CHAPTER

1. Introduction to Environment

Earth provides enough to satisfy every man's needs, but not every man's greed.
– Mahatma Gandhi

1.1 ENVIRONMENT :

[Jan. 2010, April 2010, June 2010, June 2014, Jan. 2016]

The word **'environment'** is derived from the French word 'environ' means to encircle or surround.

The meaning of the word 'environment' is the surrounding of an organism. It is defined as the condition of air, water, land and other things surrounding us.

Environment includes air, water and land and their relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organisms and property.

[Jan. 2011, May 2012]

The environment has two parts :

1. Biotic part
2. Abiotic part

[Jan. 2016]

Biotic part :

Biotic part is made up of all living organisms which includes,

- Plants
- animals
- birds
- micro-organisms

Abiotic Part :

This part is also called **physical environment**. It is the non-living component of environment.

It includes,

- light, water, air
- temperature, humidity
- minerals, soil, etc.

"The biotic and abiotic components of an environment are together known as the **biome envirement**".

→ **Categories of Environment :**

The environment can be divided into two categories :

1. Natural environment
2. Man-made environment

1. Natural environment :

It is the environment gifted by God and is operated by self regulation mechanism.

The natural environment comprises of 4 spheres :

(i) Biosphere : Space occupied by life

(ii) Atmosphere : Space occupied by air

(iii) Lithosphere : Space occupied by solid

(iv) Hydrosphere : Space occupied by water

2. Man-made environment (Anthropogenic environment) :

It is the environment created by man through modifications in natural environment for fulfilling their needs.

It includes anthropogenic (human related) ecosystems - interactions among and between humans (socio - economic), other living organisms (biotic) and abiotic factors.

It also includes physical structures like :

- Dams, canals
- Roads
- Vehicles
- Power plants, industries
- buildings

1.1.1 ECOLOGY : [Jan. 2010, Nov. 2010, June 2016, Jan. 2017]

The term ecology is composed of two Greek words 'Oikos' means house or place of living and 'logos' means to study.

Ecology is the science which deals with the study of relationship of living organisms with eachother and with their nonliving environment.

Ecology can be defined in a number of ways as described below :

1. The scientific study of the interactions of the organisms with their physical environment and with eachother is called ecology. **- Helena Crutis**
2. Ecology is defined as 'the science of the environment'. **- Karl Friendericks**
3. Ecology is defined as the study of structure and function of nature. **- E. P. Odum**
4. The study of animals and plants in their relation to eachother and to their environment. **- S. C. Kendeigh**

1.1.2 CONCEPT OF ECOSYSTEM : [Jan. 2011, Dec. 2011, May 2012, May 2015]

Living organisms (biotic components) interact with their physical environment (abiotic components) like air, water, soil, temperature, etc. and produce a stable self sustained system, which is called the **ecosystem.**

Living organisms always require their physical environment like air, water, soil, temperature, humidity, etc. to get material and energy flow for their survival. Thus interaction between living organisms and non-living environment take place.

Thus, the structural and functional unit of ecology is known as the ecosystem.

Ecosystem is a community of interdependent organisms together with the environment. There is a continuous production and exchange of materials between the living and non-living components of the ecosystem.

➔ **Characteristics of ecosystem :**

1. Ecosystem has no particular size.
   It can be as large as a desert or a lake or as small as a tree or puddle (small pool of water).
2. The ecosystem may be natural or man-made (artificial).
   Natural ecosystems - Forest, lake, desert, grassland, pond, etc.
   Man-made ecosystems - aquarium, crop field, etc.
3. Ecosystem can change with time.
   e.g. fresh water lake can become eutrophic (nutrient), both supporting different type of life.
4. In the ecosystem there is always a flow of matter and energy in and out, i.e. all ecosystems are open systems.
5. In the ecosystem, different organisms interact with eachother and every organism (species) has a role to play.
6. It is a system where biotic and abiotic components work together, i.e. water, plants, animals, microorganisms, air, temperature, light, soil, etc. all work together. If there is no light or water or the soil does not have the right nutrients, the plants will die.
7. The foundation on which ecosystem rests is the production of organic matter by photo synthesis.

1.2 ENVIRONMENTAL SCIENCE, ENVIRONMENTAL ENGINEERING ENVIRONMENTAL STUDIES :

Environmental science :

Environmental science can be defined as the scientific study of earth, air, water, living organisms and the man with his impact on environment.

It is the study of both biotic and abiotic components of the environment.

Environmental Engineering :

Environmental engineering can be defined as the application of engineering principles, to the protection and enhancement of the quality of the environment, public health and public welfare.

For example,

The environmental engineer plans, designs, constructs and operate sewage treatment plant, water treatment plant, industrial effluent treatment plant, air pollution control equipments, etc.

Environmental studies :

It can be defined as the branch of study concerned with environmental issues. It has a broader coverage than environmental science and includes the Social aspects of environment also. It deals with science where necessary, but in such a Language so that can be understood by non scientist also. It includes not only the study of physical and biological characters of the environment but also the social and cultural factors and the impact of man on the Environment. It includes the various disciplines of science, social science, law and Engineering.

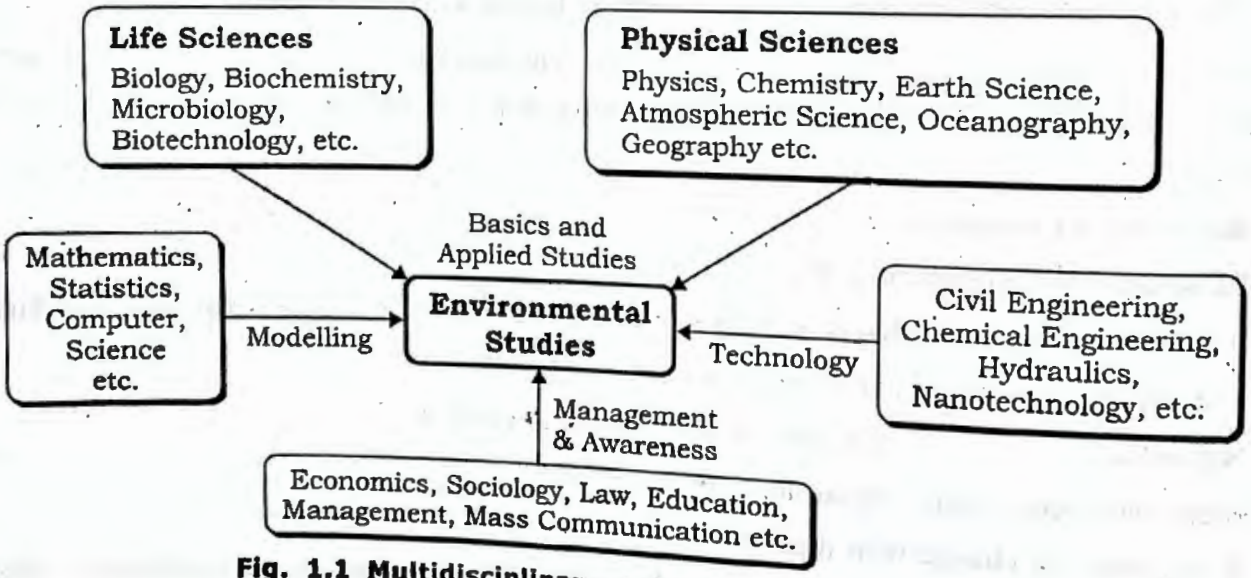

Fig. 1.1 Multidisciplinary nature of Environmental studies

1.2.1 SCOPE OF ENVIRONMENTAL STUDIES :

Environmental studies discipline has multiple and multilevel scopes. It includes a large number of areas and aspects. This study is important and necessary not only for children but also for everyone. It has direct relevance to every section of the society.

The scopes are summarized as follows:

1. The study creates awareness among the people about natural resources–their conservation and management.

2. It provides the knowledge about ecology, ecosystem, bio–diversity ,and cause and effect relationships.
3. It provides necessary information about biodiversity richness and the potential dangers to the species of plants, animals and microorganisms in the environment.
4. Environmental pollution and control.
5. Human population and environment.
6. Social issues related to development and environment.
7. The study enables one to understand the causes and consequences due to natural and main induced disasters (flood, earthquake, landslide, cyclones etc.,) and pollutions and measures to minimize the effects.
8. It enables one to evaluate alternative responses to environmental issues before deciding an alternative course of action.
9. The study enables environmentally literate citizens (by knowing the environmental acts, rights, rules, legislations, etc.) to make appropriate judgments and decisions for the protection and improvement of the earth.
10. The study exposes the problems of over population, health, hygiene, etc. and the role of arts, science and technology in eliminating/ minimizing the evils from the society.
11. The study tries to identify and develop appropriate and indigenous eco–friendly skills and technologies to various environmental issues.
12. It teaches the citizens the need for sustainable utilization of resources as these resources are inherited from our ancestors to the younger generating without deteriorating their quality.
13. The study enables theoretical knowledge into practice and the multiple uses of environment.

Environmental studies deals with every issue that affects an organism. It is essentially a multidisciplinary approach that brings about an appreciation of our natural world and human impacts on its integrity. It is an applied science as it seeks practical answers to making human civilization sustainable on the earth's finite resources.

Its components include

1. Biology, microbiology,
2. Geology, Geosciences
3. Chemistry
4. Physics
5. Engineering
6. Sociology
7. Health
8. Anthropology
9. Economics
10. Statistics
11. Philosophy

1.2.2 IMPORTANCE OF ENVIRONMENTAL STUDY :

Environmental study is based upon a comprehensive view of various environmental systems. It aims to make the citizens competent to do scientific work and to find out practical solutions to current environmental problems. The citizens acquire the ability to analyze the environmental parameters like the aquatic, terrestrial and atmospheric systems and their interactions with the biosphere and anthrosphere.

Importance :

- World population is increasing at an alarming rate especially in developing countries.
- The natural resources endowment in the earth is limited.
- The methods and techniques of exploiting natural resources are advanced.
- The resources are over–exploited and there is no foresight of leaving the resources to the future generations.
- The unplanned exploitation of natural resources lead to pollution of all types and at all levels.
- The pollution and degraded environment seriously affect the health of all living things on earth, including man.
- The people should take a combined responsibility for the deteriorating environment and begin to take appropriate actions to space the earth.
- Education and training are needed to save the biodiversity and species extinction.
- The urban area, coupled with industries, is major sources of pollution.
- The number and area extinct under protected area should be increased so that the wild life is protected at least in these sites.
- The study enables the people to understand the complexities of the environment and need for the people to adapt appropriate activities and pursue sustainable development, which are harmonious with the environment.
- The study motivates students to get involved in community action, and to participate in various environmental and management projects.
- It is a high time to reorient educational systems and curricula towards these needs.
- Environmental studies take a multidisciplinary approach to the study of human interactions with the natural environment. It integrates different approaches of the humanities , social sciences, biological sciences and physical sciences and applies these approaches to investigate environmental concerns.
- Environmental study is a key instrument for bringing about the changes in the knowledge, values, behaviors and lifestyles required to achieve sustainability and stability within and among countries.

1.2.3 ENVIRONMENTAL SCIENCE :

Environmental science can be defined as the scientific study of earth, air, water, living organisms and the man with his impact on environment. It is the study of both biotic and abiotic components of the environment.

Environmental science is defined as an interdisciplinary academic field that integrates various academic fields (particularly sciences) to study the structure and function of our life–supporting environment and to understand causes, effects, and solutions of different environmental problems. In other words, environmental science is the scientific study of all the components or factors that make or influence our life–supporting biophysical environment.

