SUBJECT: ENVIRONMENTAL SCIENCE
SUBJECT CODE: HU 401
STREAMS: IT. ME, CSE & CE
Credits: 2
Total Lectures: 24

Objective(s)

- Be able to understand the natural environment and its relationships with human activities.
- Be able to apply the fundamental knowledge of science and engineering to assess environmental and health risk.
- Be able to understand environmental laws and regulations to develop guidelines and procedures for health and safety issues.
- Be able to solve scientific problem-solving related to air, water, noise & land pollution.

Outcome(s)

- To understand the natural environment and its relationships with human activities.
- To apply the fundamental knowledge of science and engineering to assess environmental and health risk.
- To develop guidelines and procedures for health and safety issues obeying the environmental laws and regulations.
- Acquire skills for scientific problem-solving related to air, water, noise & land pollution.

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SYLLABUS

1.General

6L

1.1 Natural Resources: Forest Resource, water resource, mineral resource, energy resources: alternative source of energy

1.2 Population Growth: Exponential Growth, logistic growth, Maximum sustainable yield, demography

1.3 Disaster Management: Types of disasters (Natural & Man-made), Floods, Earthquake, Tsunamis, Cyclones, landslides (cause, effect & control)

1.4 Ecology & Ecosystem: Elements of ecology, definition of ecosystem- components types and function, Food chain & Food web,

Structure and function of the following ecosystem: Forest ecosystem, Grassland ecosystem, Desert ecosystem, Aquatic ecosystems

1.5 Environmental Management: Environmental impact assessment, Environmental laws and protection act of India(The Environment protection Act, Air pollution Act, Water Act, Wildlife Protection Act) , Hazardous waste(management and Handling) Rules.

2. Air pollution and control 7L

2.1 Sources of Pollutants: point sources, nonpoint sources and manmade sources primary & secondary pollutant

2.2 Types of air pollutants: primary & secondary pollutant ; Suspended particulate matter, oxides of carbon, oxides of nitrogen, oxides of sulphur, particulate, PAN, Smog (Photochemical smog and London smog),

2.3 Effects on human health & climate: Greenhouse effect, Global Warming, Acid rain, Ozone Layer Depletion

2.4 Air pollution and meteorology: Ambient Lapse Rate, Adiabatic Lapse Rate, Atmospheric stability & Temperature inversion

2.5 control of air pollution (ESP, cyclone separator, bag house, catalytic converter, scrubber (ventury),

3. Water Pollution 7L

3.1 Classification of water (Ground & surface water)

3.2 Pollutants of water, their origin and effects: Oxygen demanding wastes, pathogens, nutrients, Salts, heavy metals, pesticides, volatile organic compounds.

3.3 Surface water quality parameters: pH, DO, 5 day BOD test, BOD reaction rate constants, COD. Numerical related to BOD

Lake: Eutrophication [Definition, source and effect].

3.4 Ground water: Aquifers, hydraulic gradient, ground water flow (Definition only),ground water pollution (Arsenic & Fluoride; sources, effects, control)

3.5 Quality of Boiler fed water: DO, hardness, alkalinity, TDS and Chloride

3.7 Layout of waste water treatment plant (scheme only).

4. Land Pollution 2L

4.1 Types of Solid Waste: Municipal, industrial, commercial, agricultural, domestic, hazardous solid wastes (bio-medical), E-waste

4.2 Solid waste disposal method: Open dumping, Land filling, incineration, composting, recycling (Advantages and disadvantages).

4.3 Waste management: waste classification, waste segregation, treatment & disposal

5. Noise Pollution 2L

5.1 Definition of noise, effect of noise pollution on human health,

5.2 Average Noise level of some common noise sources

5.3 Definition of noise frequency, noise pressure, noise intensity, noise threshold limit value, equivalent noise level, L_{10} (18 hr Index) .

5.4 Noise pollution control.

References/Books

1. A Textbook of Environmental Studies, Shashi Chawla. Tata McGraw Hill Education Private Limited
2. Environmental Studies, Dr. J P Sharma, University Science Press
3. Environmental Engineering, J K Das Mohapatra, Vikas Publication

Lesson Plan for Environmental Science (HU 401)

Paper: Environmental Science
Code: HU 401
Contacts: 2L
Credits: 2
Total Lectures: 24

Module	**Course Content**	**Lecture Required**	**Books**
Module1	**Natural Resources**: Forest Resource, water resource, mineral resource, energy resources: alternative source of energy **(1L)** **Population Growth:** Exponential Growth, logistic growth, Maximum sustainable yield, demography **(1L)** **Disaster Management**: Types of disasters (Natural & Man-made), Floods, Earthquake, Tsunamis, Cyclones, landslides (cause, effect &control) **(1L)** **Ecology & Ecosystem:** Elements of ecology, definition of ecosystem- components types and function, Food chain & Food web, Structure and function of the following ecosystem: Forest ecosystem, Grassland ecosystem, Desert ecosystem, Aquatic ecosystems **(2L)** **Environmental Management**:	6L	**Text Book**: Basic Environmental Engineering and Elementary Biology G.K.Dasmohapatra Vikas Publications **Reference Books:** 1. A Textbook of Environmental Studies, Shashi Chawla. Tata McGraw Hill Education Private Limited 2. Environmental Studies, Dr. J P Sharma, University Science Press

	Environmental impact assessment, Environmental laws and protection act of India(The Environment protection Act, Air pollution Act, Water Act, Wildlife Protection Act), Hazardous waste(management and Handling) Rules. **(1L)**		
Module 2	**Sources of Pollutants**: point sources, nonpoint sources and manmade sources primary & secondary pollutant **(1L)** **Types of air pollutants:** primary & secondary pollutant ; Suspended particulate matter, oxides of carbon, oxides of nitrogen, oxides of sulphur, particulate, PAN, Smog (Photochemical smog and London smog), **(2L)** **Effects on human health & climate:** Greenhouse effect, Global Warming, Acid rain, Ozone Layer Depletion **(2L)** **Air pollution and meteorology:** Ambient Lapse Rate, Adiabatic Lapse Rate, Atmospheric stability & Temperature inversion **(1L)** **Control of air pollution** (ESP, cyclone separator, bag house, catalytic converter, scrubber	7 L	**Text Book**: Basic Environmental Engineering and Elementary Biology G.K.Dasmohapatra Vikas Publications **Reference Books:** 1. A Textbook of Environmental Studies, Shashi Chawla. Tata McGraw Hill Education Private Limited 2. Environmental Studies, Dr. J P Sharma, University Science Press

	(ventury). **(1L)**		
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Module 4	Types of Solid Waste: Municipal,	2L	**Text Book**: Basic Environmental Engineering

	industrial, commercial, agricultural, domestic, hazardous solid wastes (bio-medical), E-waste Solid waste disposal method: Open dumping, Land filling, **(1L)** incineration, composting, recycling (Advantages and disadvantages). Waste management: waste classification, waste segregation, treatment & disposal **(1L)**		and Elementary Biology G.K.Dasmohapatra Vikas Publications **Reference Books:** 1. A Textbook of Environmental Studies, Shashi Chawla. Tata McGraw Hill Education Private Limited 2. Environmental Studies, Dr. J P Sharma, University Science Press
Module 5	Definition of noise, effect of noise pollution on human health, Average Noise level of some common noise sources (1L) Definition of noise frequency, noise pressure, noise intensity, noise threshold limit value, equivalent noise level, L_{10} (18 hr Index) . Noise pollution control. (1L)	2L	**Text Book**: Basic Environmental Engineering and Elementary Biology G.K.Dasmohapatra Vikas Publications **Reference Books:** 1. A Textbook of Environmental Studies, Shashi Chawla. Tata McGraw Hill Education Private Limited

			2. Environmental Studies, Dr. J P Sharma, University Science Press

COURSE MATERIAL

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1.1 RESOURCE

Resource is a means, which may or may not be material. It has specific functions and can be utilized to meet the needs of individual and society as a whole, in a given space and time. Resources can be natural, like, air, water and soil, or they can be human resource like population, or cultural resource like knowledge. The generation of such important resources is hampered by various resistances such as, natural resistance like cyclone, flood, drought; human resistance like war, over or under population and cultural resistance like superstition and religious fundamentalism. Although natural resistance cannot be controlled, the other two can and should be prevented in order to safeguard existence.

Renewable Resources

These resources may be those having a life-cycle. These can be replaced from time to time, such as plants and animals, or those that do not have a life-cycle but can be recycled, for example water. Replaceable renewable resources, such as plants and animals, if not managed properly, may not become available with the same speed and become extinct soon. On the other hand, these inexhaustible resources that are hardly affected by man's activities are abundantly available and expected to be so for millions of years. Solar energy, wind energy, atomic energy etc., are examples of such kind.

The renewable resources are of two types:

1. **Conventional types,** such as water resources, plants, forests, crops, wild-life, aqua culture, etc.
2. **Non-conventional types,** such as solar energy, wind energy, biogas, atomic energy, etc.

The renewable resources are mainly Water resources and Energy resources.

Conventional Type Resources

Water

Water is essential for domestic use, for generation of electricity, irrigation, navigation and also for living organisms. Currently, a lot of underground water is being used mainly for agricultural purpose, creating enormous load on the eco-system. Sufficient care needs to be taken to manage age water efficiently. Water is a renewable resource as has a life-cycle, the hydrologic cycle, which should be properly maintained. However, due to large-scale deforestation the water cycle gets disturbed.

Forests as a Renewable Resource

Forests constitute 90 per cent of the global biomass. They are important as they regulate climatic conditions such as rainfall, humidity, temperature and protect soil from erosion. Forests provide timber, fruits, medicine (medicinal plants); protect public health by absorbing contaminants of the environment and provide suitable habitats for a number of plant as well as animal species. But due to improper management, vast stretches of forests are lost every year. To compensate the loss of forest cover due to its diversion, aforestation should be done so that the net area under the forest cover remains the same. Only then forests act as a renewable resource.

Energy

Although fossil fuels are non-renewable, they still form very slowly as compared to their consumption. Biomass although non-renewable can be made renewable by fuel-wood plantations. However, due to indiscriminate felling of trees, forests have depleted and fuel-wood has become scarce.

Non-conventional Type Resources

Solar Energy

The main source of energy for the biological world is solar energy. The readily available solar radiations, particularly in tropical countries, can be trapped and converted to electrical energy, using devices such as a photo-cell.

Wind Energy

Wind energy can be converted into electrical energy by developing suitable technology. The electrical energy or electricity can solve energy problems in small towns or villages to a large extent. e.g. windmills

Biogas

The huge amount of cattle dung can be utilized for biogas production, which can be used for cooking and to generate electricity.

Atomic Energy

Radioactive elements are utilized to generate energy in the atomic reactors. The nuclear reactors produce an enormous amount of heat that is used to produce steam, which in turn is used to run turbines to generate electricity. Atomic energy is a very important source of energy. One kilogram of natural uranium (U^{238}) generates energy equal to that generated by 35,000 kg of coal, which shows its tremendous potential.

Non-renewable Resources

These resources neither have a life-cycle nor can be recycled, for example, mineral deposits, soil, fossil fuels like coal and petrol once used cannot be regenerated and are exhaustible, as their deposits are limited. Some important non-renewable resources are:

Mineral Resources

Minerals are natural substances that occur as ores in the earth's crust. Minerals like iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and aluminium (Al) are used as building materials for manufacturing automobiles, ships, rail tracks, etc.; as nutrients for plants and as components of glass as well as ceramics. Minerals like coal and petroleum are used as energy resources and various industries depend on them on a large scale. Minerals like uranium and thorium are very important for generation of atomic energy.

Non-renewable Oceanic Resources

Below the sea-level, there are lots of minerals such as, cobalt (Co), nickel (Ni), copper (Cu), iron (Fe) etc., which exist in the form of sulfides and oxides of manganese (Mn203). These minerals as well as natural oil and gas deposits are now exploited to a great extent.

1.2 **Population Growth:** Exponential Growth, logistic growth, Maximum sustainable yield, demography

POPULATION GROWTH

In ecology, population is defined as a group of organism of a particular species, which breed among themselves or have the potential to do so and generally occupy a particular space. Population growth thus can be defined as ‘the change in strength of population per unit area at a particular time’.

The strength obviously, varies from time to time as individuals are born, they die or migrate from one place to another. The rate of increase of population depends upon the birth rate, death rate, immigration or emigration and all these factors in one way or the other are related to the ecological conditions.

Prediction or forecasting about future population is very essential in order to assess the use and demand of the resources by the growing population and also to develop strategies on how to meet this demand. For developing strategies, the focus should be on the growing demand of modern life facility to reserve the remaining amount of fossil fuels to its fullest extent, to control rapid deforestation along with the logical assessment of future population growth and only then a clear picture can be obtained and proper measures can be taken. This is vital for maintaining the economic growth rate, innovating proper scientific methods and engineering construction so as to avail alternate energy sources without polluting the environment.

The simple but powerful mathematical tools thus developed are either exponential or logistic in function and can throw light on several environmental problems.

On the basis of mathematical functions, the population growth rates can be classified as:

1. **Exponential growth**
2. **Logistic growth**

Exponential Growth

In the case of exponential growth, the rate of exchange of population is directly proportional to the size of population at that time. If in a specified time ‘t’, the population size is ‘Nt’, then population growth or rate of exchange of population can be expressed mathematically as:

$$\frac{dN_t}{dt} \propto N_t \text{or} \frac{dN_t}{dt} = RN_t$$

$$\text{If rewritten,} \qquad \frac{dN_t}{dt} = RN_t$$

Integrating the above equation, $\int \frac{dN_t}{dt} = \int RN_t$

$$\text{or } \ln N_t = Rt + Z$$

In the beginning, i.e., when t=0, the initial size of population is 'N0'.

Thus by substitution, $\ln N_0 = R \times 0$ or $Z = \ln N_0$
now putting $Z = \ln N_0$
the equation becomes, $\ln N_t = Rt + \ln N_0$ or $\ln N_t - \ln N_0 = Rt$ or $\ln \frac{N_t}{N_0} = Rt$
or $N_t = N_0 e^{Rt}$

Doubling Time of population

The time required for population to become double of its initial number (Nt) under consideration, so that it grows exponentially and the growth rate remains throughout, is called 'Doubling time' (td).

We know that, $N_t = N_0 e^{Rt}$
For double the population, it will be given by,

$$2N_0 = N_0 e^{Rt_d}$$

or $e^{Rt_d} = 2$ or $\ln e^{Rt_d} = \ln 2$

$$\text{or} t_d = \frac{\ln 2}{R} = \frac{0.693}{R}$$

now, if the growth rate R is expected as a percentage instead of a fraction, then, $t_d = \frac{69.3}{R\ (\%)} \cong \frac{70}{R\ (\%)}$
Thus, the length of time required to double a quantity growing at R percent is approximately equal to 70 divided by R percent.

Now plotting Nt vs t, the graph can be as shown in Fig. 1.

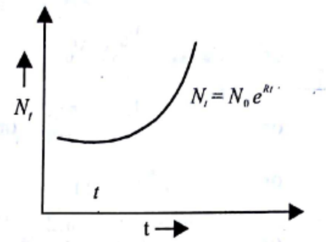


Fig.1 Exponential growth rate curve

The above equation and the graphical form are representative of smooth and continuous growth.
In case of non-continuous growth rate, i.e., when the growth rate remains constant for a certain period of time, the generalised mathematical expression is as follows:

$$N_t = N_0(1 + R)^t$$

Where, N0 = initial size of population
Nt= size of population after time t
R = growth rate per year

Half Life Time of Population

Now the exponential growth rate equation is $N_t = N_0 e^{Rt}$.

The time required for the population to become half of its present value when it decays exponentially and the decay rate remains constant throughout is called 'half-life' (t1/2).

In case of decay, the rate constant of growth and rate constant of decay may not be same, so the exponential decay will be, $N_t = N_0 e^{-R_1 t}$
(- sign indicates decay and R1 represent the decay rate constant)

For time t to be t1/2

$$N_t = \frac{N_0}{2}$$

or $\frac{N_0}{2} = N_0 e^{-R_1 t_{1/2}}$ or $e^{R_1 t_{1/2}} = \ln 2$
or $t_{1/2} = \frac{\ln 2}{R_1} = \frac{0.693}{R_1} = \frac{69.3}{R_1(\%)} \cong \frac{70}{R_1(\%)}$
under conditions of similar growth and decay rate (R = R1) the 'doubling time' and 'half life time' become equal.

Validity of Exponential Growth Rate

The equation for doubling time is, $t_d = \frac{70}{R\,(\%)}$
Now if we consider the growth rate to be 2 percent, then if the population was 3 billion in 2000, it will become 6 billion by 2035 and if the growth rate remains stable at 2 per cent, then in doubling times, i.e., in 140 years (by 2140) the population will become 48 billion. In 20 doubling times it will be in the order of quadrillion or more than one person per square foot of surface area on the earth. Such a large figure simply points out the limitations of mathematical formulation of exponential growth. Logically too, the growth of population must depend on the availability of

natural resources. With finite (limited) natural resources, a species cannot support any population beyond a certain limit. There always exists an upper limit to the number of individuals that an environment can support and is called the ‘carrying capacity’ of environment.

If exponential growth is assumed, what seems to be an abundant resource may actually be consumed very quickly thus making the fossil fuels and minerals extracted from the earth's crust to vanish rapidly. Considering the limitations of exponential growth ideas and related mathematical formulations, the population projections are mathematically modelled with a logistic or S-shaped (sigmoidal) growth curve.

Logistic growth of population

Logistic Growth of Population explained by Logistic Curve or Sigmoidal curve shown in Fig. 2.

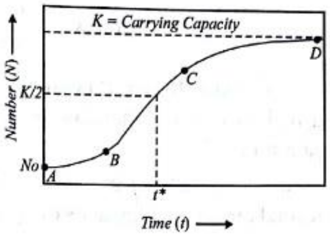


Fig. 2 Logistic Growth Curve

The logistic curve is derived from the following differential equation as proposed by Verhulst, a distinguished French mathematician,

$$\frac{\mathrm{dN}}{\mathrm{dt}} = \mathrm{rN}\left(1 - \frac{\mathrm{N}}{\mathrm{K}}\right)$$

where, N is the population size, K is called the carrying capacity of the environment and r is the logistic growth rate.

The sigmoidal growth curve can be separated into three segments, i.e., A-B, B-C and C-D.

A-B: in this part, the population size N is much less than the environmental carrying capacity K and under such circumstances,

$\frac{\mathrm{N}}{\mathrm{K}} \cong 0$ and $\frac{\mathrm{dN}}{\mathrm{dt}} = \mathrm{rN}$ or $\frac{\mathrm{dN}}{\mathrm{dt}} \infty \mathrm{N}$.

