. Apart from loss of efficiency of coal, clinker formation also leads to loss of fuel because some coal particles also get embedded in the clinkers. However, some ash is desirable since it protects the grate from direct contact with the incandescent coal, which might cause oxidation of the grate bars.

(iv) **Fixed Carbon.**

Fixed carbon content increases from low ranking coals such as lignite to high ranking coals such as anthracite. Higher the percentage of fixed carbon greater is its calorific value and better is the quality of coal. This represents the quantity of carbon that can be burnt by a primary current of air.

The percentage of fixed carbon is given by:

$$\text{Percentage of fixed carbon} = 100 - [\% \text{ of Moisture} + \text{Volatile matter} + \text{ash}]$$

From the above it appears that, what is left after the amount of moisture volatile matter and ash formed is subtracted, corresponds to the fixed carbon. However, the term fixed carbon is misnomer because it contains other non volatile elements also along with carbon.

Significance.

- Higher the percentage of fixed carbon, greater is the calorific value.
- The percentage of fixed carbon helps in designing the furnace and shape of the fire-box because it is the fixed carbon that burns in the solid state.

PROCEDURE

(I) Determination of Moisture (air dried):

1. Dry the coal (powdered) in air or in the moisture oven at 10 to 15°C above the room temperature.
2. Weigh silica crucible in an analytical or electrical balance accurately.
3. Transfer 1 g of air dried coal sample to the crucible and weigh it.
4. Keep the crucible in an electric oven maintained at 105 to 110°C for an hour.

5. Remove the crucible with a pair of tongs and keep it in a desiccator for cooling.
6. After it is cooled, weigh it. Note down the observations.

(II) Determination of volatile Matter

1. Take the dried sample of moisture free coal (obtained from step I) in a weighed and covered platinum crucible. The cover should have vent for escape of volatile matter.
2. Place the crucible in a muffle furnace maintained at $950 \pm 20^{\circ}\text{C}$ and heat it for exactly 7 minutes.
3. Remove the crucible with the help of tongs very carefully and bring down its temperature rapidly by placing it on cold iron plate.
4. Place the crucible in a desiccator so that it attains the room temperature.
5. Weigh it and note down the reading.

(III) Determination of Ash Content.

1. The residual coal (after the step II) is kept in a weighed silica or platinum crucible.
2. The crucible is heated in a muffle furnace maintained at $725 \pm 25^{\circ}\text{C}$ for nearly half an hour, without cover. Occasionally stir the residue with platinum wire.
3. The crucible is then cooled in a desiccator and weighed.

(IV) Determination of Fixed Carbon.

The fixed carbon is calculated as:

$$\% \text{ Fixed carbon} = [100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Volatile matter})]$$

OBSERVATIONS AND CALCULATIONS

1. Moisture

Weight of empty crucible = a g.

Weight of crucible + coal sample = b g.

Weight of crucible + coal sample after heating = c g.

$$\% \text{ Moisture} = \frac{b - c}{b - a} \times 100$$

2. Volatile Matter

Weight of empty crucible = a g

Weight of crucible + sample (moisture free) = c g

Weight of crucible after the removal of volatile matter = d g

$$\% \text{ Volatile matter} = \frac{c - d}{c - a} \times 100$$

(on oven dried basis)

$$\% \text{ Volatile Matter} = \frac{c - d}{c - a} \times 100$$

(on air dried basis)

3. Ash Content

Weight of empty crucible = a g

Weight of empty crucible + coal sample = b g.

Weight of empty crucible + ash = e g.

$$\% \text{ Ash} = \frac{e - a}{b - a} \times 100$$

4. Fixed Carbon

$100 - [\% \text{ Moisture} + \% \text{ Volatile matter} + \% \text{ Ash}]$.

RESULT The proximate analysis of the coal is as follows:

Moisture =%, Volatile matter =%, Ash =% and
fixed carbon =%.

PRECAUTIONS

1. After air drying the coal the moisture analysis should be done speedily so as to prevent moisture change.
2. In the determination of volatile matter, the temperature should be raised at a slow rate.
3. If black particles appear during the determination of ash content due to the presence of unburnt carbon, continue ignition for another 15 minutes.