Environmental science is the study of all the components or factors that make or influence our life–supporting biophysical environment, including earth processes, ecological systems, biodiversity, natural resource,

alternative energy systems, climate change, various types of pollutions, and so on. These entities or processes are guided by complex interaction of physical, chemical, and biological processes, as well as significant human intervention.

Therefore, environmental science integrates information from a number of other disciplines and thus is multidisciplinary in nature. Disciplines such as biology, chemistry, physics, geology, geography, sociology, economics, management, and ethics have largely been integrated to develop different subdivisions of environmental science. Its major subdivisions include ecology, geosciences, environmental chemistry, atmospheric science, environmental microbiology, environmental toxicology, environmental impact assessment, and so on.

Besides these, there are certain subdivisions—environmental studies, environmental engineering, environmental economics, environmental ethics, environmental management, environmental sociology, environmental biotechnology, and so on—that are generally treated as independent academic disciplines parallel to environmental science.

Environmental conservation is the main emphasis for most of these disciplines, but the approaches vary. For example, environmental studies incorporate more of the social sciences for understanding human relationships, perceptions, and policies towards the environment. Environmental engineering, on the contrary, focuses on design and technology for improving environmental quality.

1.2.4 SCOPE OF ENVIRONMENTAL SCIENCE :

Principles and approaches of environmental sciences are applicable in several areas of development. These areas are studied as scope of the subject. Environmental science has a vast scope since it covers a wide range of subject matters or issues related to our complex life–supporting system. Scope of the subject can be described in terms of major areas of applicability as well as career opportunities related to the subject.

Three major areas of applicability of the subject are

(i) management of natural resources,

(ii) conservation of ecosystem and biodiversity, and

(iii) prevention and control of pollution.

In addition, environmental science plays a key role in solving complex environmental issues of varying scale, including climate change, ozone layer depletion, energy crisis, desertification, urbanization, population explosion, and so on.

Scope of the subject in terms of career opportunities is fairly vast. For the last two decades, environmental science has been considered to be associated with a number of career opportunities. Major career options related to the subject can be industries, academics, research and development, consultancy, green marketing, NGOs, etc.

There are various areas in environmental sciences where extensive research and work is done. These are:

1. Pollution control board
2. Biomass
3. Renewable energy
4. Waste management
5. Ecology
6. Toxicology
7. Water management
8. Gio informatics
9. Forestry
10. Biofuels
11. Legal services

1.2.5 IMPORTANCE OF ENVIRONMENTAL SCIENCE FOR DIFFERENT ENGINEERING DISCIPLINES :

The importance of environmental science for different engineering disciplines can be summarized as follows:

1. **Civil Engineering :**

In civil engineering importance of environmental science is related to:

- Water resources, water treatment and management
- Waste water treatment, design of treatment plants
- Water pollution and control
- Air pollution and control
- Land and noise pollution and control
- Solid waste management
- Recycling and reuse
- Hazardous waste management
- Public health and sanitation
- Environmental global issues–global warming, acid rain, ozone layer depletion
- Environmental impact assessment
- Green house technology

2. **Chemical Engineering :**

Environmental "chemical" engineers, focus on environmental chemistry, advanced air and water treatment technologies and separation processes.

Industrial hygine.

3. **Mechanical Engineering :**
   - Designing machines and mechanical systems for environmental use such as water treatment facilities, pumping stations, garbage segregation plants and other mechanical facilities.
   - Designing machines and vehicles producing less carbon emission.
4. **Electronics and Electrical Engineering :**
   - Developing devices and artifacts able to monitor, measure, model and control environmental impact.
   - Monitoring and managing energy generation from renewable sources.
5. **Agriculture Engineering :**
   - Advocate for sustainable agriculture on a local and national level
   - water quality protection
   - air–pollution prevention
   - soil protection
   - waste management, etc.

1.3 COMPONENTS OF ENVIRONMENT :

[Jan. 2009, Nov., 2010, May 2012, Jan. 2016, June 2017]

The four basic components of physical environment are :

1. Atmosphere
2. Hydrosphere
3. Lithosphere
4. Biosphere

1. **Atmosphere :** **[Jan. 2009, 2010, Dec. 2014]**

The earth's atmosphere is an envelope of gases, water vapours and subatomic particles extending up to 2000 feet above the ground surface. The gases include nitrogen, oxygen, argon, carbon dioxide, traces of carbon monoxide, oxides of sulphur, nitrogen and hydrocarbon, etc. The concentration of these gases decreases with an increase in altitude. The bulk of these gases are present within the atmospheric band that stretches up to 5 km above the earth.

The atmosphere may extend up to a height of about 80 km. It is transparent, colourless and tasteless. The chief constituents of atmosphere are : **[June 2016]**

Nitrogen = 78 % by volume

Oxygen = 21% by volume

CO_2 = 0.032 % by volume

The composition of atmosphere is given in Table 1.1.

Table 1.1 Composition of atmosphere

Sr. No.	Names of gases	Concentration by % Volume	Category in atmosphere gases
1.	Nitrogen (N_2)	78.08	Major gases
2.	Oxygen (O_2)	20.95	
3.	Argon (Ar)	0.93	
4.	Water vapours	0.1	Minor gases
5.	Carbon dioxide (CO_2)	0.032	
6.	Neon (Ne)	0.0018	
7.	Methane (CH_4)	0.0002	
8.	Helium (He)	0.0005	
9.	Ozone (O_3), CO, H_2, NH_3, NO, NO_2, SO_2 and H_2S	Concentration by % Volume less then 0.000006	Trace gases

Atmosphere is very important layer on the earth surface, and life on earth is not possible without the atmosphere. The atmosphere protects the earth's biosphere by absorbing a major portion of the electromagnetic radiation and most of the cosmic rays. The atmosphere also absorbs infra-red radiation

and thereby maintains the temperature of the earth at life sustaining levels. It provide us oxygen and sunlight to leave.

At a given place, short term variations like hourly, daily and weekly variations in the properties of atmosphere (such as sun radiations, temperature, humidity, rainfall, wind and cloulds) is termed as weather. When the weather remains almost constant for long duration like in seasonal variations, it is called climate.

→ **Structure of Atmosphere :** **[Jan. 2009, 2010, June 2011, Dec. 2014]**

The atmosphere can be sub-divided into five regions as given below :

i. Troposphere
ii. Stratosphere
iii. Mesosphere
iv. Thermosphere
v. Exosphere

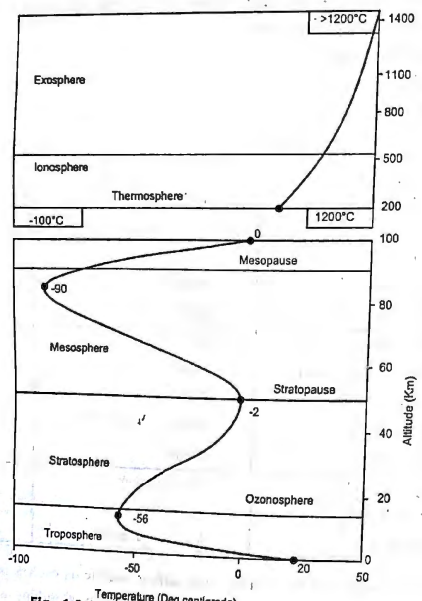

Fig. 1.2 Temperature profile of Atmosphere

(i) Troposphere : **[June 2013]**

It is the lower most layer of atmosphere in which most living organisms exist. It extends up to **8 km** at the poles and **16 km** at equator.

It contains 70% of the atmosphere's mass. The density of the troposhere decreases with altitude. The air near the ground level is heated by the radiation from the earth, but the temperature decreases uniformly with altitude. This decrease of temperature with altitude is known as lapse rate.

The cold layer (–56°C) at the top of the troposphere, which shows a temperature inversion, that is, a negative to positive lapse rate, is known as **tropopause.**

(ii) Stratosphere :

A stable layer of atmosphere above troposphere is called stratosphere. It extends about 50 – 55 km above the surface of the earth.

Stratosphere is known for the presence of **ozone** which is found at around 20 km from ground. This layer of ozone is called ozonosphere and acts as a protective layer against the harmful effects of ultra violet radiations on living organisms.

The layer separating stratosphere from mesosphere is called **stratopause.**

(iii) Mesosphere :

It exists over stratosphere and in this layer, temperature decreases with altitude (negative lapse rate) because of low levels of ozone that absorbs ultraviolet radiation. The *mesopause* separates the mesosphere from the thermosphere.

This layer is very special as all sound waves as well as short radio waves coming from earth are reflected from this layer.

(iv) Thermosphere :

After mesosphere, thermosphere starts and extends up to **500 km** above earth's surface. Temperature rises in this zone with altitude and this trend continues further.

Ionisation of elements like oxygen and nitric oxide take place in the upper most portion of layer. Therefore, the upper layer of thermosphere is also called **ionosphere.**

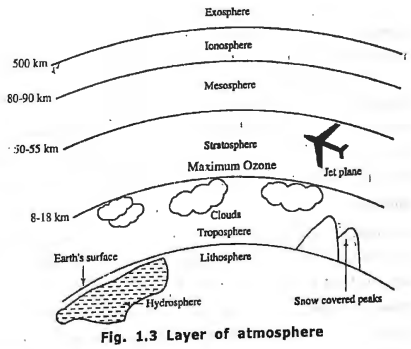

Fig. 1.3 Layer of atmosphere

(v) Exosphere :

The uppermost layer of the atmosphere is called exosphere. This extends up to a height of about 1600 km and gives way to interplanetary space. In this layer very high temperature (> 1200 °C) is found.

2. Hydrosphere :

All types of water resources, namely the oceans, seas, rivers, lakes, ponds, reservoirs, polar ice caps, glaciers, ground water and water vapour are collectively known as the **hydrosphere.**

The hydrosphere is an important part of the earth's surface. About 70% of the earth's surface is covered with water. The northern hemisphere is dominated by land surface, while the southern hemisphere is almost entirely occupied by water bodies (oceans).

The distribution of water is as under :

97 %	oceans and seas
2.0 %	in ice caps at polar regions
0.75 %	as ground water
0.25 %	lakes, ponds, rivers, streams

Total quantity of water available on the earth surface is about 1.4 billion km^3 and if this amount is spread over the earth surface, then it will form 2.5 km deep water mass.

[Jan. 2010]

3. Lithosphere :

The upper layer of the earth's crust is called **lithosphere.** It is made up of soil, minerals, rocks and other organic as well as inorganic matter.

Rocks are subjected to continuous physical, chemical and biological weathering. Plants grow and decay on the soil covering the rocks. Soil is the major component of the lithosphere. The organic matter in soil is decomposed by micro-organisms thus forming biomass. This biomass is mixed with the soil fauna. The major components of soil are air, water, minerals, and organic matter obtained from weathering of the parent rock. Soil plays a vital role in supplying nutrients to the plant kingdom.

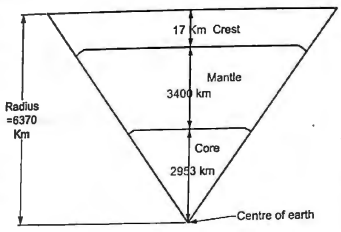

Fig. 1.4 Lithosphere

The thickness of lithosphere ranges from 64 to 96 km. The uppermost part of the lithosphere is rich in silica (Si) and aluminium (Al) and is therefore, known as the **SiAl layer.**

4. Biosphere :

It is that portion of earth's surface, hydrosphere and atmosphere where life exists. Biosphere is a biological environment where living organisms interact with physical environment, e.g. soil, water and air. It extends from the lowest sea bed level to about 24 km of the atmosphere.