Thus, in this region population grows exponentially and this is because the population is far below the environmental carrying capacity. Therefore, the environment is highly suitable for its growth.

B-C: in this part, the population increment is relatively rapid as compared to the first part. This phase is called the logarithmic phase. In this region, N is not much less than K and the population growth is steady, i.e., $\frac{\mathrm{dN}}{\mathrm{dt}} = \mathrm{Constant}$.

C-D: in this part, the population growth decreases as Nclose toK, i.e., (N-K) becomes smaller and smaller. When population size (N) becomes equivalent to the environmental carrying capacity (K), i.e., N = K, $\frac{\mathrm{dN}}{\mathrm{dt}} = 0$

The growth rate of population (r) becomes zero (zero population growth or ZPG). Population at point (D) is called the 'population at saturation value'.

An eco-system has limited resources. Therefore, if population grows beyond the carrying capacity of the eco-system, the resource limit shows an adverse effect on population by increasing death rates or reducing birth rates. Such resistance as offered by the environment is called 'environmental resistance' or 'growth realization factor'. This factor (1 – N/K) is called environmental resistance. Thus, if N becomes greater than K; (1 – N/K) becomes negative, and hence,

$$\frac{\mathrm{dN}}{\mathrm{dt}} = -\mathrm{ve}$$

The factor $\left(1-\frac{N}{K}\right)$is responsible for changing the 'exponential growth curve' into 'logistic growth curve'.

Logistic Growth Rate Constant (r)

We know, $\frac{dN}{dt} = rN\left(1-\frac{N}{K}\right)$……………….(1)
where, r is the logistic growth rate constant, N is the population size and K is the environmental carrying capacity.

Rearranging and integrating of equation (1) we get,

$$r = \frac{1}{t^*}\ln\left[\frac{K}{N_0} - 1\right]$$

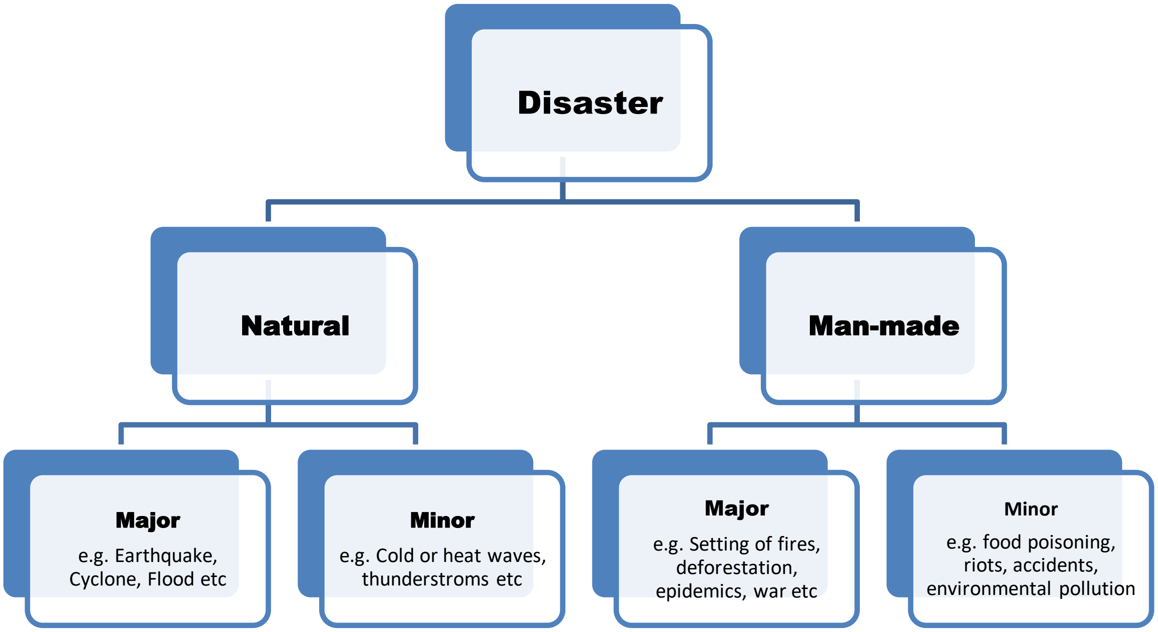
where, r is the logistic growth rate constant, N0 is the population size at time t = 0, t* is time when population is equal to half of the environmental carrying capacity (K) and K is the environmental carrying capacity.

1.3 Disaster Management: Types of disasters (Natural & Man-made), Floods, Earthquake, Tsunamis, Cyclones, landslides (cause, effect & control)

Disaster Management

Disaster can be defined as a man made or natural event (like floods, earthquake, cyclone or landslides) which results in great damage or loss of life.
A disaster is a consequence of inappropriately managed risk. The risk is the product of hazard and vulnerability.
Disaster = Risk – Capacity
Or Disaster = [Hazard × Vulnerability] – [Capacity]
Hazard is a situation which poses a level of threat to life, health, property or a dangerous condition or event that may deleteriously affect society or an environment.
Vulnerability is the extent to which damage will likely to happen by the impact of a particular hazard.

Capacity means resources and strengths which exist in households and communities enable them to cope with, withstand, prepare for, prevent or quickly recover from a disaster.



FLOOD

Flood is an overflowing of water onto land that is normally dry. As a result the land is filled with excess of water.

Causes : Floods are caused by rains, high winds, cyclones, tsunami, melting snow or dam burst. Flood can happen gradually or can happen suddenly due to heavy rains, breach of the water storage and control structures, spillover. Siltation of the rivers and reservoirs, and this can enhance the incidence and magnitude of floods.

The main steps for flood disaster management are briefly discussed below:

(1) Flood Forecasting
(2) Reduction of Runoff
(3) Reducing Flood Peaks by Volume Reduction (Constructing Dams and Detention Basins)
(4) Reducing Flood Levels
(5) Protection against Inundation (Construction of Embankments)
(6) Flood Plain Zoning (FPZ) & preparation of flood disaster management maps (FDMM)

Guidelines for preparing Flood Disaster Management Map

1. Investigate historical flood damage records, seek scientific advice and guidance as scientists can do numerical simulation of possible floods.
2. Estimate inundation prediction area
3. Display inundation prediction area as a hazard risk area in the flood hazard map(MAP)
4. Add disaster mitigation information such as
    a) Basic knowledge of flood

b) Disaster prevention facilities
c) Evacuation tips
d) Evacuation sites and routes

By adding the above information in FHM, flood disaster management maps (FDMM) are constructed.
Information on the map is presented in a comprehensive but easy-to-understand manner. The following information could be included in an FDMM:

a) Telephone number of authorities related to disaster management(police, hospital, fire department, etc)
b) Disaster prevention centers
c) Land use
d) Power , gas and water supply facilities, and sewerage facilities
e) Elementary schools
f) Others

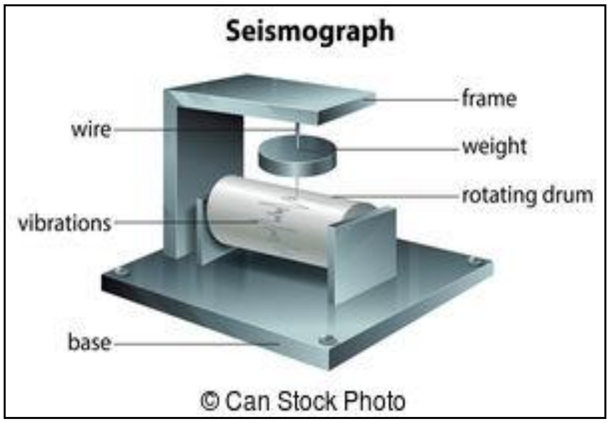
5. The flood disaster management map must be prepared in the workshops together with local residents schools and scientific representatives:
   a. To reflect local information
   b. To promote the understanding of inundation areas and evacuation sites
   c. To facilitate well prepared persons for flood rescue teams
   d. To Establish the importance of the map within the community from childhood
   e. To provide a chance for family members to talk about disaster prevention and mitigation
   f. To promote more precise flood disaster management maps in flood prone villages.

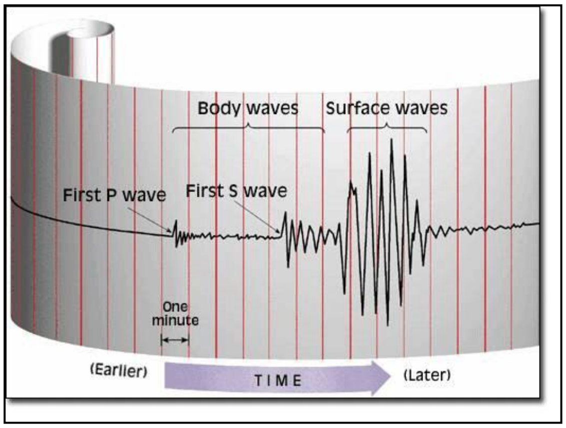
Earthquakes : Earthquakes refer to the vibration of the earth’s surface.

There is continuous activity going on below the surface of the earth. There are several large plates (size of continents) below the surface of the earth, which move (at a very slow speed). As a part of this movement, sometimes, they collide against each other. And, after the collision, they might still continue to push each other. As they continually keep pushing each other, there is a pressure building up – across these plates below the surface. And, then, at a certain time, one of the plates might slide over another. This causes an earthquake.

Some earthquakes might be caused by activity above the surface. For example in a mountainous region, there might be a heavy landslide. Due to a huge mass of land falling, at the point of the fall, there could be a minor shaking of earth, due the impact of fall. However, usually, such earthquakes are not very major.

The intensity of an earthquake is related to the amount of energy released when rocks give way to the forces within the earth. It is measured with the help of an instrument known as Seismograph.





Tsunamis: The seismic waves caused by earthquakes travelling through sea water, generates high sea waves called tsunamis. These giant sea swells can move at a speed upto 1000Km/hr or even faster. While approacjing the sea shore they may often reach 15m or sometimes 65m in height and cause massive devastation in coastal areas.

Earthquake Control

At present, earthquake prediction is insufficiently precise to provide the public with sufficient advance warning. For this reason, adequate preparedness and assistance in catastrophes is extremely important in areas affected by earthquakes. Measures of this nature enable numbers of human lives to be saved.

Technical measures

- Earthquake-proof planning and design of buildings
- The microzoning of the local geological substratum provides indicators of areas in which tremors will have a particularly strong or attenuated effect.

Personal measures

- Seek shelter under stable tables or under door frames.
- If outside, stay away from buildings, bridges and electricity pylons and move to open areas.
- Avoid areas at risk from secondary processes, such as landslides, rockfall and soil liquefaction.
- After an earthquake, check gas, water and electricity pipes and lines for damage.
- Listen to the radio and follow the instructions issued by the authorities.

Landslide

Landslides and rockfalls are mass movements. Mass movements are processes in which the solid material (stone or loose rock) is set in downward motion mainly by gravity, and without the assistance of a transport medium (e.g. snow, water, wind).

Mass movements can occur suddenly (e.g. rockfall) or as slow and continuous processes (e.g. deep creep and continuous sliding motion). The origination, progress and effects of mass movements are extremely varied.

A precondition of mass movement is the instability of slopes or parts of these. In the case of landslides, descending packets of varying area (several m2 to several km2) and thickness (several dm to several 100m) are involved.

Technical /Planning measures

- Drainage and/or grading of slope profiles increase the shear resistance
- Supporting structures such as anchors and piles (pinning of the slip plane) can restrain landslides
- Protective forest
- The use of slopes prone to landslides must be avoided, or uses suitably modified
- Hydraulic and electrical connections must be flexible.

Personal measures

- Reinforcement of floor slabs and external walls in existing buildings.
- Installation of drainage pipes for rainwater, slope drainage.
- Planting of slopes that are vulnerable to landslides with deep-rooted trees and shrubs.

Cyclones

Cyclones are caused by atmospheric disturbances around a low-pressure area distinguished by swift and often destructive air circulation. Cyclones are usually accompanied by violent storms and bad weather. The air circulates inward in an anticlockwise direction in the Northern hemisphere and clockwise in the Southern hemisphere. Cyclones are classified as: (i) extra tropical cyclones (also called temperate cyclones); and (ii) tropical cyclones. The word Cyclone is derived from the Greek word Cyclones meaning the coils of a snake. It was coined by Henry Peddington because the tropical storms in the Bay of Bengal and the Arabian Sea appear like coiled serpents of the sea.

Classifications

Cyclones are classified as extra tropical cyclones (also called temperate cyclones); and tropical cyclones.

Control or protection measures and main mitigation strategies are

1. On the coasts of India, 10 cyclone detection radars are installed by India Metrological Department (IMD).
2. A geo-stationary satellite (INSAT-IB) also monitors cyclone movements.
3. A special Disaster Warning System (DWS) provides a cyclone alert (48 hour in advance) and a cyclone warning (24 hours in advance). Such early warnings help in controlling the damages of cyclones.
4. Symmetrical designs of buildings, no empty pockets, hip or pyramidal roofs, no loose ACC sheets or tin sheets, reinforced cemented foundations, less wide doors and windows etc., are engineered structures better in withstanding impacts of powerful winds and heavy rains of cyclones.
5. Strong rooted trees with needlelike leaves can be planted in the directions facing the wind along coastline. These shelterbelt plantations lessen the impact of strong cyclonic winds and thus stop soil erosion. As a result houses cultivable fields etc are protected.

Immediate steps to be taken after the hit of cyclone:

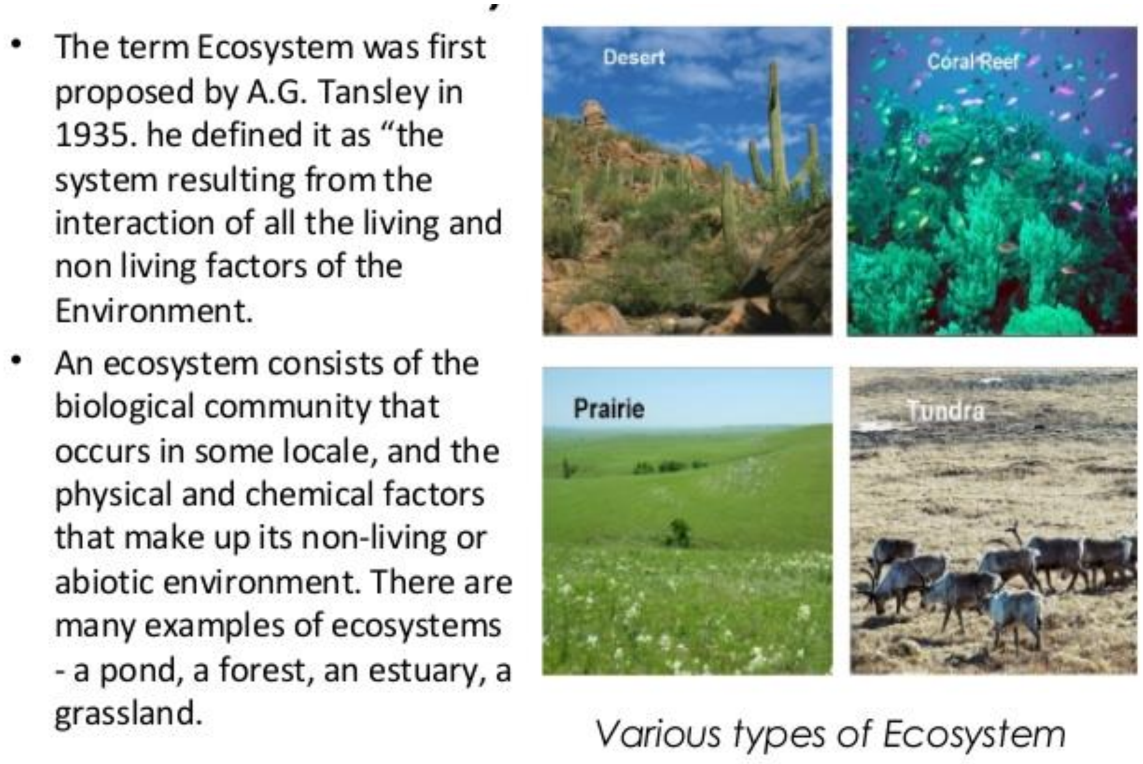
- Make sufficient stock of foodgrains, kerosene lanterns and other dry food commodities available for distribution to the victims.
- A large number of people are likely to become homeless as their houses may wash away or get destroyed Hence make arrangements for proper shelter material such as Talpatris, Tents, Water, Blankets, Utensils, etc
- Medical and Veterinary Departments should be fully equipped with required Drugs and Vaccines for taking preventive steps after cyclone and to arrest the spread of epidemics.
- All the Government vehicles should be kept in road-worthy condition for putting them to use in the emergency.
- Power failure is likely to occur in affected areas hence a list of generators available should be maintained by the Officials of State Electricity Board and advance action taken immediately to procure them when necessity arises. Electricity Board should clear the roads of fallen electric poles and restore power supply as quickly as possible.
- Communications facilities are likely to get disrupted; (both land and telecommunications) hence make immediate arrangements for satellite phones, mobile phones, etc.

1.4 Ecology & Ecosystem

Ecosystem :

An ecosystem is the combination of an area's abiotic and biotic factors. It can be visualised as a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.

- ❖ Abiotic Features: air , water, rainfall, temperature, soil , rocks, humidity.
- ❖ Biotic Features: Anything living.



- The term Ecosystem was first proposed by A.G. Tansley in 1935. he defined it as "the system resulting from the interaction of all the living and non living factors of the Environment.
- An ecosystem consists of the biological community that occurs in some locale, and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems - a pond, a forest, an estuary, a grassland.