EXERCISE

1. Why is proximate analysis so called?
2. What is the significance of determination of moisture content, volatile matter, ash content.
3. What is fixed carbon. How is it measured.

EXPERIMENT NO. 19

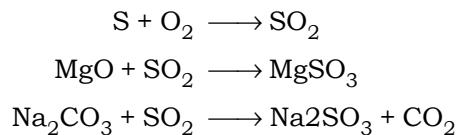
AIM Determination of sulphur content in a sample of coal

APPARATUS

REAGENTS REQUIRED Barium chloride solution (5%), Bromine solution (saturated), Conc. HCl, Dil. HCl, NaOH solution (5N), Methyl orange indicator solution, Silver nitrate solution, Eschka-Mixture

Eschka Mixture—Thoroughly mix 2 parts by weight of light calcined magnesium oxide (MgO) with 1 part of anhydrous sodium carbonate (Na_2CO_3). Both materials should be as free as possible from sulfur. Eschka mixture is also available commercially

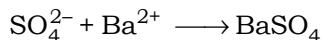
THEORY A known weight of powdered coal is fused with Eschka-mixture in presence of air. The sulphur in coal is oxidised to SO_2 which is absorbed by Eschka-mixture to produce the corresponding sulphites.



The sulphites are extracted with water and oxidised to sulphate using bromine water.



On adding barium chloride solution to the slightly acidified extract, the sulphate is precipitated as $BaSO_4$ which is filtered, washed, ignited and weighed.



From the weight of $BaSO_4$, the percentage of S in coal can be calculated as follows:

$$\%S = \frac{32}{233} \times \frac{\text{Weight of } BaSO_4}{\text{Weight of coal}} \times 100$$

PROCEDURE

1. Transfer about 1 g of accurately weighed coal powder (60 mesh) to a silica crucible.
2. Add about 3g of Eschka-mixture, mix thoroughly and cover with about 1g more of Eschka-mixture.
3. Heat the crucible, placed in a slanting position on a triangle, over a very low flame to avoid rapid expulsion of the volatile matter that

tends to prevent complete absorption of the products of combustion of the sulfur. Heat the crucible slowly for 30 min, gradually increase the temperature to $850 \pm 50^\circ\text{C}$ in about 1 hour, and occasionally stir until all black particles have disappeared, which is all indication of the completeness of the procedure.

4. Allow the crucible to cool to room temperature and remove the contents to a 200-ml beaker. Extract the residue completely using about 100 ml of hot distilled water and heat for about half an hour
5. Filter the residue under suction and with hot water.
6. Collect the filtrate and washings in a beaker, add 10-15 ml of saturated bromine solution and heat gently for a few minutes.
7. Acidify with concentrated HCl and boil off the liberated bromine.
8. Add two drops of methyl orange and just neutralise with NaOH solution.
9. Add 1 ml of dilute HCl and heat the solution to boiling.
10. Add 10-15 ml. of hot 5 per cent solution of barium chloride slowly from a pipet, while stirring constantly with a glass rod.
11. Cover the beaker with a clock glass, boil for 15 minutes and keep the solution hot, below its boiling temperature, by placing the beaker on a low temperature hot plate for 1 hour.
12. Filter through a Whatman filter paper No. 540/40. Transfer the precipitate to the filter paper and wash with small portions of hot distilled water until the washings are free from chloride (test with AgNO_3 for the presence of chloride).
13. Place the precipitate in a clean weighed silica crucible . Cover the crucible with loosely held filter paper so as to avoid spattering and place it in a slightly inclined position in a cold muffle furnace and gradually raise the temperature to dry and smoke off the paper. Then raise the temperature to above 900°C and ignite to constant weight. Cool in a desiccator and weigh.
14. Run a blank using the same amounts of reagents as in the regular determination.

Observations and Calculations

Let the weight of coal sample taken = W_g

Weight of BaSO_4 obtained from coal sample = A_g

Weight of BaSO_4 obtained in blank determiniantion = B_g

$$\%S \text{ in the sampel} = \frac{32}{233} \times \frac{(A - B)}{W} \times 100$$

RESULT The Sulphur content in coal ismg

EXPERIMENT NO. 20

AIM To determine the concentration of particulate matter in the ambient air using High Volume Sampler.