From the bottom of the sea level to the surface of the earth, whether it is desert, grass land, hills, wells, rivers, lakes or even sky where the birds and other small creatures are existing are included in biosphere. Every living organism is getting the all basic resources from the biosphere i.e. air, water food and sunlight, etc. and simultaneously the waste in the form of solid, liquid or gases produced by it are discharged into the biosphere. Biosphere has a capacity to absorb, convert or dilute the waste and make it useful once again to the next generation of organism.

1.4 INTERACTION AMONG COMPONENTS OF ENVIRONMENT :

[Sept. 2009, June 2010, June 2014, Jan. 2016]

Two major components of environment are biotic and abiotic.

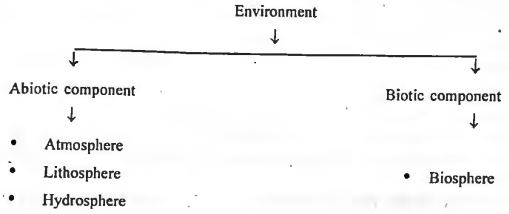

Fig. 1.5 shows a schematic representation of the four environmental components and their interrelationship. The circles represent the spheres and the curved arrows indicate the flow path of matter. All the spheres have two way linkage to other sphere including itself which represent the transfer of matter from one sphere to other, or within itself without leaving that sphere.

The atmosphere may be considered as a transport component that moves substances from atmospheric sources to the receptors. Its storage capacity is small compared to the other spheres but it has greater capacity for spatially redistributing matter.

The hydrosphere has two subcomponents i.e. rivers and oceans. The river system collects the substances within the watershed and delivers them to the second subcomponent that is ocean.

The lithosphere is composed of soil particles and rocks. Within the soil,

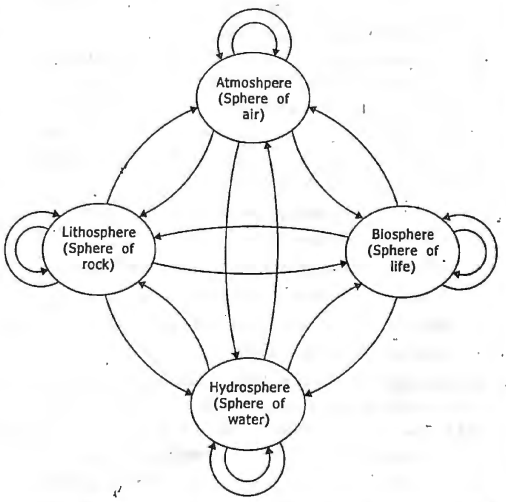

Fig. 1.5 Relationship between different components of environment

biochemical reactions by microorganisms are responsible for most of the chemical changes of matter. However, soil and rocks are mainly storage components for deposited matter.

All the components of environment are interrelated with each other. Any change in one of the components affect other components also. For example, changes in the temperature of atmosphere, cause changes in the rate of evaporation, humidity in atmosphere and after saturation of humidity when rainfall takes place, it affects lithosphere as flood may occur causing erosion of earth. This also affects the biosphere as different types of plants grow differently according to the amount of rainfall they receive.

Lithosphere is almost static component of environment while atmosphere and hydrosphere are dynamic components of environment. Different types of movements in air due to wind and storms and movements of river water as well as ocean water cause changes on the land surface and thus affect the lithosphere.

1.5 MAN AND ENVIROMENT RELATIONSHIP : [April 2010, Dec. 2011, May 2012]

Man is a biotic component at the centre of the biosphere surrounded by air, water, soil and material. The man's daily life is dependent on it's various abiotic components. For example,

- For breathing we are dependent on oxygen, i.e. air.
- For water, we are dependent on water resources.
- For food, we are dependent on soil, plants and other animals.

Thus, we are dependent on environment for our survival.

Ancient Indians used to worship nature – sun, water, air, soil, plants and animals. As per Indian tradition, bodies of plants, animals and human beings are made up of five essential elements (water, air, earth, akash, fire) and after death and decay, these bodies again converted to those five essential elements.

Since ancient times, Indians have worshipped their natural resources in the form of God. For example, Sun as Surya dev. Water as Varun dev, air as Pawan dev, soil as Pruthvi devi, trees as Van dev, fire as Agni dev, cow as Mata and Elephant as Ganesh.

With the increase in population, man started interfering with the environment in the following ways :

- Grass lands were converted to crop fields.
- Forest were cut down for fuel and building material.
- Irrigation systems were built to transport water.
- Inhabitant of some species were destroyed leading to their extinction.
- Some animals and birds were hunted to extinction.

In order to fulfill their basic needs quickly, human beings have modified the environment more, compared to other organism using advanced technologies. After the 18th century, lot of advancement in technologies and science took place, especially after the invention of steam engine and automobiles. The idea of progress spread rapidly and made a profound impact on the environment as follows :

- Deforestations are done for human settlement and infrastructure development.
- People shifted from renewable wood to non-renewable fossil fuels. (Coal, oil, natural gas)
- Factories began to use more natural resources.

- Smoke from factories and vehiclular traffic lead to heavy air pollution.
- Waste water from different industrial zones lead to water pollution.
- Urbanization leads to scarcity of land, food, water in urban areas.
- Production of chemical fertilizers and pesticides increased the food production but same time polluted the land, water and air.

1.6 IMPACT OF TECHNOLOGY ON ENVIRONMENT :

[Jan. 2011, June 2011, May 2012, June 2016, Jan. 2017]

The technology is developed and used for the human well being. The intelligent application of technology results in human well being but not without causing environmental disruptions. The impact of technology on environment can be observed on many ways. Offcourse, the development in technology has made our life very luxurious but its adverse effect on environment is devastating.

No technology can be completely free of environmental impacts.

Impact of technology on environment can be divided into three categories.

1. Direct impacts
2. Indirect impacts
3. Cumulative impacts

1. **Direct impacts :**

The direct impacts includes :

- Accidents
- Exhaustion of resources
- Removal of vegetation/forest, etc.
- Release of pollutants affecting human health
- Change in landscape

2. **Indirect impacts :**

Indirect impacts are also known as secondary impacts or chain impact. They are usually linked closely with project and many have more profound consequences on environment than direct impact.

For example,

- Deforestation may result in extinction of some of the birds and animal species in the forest.

3. **Cumulative impacts :**

These impacts are generally results of slow change of environment.

For example,

If a highway road is constructed through forest for development, than cattle/tribal may move through forest frequently which result in rapid depletion. This destroys forest edge ecotone and basic forest ecosystem.

Rapid advancement in education, technology and industrialisation has changed the living standard of people, but at the same time, this has become the cause of environmental degradation. There is a world wide concern over the disposal of toxic wastes, green house gases, disposal of nuclear and radioactive wastes, and climatic changes. Impact of technology in different fields on the environment can be summarised as follows :

Activities and Impacts

	Activity	Impacts
1.	Agriculture	• Soil erosion
		• Discharge of nutrients into water bodies/ground water.
		• Discharge of pesticides into the environment. These pesticides end up in the foodchain of the ecosystem.
		• Water pollution.
		• Imposing water burden on water resources.
2.	Water resources projects [Dams, reservoirs, canals]	• Deforestation
		• Submergence of forest and other lands
		• Water logging problems
		• Evacuation and rehabilitation of people and villages
		• Disturbance to wildlife
		• Mosquito breeding
3.	Construction	• Cutting of forests
		• Extraction of construction materials
		• Energy utilization
		• Stress on water resources
		• Natural water drainage problems
4.	Transportation	• Deforestation for constructing highways and railways
		• Utilization of valuable agricultural land for construction
		• Disruption of wildlife habitats
		• Air pollution, noise pollution
		• Pollution of marine waters due to harbours
5.	Industries	• Pressure on land and other natural resources for raw material.
		• Air pollution
		• Water pollution
		• Noise pollution
		• Pressure on transport systems
6.	Mining	• Soil erosion, subsidence of land
		• deforestation
		• Air pollution
		• Water pollution
		• Transportation of ores imposes heavy burden on transport facilities.

7.	Power generation	• Thermal power plants create water pollution, air pollution and thermal pollution.
		• Hydroelectric plants causes submergenece of valuable land, deforestation, disruption of wildlife etc.
		• Nuclear power plants carry risk of radioactive hazards.
		• Global warming and acid rain are related to combustion of fossil fuels in thermal power plants.
8.	Toursim and religious activities	• Create congestion
		• Transport problems
		• Sanitation problems
		• Spread of diseases like swine flu.
		• Solid and plastic waste problems
9.	Urbanisation	• Air, water and noise pollution
		• Water supply and sanitary problems
		• Traffic problems, accidents
		• Solid waste generation
		• Increase in electricity consumption due to use of - A.C., refrigerator, washing machine, water heater, etc.
		• Social tensions
		• Expansion of cities eats away fertile agricultural lands.
		• Slums development

1.7 ENVIRONMENTAL DEGRADATION : [June 2010, Jan. 2013, Jan. 2016]

Environmental degradation can be defined as the deterioration of the environmental quality due to different activities of living beings that pollute the key elements like air, water and soil. Environmental degradation can occur naturally or through human activities.

The factors of environmental degradation are divided into two groups :

1. Natural factors
2. Man-made factors

1. Natural factors :

The natural factors causing environmental degradation are :

- Droughts
- Storms and floods
- Earthquakes
- Volcanic eruptions
- Tsunami, etc.

These factors not only cause physical and agricultural damage but are also responsible for disruption of property and essential services like electricity and water supply.

2. Man-made factors :

The man-made factors (human factors) include

- Urbanisation
- Industrialisation
- Deforestation, etc.

The environment is degraded because of the following reasons :

1. Over population and poverty is mainly responsible for environmental degradation.
2. Over exploitation of natural resources or wasteful use of natural resources.
3. Ecological imbalance created by human and animal activities.
4. Depletion and contamination of both surface and ground water.
5. Destruction and degradation of wild life habitats.
6. Overuse of resources like water, forest, land and energy which lead to air, water and land pollution.
7. Huge deforestation.
8. Wide spread use of fossil fuels like oil and coal.
9. Heavy industrialisation leads to air, water and noise pollution.
10. Use of fertilizers and pesticides in agricultural activities cause water and land pollution and also affect food chain.
11. Soil erosion.
12. Conversion of productive crop land and grazing lands to deserts, i.e. desertification.

The major environmental problems arising out of improper utilization of natural resources are classified as :

a. Air pollution
b. Water pollution
c. Land pollution
d. Bio-diversity degradation
e. Food supply problems

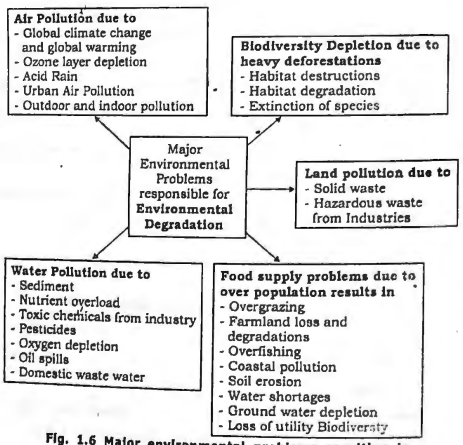

Fig. 1.6 Major environmental problems resulting in environment degradation

The Impact equation - IPAT : **[March 2009]**

Famous physicist John Holdren and biologist Paul Ehrlich studied environmental degradation and pollution in detail. They developed a model using three factors to assess the impact (I) on the environment which is called **IPAT equation.**

It was one of the earliest attempts to describe the role of three multiple factors, viz. Population (P), Affluence (A) and Technology (T), in determining environmental degradation.

$$I = P \times A \times T$$

where,

I = Environmental Impact

P = size of human population

A = Affluence - refers to the level of consumption by population

T = Technology - refers to processess used to obtain resources and transform them into useful goods and wastes.