Various types of Ecosystem

These are categorised as under:

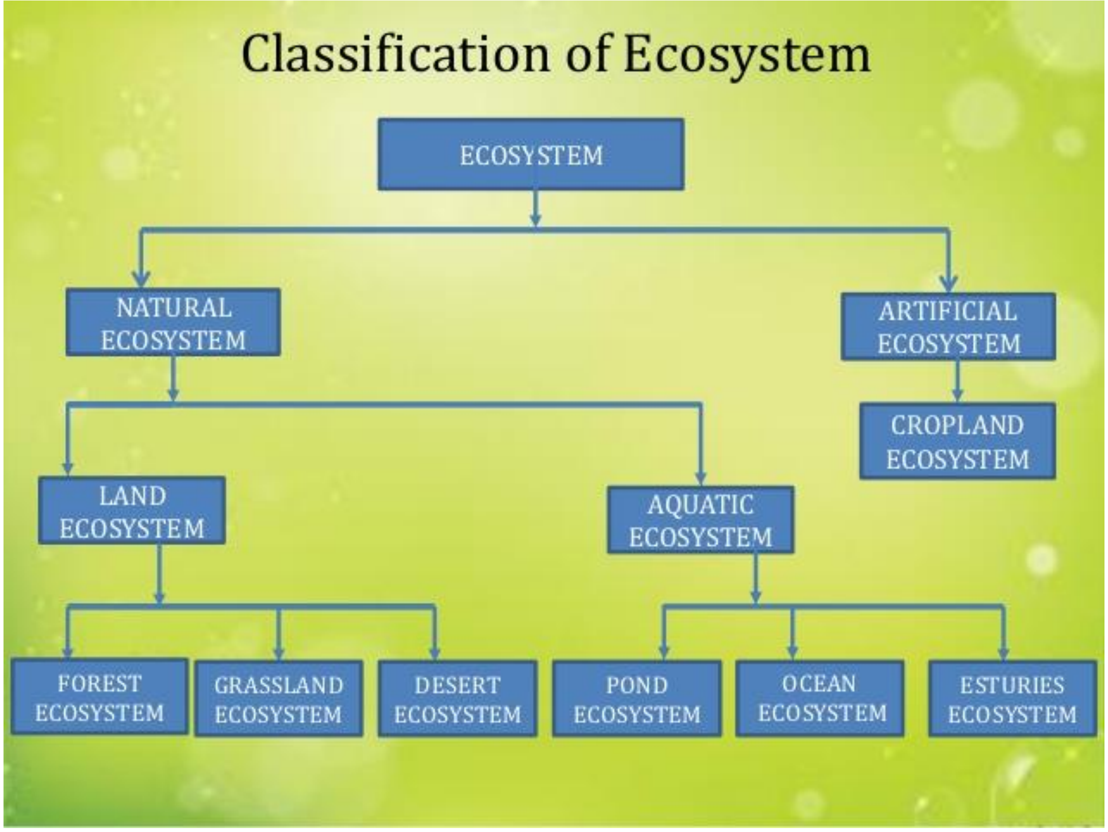
1. Natural Ecosystems: These operate under natural conditions without any major interference by man. These are further divided into

i. Terrestrial: Forest, grassland, desert, etc.

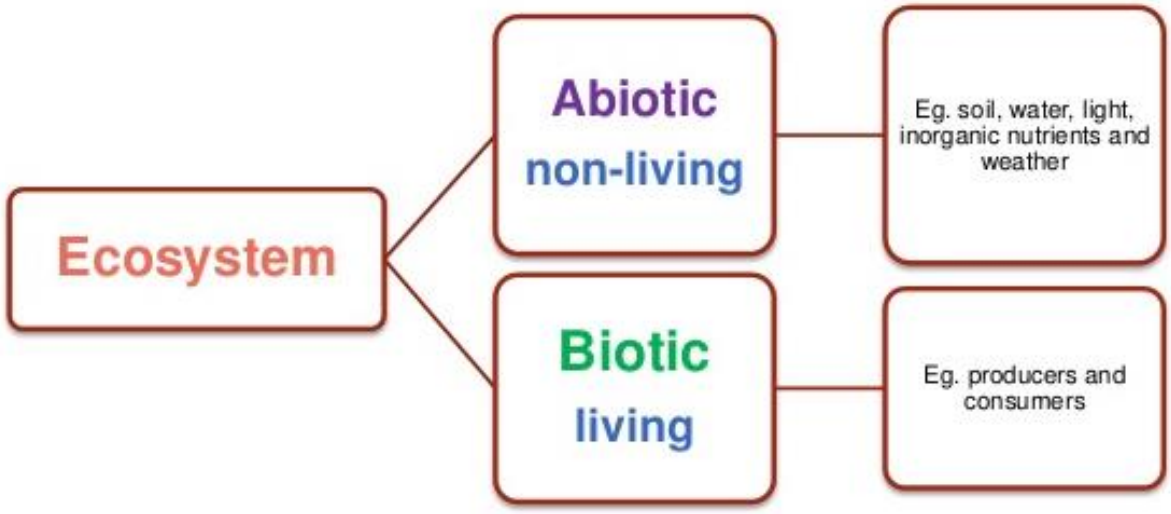
ii. Aquatic: Pond

2. Artificial Ecosystems:

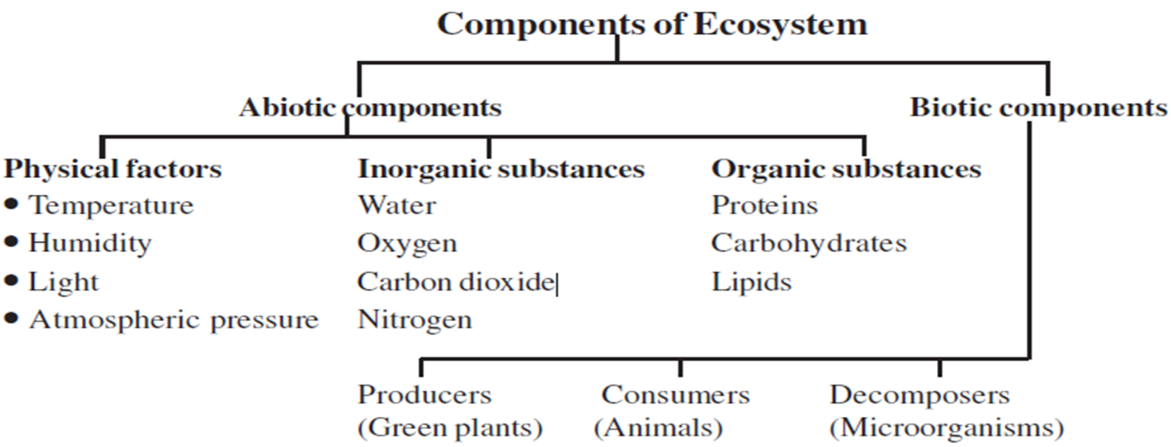
These are maintained artificially by humans where, by addition of energy and planned manipulations, natural balance is disturbed regularly. For example, croplands like wheat, rice fields, etc., where humans try to control the biotic community as well as the physio- chemical environments, are artificial ecosystems.



Structure of Ecosystem



Components of Ecosystem



Abiotic components

Biotic components

Physical factors
- Temperature
- Humidity
- Light
- Atmospheric pressure

Inorganic substances

Water
Oxygen
Carbon dioxide|
Nitrogen

Organic substances

Proteins
Carbohydrates
Lipids

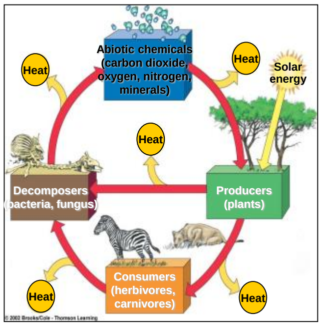
Producers (Green plants)

Consumers (Animals)

Decomposers (Microorganisms)

Biotic Components of Ecosystems

- Producers=autotroph
  - Source of all food
  - Photosynthesis
- Consumers=heterotroph
  - Aerobic respiration
  - Anaerobic respiration
    - Methane, H_2S
- Decomposers
  - Matter recyclers…
  - Release organic compounds into soil and water where they can be used by producers



Producers: the first trophic level

- **Autotrophs** ("self-feeders") = organisms that capture solar energy for photosynthesis to produce sugars
  - Green Plants
  - Cyanobacteria
  - Algae
- **Chemosynthetic bacteria** use the geothermal energy in hot springs or deep-sea vents to produce their food

Consumers: organisms that consume producers

Primary consumers = second trophic level
  - Organisms that consume producers
  - **Herbivores** consume plants
  - Deer, grasshoppers
- **Secondary consumers** = third trophic level
  - Organisms that prey on primary consumers
  - **Carnivores** consume meat
  - Wolves, rodents

Consumers occur at even higher trophic levels

- **Tertiary Consumers** = fourth trophic level
  - Predators at the highest trophic level
  - Consume secondary consumers
  - Are also carnivores
  - Hawks, owls
- **Omnivores** = consumers that eat both plants and animals

Detritivores and decomposers

- Organisms that consume nonliving organic matter
  - Enrich soils and/or recycle nutrients found in dead organisms
- **Detritivores** = scavenge waste products or dead bodies
  - Millipedes
- **Decomposers** = break down leaf litter and other non-living material
  - Fungi, bacteria
  - Enhance topsoil and recycle nutrients

Detritivores vs Decomposers

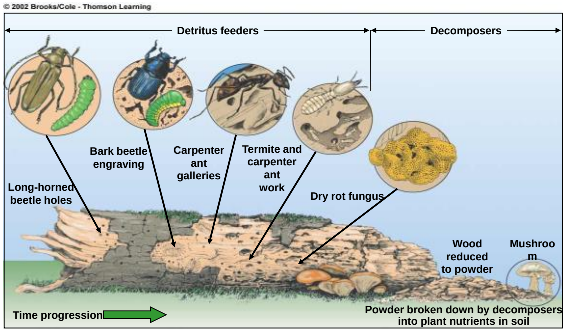
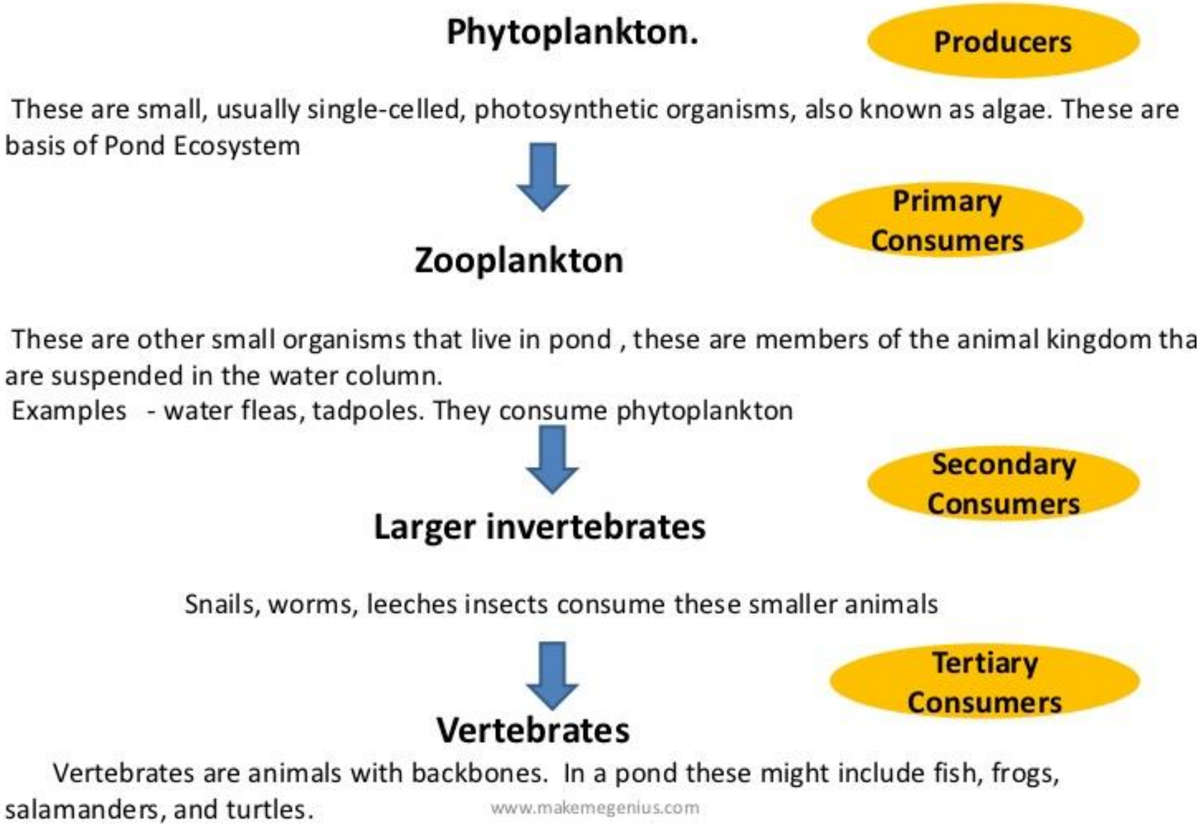


Fig. 4.15, p. 75

Pond Eco system



Phytoplankton.

Producers

These are small, usually single-celled, photosynthetic organisms, also known as algae. These are basis of Pond Ecosystem

Primary Consumers

Zooplankton

These are other small organisms that live in pond , these are members of the animal kingdom tha
are suspended in the water column.
Examples - water fleas, tadpoles. They consume phytoplankton

Secondary Consumers

Larger invertebrates

Snails, worms, leeches insects consume these smaller animals

Tertiary Consumers

Vertebrates

Vertebrates are animals with backbones. In a pond these might include fish, frogs, salamanders, and turtles.

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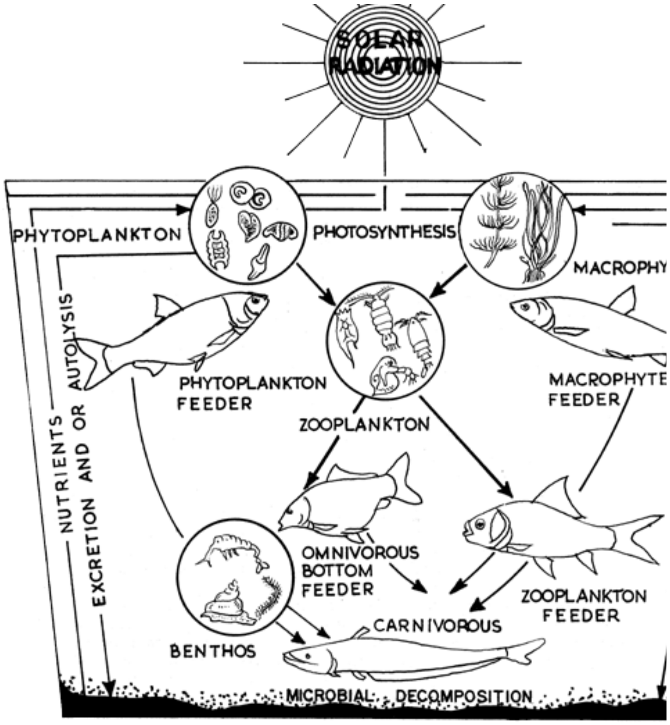
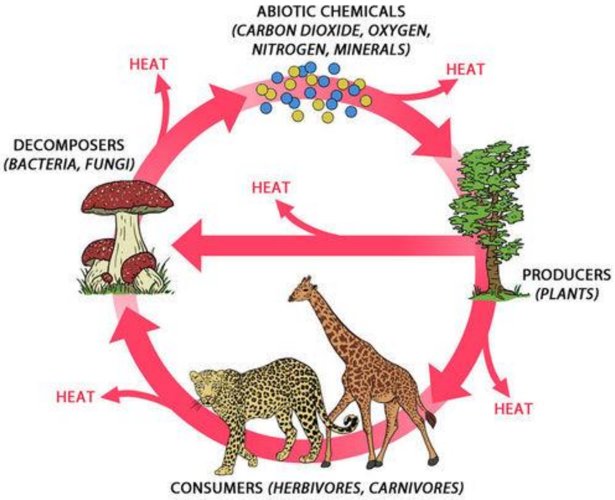
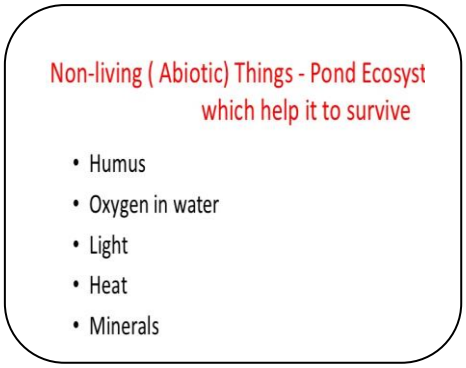





Non-living (Abiotic) Things - Pond Ecosyst
which help it to survive

- Humus
- Oxygen in water
- Light
- Heat
- Minerals

THE FOREST ECOSYSTEM

Forests occupy roughly 40% of the total land.The chief components of a forest ecosystem are as follows—

1. Abiotic substances:

- **Physical Component** : Temperature, light, air, humidity, wind etc.
- **Inorganic Components** : CO_2, Water, O_2, N_2, Inorganic salts of Ca and Mg.
- **Organic Component :** Carbohydrates, Protein, Lipids found in the dead organic bodies which form a part of the soil.

2. Producers:

- All types of green plants

3. Primary consumers:

- These are the herbivores that include the foliage arthropods such as ants, flies, beetles, leaf-hoppers, bugs and spiders, etc. and

- ❖ The larger animals grazing on shoots and fruits such as elephants, nilgai, deer, moles, squirrels, shrews, flying foxes, fruit bats and mongooses, etc.

4. Secondary consumers:

- ❖ These are the carnivores like snakes, birds, lizards and foxes feeding on herbivores.

5.Tertiary Consumers:

- ❖ The top carnivores like lion, tiger, etc, prey upon both herbivores and carnivores of the secondary consumer level.

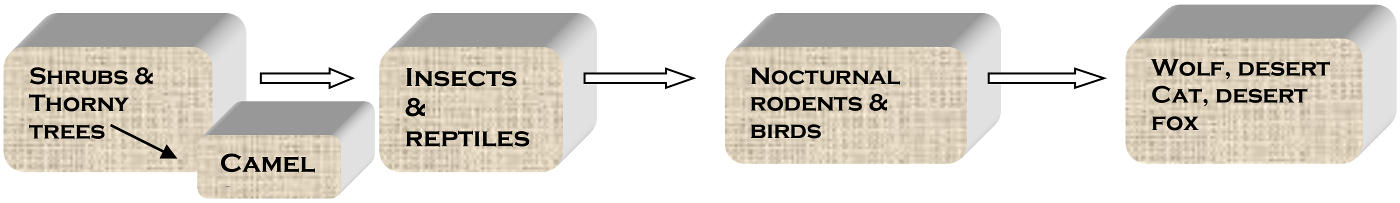
5. Decomposers:

- ❖ The decomposers of the forest ecosystem, as in other ecosystem, are the bacteria and fungi. These organisms obtain energy to carry on the life functions by breaking down the organic compounds of dead organic matter and organic wastes.