APPARATUS High Volume Sampler, Glass fibre filter (size : 203 × 254 mm)

THEORY Particles originate from numerous sources; both natural and industrial. Also, they are emitted as primary pollutants or formed in the atmosphere as secondary pollutants from precursor gases. Natural sources include wind-blown dust, sea-spray, volcanoes, and forest fires. Combustion of fossil fuels, whether in power stations or motor vehicle engines, is a major anthropogenic source of dust particles. This produces not only visible smoke, but also finer particles that result from atmospheric reactions of gases emitted by fossil fuel combustion. SO_2 and NO_x can react in the atmosphere to produce sulfate and nitrate containing particles. Many other activities also generate particulate pollution: smelting and processing of metals, cement manufacture, agricultural activities, quarrying, construction, etc. Particulates can vary considerably in size and chemical composition depending on their origin. They can extend in diameter from fine particles $< 0.1 \mu\text{m}$ to large particles $> 100 \mu\text{m}$. Generally, larger particles ($> 2 \mu\text{m}$) originate from natural sources such as wind-blown dust and sea-spary.

Table 20.1 Definition of terms relating to atmospheric aerosol

Term	Definition
Aerosol	Suspension of small particles or liquid droplets in a gas
Smoke	Ash, soot, and grit emitted from combustion processes
Haze	Suspension of small particles (less than a few microns in diameter causing reduction of visibility)
Mist	Suspension of droplets causing reduction of visibility (visibility $> 1 \text{ km}$)
Fog	Suspension of water droplets causing great reduction in visibility (visibility $< 1 \text{ km}$)

Both particle size and composition play an important role in determining the health effect of particulate matter. Particles $> 10 \mu\text{m}$ in diameter do not penetrate the respiratory system as they are removed in the nasal region. Particles $< 10 \mu\text{m}$ can be deposited in the respiratory system and are called *inhalable*. These particles can penetrate beyond the larynx into the tracheo-bronchial region. Particles $< 2.5 \mu\text{m}$ can penetrate into the pulmonary region consisting of bronchioles and alveoli, and they are called *respirable* or *fine* particles. Because of the potential health effects of the smaller particles, most air-quality monitoring stations

nowadays measure the inhalable fraction ($< 10 \mu\text{m}$), which is termed PM_{10} , using specially designed sampling devices. In the past most stations measured *total suspended particulates* (TSP), also called *suspended particulate matter* (SPM). Most air-quality standards are defined in terms of PM_{10} , and more recently $\text{PM}_{2.5}$. WHO no longer specifies guidelines for particulate matter and it considers it a no-threshold pollutant.

Particles can have harmful effects on their own or they may act synergistically to enhance the toxic effects of other pollutants. High levels of SO_2 and particulates can lead to increased mortality, morbidity, and aggravation of respiratory and cardiovascular disease. Sulfuric acid aerosols have the highest irritant potential. Atmospheric particles also contain many toxic metals (e.g. lead, cadmium, that can result in various illnesses, and carcinogenic compounds, such as PAH. An association has been found in major US cities between particulate matter and mortality and morbidity at levels of PM_{10} below the prescribed NAAQS. In addition, high concentrations of atmospheric aerosol during smog and haze episodes can significantly reduce visibility. This can lead to increased risk of traffic accidents, closure of airports, etc. An increase in the total particulate load in the atmosphere could affect the earth's radiation balance with consequent effects on weather and climate. Particles can also cause soiling of materials and increase corrosion rates. Toxic substances present in atmospheric dust are washed out and deposited at the earth's surface, and thus introduced into terrestrial and aquatic ecosystems. There they can have harmful effects on living organisms. Humans can be exposed to these compounds through the food chain and the water supply. Major constituents of airborne particles and their sources are given in Table 20.2.

Each of these compounds may contribute between 5 and 5% of the total mass of the particles, depending on the size. Various transition metals (e.g. Pb, Mn, Fe, Co, Cu, Zn, Ni, Sn, Cd) are also found in atmospheric particles. Generally, each of the trace metals contributes $< 1\%$ of the total particulate mass. Anthropogenic sources of trace metals include metal manufacturing industries, fossil fuel combustion, and incineration. Typical ranges of concentrations measured in air are given in Table 20.3.