In developing countries like India, basically population, poverty and pollution are three key factors responsible for rapid environmental degradation which is called as P^3 syndrome.

In developed countries, use of natural resources with very high rate is the main reason of environmental degradation.

1.8 ENVIRONMENTAL EDUCATION :

Environmental Education is an integral process, which deals with man's interrelationship with his natural and man made surroundings, including the relation of population growth, pollution, resource allocation and depletion, conservation, technology, urban and rural planning to the total human environment. **Environmental Education** is a study of the factors influencing ecosystems, mental and physical health, living and working conditions, decaying cities and population pressures. **Environmental Education is intended** to promote among cirizens the awareness and understanding of the environment, our relationship to it, and the concern and responsible action necessary to assure our survival and to improve the quality of life.

→ **Importance of Environmental Education :**

[May 2012, Dec. 2013, Dec. 2014, May 2015, June 2016, June 2017]

The objective of environmental education is to make public aware about environmental problems, and importance of environment protection. Environmental education is important from the following view points.

1. It gives us the basic understanding about various aspects of environment and its associated problems.
2. It teaches us the concept of sustainable development.
3. It gives an idea about beneficial use of natural resources without damaging it much.
4. It imparts the knowledge of eco-friendly techniques to be used in various fields.
5. It helps to promote the use of non-conventional energy resources such as solar energy, wind energy, biomass energy, etc.

6. It teaches us how to conserve energy and save our planet.
7. It teaches us about bad effects of pollution and suggest measures to minimise environmental pollution.
8. It helps us to understand about ecological imbalance and various ways to maintain ecological balance.
9. It gives the knowledge about interdepedency of man and nature.
10. It develops skills to identify environmental problems and their solutions.

[Jan. 2010, June 2013, May 2015]

→ **Objectives of Environmental Education :**

- To increase awareness and sensitivity to the environment among the people.
- To increase the knowledge of environment.
- To improve attitude towards the environment.
- To acquire skills for solving environmental problems.
- To increase participation and to develop a sense of responsibility.

→ **Principles of Environmental Education :** **[June 2013, May 2015]**

The major principles of Environmental Education are as follows :

- Environmental Education considers environment in its totality.
- Environmental Education is not a one short learning approach. It is a challenging area requiring both disciplinary and interdisciplinary approach. This calls for a holistic rather than a piece meal subject oriented approach.
- Environmental **hazards are controllable** and every cirizens has a moral obligation and responsibility towards this.
- Concerns of environment are concerns of several agencies. **Formal and nonformal education** system and programmes must work in unison.
- Education must cater to all sections of society-the general public, and non specialists, socio professional groups and technologists as well.
- Promote the value and necessity of local, national and interpersonal cooperation in the prevention of and solution to environmental problems.
- To appreciate the gifts of the Nature i.e. **Natural Resources.**
- Help learners discover the symptoms and causes of environmental problems.
- To help and understand the effect of over population and over exploitation of natural resources.
- To promte the value and necessity of local, national, international cooperation in the prevention and solution of Environmental problems.

1.9 ROLE OF ENVIRONMENTAL ENGINEER : [June 2011]

Environmental engineers are the technocrats who are committed to protect human beings from the harmful effets of environmental degradation caused by the pollution in the environment due to population explosion, urbanisation and industrialisation.

The major roles of environmental engineers are :

1. The environmental engineers make environmental strategies like evaluation of environmental quality, steps for improvement in quality of water, air and food.
2. They conduct research on proposed environmental projects, analyse scientific data, and perform quality control checks by Environmental impact assessment.
3. They do the design, construction and operation of **municipal water supply system** for providing safe drinking water to the people.
4. They do the design, construction and operation of **sewage treatment plants** depending upon the characteristics of waste water.
5. They also design sewage and storm water drainage, network for proper disposal of sewage and storm water.
6. They design various treatment technologies for the municipal **industrial solid waste management.**
7. They deal with the concept of **recycling and reuse of wastewater.**
8. Environmental engineers also keep in their mind to protect natural resources from the effects of disposal of hazardous waste, toxic chemicals and radioactive waste.
9. They provide legal and financial consulting on matters related to the environment.
10. Using the principles of biology and chemistry, environmental engineers develop solutions to environmental problems.
11. They are also involved in the **protection of wildlife.**
12. They are concerned with local and worldwide environmental issues. They study and attempt to minimize the effects of acid rain, global warming and ozone layer depletion.

Important days of Environmental significance **[Dec. 2014]**

World environment day	5th June
World Nature day	3rd October
Earth day	22nd April
World Water day	22nd March
World Forest day	21st March
Wild-life Week	1-7 October
World population day	11th July
Ozone day	16th September
World animal welfare day	4th October
World food day	16th October

CHAPTER

2. Environmental Pollution - Water Pollution

→ *In the waters between 0.25 km to 0.45 km deep, CO_2 levels are rising at nearly twice the rate as in the surface waters.*
– Daniel Glick

2.1 ENVIRONMENTAL POLLUTION :

[Dec. 2014]

Environmental pollution can be defined as any undesirable change in the physical, chemical or biological characteristics of any component of the environment (i.e. air, water and land) which can cause harmful effects on various forms of life or property.

Environmental pollution dates back to the time when man discovered the use of fire. The burning of fossil fuels (coal, oil, natural gas) and wood releases a number of poisonous gases into the atmosphere. Environmental pollution includes air, water, land, noise and radioactive pollution.

Causes of Pollution

[Dec. 2011]

Natural causes	Man-made causes
• Volcanic eruptions	• Commercial activities
• Earthquakes	• Industrial activities
• Storms and dust	• Over Population
• UV radiations	• Urbanisation
• Decay of organic matter (release of H_2S and mecroplans)	• Insecticides, pesticides
	• Organic chemicals
	• Use of vehicles
	• Mining
	• Nuclear explosions
	• Explosives used in wars
	• Construction of buildings, roads, dams

At the begining of the human Civilization our environment was pure, virgin and uncontaminated. It was most supportive and hospitable to living organisms. The advancement of science and technology led to the exploitation of natural resources. Progress in agriculture, followed by rapid industrialization has left us with barren land, contaminated soil, polluted rivers and lakes, depleted wildlife and exhausted our natural resources.

2.2 POLLUTANTS AND THEIR CLASSIFICATION :

[Dec. 2014]

A **pollutant** may be defined as any substance present in the environment in such concentration, that alter the quality of environment and affect the living things adversely.

Pollutants are those agents which cause pollution due to production of end waste products or by-products by consumption of natural resources which may deteriorate the quality of environment. All pollutants are not always harmful, if not present in excess amount. For example, phophorus, nitrogen and sulphur increaes the fertility of soil and helps in the growth of plants if not present in excess amount than their requirement.

→ **Classification of pollutants :**

1. **On the basis of nature of material :**

   (a) Biodegradable pollutants :

   These are the pollutants which are degraded/decomposed naturally by the action of bacteria.

   e.g. • municipal waste water (sewage)
   • Wood • Paper
   • garbage • Cardboard, etc.

   (b) Non-biodegradable Pollutants :

   These are the pollutants which can not be degraded/decomposed naturally by the action of water or degrade very slowly.

   e.g. • DDT • Plastic
   • glass • polythene bags
   • E–waste, etc.

2. **On the basis of their concentration in nature :**

   (a) Quantitative pollutants :

   These are the substances which normally occur in the environment, but become pollutants when their concentration increases the allowable limit.

   For example, CO_2 when released in excess amount in the atmosphere can cause green house effect.

   (b) Qualitative pollutants :

   These are the substances which do not occur naturally in the environment, but are added by human for different purposes.

   e.g. • Insecticides
   • Pesticides
   • Germicides, etc.

3. **On the basis of form of pollutants :**

   (a) Primary pollutants :

   These are the substances which remain in the environment in the same form in which they are added to the environment. They are also called direct pollutants.

   e.g. • Smoke • ash
   • dust • hydrocarbon, etc.

   (b) Secondary Pollutants :

   These are the substances which are formed from primary pollutants. These are considered more toxic than secondary pollutants.

   e.g. • SO_3 • Ketones
   • PAN (Peroxyacyl nitrate) • Ozone
   • aldehydes, etc.

4. **On the basis of their source :**

(a) Natural pollutants :

This includes the pollutants released naturally due to volcanic eruptions, forest fires, storms, decay of organic material, wind borne dust, etc.

(b) Man-made (anthropogenic) Pollutants :

This includes the pollutants generated by different human activities like

- industrialisation
- deforestation
- mining
- Urbanisation
- Explosions in wars
- Use of fertilizers, pesticides, etc.

2.3 TYPES OF ENVIRONMENTAL POLLUTION : [April 2010, June 2011]

The various types of environmental pollution are :

1. Water pollution
2. Air pollution
3. Land pollution
4. Noise pollution
5. Radioactive pollution
6. Thermal pollution

Today, environmental pollution is a serious problem. Air, water and land are essential for survival of life on earth but unfortunately pollution is causing them irrepairable harm.

- Polluted water causes fish and other aquatic life to perish and is also dangerous to human health.
- Beyond certain limits air pollution can cause illness and even death.
- Soil or land pollution reduces the amount of land available for growing crops, fruits and vegetables.

2.4 WATER POLLUTION : [March 2009, Dec. 2011]

Any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for certain uses is referred as water pollution.

It can also be defined as the presence of some foreign substances or impurities (organic, inorganic, biological, radioactive) in water in such quantity so as to constitute a health hazard by lowering the water quality and making it unfit for use.

➔ **Signs of polluted water :**

1. Water has a bad taste or odour.
2. Offensive odours from rivers, lakes, oceans.
3. There is a reduction in the number of aquatic lives (fish) in rivers, sea or fresh water.
4. Oil or grease floating on the surface of water.
5. Unchecked growth of aquatic weeds in water bodies.
6. Presence of colour due to organic matter.

➔ **Potable water :** [Jan. 2013]

The water which is suitable for drinking is known as **'Potable water'** or **'Wholesome water'**.

It is free from impurities, but essentially consists of some minerals in order to give it some taste.

The potable water should have the following qualities :

1. It should be odourless and colourless.
2. It should be free from suspended solids and turbidity.
3. It should be free from toxic substances.
4. It should be free from pathogenic organisms.
5. It should be moderately soft.
6. It should be asthetically pleasant, i.e. cool and fresh.
7. pH value should be between 6.5 to 8.5.

Types of water

Pure form of water	:	In the form of H_2O, also known as distilled water.
Mineral water	:	Water with acceptable limits of minerals specified by potable water standards.
Tap water	:	Water supplied by the concerned authority available at homes.
Polluted water	:	Water containing impurities not suitable for drinking.
Contaminated water	:	Water containing harmful impurities, not suitable for any purpose nor even can be thrown in water boides.