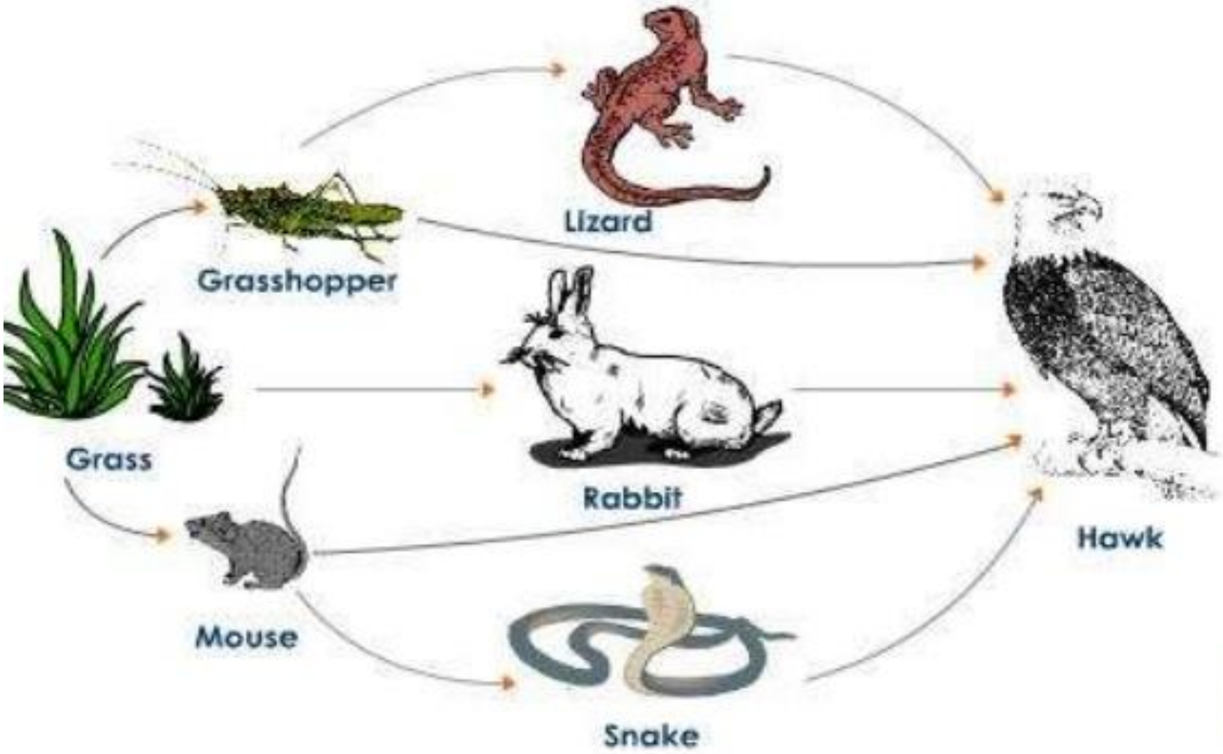
DESERT ECOSYSTEM

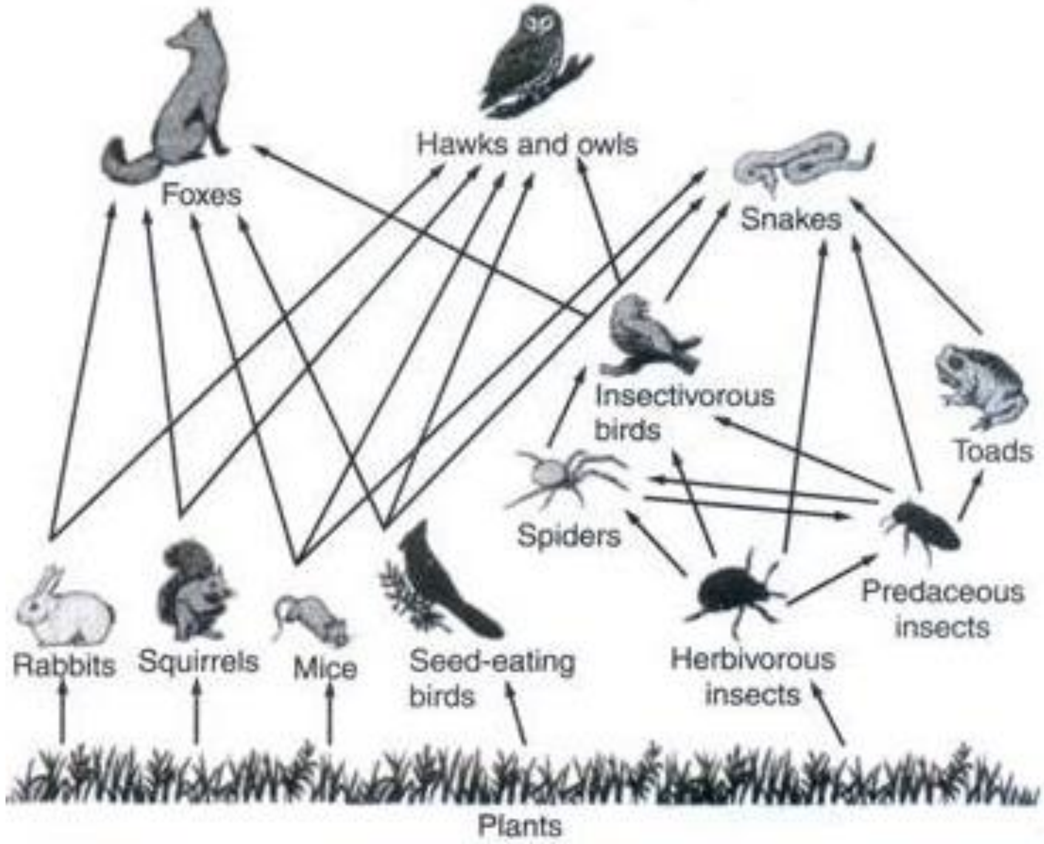
Desert Ecosystem

- Desert occupy 17 % of land.
- ***Abiotic components*** include, light, temperature, minerals.
- ***Biotic Components:***
- ***Producers :*** These are shrubs, especially bushes, some grasses, and few trees.
- E.g. Cacti, Xerophytes, mosses
- ***Consumers:*** The most common animals are reptiles, and insects, there are some rodents, and birds, and above all ship of desert camels, feed on tender plants.
- ***Decomposers:*** These are very few as due to poor vegetation the amount of dead organic matter is less. They are some fungi and bacteria.

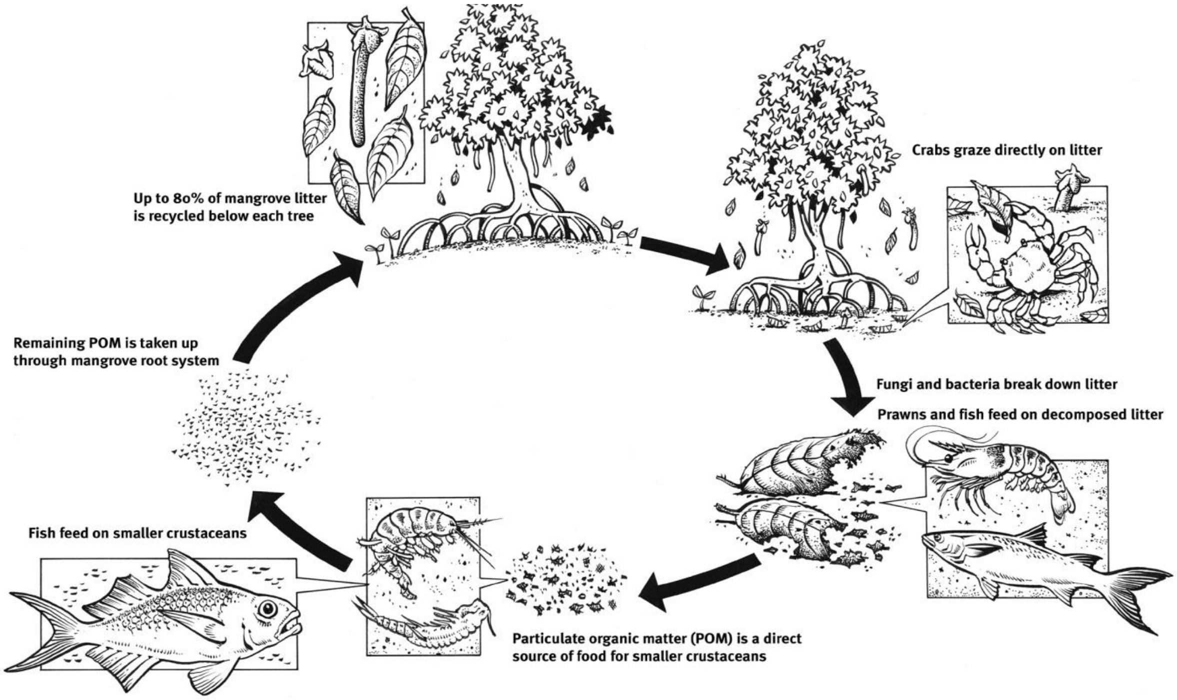


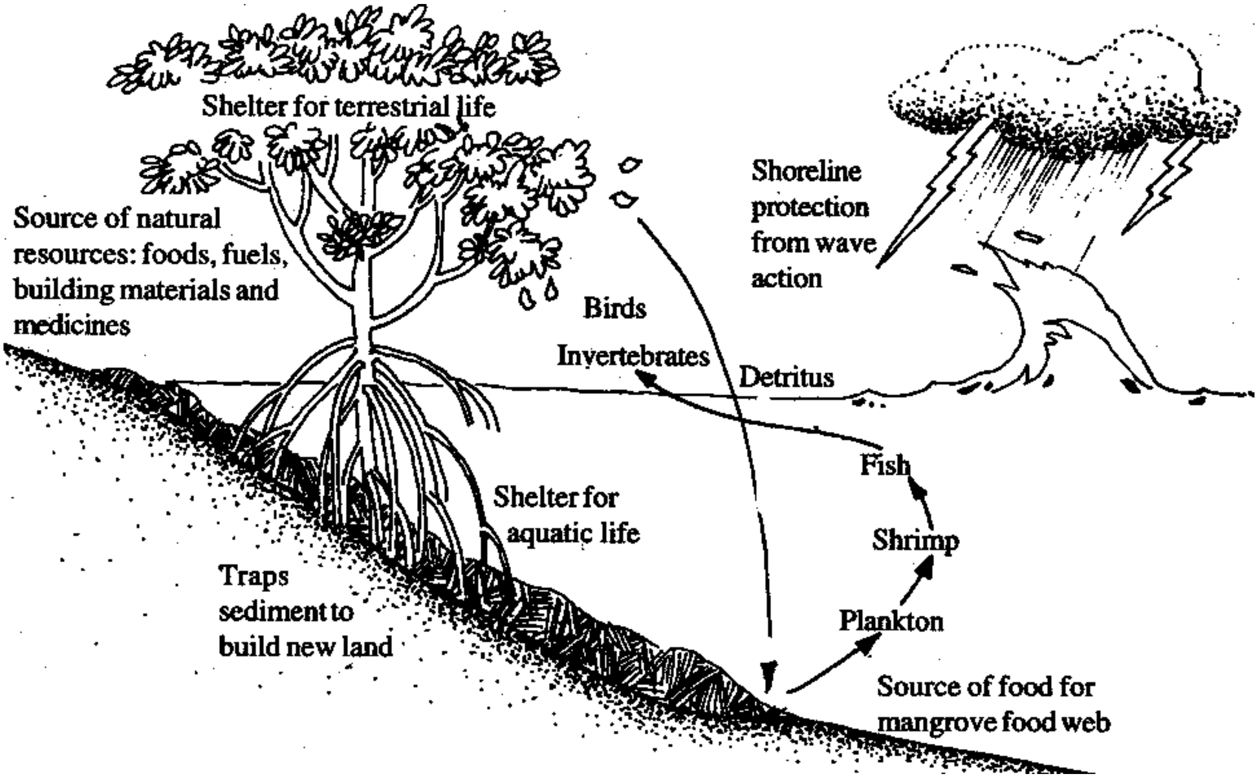
GRASSLAND ECOSYSTEM





MANGROVE ECOSYSTEM





1.5 Environmental Management

The irrepressible human curiosity and the unquenchable thirst for knowledge are the fundamental basis for scientific development. A major part of innovations in scientific and technological development has been directed towards generation or elevation of human comforts, thereby increasing standard of living in the society. This led to increase in industrialization. Some of the important improvements to our standard of living that can be attributed to the application of science and technology include:

1) Production of more and better quality of food.
2) Elimination of many infectious diseases.
3) Invention of new faster communication systems.
4) Creation of more reliable and faster transportation.
5) Supply of safe water.
6) Invention of machines to replace human and animal power.
7) Minimizing water-borne diseases through improve water technology.

Consequent to these improvements disturbing side effects such as environmental pollution, deforestations, urbanization, loss of arable land, evolution of new organisms resistant to control, etc., have emerged. These effects are considered as potential threats to environment and to humans. The blame for deterioration of environmental quality cannot be laid only on industrial activities. Wastes from residential and commercial sources also caused environmental stress. Further, both affluence and poverty also cause pollution in their own ways. Natural calamities, illiteracy, and lack of environmental ethics are also partially responsible.

Therefore, skillful and equitable environmental management often requires balancing of a number of factors some of which, at times, may be conflicting with each other. Environmental management is not the management of the environment as such, but management of interaction by the modern societies with and impact upon the environment. Environmental management offers research and opinions on use and conservation of natural resources, protection of habitats and control of hazards.

Objectives of Environmental Management

1) Regulating the exploitation of natural resources.
2) Protecting environmental degradation and maintaining environmental quality.
3) Balancing the ecosystem.
4) Preserving the biological diversity.
5) Adopting engineered technology without creating adverse effects on environment.
6) Formulation of suitable environmental laws and regulations and effective implementation of the same.

Components of Environmental Management

1) Environmental impact assessment (EIA).
2) Environmental management planning.
3) Environmental auditing.

4) Socio-economic assessment.
5) Solid waste management.
6) Air quality monitoring.
7) Water quality assessment.
8) Soil quality assessment.
9) Water and waste water management.

Environmental Impact Assessment (EIA)

An environmental impact assessment reveals possible positive or negative impact that a proposed project may have on the environment in all natural, social and economic aspects.

Thus, "Environmental Impact Assessment (EIA) is an activity designed to identify and predict the impact on the bio geophysical environment and on human health and well-being of Legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about the impacts".

EIA is widely accepted as a tool in environmental management. It has been adopted in many countries.

Environmental Impact Statement (EIS)

EIS is a public document written in a format specified by authorized national, state, and/or local agencies.

Environmental Regulations and Legal Framework in India

1) Wildlife (Protection) Act, 1972
2) The Water (Prevention and Control of Pollution) Act, 1974 (Amended in 1988)
3) The Forest (Conservation) Act, 1980
4) Air (Prevention & Control of Pollution) Act, 1981
5) Environment (Protection) Act, 1986
6) Ozone depletion substances (Regulation & Control) Rules, 2000.
7) Biological diversity Act, 2002.

1) The Wild Life Protection Act, 1972 (Amended in 1983, 1986 and 1991):

As per the provisions of the Act, no one is permitted to hunt any wild animal, except Vermin, without a license from the chief Wild Life warden. The Act provides for the establishment of sanctuaries, national parks, game reserves, and closed area.

All wild life animals are the property of the Government. Trade or Commerce in wild animals and animal's articles and trophies is strictly regulated. No person can cook or serve meat of wild animals in any eating house without a license. Penalties for violating the provisions of the Act have also be laid down in the Act. The minimum imprisonment prescribed is three years which may extend to seven years, with a minimum fine of Rs. 10,000.

2) The Water (Prevention and Control of Pollution) Act, 1974 (Amended in 1988):

This Act provides for the prevention and control of water pollution and for maintaining or resorting of wholesomeness of water.

The Act defines the terms like pollution, sewage effluent, stream and broads. The Act also assigns the functions to be carried out by the Central and State Boards.

The Act prohibits disposal of any poisonous, noxious or polluting matter or any matter causing obstruction to the proper flow of water in a stream.

The Act provides for severe and deterrent punishments for violation of the Act with includes fine and imprisonment.

3) The Forest Conservation Act, 1980 (Amended in 1988):

As per this Act, no forest land or any portion thereof may be used for any non-forest purposes without the prior permission of the Central Government. No State Government or other authority may issue order directing 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 without prior approval of Central Government.

4) Air (Prevention & Control of Pollution) Act, 1981 (Amended in 1987) :

This Act was passed under Article 253 of the Constitution of India and in pursuance of decisions of Stockholm Conference. The objective of this Act is to provide for the prevention control and abetment of air pollution in order to preserve the quality of air.

The Act defines relevant terms such as air pollution, air pollutant, automobile, industrial plant, etc.

Air pollutant is defined as the “presence of any liquid or gaseous substances in the atmosphere in such concentration as may be or tend to be injurious to human being or other living creatures or plants or property or environment”.

All sources of pollution such as automobiles, diesel vehicles, industries, transport, railways and domestic fuels.

The State Board have powers to sue a polluter in a court of law to prevent him from polluting the air, and the expenses incurred by the Board for doing so will be recovered from the polluter.

The Act has been amended comprehensively in 1987 to render it more effective and to include 'noise' also under the definition of air pollution.

5) The Environment (Protection) Act, 1986 :

The environment (Protection) Act, 1986 was enacted as per the spirit of the Stockholm Conference held in June, 1972 to take appropriate steps for the protection and improvement to prevent hazards to human beings, living creatures and property. This is a landmark legislation to provide a single focus in the country for protection of environment and to plug the loopholes in the earlier laws.

This Act ensures enforcement of several Acts/regulations concerning pollution control and environmental protection/safety.

The Act also empowered the Central Government to make rules for the first time for the

(i) Standardof quality of air, water and soil for various areas and for various purposes
(ii) Maximum permissible limits of concentration for various environmental pollutants (including noise) for different areas
(iii) Procedures and safeguards for handling of hazardous substances
(iv) Prohibition and restrictions on the location of industries
(v) Procedures and safeguards for prevention of accidents which may cause environmental pollution
(vi) Providing remedial measures in case of accidents.

It is mandatory for persons carrying or any industry, operation etc. not to allow emission or discharge of environmental pollutants. The Act provides for stringent penalties for defaulters. Any person can make a complaint of violation of provisions of the Act to the Central Government or Authority or Officer authorized for this purpose.

6) Ozone Depletion Substances (Regulation & Control) Rules, 2000

These rules may be called 'Ozone Depletion Substances (Regulation & Control) Rules, 2000'. The comprehensive road map for phasing out hydrochlorofluorocarbons (HCFCs) in various sectors as per the reduction targets of Montreal Protocol was released by the Ministry of Environment and Forests. India plan to cut the use of HCFCs by 10% by 2015 and then to zero by 2030.

7) Biological Diversity Act, 2002

The ministry of Environment and Forests has enacted the Biological Diversity Act, 2002 under the United Nations Convention on Biological Diversity signed at Rio de Janeior on 5th of June, 1992 of which India is also a party. As per the provision of the Act area rich in biodiversity and encompassing unique and representative ecosystems are identified and designated as biosphere reserves to facilitate their conservation. All restrictions applicable to protect areas like national parks and sanctuaries are also applicable to these reserves.