Sampling and Analysis The most common method of sampling dust particles in the air is by means of filtration using High-volume samplers. Hi-Vol samplers suck air through a large filter paper ($203 \times 254 \text{ mm}$) at a flow rate ($1\text{--}2 \text{ m}^3 \text{ min}^{-1}$). This improves accuracy and allows for the analysis of many compounds in the dust. The sampler is mounted in a shelter of heavy gauge aluminium, so that the filter is parallel to the ground and the gabled roof protects the filter from direct precipitation. The filter is generally changed every 24 or 48 h, weighed, extracted, and analysed. Longer sampling periods can be used if required. The high volume (Hi-Vol) sampler is efficient for particles $< 100 \mu\text{m}$ and it is used to determine the concentration of TSP, also called SPM.

Table 13.2 Major constituents of atmospheric particles and their sources

<i>Component</i>	<i>Major source</i>
Carbonaceous material	Smoke emissions from combustion
Na^+ , K^+ , Ca^{2+} , Mg^{2+}	Sea salt, wind-blown dust
SO_4^{2-}	SO_2 emissions from coal combustion
NO_3^-	NO_x emissions from combustion
NH_4^+	NH_3 emissions from animal waste
Cl^-	Sea salt, HCl from coal combustion
Insoluble minerals	Wind-blown dust

Table 13.3 Typical concentrations of some trace metals in air

<i>Element</i>	<i>Concentrations range ($\mu\text{g m}^{-3}$)</i>	
	<i>Urban</i>	<i>Background/Rural</i>
Fe	0.1–10	0.04–2
Pb	0.1–10	0.02–2
Mn	0.01–0.5	0.001–0.1
Cu	0.05–1	0.001–0.1
Cd	0.0005–0.5	0.0001–0.1
Zn	0.02–2	0.003–0.1
V	0.02–0.2	0.001–0.05



High Volume Sampler

The High Volume Sampler is usually operated at ground level. In normal usage it is never operated more than 15 meters above ground level. In order to obtain a representative sample, the Sampler should not be positioned near a wall or other obstructions that would prevent free air flow. In excessively turbulent conditions or in the presence of strong surface winds or otherwise bad weather, the sampling rate is likely to decrease rapidly and perhaps in a non-linear fashion due to filter choking. If the sampler is operating in the vicinity of a source day-to-day variations in the measurement are expected due to varying meteorological conditions and changing atmospheric phenomena, like wind speed and direction, dispersal, diffusion, etc.

PROCEDURE Leave the glass fibre filter paper (203×254 mm) to equilibrate in dessicator for 24 h before and after sampling.. The relative humidity should be in the range of 20–45%. Weigh on an analytical balance sensitive to 0.1 mg. You may roll the filter paper loosely for weighing if necessary. Place the filter paper in the sampling assembly and sample for 24 or 48 h. Measure the flow rate of the Hi-Vol sampler according to the manufacturer's instructions at the start and at the end of the sampling period, and calculate the mean flow rate. The effective filtration area is 178×229 mm (you may have to measure this for your particular case). After sampling, the filter paper should be folded along the long axis with the exposed surface facing inward. Filter papers can be stored in envelopes. After determining the mass concentration filter papers can be stored for up to 1 year for chemical analysis.

From the difference in weight of the filter paper after and before sampling, the duration of sampling and the average flow rate, determine the concentration of TSP in the air:

$$\text{TSP } (\mu\text{g m}^{-3}) = \frac{[\text{Final weight (mg)} - \text{initial weight (mg)}] \times 1000}{\text{Flow rate } (\text{m}^3 \text{ min}^{-1}) \times \text{sampling period (min)}}$$

RESULT The total suspended particulate matter in the ambient air is _____ $\mu\text{g/m}^3$.

EXPERIMENT NO. 21

AIM Base catalyzed aldol condensation by Green Methodology.

Refer to dst.gov.in/green-chem.pdf (monograph of green chemistry laboratory experiments).

EXPERIMENT NO. 22

AIM Acetylation of primary amines using eco-friendly method.

Refer to dst.gov.in/green-chem.pdf (monograph of green chemistry laboratory experiments).