2.4.1 WATER QUALITY STANDARDS : [Jan. 2011, May 2012, Dec. 2013]

The definition of **water quality** depends on its intended use. Infact, the water quality determines the use of water, which may be either domestic use or it may be for industries, irrigation, power generation, recreation, etc.

Depending upon the intended use of water, certain quality criteria are established and based on these criteria, quality standards are specified by health and other regulating agencies. Different types of water use require different levels of water purity. Drinking water requires the highest standards of purity whereas other uses like irrigation, hydropower generation, industrial use, etc. requires lower quality standards.

Earlier, people could judge the quality of water only through the physical senses, i.e. sense of sight, taste and smell. But due to the advancement in the biological, chemical and medical sciences, highly developed methods are available for measuring the quality of water.

Various parameters which are used to assess the quality of water are divided into three groups.

Water quality parameters

Physical Parameters	Chemical Parameters	Biological Parameters
1. Turbidity	1. Total dissolved solids	1. E–coli test for MPN (Most probable number)
2. Colour	2. pH	**Pathogens**
3. Odour and taste	3. Acidity	• Bacteria
4. Suspended solids	4. Alkalinity	• Viruses
5. Temperature	5. Hardness	• Protozoa
	6. Chlorides	• Helminth
	7. Fluorides	
	8. Metals	
	9. Organic matter	

The agencies playing an important role in specifying the norms for various effluent to be discharged in the water bodies as well as for drinking water are :

1. Indian Standard Institution (ISI)
2. World Health Organization (WHO)
3. Indian Council of Medical Research (ICMR)
4. United States Public Health Services (USPHS)

(a) Physical Parameters :

These are the parameters which respond to the sense of sight, taste and smell.

These are,

1. Turbidity
2. Colour
3. Odour and taste
4. Suspended solids
5. Temperature

1. Turbidity :

The pressure of suspended material like clay, silt, finely divided organic material, plankton, and other inorganic material in water is known as turbidity.

It indicates the dirtiness of water and thus measure the extent to which light absorbed or scattered by fine suspended solids and colloidal solids.

Turbidity is measured in Nephlometric unit, permissible limit is 5 NTU.

The turbidity in water can be removed by filtration, sedimentation, clarification.

Environmental significance of turbidity :

- Pressure of turbidity in natural water body imparts colour.
- It interfere with penetration of light and photosynthesis process.
- Water containing clay and other suspended particles may require treatment to make it suitable for intended use.

2. Colour :

Pure water is colourless, but the presence of suspended solids give apparent colour to the water, while dissolved solids may impart true colour to water.

This colour in water is due to organic matter (leaves, wood, weeds, etc.), industrial wastes from paper and pulp production, textile and dyeing operations, and iron and manganese oxides as well.

Colour is measured by **'Tintometer'.**

Permissible limit is 15 Hazen units.

It can be removed by aeration, adsorption and oxidation processes.

Environmental significance of colour :

- Pressure of colour in water is not asthetically acceptable.
- Highly coloured water is not suitable for dyeing, laundering, beverage, dairy production, etc.

3. Odour and taste :

The odour and taste in water may be due to the presence of mineral salts, domestic sewage, decomposing organic matter, industrial wastes, chemical compounds as phenol, etc.

Odour is measured in terms of threshold odour Number. **'Osmoscope'** is used to measure odour.

Environmental significance of odour and taste :

- The pressure of odour and taste in water is asthetically displeasing and sometimes may be carcinogenic.

The odour and taste in water may be removed by aeration, dilution and disinfection process.

4. Suspended solids :

Suspended solids are inorganic particles (clay, silt, fine sand) and organic particles (plant residues, bacteria, algae, etc.) present in water.

Size of these particles varies from 100 μm to 1 μm.

Environmental significance of suspended solids :

- The presence of suspended solids in water is displeasing.
- Degradation of organic matter may result in objectionable smell.

They may be removed by detaining water in clarifier or sedimentation tank and filtering water through sand beds.

5. Temperature :

It is one of the important parameters in natural surface water systems. The shallow water bodies are affected by ambient temperature while discharge of thermal power waste water which is too hot may alter flora and fauna.

Biological activity increases with increase in temperature (double with an increase of 10°C.)

Environmental significance of temperature :

- The temperature of water supplied for domestic use should be between 10°C to 20°C. Temperature higher than 20°C is objectionable.
- Density of water is maximum at 4°C temperature.

(b) Chemical parameters :

The chemical parameters of water includes :

1. Total dissolved solids (TDS)
2. pH
3. Acidity
4. Alkalinity
5. Hardness
6. Chlorides
7. Fluorides
8. Metals
9. Organic matter

1. Total dissolved solids (TDS) :

These are organic particles (decay products, organic chemicals and gases etc.) and inorganic particles (minerals, metals and gases) present in water in dissolved form.

Size of these particles varies from 10^{-3} μm to 10^{-5} μm.

Environmental Significance :

- Dissolved solids may impart colour, taste and toxicity to water.
- Some of the dissolved organic constituents have been found carcinogenic.
- Degradation of organic matter may impart objectionable smell.

They can be removed by tertiary treatments like reverse osmosis, electro dialysis, distillation, ion exchange process, zeolite process, etc.

2. pH :

It is defined as the negative logarithm of hydrogen ion concentration in water.

It is a measure of degree of acidity or alkalinity of water. It is measured on pH scale, which varies from 0 to 14.

$$pH = -\log_{10} H^+ = \log_{10}\left(\frac{1}{H^+}\right)$$

H^+ ion concentration = 10^{-7}

$$\therefore \quad pH = \log_{10}\left(\frac{1}{10^{-7}}\right)$$

$$= \log_{10} 10^7 = 7$$

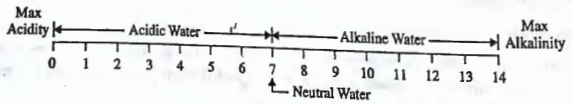

Fig. 2.1 pH scale

$\therefore$ pH value of neutral water is 7.

At pH = 7 water is neutral

for pH = 0 to 7, water is acidic.

for pH = 7 to 14, water is alkaline.

Environmental significance :

- For potable water, pH of water should be between **6.5 to 8.5.**
- Very low values of pH (acidic water) may cause corrosion and tuberculation.
- Very high values of pH (alkaline water) may shut biological activities.

3. Acidity :

It is the capacity of substances to neutralise hydroxyl ions OH^- (basics).

It is due to the presence of minerals and dissolution of carbon dioxide.

Mineral acidity :

- It is due to the presence of minerals like sulphur and iron pyrites.
- pH range may be 0 – 4.5.

CO_2 acidity :

- It is due to dissolution of CO_2 in water from atmosphere.
- pH range may be 4.5 – 8.5

Acidity is measured in mg/*l* as $CaCO_3$.

Environmental significance :

- Acidity interferes in the treatment of water (as in softening).
- Presence of acidity causes the corrosion of metals and pipelines.
- Industrial wastes containing acidity and alkalinity, must be neutralized before they are subjected to bilogical treatment.

4. Alkalinity :

It is the capacity of substances to neutralise acids.

It is due to the presence of bicarbonates, carbonates and hydroxides.

Alkalinity is measured in mg/*l* as $CaCO_3$.

Environmental Significance :

- Presence of alkalinity give a bitter taste to water and water becomes unpalatable.
- It is also required for chemical reaction with coagulants like alum.

5. Hardness :

Hardness of water may be defined as the soap destroying property of water. The hardness may be of two types : temporary hardness and permanent hardness.

The **temporary hardness** is due to the presence of carbonates and bicarbonates of calcium and magnesium. It is also called carbonate hardness. It can be easily removed by either boiling of water or adding lime to the water.

The **permanent hardness** is due to the presence of sulphates, chlorides and nitrates of calcium and magnesium. It cannot be removed by boiling and requires special methods of water softening like zeolite or soda lime process. The permanent hardness is also called non–carbonate hardness.

The hardness is measured in mg/l of calcium carbonate ($CaCO_3$).

Environmental significance :

- The hard water cause excessive consumption of soap in laundries.
- Hard water forms deposits (bolier scales) in the boilers.
- Ground water is generally harder compared to surface water.
- The prescribed hardness limit for public supplies range between 75 to 115 ppm.

In terms of degree of hardness, water can be classified as under :

Type of water	Hardness (mg/l as $CaCO_3$)
Soft water	0 to 75 ppm
Hard water	75 to 150 ppm
Very hard water	150 to 300 ppm
Extremely hard water	> 300 ppm

6. **Chlorides :**

Chlorides are mainly due to the intrusion of sea water, brine, industrial wastes and domestic wastes into the water supply source.

Chlorides are generally present in the water in the form of calcium chloride, sodium chloride and magnesium chloride.

Environmental significance :

- Chloride concentration in excess of 250 mg/l produce a noticeable salty taste in drinking water and are thus objectionable.
- The presence of high quantity of chloride in river or stream waters may indicate pollution of water due to sewage and industrial wastes.

7. **Fluorides :**

Water sources contain natural fluorides. Fluorides are mainly associated with some sedimentary and igneous rocks. It is toxic to humans and other animals in large quantities while small concentrations can be beneficial.

Environmental significance :

- Fluoride in water less than 1.0 mg/l can cause dental cavities in children, while more than 1.5 mg/l may cause discoloration or mottling of teeth (fluorosis).

8. **Metals :**

All metals are soluble to some extent in water. Metals in natural water includes dissolution from natural deposits, discharge of domestic, industrial or agricultural waste water.

Environmental significance of Metals :

- Toxic metals are harmful to humans and other organisms in small quantities, added to water by mining, industrial or agricultural sources.
- Arsenic, Barium, Cadmium, Chromium, lead and mercury are toxic metals.

- Non–toxic metals commonly found in water include sodium, iron, manganese, aluminium, copper and zinc.
- Excessive concentration of Sodium cause a bitter taste in water, cause health hazard like cardiac and kideny.
- Iron and manganese impart colour in very small quanities also.

(a) **Organic matter :** Many organic materials are soluble in water. They come from natural sources (decay products of organic solids) or from human activities (waste water from domestic, industrial and agricultural sources)

Dissolved organics are divided into two categories :

- Biodegradable organics consists of starches, fats, proteins, alcohols, acids, aldehydes etc. They are utilized for food by natural micro–organisms.
- Non–biodegradable organic consists of tannic acids, cellulose and phenols. They are resistant to biological degradation.

Environmental significance of Organic Matter :

Organic matter in water bodies utilized dissolved oxygen for their degradation. The amount of oxygen consumed during microbial utilization of organics is called the Biochemical Oxygen Demand (BOD). This may decrease dissolved oxygen (DO) level and affects on aquatic system.

(c) **Biological parameters :**

The natural water contains living organisms like bacteria, viruses and protozoa, but pathogens (those organisms which cause diseases) are most important.

Various diseases caused by pathogens are :

Pathogen		diseases caused
Bacteria	–	Cholera, diarrhea, typhoid, jaundice, etc.
Protozoa	–	amebic dysentery, giardiasis etc.
Viruses	–	hepatitis, meningitis, poliomylitis, etc.

The bacteria may be of two types – pathogenic bacteria and non–pathrgenic bacteria. The pathogenic bacteria are harmful. It causes diseases like cholera, typhoid, diarrhea, etc. The non–pathogenic bacteria is not harmful. But it is difficult to isolate the two.

The combined group of the two bacteria (pathogenic and non–pathogenic) is termed as **B–coil** group (i.e. bacterium and coli). Sometimes the group is termed as coliform group.