Montreal Protocol:

The Montreal Protocol, finalized in 1987, is a global agreement to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS). The stratospheric ozone layer filters out harmful ultraviolet radiation, which is associated with an increased prevalence of skin cancer and cataracts. The United States ratified the Montreal Protocol in 1988 and has joined its four subsequent amendments. The United States has been a leader within the Protocol throughout its existence, and has taken strong domestic action to phase out the use of ODS such as chlorofluorocarbons (CFCs) and halons.

The Montreal Protocol has proven to be innovative and successful, and is the first treaty to achieve universal ratification by all countries in the world. Leveraging global participation, the Montreal Protocol has sent clear signals to the global market and placed the ozone layer, which was in peril, on a path to repair. This unprecedented global cooperation to address an environmental problem prevented widespread global impacts such as preventing over two million cases of skin cancer per year by 2030, preventing increased prevalence of cataracts and averting damage to agricultural crops, and preventing disruption of marine ecosystems. By 2035, the Parties will have eliminated the vast majority of ozone depleting substances. The Montreal Protocol's Scientific Assessment Panel estimates that implementation of the Montreal Protocol will allow the ozone layer to return to its pre-industrial levels by mid-century.

Most recently, the Montreal Protocol Parties in 2016 agreed to the Kigali amendment, which adds a new class of substances to its controls, known as hydrofluorocarbons or HFCs.

On October 15, 2016, the 197 Parties to the Montreal Protocol adopted the Kigali Amendment to phase down production and consumption of Hydrofluorocarbons (HFCs) worldwide. HFCs are widely used alternatives to ozone depleting substances such as hydrochlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs) that are already subject to controls under the Protocol.

Kyoto Protocol

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at fighting global warming. This is an international environmental treaty with a goal to achieve the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

The Protocol was initially adopted on 11 December 1997 in Kyoto, Japan and entered into force on 16 February 2005. As on April 2010, 191 countries have signed and ratified the Protocol.

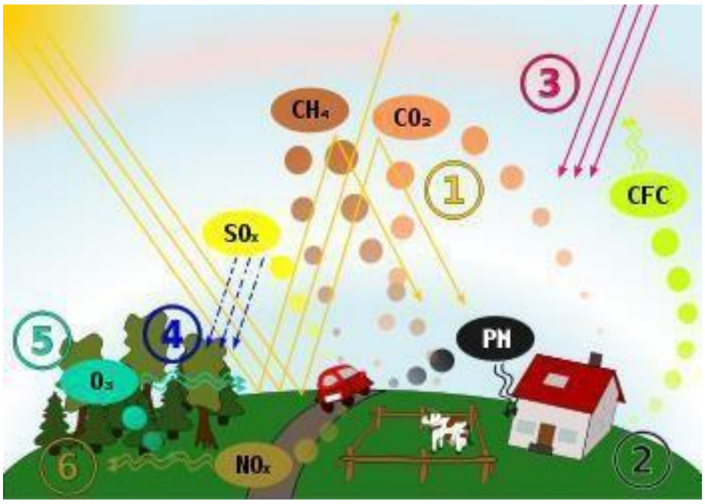
Under the Protocol, 37 countries (‘Annex I countries’) commit themselves to a reduction of four greenhouse gases (carbon dioxide, methane, nitrous oxide, Sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by them, and all member countries give general commitments. Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2 per cent from the 1990 level. Emission limit do not include emissions by international aviation shipping, but are in addition to the industrial gases, chlorofluorocarbons, or CFCs, which are dealt with under the 1987 Montreal Protocol on substances that deplete the Ozone Layer.

Air Pollution

Introduction

Air is the ocean we breathe. Air supplies us with *oxygen* which is essential for our bodies to live. Air is 99.9% nitrogen, oxygen, water vapour and inert gases. Human activities can release substances into the air, some of which can cause problems for humans, plants, and animals. There are several main *types* of pollution and well-known *effects* of pollution which are commonly discussed. These include smog, acid rain, the greenhouse effect, and "holes" in the ozone layer. Each of these problems has serious implications for our health and well-being as well as for the whole environment. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems. Indoor air pollution and urban air quality are listed as two of the world's worst pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report.

Pollutants



Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground level ozone concentration, (6) increased levels of nitrogen oxides.

An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made.

Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants.

About 4 percent of deaths in the United States can be attributed to air pollution, according to the Environmental Science Engineering Program at the Harvard School of Public Health.

Major primary pollutants produced by human activity include:

Sulphur oxides (SO_x) - especially sulphur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulphur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

Nitrogen oxides (NO_x) - especially nitrogen dioxide are emitted from high temperature combustion. Can be seen as the brown haze dome above or plume downwind of cities. Nitrogen dioxide is the chemical compound with the formula NO_2. It is one of the several nitrogen oxides. This reddish-brown toxic gas has a characteristic sharp, biting odor. NO_2 is one of the most prominent air pollutants.

Carbon monoxide - is a colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

Carbon dioxide (CO_2) - a colourless, odourless, non-toxic greenhouse gas associated with ocean acidification, emitted from sources such as combustion, cement production, and respiration.

Volatile organic compounds - VOCs are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH_4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhance global warming. Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere, although the effect varies depending on local air quality. Within the NMVOCs, the aromatic compounds benzene, toluene and xylene are suspected carcinogens and may lead to leukaemia through prolonged exposure. 1,3-butadiene is another dangerous compound which is often associated with industrial uses.

Particulate matter - Particulates alternatively referred to as particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to particles and the gas together. Sources of particulate matter can be manmade or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10 percent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

Persistent free radicals connected to airborne fine particles could cause cardiopulmonary disease.

- Toxic metals, such as lead, cadmium and copper.
- Chlorofluorocarbons (CFCs) - harmful to the ozone layer emitted from products currently banned from use.
- Ammonia (NH_3) - emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.
- Odours — such as from garbage, sewage, and industrial processes
- Radioactive pollutants - produced by nuclear explosions, war explosives, and natural processes such as the radioactive decay of radon.

Secondary pollutants include:

- Particulate matter formed from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution; the word "smog" is a portmanteau of smoke and fog. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.
- Ground level ozone (O_3) formed from NO_x and VOCs. Ozone (O_3) is a key constituent of the troposphere. It is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.
- Peroxyacetyl nitrate (PAN) - similarly formed from NO_x and VOCs.

Minor air pollutants include:

- A large number of minor hazardous air pollutants. Some of these are regulated in USA under the Clean Air Act and in Europe under the Air Framework Directive .
- A variety of persistent organic pollutants, which can attach to particulate matter.

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. Because of this, they have been observed to persist in the environment, to be capable of long-range transport, bioaccumulation in human and animal tissue, biomagnified in food chains, and to have potential significant impacts on human health and the environment.

Sources of Pollutants

The two main sources of pollutants in urban areas are transportation (predominantly automobiles) and fuel combustion in stationary sources, including residential, commercial, and industrial heating and cooling and coal-burning power plants. Motor vehicles produce high levels of carbon monoxides (CO) and a major source of hydrocarbons (HC) and nitrogen oxides (NOx). Whereas, fuel combustion in stationary sources is the dominant source of sulfur dioxide (SO2).

Carbon Dioxide

Carbon dioxide (CO2) is one of the major pollutants in the atmosphere. Major sources of CO2 are fossil fuels burning and deforestation. "The concentrations of CO2 in the air around 1860 before the effects of industrialization were felt, is assumed to have been about 290 parts per million (ppm). In the hundred years and more since then, the concentration has increased by about 30 to 35 ppm that is by 10 percent". (Breuer 67) Industrial countries account for 65% of CO2 emissions with the United States and Soviet Union responsible for 50%. Less developed countries (LDCs), with 80% of the world's people, are responsible for 35% of CO2 emissions but may contribute 50% by 2020. "Carbon dioxide emissions are increasing by 4% a year". (Miller 450)

In 1975, 18 thousand million tons of carbon dioxide (equivalent to 5 thousand million tons of carbon) was released into the atmosphere, but the atmosphere showed an increase of only 8 billion tons (equivalent to 2.2 billion tons of carbon". (Breuer 70) The ocean waters contain about sixty times more CO2 than the atmosphere. If the equilibrium is disturbed by externally increasing the concentration of CO2 in the air, then the oceans would absorb more and more CO2. If the oceans can no longer keep pace, then more CO2 will remain into the atmosphere. As water warms, its ability to absorb CO2 is reduced.

CO2 is a good transmitter of sunlight, but partially restricts infrared radiation going back from the earth into space. This produces the so-called greenhouse effect that prevents a drastic cooling of the Earth during the night. Increasing the amount of CO2 in the atmosphere reinforces this effect and is expected to result in a warming of the Earth's surface. Currently carbon dioxide is responsible for 57% of the global warming trend. Nitrogen oxides contribute most of the atmospheric contaminants.

NOX - nitric oxide (NO) and nitrogen dioxide (NO2)

Natural component of the Earth's atmosphere. Important in the formation of both acid precipitation and photochemical smog (ozone), and causes nitrogen loading. Comes from the burning of biomass and fossil fuels. 30 to 50 million tons per year from human activities, and natural 10 to 20 million tons per year. Average residence time in the atmosphere is days. Has a role in reducing stratospheric ozone.

N2O - nitrous oxide

Natural component of the Earth's atmosphere. Important in the greenhouse effect and causes nitrogen loading. Human inputs 6 million tons per year, and 19 million tons per year by nature. Residence time in the atmosphere about 170 years. 1700 (285 parts per billion), 1990 (310 parts per billion), 2030 (340 parts per billion).

Comes from nitrogen based fertilizers, deforestation, and biomass burning.

Sulphur and chlorofluorocarbons (CFCs)

Sulphur dioxide is produced by combustion of sulphur-containing fuels, such as coal and fuel oils. Also, in the process of producing sulphuric acid and in metallurgical process involving ores that contain sulphur. Sulphur oxides can injure man, plants and materials. At sufficiently high concentrations, sulphur dioxide irritates the upper respiratory tract of human beings because potential effect of sulphur dioxide is to make breathing more difficult by causing the finer air tubes of the lung to constrict. "Power plants and factories emit 90% to 95% of the sulphur dioxide and 57% of the nitrogen oxides in the United States. Almost 60% of the SO2 emissions are released by tall smoke stakes, enabling the emissions to travel long distances". (Miller 494) As emissions of sulphur dioxide and nitric oxide from stationary sources are transported long distances by winds, they form secondary pollutants such as nitrogen dioxide, nitric acid vapour, and droplets containing solutions of sulphuric acid, sulphate, and nitrate salts. These chemicals descend to the earth's surface in wet form as rain or snow and in dry form as a gases fog, dew, or solid particles. This is known as acid deposition or acid rain.

Chlorofluorocarbons (CFCs)

CFCs are lowering the average concentration of ozone in the stratosphere. "Since 1978 the use of CFCs in aerosol cans has been banned in the United States, Canada, and most Scandinavian countries. Aerosols are still the largest use, accounting for 25% of global CFC use". (Miller 448) Spray cans, discarded or leaking refrigeration and air conditioning equipment, and the burning plastic foam products release the CFCs into the atmosphere. Depending on the type, CFCs stay in the atmosphere from 22 to 111 years. Chlorofluorocarbons move up to the stratosphere gradually over several decades. Under high energy ultra violet (UV) radiation, they break down and release chlorine atoms, which speed up the breakdown of ozone (O3) into oxygen gas (O2).

Chlorofluorocarbons, also known as Freons, are greenhouse gases that contribute to global warming. Photochemical air pollution is commonly referred to as "smog". Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal. With the introduction of petroleum to replace coal economies in countries, photochemical smog has become predominant in many cities, which are located in sunny, warm, and dry climates with many motor vehicles. The worst episodes of photochemical smog tend to occur in summer.

Smog

Photochemical smog is also appearing in regions of the tropics and subtropics where savanna grasses are periodically burned. Smog's unpleasant properties result from the irradiation by sunlight of hydrocarbons caused primarily by unburned gasoline emitted by automobiles and other combustion sources. The products of photochemical reactions include organic particles, ozone, aldehydes, ketones, peroxyacetyl nitrate, organic acids, and other oxidants. Ozone is a gas created by nitrogen dioxide or nitric oxide when exposed to sunlight. Ozone causes eye irritation, impaired lung function, and damage to trees and crops. Another form of smog is called industrial smog.

This smog is created by burning coal and heavy oil that contain sulphur impurities in power plants, industrial plants, etc... The smog consists mostly of a mixture of sulphur dioxide and fog. Suspended droplets of sulphuric acid are formed from some of the sulphur dioxide, and a variety of suspended solid particles. This smog is common during the winter in cities such as London, Chicago, and Pittsburgh. When these cities burned large amounts of coal and heavy oil without control of the output, large-scale problems were witnessed. In 1952 London, England, 4,000 people died as a result of this form of fog. Today coal and heavy oil are burned only in large boilers and with reasonably good control or tall smokestacks so that industrial smog is less of a problem. However, some countries such as China, Poland, Czechoslovakia, and some other eastern European countries, still burn large quantities of coal without using adequate controls.

Causes of Air Pollution

Increase in urban population

Between 1951 and 1991, the urban population has tripled, from 62.4 million to 217.6 million, and its proportion has increased from 17.3% to 25.7%. Nearly two-thirds of the urban population is concentrated in 317 class I cities (population of over 100 000), half of which lives in 23 metropolitan areas with populations exceeding 1 million. The number of urban agglomerations/cities with populations of over a million has increased from 5 in 1951 to 9 in 1971 and 23 in 1991 (Pachauri and Sridharan 1998). This rapid increase in urban population has resulted in unplanned urban development, increase in consumption patterns and higher demands for transport, energy, other infrastructure, thereby leading to pollution problems.

Increase in number of vehicles

The number of motor vehicles has increased from 0.3 million in 1951 to 37.2 million in 1997 (Most 2000). Out of these, 32% are concentrated in 23 metropolitan cities. Delhi itself accounts for about 8% of the total registered vehicles and has more registered vehicles than those in the other three metros (Mumbai, Calcutta, and Chennai) taken together. At the all-India level, the percentage of two-wheeled vehicles in the total number of motor vehicles increased from 9% in 1951 to 69% in 1997, and the share of buses declined from 11% to 1.3% during the same period (MoST 2000). This clearly points to a tremendous increase in the share of personal transport vehicles. In 1997, personal transport vehicles (two-wheeled vehicles and cars only) constituted 78.5% of the total number of registered vehicles. Road-based passenger transport has recorded very high growth in recent years especially since 1980-81. It is estimated that the roads accounted for 44.8 billion passenger kilometre (PKM) in 1951 which has since grown to 2,515 billion PKM in 1996. The freight traffic handled by road in 1996 was about 720 billion tonne kilometre (TKM) which has increased from 12.1 TKM in 1951 (Most 1996). In contrast, the total road network has increased only 8 times from 0.4 million kms in 1950-51 to 3.3 million kms in 1995-96. The slow growth of road infrastructure and high growth of transport performance and number of vehicles all imply that Indian roads are reaching a saturation point in utilising the existing capacities. The consumption of gasoline and HSD has grown more than 3 times during the period 1980-1997. While the consumption of gasoline and HSD were 1,522 and 9,050 thousand tonnes in

1980-81, it increased to 4,955 and 30,357 thousand tonnes in 1996-97, respectively (CMIE 2000).

Increase in industrial activity

India has made rapid strides in industrialisation, and it is one of the ten most industrialised nations of the world. But this status, has brought with it unwanted and unanticipated consequences such as unplanned urbanisation, pollution and the risk of accidents. The CPCB (Central Pollution Control Board) has identified seventeen categories of industries (large and medium scale) as significantly polluting and the list includes highly air polluting industries such as integrated iron and steel, thermal power plants, copper/zinc/aluminium smelters, cement, oil refineries, petrochemicals, pesticides and fertiliser units. The state-wise distribution of these pre- 1991 industries indicates that the states of Maharashtra, Uttar Pradesh, Gujarat, Andhra Pradesh and Tamil Nadu have a large number of industries in these sectors. The category wise distribution of these units reveals that sugar sector has the maximum number of industries, followed by pharmaceuticals, distillery, cement and fertiliser. It also indicates that agro-based and chemical industries have major shares of 47% and 37% of the total number of industries respectively. The status of pollution control as on 30 June 2000 is as follows: out of 1,551 industries, 1,324 have so far been provided the necessary pollution control facilities, 165 industries have been closed down and the remaining 62 industries are defaulters (CPCB 2000a). It may be noted that in some of the key sectors such as iron and steel, 6 out of 8 units belong to the defaulters' category in terms of having pollution control facilities to comply with the standards. On the other hand, cement, petrochemicals and oil refinery sectors do not have any defaulters. Small scale industries are a special feature of the Indian economy and play an important role in pollution. India has over 3 million small scale units accounting for over 40 percent of the total industrial output in the country (CII and SII 1996). In general, Indian small scale industries lack pollution control mechanisms. While the larger industries are better organised to adopt pollution control measures, the small scale sector is poorly equipped (both financially and technically) to handle this problem. They have a very high aggregate pollution potential. Also, in many urban centres, industrial units are located in densely populated areas, thereby affecting a large number of people.

Increase in power generation

Since 1950-51, the electricity generation capacity in India has multiplied 55 times from a meagre 1.7 thousand MW to 93.3 thousand MW (MoF 2000). The generating capacity in India comprises a mix of hydro, thermal, and nuclear plants. Since the early seventies, the hydro-thermal capacity mix has changed significantly with the share of hydro in total capacity declining from 43% in 1970-71 to 24% in 1998-99. Thermal power constitutes about 74% of the total installed power generation capacity. However, increasing reliance on this source of energy leads to many environmental problems. India's coal has a very high in ash content (24%–45%). The increased dependence of the power sector on an inferior quality coal has been associated with emissions from power plants in the form of particulate matter, toxic elements, fly ash, and oxides of nitrogen, sulphur and carbon besides ash, which required vast stretches of land for disposal. During 1998-99, the power stations consumed

208 million tonnes of coal, which in turn produced 80 million tonnes of ash posing a major problem disposal (CPCB 2000b). Thermal power plants belong to the 17 categories of highly polluting industries. As on 30 June 2000, out of the 97 pre-1991 TPP's, 20 plants had not yet provided the requisite pollution control facilities (CPCB 2000a).

Domestic pollution

Pollution from different types of cooking stoves using coal, fuel wood, and other biomass fuels contributes to some extent, to the overall pollution load in urban areas. For example, in Delhi, the share of the domestic sector is about 7%–8% of the total pollution load (MoEF 1997). The main concern is the use of inefficient and highly polluting fuels in the poorer households leading to deterioration in indoor air-quality and health. However, a positive development in the domestic energy consumption is that liquefied petroleum gas is fast becoming the most popular cooking fuel, especially in urban areas, as it is cleaner and more efficient than traditional cooking fuels.