The common bacteria in this group is known as **E–coli** (Escherichia coli).

The presence of pathogens in water can be detected by the following techniques :

Tests for detecting pathogens in water

↓

↓ ↓

E–coil test (B–coli test)

- Presumptive test
- Confirmed test
- Completed test

Membrane Filter technique

(a) E–coli test for MPN :

The presence of pathogens in water can be detected indirectly by indicator organisms. An indicator organisum is one whose presence in water indicates the presence of pathogens. The presence of indicator organisms is detected by **E–coli test.**

The E–coli test determines the MPN (Most Probable Number) of coliform bacteria in 100 ml water sample.

The E-coli test is carried out in three phases :

1. Presumptive test :

This test is based on the belief that the coliform group can ferment the lactose broth and can produce gas. The procedure of the test is described below :

- A known amount diluted sample of water is taken in a standard fermentation tube containing lactose broth.
- The trube is kept at a temperature of 37°C for 48 hours.

After this period, if gas is seen in the tube, then this is an indication of presence of B–coli. This result is positive and the sample of water is unsafe for drinking.

If no gas is seen, then the sample of water is free from B–coli. This is a negative result and the water is safe for drinking.

2. Confirmed test :

This test may be carried out by any one of the following two methods :

Method–1 :

A small quantity of lactose broth showing positive presumptive test is taken on a plate containing Endo or eosin – methy lene – blue agar. It is kept for 24 hours at 37°C. If colonies of bacteria are seen, the positive result is confirmed. So, the completed test must be done.

Method–2 :

A small quantity of broth showing positive result in presumptive test is taken to another fermentation tube containing green lactose bile and kept for 48 hours. If gas is seen, then the presence of B–coli is confirmed. So, the completed test must be done.

3. Completed test :

In this test, the samples of the previous test are taken into lactose broth fermentation tube and agar tube, and both tubes are incubated at 37°C for 24 to 48 hours. If gas is seen after this period, then it indicates positive result. So, this type of water is unsafe for drinking.

$$\text{MPN Per 100 ml} = \frac{\text{Number of Positive tubes}}{\sqrt{\left(\begin{matrix}\text{ml of sample in}\\ \text{negative tubes}\end{matrix}\right) \times \left(\begin{matrix}\text{ml of sample}\\ \text{in all tubes}\end{matrix}\right)}}$$

(b) Membrane filter technique :

Membrane filter technique gives a direct count of coliform bacteria and it is preferred by environmental engineers as the results are obtained in 24 hours as compared to 72 hours in MPN test.

In this method, water sample is filtered through 0.45 µm size filter and filtered bacteria are allowed to grow with selective media and inhibitors of other bacteria at appropriate temperature for 24 hours. After incubation period, the visible colonies are counted by colony meter and the results are reported in numbers of bacteria in 100 ml of water.

Table 2.1 Indian Standards for Water quality (IS – 1050-2012)

[Jan. 2010, April 2010]

No.	Parameter	Desirable limit	Permissible limit
1	Colour (Hazen units)	5	15
2	Odour (Threshold Number)	Agreeable	Agreeable
3	Taste	Agreeable	Agreeable
4	Turbidity (NTU)	1	5
5	pH value	6.5 to 8.5	No relaxation
6	Total Hardness (as $CaCO_3$) mg/l	200	600
7	Iron (as Fe mg/l)	0.3	No relaxation
8	Chlorides (as Cl mg/l)	250	1000
9	Residual free chlorine mg/l min	0.2	1.0
10	Fluoride (as F mg/l)	1.0	1.5
11	Dissolved solids Mg/l	500	2000
12	Calcium (as Ca mg/l)	75	200
13	Magnesium (as mg mg/l)	30	100
14	Copper (as Cu mg/l)	0.05	1.5
15	Manganese (as Mn mg/l)	0.1	0.3
16	Sulphate (as SO_4 mg/l)	200	400
17	Nitrate (as NO_3 mg/l)	45	No relaxation
18	Alkalinity (as $CaCO_3$) Mg/l	200	600
19	Phenolic compounds mg/l (as C_6H_5OH)	0.001	0.002
20	Mercury (as Hg mg/l)	0.001	No relaxation
21	Cadmium (as Cd mg/l)	0.003	No relaxation
22	Selenium (as Se mg/l)	0.01	No relaxation
23	Arsenic (as As mg/l)	0.05	No relaxation
24	Cyanide (as Cn mg/l)	0.05	No relaxation
25	Lead (as Pb mg/l)	0.01	No relaxation
26	Zinc (as Zn mg/l)	5	15
27	Cromium (as Cr^{+6} mg/l)	0.05	No relaxation
28	Aluminium (as Al mg/l)	0.03	0.2
29	Boron (as Bo mg/l)	0.5	1.0
30	Radioactive materials		
	Alpha–emitters Bq/l	0.1	No relaxation
	Beta–emitters pci/l	1.0	No relaxation
31	E–Coli	No E–Coli in 100 ml	

Source : Indian standard drinking water – specification (Second Revision) IS – 10500 : 2012, BIS, New Delhi, India.

Table 2.2 BIS (ISI) Standards for Discharge of wastewater

Characteristics of wastewater	Tolerance limits for Domestic effluents discharged into inland surface water : IS:4764–1973	Tolerance limits for Industrial effluents discharged into inland surface water : IS:2490–1974	Tolerance limits for Industrial effluents discharged into public sewer : IS:3306–1974	Tolerance limits for Inland surface water used public water supplies and bathing ghats : IS:2296–1974
BOD (5 days at 20 °C), mg/l	20	30	500	3
COD, mg/l	–	250	–	–
pH value	–	5.5 to 9.0	5.5 to 9.0	6.0 to 9.0
Total suspended solids Mg/l	30	100	600	– 600
Temperature, °C	–	40 °C	45 °C	–
Oil and grease (mg/l)	–	10	100	0.1
Phenolic compounds mg/l	–	1	5	0.005
Fluoride (as F mg/l)	–	2.0	–	1.5
Chlorides (as Cl mg/l)	–	–	600	600
Sulphids (as S mg/l)	–	2	–	–
Total residual chlorine mg/l	–	1.0	–	–
Insecticides (mg/l)	–	0.1	–	–
Mercury (as Hg mg/l)	–	0.01	–	–
Cadmium (as Cd mg/l)	–	2	–	–
Selenium (as Se mg./l)	–	0.05	–	0.05
Arsenic (as As mg/l)	–	0.2	–	0.2

Cyanide (as Cn mg/l)	–	0.2	–	2
Lead (as Pb mg/l)	–	0.01	1	0.1
Zinc (as Zn mg/l)	–	5	15	–
Cromium (as Cr^{+6} mg/l)	–	0.01	2	0.05
Nickel (mg/l)	–	3	2	–
Sulphates (mg/l)	–	–	–	1000
Radioactive materials Alpha-emitters mi/ml	–	10^{-7}		10^{-9}
Beta–emitters mi/ml	–	10^{-6}		10^{-8}
% sodium	–	–	60	–
Ammonical nitrogen, mg/l	–	50	50	–
Nitrate (as NO_3 mg/l)	–	–	–	50

Table 2.3 The WHO Standards for Water quality

No.	Parameter	Permissible limit
1	BOD (5 days at 20 °C), mg/l	6
2	COD, mg/l	10
3	pH value	6.5 to 9.2
4	Total hardness (as $CaCO_3$) mg/l	500
5	Iron (as Fe mg/l)	1.0
6	Chlorides (as Cl mg/l)	500
7	Dissolved solids mg/l)	500
8	Calcium (as Ca mg/l)	100
9	Magnecium (as Mg mg/l)	150
10	Copper (as Cu mg/l)	1.5
11	Manganese (as Mn mg/l)	0.5
12	Nitrate and Nitrite (mg/l)	45
13	Mercury (as Hg mg/l)	0.001
14	Cadmium (as Cd mg/l)	0.01

15	Selenium (as Se mg/l)	0.01
16	Arsenic (as As mg/l)	0.05
17	Cyanide (as Cn mg/l)	0.05
18	Lead (as Pb mg/l)	0.01
19	PAH	0.2
20	Cromuim (as Cr^{+6} mg/l)	0.05
21	Ammonium (mg/l)	0.5
22	Boron (as Bo mg/l)	–
23	Pesticide	–
24	E-Coli	1–No E–Coli in 100 ml

2.4.2 SOURCES OF WATER POLLUTION : [Jan. 2011, June 2014, June 2016]

Following are the two major sources of water pollution :

(1) Point Source :

They are the source of pollution from single identified location

Examples :

(i) Discharge from domestic, commercial and small industrial waste water into sewer.

(ii) Wastewater generated from industries e.g. dye, textile, pulp and paper, oil, refineries, food processing etc. are major sources of water pollution. It has organic and inorganic matter.

Inorganic Pollutants : Chlorides, sulphates, metals, oxides of metals, acids and alkalies etc.

Organic Pollutants : Carbohydrates, proteins, oils, fats, cellulose and phenols etc.

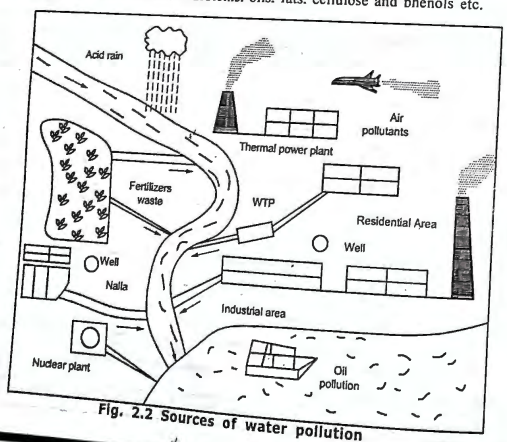

Fig. 2.2 Sources of water pollution

Infilteration of industrial effluents, municipal sewage etc. contaminate the groundwater and cause water pollution.

(2) Non–point source (diffused source) :

Those source whose location cannot be easily identified are called diffused sources.

- The pollutants scattered on the ground ultimately reach the water sources and cause water pollution.

  e.g. Runoff from agricultural fields eventually enters streams, rivers, lakes and the ocean.
- Air pollution gets dissolved in rain water and contaminate the ground water as well as surface water sources.

→ **Ground Water Pollution :**

The total water requirement will be served from ground water, which is about 30 times more than surface water. Ground water seems to be less prone to pollution as the soil mantle through which water passes helps to retain various contaminants due to its cation exchange capacity. Fig. No. 7.3 shows the potential sources of ground water contamination. Ground water pollution with arsenic, fluoride and nitrate are posing serious health hazards.

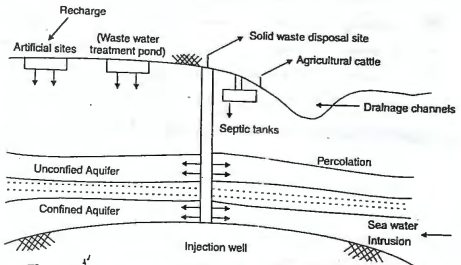

Fig. 2.3 Potential sources of ground water pollution

→ **Surface Water Pollution :**

The major sources of surface water pollution are :

(1) Industrial / Municipal Discharge :

The principal point sources like municipal and industrial wastewater discharges, cooling water from power plants and intermittent discharges such as overflows from stabilization ponds and treatment facilities contribute significantly to surface water quality changes. Industrial wastes containing toxic chemicals, acids, alkalis, cyanides, radioactive substances, ammonia etc. are sources of water pollution.

(2) Agrochemicals :

The diffuse non point sources which effect surface water quality are discharges from drainage channels, agriculture fields, runoff from rain fall covering different land use patterns, varying geology, vegetative cover which transport significant level of dissolved organic matter, sediment, decaying matter etc.

(3) Oil :

Oil spillage into sea–water during drilling and shipment pollute it.

(4) Synthetic detergents :

Synthetic detergents used in washing and cleaning produce foam and pollute water.

→ Major sources of surface water pollution are :

1. Sewage : discharge of sewers and drains.
2. Industrial effluents –chemical, dying, paper, tannery, etc.
3. Intensive use of chemical fertilizers for agriculture.
4. Use of insecticides in agricultural fields.
5. Synthetic detergents used for washing and cleaning.
6. Oil spillage during drilling and shipment.
7. Discharge from nuclear power plant.
8. Discharge from nuclear research centre.
9. Radioactive ash which may spread due to nuclear explosion.
10. Throwing of dead animals in water bodies.
11. Waste heat from industrial discharge and thermal power plants.

2.4.3 CLASSIFICATION OF WATER POLLUTANTS :

[June 2010, June 2013, May 2015, June 2017]

The large no of water pollutants may be broadly classified under the following categories :

(1) Organic Pollutants (2) Inorganic Pollutants
(3) Sediments (4) Radioactive materials
(5) Thermal Pollutants

(1) Organic Pollutants :

The organic pollutants present in water may be classified into five different categories such as :

(i) Oxygen demanding waste (ii) Disease causing waste
(iii) Synthetic organic compounds (iv) Oil
(v) Sewage and Agricultural runoff

Along with pathogens, human and animal wastes contain organic matter that creates serious problems if it enters bodies of water untreated. Other kinds of organic matter (leaves, grass clippings, trash etc.) can enter bodies of water as a consequence of runoff and, in the case of excessive aquatic plant growth, can grow within the water with the exception of plastics and some human made chemicals, these wastes are biodegradable.

(i) Oxygen demanding wastes :

The amount of organic pollutant in water can be estimated by finding dissolved oxygen (DO) in water. The oxygen demanding wastes are generally biodegradable organic matter contained in sewage, industrial wastes from food processing, paper mills, agricultural return etc. These organic wastes provide a good substrate for the growth of aerobic bacteria which decompose the waste and deplete the oxygen.

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

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

The two most important measures of oxygen demand are :

(a) Biochemical Oxygen Demand (BOD) : **[Jan. 2016]**

BOD is a measure of the amount of organic material in water, in terms of how much oxygen will be required to break it down biologically.

(b) Chemical Oxygen Demand (COD) :

It is a amount of oxygen required to oxidize the waste chemically.

(ii) Disease causing waste :

The most serious water pollutants are the infectious agents that cause sickness and death. The excrement from humans and other animals infected with certain pathogens (disease – causing bacteria viruses and other parasitic organisms) contains large number of these organisms or their eggs.

(iii) Synthetic Organic Compounds :

Because water is such an excellent solvent, it is able to hold many chemical substances in solution that have undesirable effects.

Organic chemicals are another group of substances found in polluted waters. Petroleum products pollute many bodies of water, from the major oil spills in the ocean to small streams receiving runoff from parking lots.

Pesticides :

Other organic substances with serious impacts are the pesticides that drift down from aerial spraying or that runoff from land areas and various industrial chemicals, such as Polychorinated Bipheyls (PCBs), cleaning solvents and detergents.

Many of these pollutants are toxic even at low concentrations. Some may become concentrated by passing up the food chain in a process called **biomagnification.** Even at very low concentrations, they can render water unpalatable to humans and dangerous to aquatic life. At higher concentration they can change the properties of bodies of water so as to prevent them from serving any useful purpose except navigation.

(2) Inorganic Pollutants :

This include inorganic salts, mineral acids, finly divided metals or metal compounds, trace elements, complexes of metals with organic compounds in natural water.

Major sources of inorganic pollutants in water are :

- Suspended solids, iron, cyanide; sulphides, oxides of Cu, Cd, Hg, bleaching liquors come from iron and steel, paper and pulp industry.
- Acid come from wastewater of various industries. Acids destroy the bacteria and other microorganisms.
- Phosphates come from detergents and nitrates from fertilizers.
- Ferric and ferrous ions are derived from fertilizers.
- Chemical Industries and mining activities are adding chlorides, various metals, acids, alkalies, sulphates, nitrates etc.

- Toxic metals are added in aquatic system from industrial processes, domestic sewage discharge, street dust, land runoff and fossil fuel burning. Traces of heavy metals like Hg, Cd, Pb, As, Co, Mn, Fe and Cr have been identified as harmful to aquatic ecosystem and human health.

(3) Sediments :

Sediments are soil and mineral particles which are washed away from the land by flood waters and cause pollution of surface water. However, erosion from farmlands, deforested slopes, construction sites, mining sites, roads can greatly increase the load of sediment entering waterways, sediments includes silt, debris, sand and clay, which have direct and extreme physical impacts on streams and rivers.

Sand, silt, clay and organic particles (humus) are quickly seperated by the agitation of flowing water and are carried at different rates. Clay and humans are carried in suspension, making the water muddy and reducing the amount of light penetrating the water and, reducing photosynthesis. As the material, settles, it coats everything and continuous to block photosynthesis. It also kills the animals by clogging their gills and feeding structures.

(4) Radioactive materials :

Radioactive wastes enter in aquatic bodies in following ways :

(1) Water from nuclear power plants

(2) Fallout from nuclear weapons testing

(3) Uranium ore processing

(4) Waste from research laboratories and hospitals that use isotopes in dignosis and therapeutic procedures.

(5) Thermal Pollutants :

Since water is able to absorb large amounts of heat with small increases in its own temperature, it is much in use as a cooling medium. This explains the location of many industrial plants along rivers. The heat in water body is regarded as a pollutant, as high temperatures may disrupt life and ecosystem processes. Since, species vary in their temperature tolerance ranges and levels at which they perform the best, rise in water temperature leads to change in species composition. In a lake, the rise in temperature may lead to disapperance of blue–green algae.

Increase in BOD and consequent oxygen depletion is one of the common and principal consequences of heat. Less oxygen dissolves in warm water than in cold water. In well mixed water, oxygen content is about 14.6 ppm at 0°C, but it is only 6 ppm at 40 °C

Table 2.4 The Major Types of Pollutants

Pollutant	Major Sources	Effects
Oxygen demanding wastes	Sewage effluent; agricultural runoff including animal wastes; some industrial effluents (from paper mills, food–processing, etc.)	Decomposition by aerobic bacteria depletes level of dissolved oxygen in water; flora and fauna perish; further decomposition by anaerobic bacterial produces foul–smelling, toxic substances such as hydrogen sulfide.

Plant nutrients	Sewage effluent including phosphates from detergents; agricultural runoff, especially nitrates from fertilizers.	Algablooms; death of submerged vegetation; production of large amounts of dead organic matter with subsequent problems of oxygen depletion.
Acids	Acids rain; mine drainage; planting of extensive areas of coniferous forests, which acidify the soil.	Acidification of natural waters; sharp decline species richness; fish loss; contamination increase in level of toxic metals in solution, e.g., aluminium.
Toxic metals Hg, Pb, Cd, Zn, Sn	Ore mining; associated industries; lead from vehicle exhaust emissions.	Biomagnification of toxic metal with each successive stage of food chain; threat to consumers including humans.
Oil	Drilling operations; oil tankers–pills; natural seepage; waste disposal.	Contamination of the aquatic environment, death of birds and mammals.
DDT (an organochlorine)	Direct application; agricultural runoff and via aerial crop–spraying.	Biomagnification; top carnivores (especially birds) at risk; very persistent in the environment.
PCBs	Sewage effluent; landfill sites	Biomagnification; top carnivores at risk; effects on human health include joint pain, chlorance and fatigue.
Radiation	0 % from natural sources; 20 % from nuclear weapons testing, medical X–rays, nuclear energy industry, etc.	Degree of tissue damage and risk of death depended on exposure; radionuclides can be biomagnified, and some are very persistent in the environment.
Heat	Coolant waters from industry, principally the electricity generating industry.	Change in species composition usually accompanied by a decrease in species richness; fish may migrate or be killed by suffocation; reproductive cycle of fish and other aquatic organism disrupted.

2.4.4 EFFECTS OF WATER POLLUTANTS :

Some important effects of water pollutants are as follows :

1. Water borne diseases :

Water borne diseases are caused by pathogenic organisms (bacteria, viruses, protozoa) carried by water containing sewage contamination.

The important water borne diseases are :

- Cholera
- Typhoid
- Dysentery
- Infections hepatitis, etc.

2. Organic waste :

Organic matter present in water is decomposed by microorganisms present in water. Microorganisms (bacteria) required oxygen to decompose organic matter. Amount of oxygen required by bacteria to decompose the organic matter under aerobic conditions is known as **Biochemical Oxygen Demand (BOD).**

The saturated value of dissolved oxygen (DO) in water is in the range of 8 to 15 mg/l (ppm). Due to decomposition of organic waste by bacteria in water, the DO level decreases. If DO level drops below 4 ppm fish and other aquatic life is threatened and in extreme cases killed.

Other effects of reduced DO are undesirable taste, colour and odour of water prohibiting its use for domestic and recreational purpose.

3. Nitrogen and phophorous compounds (Nutrients) :

Addition of nitrogen and phophorous compounds in water helps in growth of algae and other plants. Their high concentration in water causes rapid growth of algae called **algal bloom.** It covers up water surface and prevents entry of sunlight into water bodies.

Aquatic plants along with algae thus die, the bacteria present in water decompose these dead plants. The decayed organic matter adds unwanted colour, odour and taste to water. It also reduces DO of water leading to death of fish and other aquatic animals.

4. Toxic compounds :

(i) DDT : DDT is not water soluble and have affinity for body lipids. These substances tend to accumulate in the organism's body. This process is called **bio–accumulation.**

The concentration of these toxic substances builds up at successive levels of food chain. This process is called **biomagnification.**

Biomagnification is harmful to aquatic animals and humans.

(ii) Mercury : Mercury dumped in water is converted to methyl mercury by bacterial action. A disease called **'Minamata'** occurs due to consumption of fish contaminated with methyl mercury.

(iii) Nitrate : Concentration of nitrate more than 45 mg/l in water causes **'blue baby'** (mathemoglobinemia) disease in infants.

(iv) Fluoride : Fluoride in water less than 1.0 ppm causes **'dental cavities'**, while more than 1.5 ppm causes **'mottling teeth' (fluorosis)** i.e. discoloration of teeth.

(v) Pesticides : Affects central nervous system.

5. Metals : All metals are soluable in water to some extent. Metals are added to water by mining, industrial or agricultural sources.

(i) **Lead :** damage to kidneys

(ii) **Mercury :** causes **'minamata'** diseases

(iii) **Arsenic :** Toxic, affect nervous system, carcinogenic

(iv) **Chromium :** Carcinogenic

(v) **Cadmium :** highly toxic, causes **'itai–itai'** disease with painful rheumatic condition.

(vi) **Aluminium :** Causes **'Alzheimer'** disease.

6. Suspended matter :

- Makes water aesthetically displacing.
- biodegradable suspended matter causes DO depletion in water.
- It reduces sunlight penetration into water bodies thereby reducing photosynthesis process, resulting in plants death.