Other sources

The problem of air pollution in urban areas is also aggravated due to inadequate power supply for industrial, commercial and residential activities due to, which consumers have to use diesel-based captive power generation units emitting high levels NOX and SOX. In addition, non-point sources such as waste burning, construction activities, and roadside air borne dust due to vehicular movement also contribute to the total emission load.

Ambient air quality

Under the National Ambient Air Quality Monitoring (NAAQM) network, three criteria air pollutants, namely, SPM, SO2, and NO2 have been identified for regular monitoring at all the
290 stations spread across the country. CPCB (2000c) analyses the status and trends of air quality at various cities in India for the period 1990-98. The most prevalent form of air pollution appears to be SPM although there are many stations at which SO2 and NO2 levels exceed permissible limits. The high influx of population to urban areas increase in consumption patterns, unplanned urban and industrial development and poor enforcement mechanism has led to the problem of air pollution. The government has taken a number of measures such as legislation, emission standards for industries, guidelines for siting of industries, environmental audit, EIA, vehicular pollution control measures, pollution prevention technologies, action plan for problem areas, development of environmental standards, and promotion of environmental awareness. However, despite all these measures, air pollution still remains one of the major environmental problems. At the same time, there have been success stories as well such as the reduction of ambient lead levels (due to introduction of unleaded petrol) and comparatively lower SO2 levels (due to progressive reduction of sulphur content in fuel).

SPM

Suspended particulate matter is one of the most critical air pollutants in most of the urban areas in the country and permissible standards are frequently violated several monitored locations. Its levels have been consistently high in various cities over the past several years. The annual average minimum and maximum SPM concentration in residential areas of various cities ranged from 60 µg/m3 (at Bangalore during 1991) to 521 µg/m3 (at Patna during 1995), while in industrial areas the annual average ranged between 53 µg/m3 (Chennai during 1992) and 640 µg/m3 (Calcutta during 1993). The mean of average values of SPM for nine years (1990 to 1998) ranged between 99 µg/m3 and 390 µg/m3 in residential areas and between 123 µg/m3 and 457 µg/m3 in industrial areas indicating that the annual average limit of suspended particulate matter for residential areas (140 µg/m3) and for industrial areas (360 µg/m3) had been frequently violated in most cities. The maximum suspended particulate matter (SPM) values were observed in Kanpur, Calcutta, and Delhi, while low values have been recorded in the south Indian cities of Chennai, Bangalore, and Hyderabad. The SPM non-attainment areas are dispersed throughout the country. The states with maximum SPM problems are Gujarat, Maharashtra, and Madhya Pradesh, where SPM problems are high to critical in a large number of cities. The widespread criticality of the SPM problem in the country is due to the synergistic effects of both anthropogenic and natural sources. Some of these are extensive urbanisation and construction activities, vehicular pollution increase, extensive use of fossil fuel in industrial activities, inadequacy of pollution control measures, biomass burning, presence of large acid and semi-acid area in north-west part of India, increasing desertification, and decreasing vegetation cover.

Health effects

The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution. "Epidemiological studies suggest that more than 500,000 Americans die each year from cardiopulmonary disease linked to breathing fine particle air pollution. . ." A study by the University of Birmingham has shown a strong correlation between pneumonia related deaths and air pollution from motor vehicles. Worldwide more deaths per year are linked to air pollution than to automobile accidents. Published in 2005 suggests that 310,000 Europeans die from air pollution annually. Direct causes of air pollution related deaths include aggravated asthma, bronchitis, emphysema, lung and heart diseases, and respiratory allergies. The US EPA estimates that a proposed set of changes in diesel engine technology (*Tier 2*) could result in 12,000 fewer *premature mortalities*, 15,000 fewer heart attacks, 6,000 fewer emergency room visits by children with asthma, and 8,900 fewer respiratory-related hospital admissions each year in the United States.

The worst short term civilian pollution crisis in India was the 1984 Bhopal Disaster. Leaked industrial vapours from the Union Carbide factory, belonging to Union Carbide, Inc., U.S.A., killed more than 2,000 people outright and injured anywhere from 150,000 to 600,000 others, some 6,000 of whom would later die from their injuries. The United Kingdom suffered its worst air pollution event when the December 4 Great Smog of 1952 formed over London. In six days more than 4,000 died, and 8,000 more died within the following months. An accidental leak of anthrax spores from a biological warfare laboratory in the former USSR in 1979 near Sverdlovsk is believed to have been the cause of hundreds of civilian deaths. The worst single incident of air pollution to occur in the United States of America occurred in Donora, Pennsylvania in late October, 1948, when 20 people died and over 7,000 were injured.

The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics.

A new economic study of the health impacts and associated costs of air pollution in the Los Angeles Basin and San Joaquin Valley of Southern California shows that more than 3800 people die prematurely (approximately 14 years earlier than normal) each year because air pollution levels violate federal standards. The number of annual premature deaths is considerably higher than the fatalities related to auto collisions in the same area, which average fewer than 2,000 per year.

Diesel exhaust (DE) is a major contributor to combustion derived particulate matter air pollution. In several human experimental studies, using a well validated exposure chamber setup, DE has been linked to acute vascular dysfunction and increased thrombus formation. This serves as a plausible mechanistic link between the previously described association between particulate matter air pollution and increased cardiovascular morbidity and mortality.

Effects on cystic fibrosis

A study from 1999 to 2000 by the University of Washington showed that patients near and around particulate matter air pollution had an increased risk of pulmonary exacerbations and decrease in lung function. Patients were examined before the study for amounts of specific pollutants like *Pseudomonas aeruginosa* or *Burkholderia cenocepacia* as well as their socioeconomic standing. Participants involved in the study were located in the United States in close proximity to an Environmental Protection Agency. During the time of the study 117 deaths were associated with air pollution. A trend was noticed that patients living closer or in large metropolitan areas to be close to medical help also had higher level of pollutants found in their system because of more emissions in larger cities. With cystic fibrosis patients already being born with decreased lung function everyday pollutants such as smoke emissions from automobiles, tobacco smoke and improper use of indoor heating devices could add to the disintegration of lung function.

Effects on COPD

Chronic obstructive pulmonary disease (COPD) include diseases such as chronic bronchitis, emphysema, and some forms of asthma.

A study conducted in 1960-1961 in the wake of the Great Smog of 1952 compared 293 London residents with 477 residents of Gloucester, Peterborough, and Norwich, three towns with low reported death rates from chronic bronchitis. All subjects were male postal truck drivers aged 40 to 59. Compared to the subjects from the outlying towns, the London subjects exhibited more severe respiratory symptoms (including cough, phlegm, and dyspnoea), reduced lung function (FEV1 and peak flow rate), and increased sputum production and purulence. The differences were more pronounced for subjects aged 50 to 59. The study controlled for age and smoking habits, so concluded that air pollution was the most likely cause of the observed differences.

It is believed that much like cystic fibrosis, by living in a more urban environment serious health hazards become more apparent. Studies have shown that in urban areas patients suffer mucus hyper secretion, lower levels of lung function, and more self diagnosis of chronic bronchitis and emphysema.

The Great Smog of 1952

Early in December 1952, a cold fog descended upon London. Because of the cold, Londoners began to burn more coal than usual. The resulting air pollution was trapped by the inversion layer formed by the dense mass of cold air. Concentrations of pollutants, coal smoke in particular, built up dramatically. The problem was made worse by use of low-quality, high-sulphur coal for home heating in London in order to permit export of higher-quality coal, because of the country's tenuous post-war economic situation. The "fog", or smog, was so thick that driving became difficult or impossible. The extreme reduction in visibility was accompanied by an increase in criminal activity as well as transportation delays and a virtual shut down of the city. During the 4 day period of fog, at least 4,000 people died as a direct result of the weather.

Effects on children

Cities around the world with high exposure to air pollutants have the possibility of children living within them to develop asthma, pneumonia and other lower respiratory infections as well as a low initial birth rate. Protective measures to ensure the youths' health are being taken in cities such as New Delhi, India where buses now use compressed natural gas to help eliminate the “pea-soup” smog. Research by the World Health Organization shows there is the greatest concentration of particulate matter particles in countries with low economic world power and high poverty and population rates. Examples of these countries include Egypt, Sudan, Mongolia, and Indonesia. The Clean Air Act was passed in 1970; however in 2002 at least 146 million Americans were living in areas that did not meet at least one of the “criteria pollutants” laid out in the 1997 National Ambient Air Quality Standards. Those pollutants included: ozone, particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, and lead. Because children are outdoors more and have higher minute ventilation they are more susceptible to the dangers of air pollution.

Health effects in relatively "clean" areas

Even in areas with relatively low levels of air pollution, public health effects can be substantial and costly. This is because effects can occur at very low levels and a large number of people can potentially breathe in such pollutants. A 2005 scientific study for the British Columbia Lung Association showed that a 1% improvement in ambient PM2.5 and ozone concentrations will produce a $29 million in annual savings in the region in 2010. This finding is based on health valuation of lethal (mortality) and sub-lethal (morbidity) effects.

Reduction efforts

There are various air pollution control technologies and land use planning strategies available to reduce air pollution. At its most basic level land use planning is likely to involve zoning and transport infrastructure planning. In most developed countries, land use planning is an important part of social policy, ensuring that land is used efficiently for the benefit of the wider economy and population as well as to protect the environment.

Efforts to reduce pollution from mobile sources includes primary regulation (many developing countries have permissive regulations), expanding regulation to new sources (such as cruise and transport ships, farm equipment, and small gas-powered equipment such as lawn trimmers, chainsaws, and snowmobiles), increased fuel efficiency (such as through the use of hybrid vehicles), conversion to cleaner fuels (such as bioethanol, biodiesel, or conversion to electric vehicles).

Control devices

The following items are commonly used as pollution control devices by industry or transportation devices. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

Particulate control

- Mechanical collectors (dust cyclones, multicyclones)
- Electrostatic precipitators: An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream.

- Baghouses: Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).
- Particulate scrubbers: Wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

Scrubbers

- Baffle spray scrubber
- Cyclonic spray scrubber
- Ejector venture scrubber
- Mechanically aided scrubber
- Spray tower
- Wet scrubber

NOx control

- Low NOx burners
- Selective catalytic reduction (SCR)
- Selective non-catalytic reduction (SNCR)
- NOx scrubbers
- Exhaust gas recirculation
- Catalytic converter (also for VOC control)

VOC abatement

- Adsorption systems, such as activated carbon
- Flares
- Thermal oxidizers
- Catalytic oxidizers
- Biofilters
- Absorption (scrubbing)
- Cryogenic condensers
- Vapor recovery systems

Acid Gas/SO2 control

- Wet scrubbers
- Dry scrubbers
- Flue gas desulfurization

Mercury control

- Sorbent Injection Technology
- Electro-Catalytic Oxidation (ECO)
- K-Fuel

Dioxin and furan control

Miscellaneous associated equipment

- Source capturing systems
- Continuous emissions monitoring systems (CEMS)

In general, there are two types of air quality standards. The first class of standards (such as the U.S. National Ambient Air Quality Standards) set maximum atmospheric concentrations for specific pollutants. Environmental agencies enact regulations which are intended to result in attainment of these target levels. The second class (such as the North American Air Quality Index) take the form of a scale with various thresholds, which is used to communicate to the public the relative risk of outdoor activity. The scale may or may not distinguish between different pollutants.

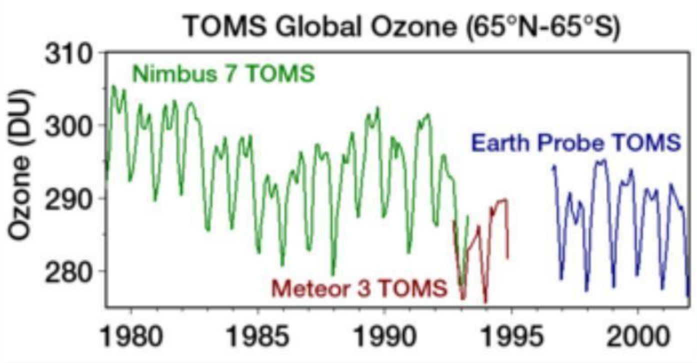
Ozone layer depletion

Ozone depletion describes two distinct, but related observations: a slow, steady decline of about 4% per decade in the total volume of ozone in Earth's stratosphere (ozone layer) since the late 1970s, and a much larger, but seasonal, decrease in stratospheric ozone over Earth's polar regions during the same period. The latter phenomenon is commonly referred to as the **ozone hole**. In addition to this well-known stratospheric ozone depletion, there are also tropospheric ozone depletion events, which occur near the surface in Polar Regions during spring.

The detailed mechanism by which the polar ozone holes form is different from that for the mid-latitude thinning, but the most important process in both trends is catalytic destruction of ozone by atomic chlorine and bromine. The main source of these halogen atoms in the stratosphere is photodissociation of chlorofluorocarbon (CFC) compounds, commonly called freons, and of bromofluorocarbon compounds known as halons. These compounds are transported into the stratosphere after being emitted at the surface. Both ozone depletion mechanisms strengthened as emissions of CFCs and halos increased.

CFCs and other contributory substances are commonly referred to as **ozone-depleting substances** (**ODS**). Since the ozone layer prevents most harmful UVB wavelengths (270–315 nm) of ultraviolet light (UV light) from passing through the Earth's atmosphere, observed and projected decreases in ozone have generated worldwide concern leading to adoption of the Montreal Protocol that bans the production of CFCs and halos as well as related ozone depleting chemicals such as carbon tetrachloride and trichloroethane. It is suspected that a variety of biological consequences such as increases in skin cancer, cataracts, damage to plants, and reduction of plankton populations in the ocean's photic zone may result from the increased UV exposure due to ozone depletion.

Three forms (or allotropes) of oxygen are involved in the ozone-oxygen cycle: oxygen atoms (O or atomic oxygen), oxygen gas (O_2 or diatomic oxygen), and ozone gas (O_3 or triatomic oxygen). Ozone is formed in the stratosphere when oxygen molecules photo dissociate after absorbing an ultraviolet photon whose wavelength is shorter than 240 nm. This produces two oxygen atoms. The atomic oxygen then combines with O_2 to create O_3. Ozone molecules absorb UV light between 310 and 200 nm, following which ozone splits into a molecule of O_2 and an oxygen atom. The oxygen atom then joins up with an oxygen molecule to regenerate ozone. This is a continuing process which terminates when an oxygen atom "recombines" with an ozone molecule to make two O_2 molecules: $O + O_3 \rightarrow 2\,O_2$



Global monthly average total ozone amount.

The **greenhouse effect** is the heating of the surface of a planet or moon due to the presence of an atmosphere containing gases that absorb and emit infrared radiation. Thus, greenhouse gases trap heat within the surface-troposphere system. This mechanism is fundamentally different from that of an actual greenhouse, which works by isolating warm air inside the structure so that heat is not lost by convection. The greenhouse effect was discovered by Joseph Fourier in 1824, first reliably experimented on by John Tyndall in 1858, and first reported quantitatively by Svante Arrhenius in 1896.

The black body temperature of the Earth is 5.5 °C. Since the Earth's surface reflects about 28% of incoming sunlight, the planet's mean temperature would be far lower - about -18 or -19 °C - in the absence of the effect. Because of the effect, it is instead much higher at about 14 °C.

Global warming, a recent warming of the Earth's surface and lower atmosphere, is believed to be the result of an "enhanced greenhouse effect" mostly due to human-produced increases in atmospheric greenhouse gases. This human induced part is referred to as *anthropogenic global warming* (AGW).

The Earth receives energy from the Sun mostly in the form of visible light and nearby wavelengths. About 50% of the sun's energy is absorbed at the Earth's surface. Like all bodies with a temperature above absolute zero the Earth's surface radiates energy in the infrared range. Greenhouse gases in the atmosphere absorb most of the infrared radiation emitted by the surface and pass the absorbed heat to other atmospheric gases through molecular collisions. The greenhouse gases also radiate in the infrared range. Radiation is emitted both upward, with part escaping to space, and downward toward Earth's surface. The surface and lower atmosphere are warmed by the part of the energy that is radiated downward, making our life on earth possible.

Greenhouse gases

In order of volume, Earth's most abundant greenhouse gases are:

water vapour
carbon dioxide
methane
nitrous oxide
ozone
CFCs

By their percentage contribution to the greenhouse effect the four major gases are:

water vapour, 36–70%
carbon dioxide, 9–26%
methane, 4–9%
ozone, 3–7%

The major non-gas contributor to the Earth's greenhouse effect, clouds, also absorb and emit infrared radiation and thus have an effect on radioactive properties of the atmosphere.

The overall amount of ozone in the stratosphere is determined by a balance between photochemical production and recombination.

Ozone can be destroyed by a number of free radical catalysts, the most important of which are the hydroxyl radical (OH·), the nitric oxide radical (NO·), atomic chlorine (Cl·) and bromine (Br·). All of these have both natural and manmade sources; at the present time, most of the OH· and NO· in the stratosphere is of natural origin, but human activity has dramatically increased the levels of chlorine and bromine. These elements are found in certain stable organic compounds, especially chlorofluorocarbons (CFCs), which may find their way to the stratosphere without being destroyed in the troposphere due to their low reactivity. Once in the stratosphere, the Cl and Br atoms are liberated from the parent compounds by the action of ultraviolet light, e.g. ('h' is Planck's constant, 'ν' is frequency of electromagnetic radiation)

$CFCl3 + h\nu \rightarrow CFCl2 + Cl$

The Cl and Br atoms can then destroy ozone molecules through a variety of catalytic cycles. In the simplest example of such a cycle, a chlorine atom reacts with an ozone molecule, taking an oxygen atom with it (forming ClO) and leaving a normal oxygen molecule. The chlorine monoxide (i.e., the ClO) can react with a second molecule of ozone (i.e., O3) to yield another chlorine atom and two molecules of oxygen. The chemical shorthand for these gas-phase reactions is:

$Cl + O3 \rightarrow ClO + O2$

$ClO + O3 \rightarrow Cl + 2 O2$

The overall effect is a decrease in the amount of ozone. More complicated mechanisms have been discovered that lead to ozone destruction in the lower stratosphere as well.

A single chlorine atom would keep on destroying ozone (thus a catalyst) for up to two years (the time scale for transport back down to the troposphere) were it not for reactions that remove them from this cycle by forming reservoir species such as hydrogen chloride (HCl) and chlorine nitrate (ClONO2). On a per atom basis, bromine is even more efficient than chlorine at destroying ozone, but there is much less bromine in the atmosphere at present. As a result, both chlorine and bromine contribute significantly to the overall ozone depletion. Laboratory studies have shown that fluorine and iodine atoms participate in analogous catalytic cycles. However, in the Earth's stratosphere, fluorine atoms react rapidly with water and methane to form strongly-bound HF, while organic molecules which contain iodine react so rapidly in the lower atmosphere that they do not reach the stratosphere in significant quantities. Furthermore, a single chlorine atom is able to react with 100,000 ozone molecules. This fact plus the amount of chlorine released into the atmosphere by chlorofluorocarbons (CFCs) yearly demonstrates how dangerous CFCs are to the environment.

3. Water Pollution :

3.1 Classification of Water

Ground Water

1. Little suspended materials
2. Less chances of contemination
3. Less hardness
4. Chances of greater concentration of objectionable dissolved gases

Surface Water

1. High concentration of suspended materials
2. Greater chances of pollution
3. Greater chances of hardness
4. Objectionable dissolves gas, depending on the type of water resources.

3.2 Pollutants of Water, their origin and effects:

Oxygen demanding wastes:

One of the most important measures of water quality is the amount of dissolved oxygen (DO) present in it. The saturated value of DO in water is in the order of 8 to 15 mg/l. Optimum DO required for healthy fish and other aquatic life in natural water is 5 to 8 mg/l. If do drops, fish and other aquatic life is threatened and in extreme cases, killed.

The bacterial decomposition of organic wastes in the presence of dissolved oxygen (DO) can be represented as:

$$\text{Organic matter} + \text{DO } (O_2) \xrightarrow{bacteria} CO_2 + H_2O$$

Pathogens :

It is an organic **pollution** (biological hazard) and occurs from fecal contaminations. Fecal contaminations of **water** can introduce a variety of**pathogens** into waterways, including bacteria, viruses, protozoa and parasitic worms. A very well known **pathogenic** bacteria is Salmonella.

Nutrients:

Nutrient pollution is the process where too many **nutrients**, mainly nitrogen and phosphorus, are added to bodies of **water** and can act like fertilizer, causing excessive growth of algae. **Nutrients** can run off of land in urban areas where lawn fertilizers are used.

The phosphorus from chemical fertilizers as well as detergents helps algae growth, resulting in enormous blooms. In detergents, the phosphates are in the form of tri polyphosphate. This tri polyphosphate slowly reacts with water forming orthophosphate and is used by plants for their growth.

$$P_3O_{10}^{\;5-} + 2H_2O \rightarrow 3PO_4^{\;3-} + 4H^+$$

Salts :

Water is taken up by the fine roots of plants through the process of osmosis, which involves the movement of water from regions of low salt concentration (such as the soil) to regions of high salt concentration (such as the inside of root cells). When salt concentrations in the soil are high, the movement of water from the soil to the root is slowed down. When the salt concentrations in the soil are higher than inside the root cells, the soil will draw water from the root, and the plant will wilt and die. This is the basic way in which sanitization affects plant production.

The damaging effects of salt on plants are caused not only by osmotic forces, but also by toxic levels of sodium and chloride. Fruit crops and woody ornamentals are especially sensitive to high levels of these elements. Also, the high pH value (a measure of the acid/alkaline balance) caused by excess sodium may result in micronutrient deficiencies.

Drinking water has the recommended maximum TDS concentration of 500 mg/l. With concentration of TDS exceeding 2100 mg/l, irrigation becomes difficult.

Heavy Metals :

Environmental pollution from hazardous metals and minerals can arise from naturalas well as anthropogenic sources. Natural sources are: seepage from rocks into water, volcanic activity, forest fires etc. Pollution also arises from partitioning of polluting elements (which are concentrated in clay minerals with high absorption capacities),between sedimentary rocks and their precursor sediments and water. With rapid industrialization and consumerist life style, sources of environmental pollution have increased. The pollution occurs both at the level of industrial production as well as end use of the products and run-off. These toxic elements enter the human body mostly through food and water and to a lesser extent through inhalation of polluted air, use of cosmetics, drugs, poor quality herbal formulations‘(herbo-mineral preparations) and `Unani’ formulations, and even items like toys which have paints containing lead.

Sources of heavy metals Chromium (Cr)-Mining, industrial coolants, chromium salts manufacturing, leather tanning

- Lead (Pb) lead acid batteries, paints, E-waste, Smelting operations, coal- based thermal power plants, ceramics, bangle industry
- Mercury (Hg) Chlor-alkali plants, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers, sphygmomanometers), electrical appliances etc.
- Arsenic (As) Geogenic/natural processes, smelting operations, thermal power plants, fuel
- Copper (Cu) Mining, electroplating, smelting operations
- Vanadium (Va) Spent catalyst, sulphuric acid plant
- Nickel (Ni) Smelting operations, thermal power plants, battery industry Recent Research in Science and Technology
- Cadmium (Cd) Zinc smelting, waste batteries, e-waste, paint sludge, incinerations & fuel combustion • Molybdenum (Mo) Spent catalyst
- Zinc (Zn) Smelting, electroplating

One group of factors that may be detrimental to all organisms within urban ecosystems is metal contaminants, such as lead, zinc, copper, cadmium, mercury, nickel, and iron, that get deposited in soil. Metal contaminants are introduced into food webs at the bottom of the food chain and reach earthworms and other invertebrates that live in the soil. When consumed by organisms such as birds and snakes, the contaminants and their potential toxic effects accumulate within sensitive organs and tissues.

Pesticides:

Chemicals which prevent, destroy or mitigate any pest (insects fungus, bacteria, viruses, etc) are called pesticides. Pesticides are classified on the basis of (i) chemical structure (ii) biological action (iii) class of pests they combat.

TABLE : **Chronology of pesticide development**

Period	Example	Source	Characteristics
1800-1920	Early organics, nitro-phenols, chlorophenols, creosote, naphthalene, petroleum oils	Organic chemistry, by-products of coal gas production, etc.	Often lack specificity and were toxic to user or non-target organisms
1945-1955	Chlorinated organics, DDT, HCCH, chlorinated cyclodienes	Organic synthesis	Persistent, good selectivity, good agricultural properties, good public health performance, resistance, harmful ecological effects
1945-1970	Cholinesterase inhibitors, organophosphorus compounds, carbamates	Organic synthesis, good use of structure-activity relationships	Lower persistence, some user toxicity, some environmental problems
1970-1985	Synthetic pyrethroids, avermectins, juvenile hormone mimics, biological pesticides	Refinement of structure activity relationships, new target systems	Some lack of selectivity, resistance, costs and variable persistence
1985-	Genetically engineered organisms	Transfer of genes for biological pesticides to other organisms and into beneficial plants and animals. Genetic alteration of plants to resist non-target effects of pesticides	Possible problems with mutations and escapes, disruption of microbiological ecology, monopoly on products

The impact on water quality by pesticides is associated with the following factors:

- Active ingredient in the pesticide formulation.
- Contaminants that exist as impurities in the active ingredient.
- Additives that are mixed with the active ingredient (wetting agents, diluents or solvents, extenders, adhesives, buffers, preservatives and emulsifiers).
- Degradate that is formed during chemical, microbial or photochemical degradation of the active ingredient.

Volatile organic compounds :

Volatile Organic Chemicals (VOCs) are carbon-containing compounds that evaporate easily from water into air at normal air temperatures. (This is why the distinctive odor of gasoline and many solvents can easily be detected.) VOCs are contained in a wide variety of commercial, industrial and residential products including fuel oils, gasoline, solvents, cleaners and degreasers, paints, inks, dyes, refrigerants and pesticides.

People are most commonly exposed to VOCs through the air, in food, through skin contact, and potentially in drinking water supplies.

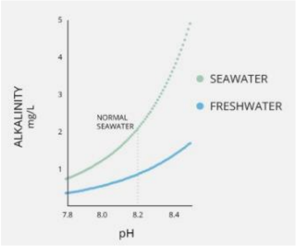
Most VOCs found in the environment result from human activity. When VOCs are spilled or improperly disposed of, a portion will evaporate, but some will soak into the ground. In soil, VOCs may be carried deeper by rain, water or snow melt and eventually reach the groundwater table. When VOCs migrate underground to nearby wells, they can eventually end up in drinking water supplies.

3.3 Surface water quality parameters:

P^{H}

pH is a determined value based on a defined scale, similar to temperature. This means that pH of water is not a physical parameter that can be measured as a concentration or in a quantity. Instead, it is a figure between 0 and 14 defining how acidic or basic a body of water is along a logarithmic scale. The lower the number, the more acidic the water is. The higher the number, the more basic it is. A pH of 7 is considered neutral. The logarithmic scale means that each number below 7 is 10 times more acidic than the previous number when counting down. Likewise, when counting up above 7, each number is 10 times more basic than the previous number.

Alkalinity does not refer to alkalis as alkaline does . While alkalinity and pH are closely related, there are distinct differences. The alkalinity of water or a solution is the quantitative capacity of that solution to buffer or neutralize an acid. In other words, alkalinity is a measurement of water's ability to resist changes in pH. This term is used interchangeably with acid-neutralizing capacity (ANC) . If a body of water has a high alkalinity, it can limit pH changes due to acid rain, pollution or other factors. The alkalinity of a stream or other body of water is increased by carbonate-rich soils (carbonates and bicarbonates) such as limestone, and decreased by sewage outflow and aerobic respiration. Due to the presence of carbonates, alkalinity is more closely related to hardness than to pH (though there are still distinct differences). However, changes in pH can also affect alkalinity levels (as pH lowers, the buffering capacity of water lowers as well). pH and alkalinity are directly related when water is at 100% air saturation.



The alkalinity of water also plays an important role in daily pH levels. The process of photosynthesis by algae and plants uses hydrogen, thus increasing pH levels. Likewise, respiration and decomposition can lower pH levels. Most bodies of water are able to buffer these changes due to their alkalinity, so small or localized fluctuations are quickly modified and may be difficult to detect.

DO

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In limnology (the study of lakes), dissolved oxygen is an essential factor second only to water itself. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality.

Non-compound oxygen, or free oxygen (O_2), is oxygen that is not bonded to any other element. Dissolved oxygen is the presence of these free O_2 molecules within water .The bonded oxygen molecule in water (H_2O) is in a compound and does not count toward dissolved oxygen levels. One can imagine that free oxygen molecules dissolve in water much the way salt or sugar does when it is stirred.

5 Day BOD Test :

1. Determine the amount of sample to be analyzed; if available, use the historical results of a previous test of BOD5 for a particular sampling site, and refer to table 7.0-2.

2. Place a clean, calibrated thermometer into the constant temperature chamber. (See NFM 6.1 for thermometer care and calibration.)

3. Turn on the constant temperature chamber to allow the controlled temperature to stabilize at 20°C ±1°C.
4. Turn on the DO instrument, but not the stirring attachment. Some DO instruments need to be turned on 30 to 60 minutes before calibration—check the manufacturer's instruction manual.

5. Aerate dilution water before adding nutrient solutions.

6. After aeration, a. Add to dilution water
- 1 mL each of the potassium phosphate, magnesium sulfate, calcium chloride, and ferric chloride solutions per 1 L of dilution water, or
- Hach Company nutrient buffer pillows to a selected volume of dilution water per the manufacturer's recommendation. b. Shake the container of dilution water for about 1 minute to dissolve the slurry and to saturate the water with oxygen. c. Place the dilution water in the constant temperature chamber to maintain a temperature of 20°C until sample dilutions and analyses begin. d. The initial and final (after 5 days ± 4 hours) DO tests of the dilution water is determined and recorded simultaneously with each batch of environmental samples.

7. Check the temperature of the air incubator or water bath using a laboratory thermometer to ensure that the temperature has been maintained at 20° ± 1°C. A minimum/maximum recording thermometer can be used to audit the temperature during times when checks cannot be made.

8. Place the sample container in the constant-temperature chamber or water bath to begin warming the sample to 20°C ± 1°C. While the sample is warming, insert the air diffusion stone into the container and aerate the sample for about 15 minutes. After removing the air diffusion stone, allow several minutes for excess air bubbles to dissipate. The initial DO of the BOD sample needs to be at or slightly below saturation.

9. Prepare dilutions as required—Measure the appropriate amounts of sample necessary for the analysis. BOD5 dilutions should result in a DO residual of at least 1 mg/L and a DO depletion of at least 2 mg/L after a 5-day incubation to produce the most reliable results. Prepare the dilutions to obtain a DO uptake in this range using the dilution water prepared earlier.
a. For each subsample, mix thoroughly by inverting 20 times.
- Use a large-bore pipet for sample volumes less than 50 mL. Withdraw a subsample that is representative of all the particle sizes present.

- Use a graduated cylinder for sample volumes greater than or equal to 50 mL.

b. Dilute two additional samples to bracket the appropriate dilution by a factor of two to three. Prepare at least three samples diluted according to volumes specified in table 7.0-2.
c. Pour the sample from the pipet or graduated cylinder into a clean BOD bottle.
- Agitate the dilution water and fill the remaining portion of the BOD bottle with dilution water.
- Prepare three samples containing only dilution water. These samples serve as blanks for quality control. If two of the three samples meet the blank-water criterion, accept the data.

10. Calibrate the DO instrument in accordance with the procedures outlined in NFM 6.2.

11. After bringing the samples to saturation and preparing the dilutions (steps 8 and 9 above), measure the initial DO concentration (D1) of each sample and each dilution blank.
a. Carefully insert the self-stirring sensor into the BOD bottle, avoiding air entrapment.
b. Turn on the stirrer and allow 1 to 2 minutes for the DO and temperature readings to stabilize.

12. Record the bottle number, date, time, and D1 on a form similar to that shown in figure 7.0-2.

13. Turn off the stirrer and remove the sensor from the BOD bottle. Rinse the sensor and stirrer with deionized water from a wash bottle. Discard rinse water into a waste container.

14. Add glass beads to the BOD bottle, if necessary, to displace the sample up to the neck of the bottle so that inserting a glass stopper will displace all air, leaving no bubbles.
15. Carefully cap the BOD bottle with the ground-glass stopper. Tip the bottle to one side and check for an air bubble.
- If an air bubble is present, add glass beads to the bottle until the bubble is removed. Cap the bottle and check again for an air bubble. Repeat if necessary.
- If no bubble is present in the sample, create a water seal by adding distilled or deionized water to the top of the BOD bottle around the glass stopper. Then place the overcap over the stopper on the BOD bottle to minimize evaporation from the water seal.

16. Place the sealed BOD sample in the air incubator or water bath and incubate the sample at 20°C ± 1°C for 5 days.

17. At the end of 5 days ± 4 hours, remove the BOD bottles from the incubator, remove the overcap, pour off the water seal, remove the ground-glass stopper, and measure the final DO concentration (D2).
- The DO uptake (DO0 days - DO5 days) in the dilution water should not be greater than 0.2 mg/L and preferably not more than 0.1 mg/L. Exceeding the 0.2-mg/L criterion could be grounds for rejecting results of the BOD analysis of the environmental sample.
- Dilution water of poor quality will cause an oxygen demand and appear as sample BOD. Improve purification or get the dilution water from another source if DO uptake exceeds 0.2 mg/L (see section 7.0.5, Troubleshooting).

18. Complete the field form by recording the date, time, and D2 for each respective sample bottle (fig. 7.0-2). Quality control. The BOD5 test can be quite variable. Collect sufficient field and split replicates (10 to 20 percent) to provide an estimate of method variability.

Calculation : The general equation for the determination of a BOD5 value is:

$$BOD_5 \text{ (mg/L)} = \frac{D1-D2}{P}$$

where D1 = initial DO of the sample,
D2 = final DO of the sample after 5 days, and
P = decimal volumetric fraction of sample used.

If 100 mL of sample are diluted to 300 mL, then P = = 0.33. Notice that if no dilution was necessary, P = 1.0 and the BOD5 is determined by D_1 - D_2.

If more than one dilution of the sample results in residual DO of at least 1 mg/L and a DO depletion of at least 2 mg/L, and there is no evidence of toxicity at higher sample concentrations or the existence of an obvious anomaly, average the results that are in the acceptable range.

BOD Reaction rate Constants:

The reactions occur in the BOD bottle as well as in the streams are very complicated it could be a first order, or half order, or second order reaction. It could be a mixture of these reactions. However, the reaction will be considered here as a first order reaction, so the equation is:

$$y = L\ (1- e^{-kt})$$

Where: y = the BOD consumed (mg/L)
L = the ultimate first stage BOD (mg/L)
k = the rate constant (t -1) to the base e
t = time in days

Under this condition, k is the reaction rate co-efficient to the base 10. It can be shown that

$$k = K\ ln 10 = 2.303K.$$

COD :

During COD determination total organic content of the waste is oxidized by dichromate in acid solution.

- In this test to determine the oxygen requirement of the wastewater, strong oxidizing agent ‘potassium dichromate’ is used.
- Acidic environment is provided to accelerate the reactions by addition of sulphuric acid.
- The reflux flasks (closed reflux vials), used for the test, are heated to 150o C for two hours with silver sulphate as catalyst. When silver sulphate catalyst is used, the recovery of most organic compounds is greater than 92 percent.
- COD test measures virtually all oxidizable organic compounds whether biodegradable or not, except some aromatic compounds which resists dichromate oxidation.
- The COD is proportional to BOD only for readily assimilable organic matter in dissolved form e.g. sugars.

Numerical related to BOD

- No correlation between BOD and COD exists when: o Organic matter is present in suspended form, under such situation filtered samples should be used. o Complex wastewater containing refractory substances.
- For readily biodegradable waste, such as dairy COD = BODu/0.92

Eutrophication :

Definition : *“Eutrophication is an enrichment of water by nutrient salts that causes structural changes to the ecosystem such as: increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and preclude use”.*

Effect :

- abundance of particulate substances (phytoplankton, zooplankton, bacteria, fungi and debris) that determine the turbidity and coloration of the water;

- abundance of inorganic chemicals such ammonia, nitrites, hydrogen sulphide etc. that in the drinking water treatment plants induce the formation of harmful substances such as nitrosamines suspected of mutagen city;

- abundance of organic substances that give the water disagreeable odours or tastes, barely masked by chlorination in the case of drinking water. These substances, moreover, form complex chemical compounds that prevent normal purification processes and are deposited on the walls of the water purifier inlet tubes, accelerating corrosion and limiting the flow rate;

Control :

- improvement of the purifying performance of waste water treatment plants, installing tertiary treatment systems to reduce nutrient concentrations;
- implementation of effective filter ecosystems to remove nitrogen and phosphorus present in the run-off water (such as phyto-purification plants);
- reduction of phosphorous in detergents;
- rationalization of agricultural techniques through proper planning of fertilisation and use of slow release fertilizers;
- Use of alternative practices in animal husbandry to limit the production of waste water.

3.4 : Ground Water :

Aquifers :

Groundwater is one of our most valuable resource—even though you probably never see it or even realize it is there. As you may have read, most of the void spaces in the rocks below the water table are filled with water. But rocks have different porosity and permeability characteristics, which means that water does not move around the same way in all rocks below ground.

When a water-bearing rock readily transmits water to wells and springs, it is called an aquifer. Wells can be drilled into the aquifers and water can be pumped out. Precipitation eventually adds water (recharge) into the porous rock of the aquifer. The rate of recharge is not the same for all aquifers, though, and that must be considered when pumping water from a well. Pumping too much water too fast draws down the water in the aquifer and eventually causes a well to yield less and less water and even run dry. In fact, pumping your well too much can even cause your neighbor's well to run dry if you both are pumping from the same aquifer.

Hydraulic Gradient:

Hydraulic head or **piezometric head** is a specific measurement of liquid pressure above a geodetic datum.

It is usually measured as a liquid surface elevation, expressed in units of length, at the entrance (or bottom) of a piezometer. In an aquifer, it can be calculated from the depth to water in a piezometric well (a specialized water well), and given information of the piezometer's elevation and screen depth. Hydraulic head can similarly be measured in a column of water using a standpipe piezometer by measuring the height of the water surface in the tube relative to a common datum. The hydraulic head can be used to determine a *hydraulic gradient* between two or more points.

Ground Water Flow Definition :

Groundwater is a part of the **water cycle**. Some part of the precipitation that lands on the ground surface infiltrates into the subsurface. The part that continues downward through the soil until it reaches rock material that is saturated is **groundwater** recharge

Arsenic Pollution in water:

Arsenic is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land. It is highly toxic in its inorganic form.

People are exposed to elevated levels of inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food and smoking tobacco.

Long-term exposure to inorganic arsenic, mainly through drinking of contaminated water, eating of food prepared with this water and eating food irrigated with arsenic-rich water, can lead to chronic arsenic poisoning. Skin lesions and skin cancer are the most characteristic effects.

Health effects

Arsenic occurs in inorganic and organic forms. Inorganic arsenic compounds (such as those found in water) are highly toxic while organic arsenic compounds (such as those found in seafood) are less harmful to health.

Acute effects

The immediate symptoms of acute arsenic poisoning include vomiting, abdominal pain and diarrhoea. These are followed by numbness and tingling of the extremities, muscle cramping and death, in extreme cases.

Long-term effects

The first symptoms of long-term exposure to high levels of inorganic arsenic (e.g. through drinking-water and food) are usually observed in the skin, and include pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis). These occur after a minimum exposure of approximately five years and may be a precursor to skin cancer.
In addition to skin cancer, long-term exposure to arsenic may also cause cancers of the bladder and lungs. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans, and has also stated that arsenic in drinking-water is carcinogenic to humans.

Other adverse health effects that may be associated with long-term ingestion of inorganic arsenic include developmental effects, neurotoxicity, diabetes, pulmonary disease and cardiovascular disease. Arsenic-induced myocardial infarction, in particular, can be a significant cause of excess mortality. In China (Province of Taiwan), arsenic exposure has been linked to "blackfoot disease", which is a severe disease of blood vessels leading to gangrene. This disease has not been observed in other parts of the world however, and it is possible that malnutrition contributes to its development.

Arsenic is also associated with adverse pregnancy outcomes and infant mortality, with impacts on child health[1], and there is some evidence of negative impacts on cognitive development.

Control :

The most important action in affected communities is the prevention of further exposure to arsenic by the provision of a safe water supply for drinking, food preparation and irrigation of food crops. There are a number of options to reduce levels of arsenic in drinking-water.

- Substitute high-arsenic sources, such as groundwater, with low-arsenic, microbiologically safe sources such as rain water and treated surface water. Low-arsenic water can be used for drinking, cooking and irrigation purposes, whereas high-arsenic water can be used for other purposes such as bathing and washing clothes.
- Discriminate between high-arsenic and low-arsenic sources. For example, test water for arsenic levels and paint tube wells or hand pumps different colours. This can be an effective and low-cost means to rapidly reduce exposure to arsenic when accompanied by effective education.
- Blend low-arsenic water with higher-arsenic water to achieve an acceptable arsenic concentration level.

Fluoride Pollution in Water :

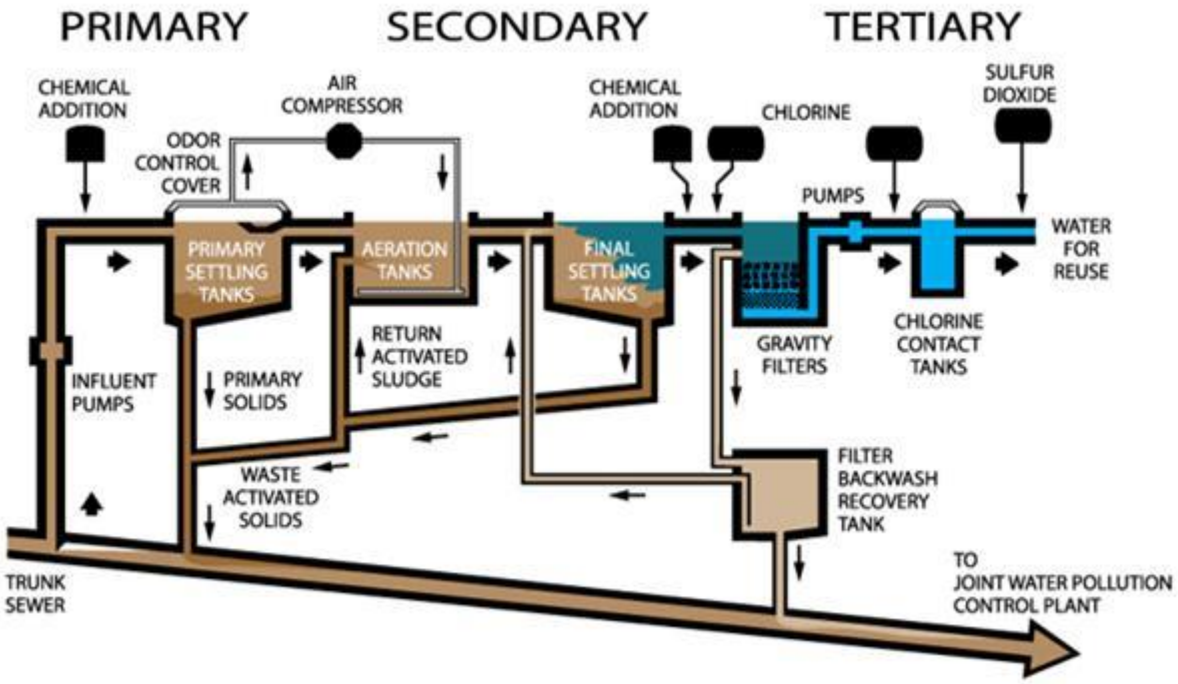
The major minerals of fluoride found in hardrock are fluorite, appatite, cryolite etc. It is not only the presence of minerals, but also the hydrogeological conditions contribute more towards the mobilization of fluoride in groundwater. Alkaline groundwaters generally tend to solublize fluoride minerals. Fluoride rich groundwaters generally have more Mg than Ca. Salinity buildup due to extensive irrigation also contribute to fluoride in ground water e.g. Haryana, Punjab. States such as AP, Tamil nadu, karnataka, UP, WB, the occurance of high fluordie is due to prevaliing hydrogeological conditions.

Anthropogenic sources contributing to fluoride are mainly mining activities, phosphate fertilizer effluents. Globally, fluoride in groundwater is mostly due to geogenic in nature.

Over 100 animal studies showing that prolonged exposure to varying levels of**fluoride** can damage the **brain**, particularly when coupled with an iodine deficiency, or aluminum excess; ... 3 human studies linking **fluoride** exposure with impaired fetal **brain** development.

3.5 Quality of Boiler fed water: DO, hardness, alkalinity, TDS and Chloride

3.7 Layout of waste water treatment plant (scheme only).


PRIMARY
SECONDARY
TERTIARY
CHEMICAL ADDITION
AIR COMPRESSOR
ODOR CONTROL COVER
CHEMICAL ADDITION
CHLORINE
SULFUR DIOXIDE
PUMPS
WATER FOR REUSE
PRIMARY SETTLING TANKS
AERATION TANKS
FINAL SETTLING TANKS
GRAVITY FILTERS
CHLORINE CONTACT TANKS
RETURN ACTIVATED SLUDGE
INFLUENT PUMPS
PRIMARY SOLIDS
WASTE ACTIVATED SOLIDS
FILTER BACKWASH RECOVERY TANK
TRUNK SEWER
TO JOINT WATER POLLUTION CONTROL PLANT

4. Land Pollution

Land pollution is defines as the deterioration (destruction) of the earth's land surfaces, often directly or indirectly as a result of man's activities and their misuse of land resources. It is the introduction of some substances into the environment that don't normally belong there, which, in great concentrations, can have harmful effects on plants, animals, and humans.

4.1 Solid Waste

Materials which are mainly generated through anthropogenic activities and are discarded as useless or unwanted are called solid wastes.

Types of Solid Waste

Solid wastes are generally of the following types:

1. **Municipal solid wastes (MSW):**

These are generally the non-hazardous solid wastes from a city, town or village which are collected and transported for recycling and for disposal.

2. **Industrial solid wastes:**

These are the wastes that are generated from the industries. They can be organic or inorganic depending on its nature. They may be biodegradable or non-biodegradable. They are generally discharged from chemical industries, oil refineries, textile industries, drug industries, etc.

3. **Commercial solid wastes:**

These wastes are generated from commercial places like markets, shops, godowns and departmental stores. These include discarded goods, packing materials, papers, glass, ceramics, plastic, vegetable and fish remains.

4. **Agricultural solid wastes:**

They generally consists of roots and stems of crops, stalk, hay, animal dung and the remains of pesticides, herbicides and insecticides.

5. **Domestic solid wastes:**

These wastes are generated from household preparation and sweeping. The common ingredients are old paper, plastic, cloth, bottles, crockery wastes, vegetable wastes, etc.

6. **Bio-medical wastes:**

These are generated from hospitals, nursing homes, clinics, etc. These include disposable syringes, used surgical dressings, expired drugs, etc which can be highly contaminated and should be treated with great care.

7. **E-wastes:**

E-Waste may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal.

4.2 Methods of solid waste disposal:

There are several methods for disposal of solid wastes. These include:

1. **Open-dumping:** An open dumping is defined as a land disposal site at which solid wastes are disposed of in a manner that does not protect the environment, are susceptible to open burning, and are exposed to the elements, vectors, and scavengers. Open dumping can include solid waste disposal facilities or practices that pose a reasonable probability of adverse effects on health or the environment.

   Advantage:
   - Dumping is easy and cheap.
   - Requires less capital and less labour.

   Disadvantage:
   - It does not protect the environment.,
   - The waste materials cause foul smell.
   -]The wastes are susceptible to the disease spreading organisms like flies, mosquitoes, rodents, etc.

2. **Landfill:** A landfill site is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world.Some landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). A landfill is carefully designed structure built into or on top of the ground, in which trash is separated from the area around it. Landfills contain garbage and serve to prevent contamination between the waste and the surrounding environment, especially groundwater.

   Sanitary landfills are sites where waste is isolated from the environment until it is safe. It is considered when it has completely degraded biologically, chemically and physically. Sanitary landfills work by layering waste and soil in a large hole in the ground that is lined with plastic and clay. The waste is allowed to decompose and the linings help prevent contamination. When landfills are full, they are often capped and transformed into parks or natural areas.

   Advantage:
   - Air pollution is prevented to a large extent.
   - Disease spreading organisms like flies, mosquitoes, rodents, etc. cannot come in direct contact with the wastes and hence spreading of diseases can be minimized.
   - A specific location for disposal that can be monitored, where waste can be processed to remove all recyclable materials before tipping.
   - Landfills have fewer costs, allowing them to compete favorably with other disposal methods.

   Disadvantage:
   - Ground water pollution is the main problem.

3. **Incineration:** It is a waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas and heat. The ash is mostly formed by

the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. In some cases, the heat generated by incineration can be used to generate electric power. Incinerators reduce the solid mass of the original waste by 80–85% and the volume by 95–96%, depending on composition and degree of recovery of materials such as metals from the ash for recycling. Incineration has particularly strong benefits for the treatment of certain waste types in niche areas such as clinical wastes and certain hazardous wastes where pathogens and toxins can be destroyed by high temperatures.

There are three types of incineration:

- Rotary kiln.
- Open pit incinerators.
- Controlled-air incinerators.

Advantage:

- Utilization of energy generated through oxidation reaction.
- Reduction of amount of waste.

Disadvantage:

- Expensive to build, operate, and maintain
- Smoke and ash emitted by the chimneys include gases, heavy metals, particulates,

4. **Composting:** Composting is a form of waste disposal where organic waste decomposes naturally under oxygen-rich conditions. Although all waste will eventually decompose, only certain waste items are considered compostable and should be added to compost containers. Food waste, such as banana peels, coffee grinds and eggshells, are great items to compost.

Advantage:

- Foul smell is eliminated.
- Flies and mosquitoes cannot breed.
- Harmful pathogens are killed.
- Maximum nutrient(N, P, K) is obtained in usable form.
- Excessive use of chemical fertilizer is reduced.

Disadvantage:

- Its dirty and can be smelly too depending on the type of materials used.

5. **Recycling:** Recycling is the process of converting waste materials into new materials and objects. It is an alternative to "conventional" waste disposal that can save material and help lower greenhouse gas emissions. Recycling can prevent the waste of potentially useful materials and reduce the consumption of fresh raw materials, thereby reducing: energy usage, air pollution and water pollution.

Advantage:

- Recycling minimizes pollution.
- Protects the environment.
- Conserves natural resources.
- Ensures sustainable use of resources.
- Reduces energy consumption

Disadvantage:

- Recycling sites are always unhygienic and unsafe.
- Products recycled from wastes may not be durable.
- Recycling is not widespread on a large scale.
- Recycling might not be inexpensive.

5. Noise Pollution 2L

5.2 Average Noise level of some common noise sources

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5. Noise Pollution

5.1 Definition of noise, effect of noise pollution on human health

Noise is an unwanted, irregular, unpleasant and annoying sound, ie., sound with no musical quality. The definition however, is subjective, because one man's sound may be another man's noise. Thus, noise can be defined as 'wrong sound, in the wrong place, at the wrong time'. However, it is always true that if the sound is loud and it prolongs for a longer period of time, it becomes noise for all.

Noise pollution can be defined as the unwanted sound dumped into the environment, without considering the adverse effects it may have in relation to physical and mental health, displeasing effect, human communication, etc.

Effects of noise pollution:

- A sound of 65(dBA) is the noise level for conversation heard at a distance of one meter. Sound of 110(dBA) gives discomfort and 135(dBA) is paiful and 150 (dBA) might kill a person.
- A sound level in the range of 110-150(dBA), affects respiratory system, cause of physical control and other physiological changes might occur.
- Loud sounds can cause an increased secretion of various hormones of the pituitary gland, leading to increase blood sugar level, reducing immune system capability, effecting liver, heart, brain and kidney.
- Noise affects mental capability, thereby reducing mind concentration. Noise causes chronic headache and irritability, thereby reduce work efficiency. Expose in high noise levels caused of deafness. The hearing loss starts in the frequency range of about 4000 Hz.

5.3 Definition of noise frequency, noise pressure, noise intensity, noise threshold limit value, equivalent noise level, L_{10} (18 hr Index) .

1. Noise Intensity: The unit of sound intensity is decibel (dB). Generally, the sound intensity from 0 to 100 dB is considered to be pleasant, but when the intensity exceeds 120 dB, it cause noise. Sound intensity of 130 dB is the upper limit of

hearing and beyond this is threshold of noise, causing pain to ear. The sound more than 130 dB causes noise pollution.

Two important parameters of sound are sound pressure and intensity. Common unit is decibel (dB), it is a ratio expressed in terms of logarithmic scale and is mathematically given as –

$$\text{Decibel (dB)} = 10 \log_{10} \frac{I\ (measured\ intensity)}{Io\ (reference\ intemsity)}$$

2. Noise Frequency(ν): The number of wave passing through a point in one second or number of oscillations per second is called frequency.
   SI unit is hertz or cycles/second.

3. Noise Pressure: Pressure is the force/unit area. Thus the sound waves creating pressure on the medium through which it propagates is measured in mewton/meter^2.

L_{10} (18 hours) Index:

It is the arithmetic average hourly values of the noise level exceeded for the 10% time over 18 hours between 06:00 and 24:00 hours on any normal week day. This scale is used to measure road noise in the UK.

Equivalent Noise Level (L_{eq}):

It is the weight average sound level over time of measurement and is represented as L_{eq} and given in dBA unit. The time of measurement is specific and measured for a short duration usually when the noise level is most prominent. If the measurement is done for different time duration the value will differ. If the measurement is done for a specific period of the time started at the same time but in different place, it may not be same. Equivalent noise accepted by International Organisation for Standarisation (ISO). L_{eq} is used for measurement of noise level in the industrial. traffic as well as residential areas.

Anthropogenic Noise:

1. The different types of anthropogenic noise are (1) transport noise (2) occupational noise (3) neighbourhood noise. The transport noise is sub-divided into three categories (a) Road traffic noise (b) Rail traffic noise (c) Aircraft noise.

Noise Threshold Limit Values:

When daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect needs to be considered rather than the individual effect of each. When the sum of following fractions

$$C_1/T_1 + C_2/T_2 + \ldots\ldots + C_n/T_n$$

exceeds unity, then the mixed exposure is consider to exceed the **threshold limit values**. C_n indicates the total duration of exposure permitted at that level and T_n indicates the total duration of exposure permitted at that level.

- Example: In a work area, the noise levels are read as 100(dBA) for 3 hours a day, 85(dBA) for 2 hrs. a day and 80(dBA) for remaining 3 hrs. a day. (The permissible exposures are 100(dBA)=1 hr., 85(dBA)=8 hrs. and 80(dBA)=16 hrs.)

Solution: The problem is to find out the permissible limit.
Given,

Noise levels (dBA)	100	85	80

Measured hours	3	2	3
Permissible (hrs.)	1	8	16

Hence,

3/1 + 2/8 + 3/16 = 3 + ¼ + 3/16 = 55/16 =$3\frac{7}{16}$

This exceeds the permissible limit of 1.

5.4 Noise pollution control

The noise generated in the Environment can never be eliminated completely, however , it can be controlled.

- Control at source: In the industrial establishment, it can be done by proper design, proper operation and regular maintenance of the machines.
- Control at path: The noise transmission path can be covered with such a material, that can absorb sound, can insulate sound. Sound absorbers are like- glass wool, porous panels, perforated panels, tiles, carpets, curtains etc.
- Control at receiver: For controlling the sound pollution, the personal protection also very important for safety of the workers. For such cases, ear protection and in extreme cases personal isolation will help a lot. The commonly used hearing protectors are ear plugs, ear muffs etc.
- Lastly plants are great absorbers of sound. Hence plantation along highways, streets and industrial areas should be done.