7. Thermal pollutants :

The heat in water body is regarded as a pollutant, as high temperatures may disrupt aquatic life and ecosystem processes.

Increase in BOD and DO depletion is one of the common consequences of heat. Less oxygen dissolves in warm water than in cold water.

Increased temperature of water has following effects :

- Increases biological activities.
- Increase BOD and decrease DO.
- Increase in algae growth.
- Cause death of some heat sensitive animals.
- Toxicity of chemical pollutants increases.

2.4.5 HEALTH EFFECTS OF CHEMICAL PARAMETERS : [April 2010]

Table 2.5 Heath Effects of Chemical Parameters

Parameter	BIS Guideline value (maximum allowable)	General and Health effect
Total dissolved solids	2000 mg/L	Undesirable taste; gastro intestinal irritations; corrosion or incrustation
pH	6.5–8.5	Affects mucous membrane; bitter taste; corrosion; affects aquatic life
Alkalinity	600 mg/L	Boiled rice turns yellowish
Hardness	600 mg/L	Poor lathering with soap; deterioration of the quality of clothes; scale forming; skin irritation; boiled meat and food became poor in quality

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Hardness	600 mg/L	Poor lathering with soap; deterioration of the quality of clothes; scale forming; skin irritation; boiled meat and food became poor in quality

Calcium	200	Poor lathering and deterioration of the quality of clothes; incrustation in pipes; scale formation
Magnesium	100	Poor lathering and deterioration of clothes; with sulfate laxative
Iron	1.0	Poor or sometimes bitter taste, colour and turbidity; staining of clothes materials; iron bacteria cuasing slime
Manganese	0.3	Poor taste, colour and turbidity; staining; black slime
Aluminium	0.2	Neurological disorders; **Alzheimer's** disease
Copper	1.5	Liver damage; mucosal irritation, renal damage and depression; restricts growth of aquatic plants
Zinc	15	Astringent taste; opalescence in water; gastro intestinal irritation; vomiting; dehydration, abdominal pain, nausea and dizziness
Ammonia	–	Indicates pollution; growth of algae
Nitrite	–	Forms nitrosoamines which are carcinogenic
Nitrate	100	**'Blue baby'** disease (methemoglobineamia); algal growth
Sulfate	400	Taste affected; laxative effect; gastro intestinal irritation
Chloride	1000	Taste affected; corrosive
Fluoride	1.5	Dental and skeletal **'fluorosis'**; non–skeletal
Phosphate	–	Algal growth
Arsenic	0.05	Toxic; bio–accumulation; central nervous system affected; carcinogenic
Mercury	0.001	Highly toxic; causes **'minamata'** disease–neurological impairment and renal disturbances; mutagenic
Cadmium	0.01	Highly toxic; causes 'itai–itai' diesase – painful rheumatic condtion; cardio vascular system affected; gastro intestinal upsets and hyper tension
Lead	0.05	Causes plumbism–tiredness; lassitudes, abdominal discomfort, irritability, anaemia; bio–accumulation; impaired neurological and motor development, and damage to kidneys
Chromium	0.05	Carcinogenic; ulcerations, respiratory problems and skin complaints
Pesticide	0.001	Affects central nervous system
Detergent	–	Undesirable foaming

2.5 EUTROPHICATION : [June 2011, Jan. 2013, June 2016]

The word 'eutrophication' is originated from Greek words,

'eu' means **'well'**

'trophes' means **'feed'.**

Thus, **'eutrophication'** means **'well fed'** or **'nutrient rich'.**

Thus eutrophication can be defined as an excessive nutrient load in a water body or enrichment of water body by nutrients like phosphorus and nitrogen.

Presence of nutrients is must for growth of organisms, but if these nutrients are peresent in excessive amour .hen they act as pollutants, because they allow excessive growth of aquatic plants like algae.

Depending upon the presence of nutrients, the water bodies (aquatic system) may be classified as under :

1. **Oligotrophic :**

   Water bodies with poor concentration of nutrients and very low productivity of aquatic plants.

2. **Mesotrophic :**

   Water bodies with moderate concentration of nutrients and average productivity of aquatic plants.

3. **Eutrophic :**

   Water bodies with very high concentration of nutrients and very high productivity of aquatic plants.

→ **What causes eutrophication ?** **[June 2011, Dec. 2010, Jan. 2011, May 2015]**

Newly formed water bodies such as lakes, ponds and reservoirs, whether natural or man–made do not support aquatic life as they are poor in nutrient supply. Gradually, with the passage of time these water bodies become rich, in nutrients through the deposit of domestic waste, agricultural residue (rich in nitrogen and phosphorus), land drainage and industrial waste. As a result, eutrophication that is enrichment of the water body starts.

Natural eutrophication is a very slow process, often taking more than 100 years. But artificial eutrophication is very fast as it depends on the input of organic waste matters. The aerobic decomposition of organic waste in the presence of oxygen by bacteria leads to eutrophication.

The nutrient rich water body supports the growth of algae and the entire water body becomes green. As more plants grow due to the additional supply of nutrients, more plants also die. Bacteria decompose these dead plants and organic waste using dissolved oxygen. As a result, BOD of water increses. Fish and other aquatic animals start dying due to the depletion of oxygen. Such a water body is said to be eutrophied. With an increase in BOD, water starts emitting an offensive smell and asthetic and recreational importance of the water body decreases.

Generally, it is observed that concentration of nitrogen higher than 0.3 mg/*l* and phosphorus more than 0.15 mg/*l* causes eutrophication.

→ **Effects of eutrophication :** **[Dec. 2010, Jan. 2011, June 2011]**

1. Increase in plant growth (i.e. algae) and decay.
2. Decrease in DO and high BOD.

3. Increase in turbidity of water.
4. Increase in rate of sedimentation.
5. Algal boom releases toxic chemicals which kill fish, birds and other aquatic animals causing fish water to stink badly.
6. Asthetic and recreational importance of the water body decreases i.e. fishing, swimming, boating etc.
7. Health related problems can occur where eutrophic conditions interfere with drinking water treatment.

[May 2015]

→ **Control of eutrophication :**

Eutrophication can be controlled by :

1. Limited input of nutrients through treatment of waste water before discharge into water bodies.
2. Reduction in the discharge of agricultural runoff in the pond of lake.
3. Reduction in the intrusion of domestic waste water in the pond or lake.
4. Removal of algal blooms by dredging.
5. Reducing the use of phosphates in detergents.
6. Reducing the use of nitrate containing fertilizers.
7. Application of algaecides (copper sulphate) on water surface, to kill algae.
8. Using lime treatment for precipitation of phosphorous, i.e. removal of phosphorous.
9. Soil erosion control.
10. Physical, chemical or biological methods can be adopted to remove dissolved nutrients from water, i.e. phosphorus can be removed by precipitation and nitrogen by nitrification or denitrification, electrodialysis, osmosis and iou exchange methods.

2.6 CONTROL OF WATER POLLUTION : [June 2014]

The following measures may be adopted to control water pollution :

1. By proper sewage treatment :

The sewage should be properly treated before discharging it into water bodies. The sewage should be given following treatments before discharging into water bodies.

(i) Primary treatment :

Screening – removal of floating particles

sedimentation – removal of settleable solids.

Grit chamber – removal of grit and sand.

Skimming tanks – removal of oil and grease.

(ii) Secondary treatment :

In this treatment biodegradable organic matter and suspended solids are removed, by an action of aerobic and anaeribic bacteria.

- **Activated sludge process** – reduces organic matter (BOD and COD) by aerobic biological oxidation through suspended growth.
- **Trickling filter process** – reduces BOD by aerobic biological oxidation through attached growth.

(iii) Tertiary treatment :

1. Tertiary treatment like chemical oxidation which removes dissolved organic matters, nutrients and microbes by chlorine gas or ozone, etc.
2. The industrial effluents should be properly treated before discharging it into water bodies.
3. By enforcing stringent standards for disposal of sewage and industrial wastes into water bodies.
4. By prohibiting direct washing of clothes and animals in water bodies used for drinking water supply.
5. Pesticides and chemical fertilizers should be judiciously used to reduce chemical pollution due to surface runoff from agricultural fields.
6. By reducing oil spills and discharge of pesticides in water bodies.
7. Increasing vegetation cover to reduce water pollution due to soil erosion.
8. Encouraging reuse of water.
9. By preventing the discharge of hot water from thermal power plants directly into the water bodies.
10. By preventing discharge of effluents from nuclear power plants directly into the water bodies.
11. By making public aware about the adverse effects of water pollution and educating people to prevent water pollution by human activities.

SHORT ANSWER QUESTIONS

1. Define 'environmental pollution'.

Environmental pollution can be defined as any undesirable change in the physical, chemical or biological characteristics of any component of the environment (i.e. air, water and land) which can cause harmful effects on various forms of life or property.

2. Define 'pollutant'.

A pollutant may be defined as any substance present in the environment in such concentration, that alter the quality of environment and affect the living things adversely.

3. What are the non–biodegradable pollutants ?

Non–biodegradable Pollutants :

These are the pollutants which can not be degraded/decomposed naturally by the action of water or degrade very slowly.

e.g. • DDT • Plastic
• glass • polythene bags
• E–waste, etc.

[Jan. 2013]

4. Define 'potable water'.

The water which is fit for drinking is known as potable water or wholesome water.

5. Give permissible limits of the following parameters for drinking water as per BIS. Colour, turbidity, temperature, pH, taste

CHAPTER

3. Air Pollution

– *CO_2 is up from 280 ppm in 19th century in atmosphere to 400 ppm now – about 43% increase.*
– NASA

[Jan. 2013, Jan. 2017]

3.1 AIR POLLUTION :

Air pollution is defined as the presence of unwanted and undesirable foreign particles and gases (in sufficient quantity and duration) in the air which may have adverse effects on human beings, animals, plants, vegetations and important structures.

As per IS : 4167 (1966) air pollution is defined as under :

"Air pollution is the presence in ambient atmosphere of substances, generally resulting from the activity of man, in sufficient concentration, present for a sufficient time and causes the harmful effects on humans, plants and animals."

Unit of Measurement : $\mu g/m^3$ or ppm

Air pollution is of public health concern and can occur as :

(i) Indoor air pollution - Micro scale

(ii) Outdoor air pollution (ambient) - Meso scale

(iii) Air pollution at global level - Macro scale

Pollutant :

Any substance present in the environment in harmful concentration which adversely alters the environment by damaging the growth-rate of a species and by interfering with the food chains, is toxic and affects the health, comfort and property etc. is considered as a pollutant.

e.g. smoke (industries and automobiles), domestic sweage, discarded items (tins, bottles etc.)

3.2 COMPOSITION OF AIR :

Atmospheric air is a mixture of various gases, water, vapour and fine particulate matters. The major gases present in atmospheric air are nitrogen (78%), oxygen (21%), argon (0.9 - 1.0 %) and carbon dioxide. The important minor gases are neon, helium, methane, hydrogen and ozone.

Table 3.1 gives the composition of clean, dry, atmospheric air.

Table 3.1 Composition of clean, dry atmospheric air

Constituent	Concentration (% by volume)
Major gases	
1. Nitrogen (N_2)	78.08
2. Oxygen (O_2)	20.95
3. Argon (Ar)	0.93
Minor gases	
4. Water vapours	0.10
5. Carbon dioxide (CO_2)	0.032
6. Neon (Ne)	0.0018
7. Helium (He)	0.0005
8. Methane (CH_4)	0.0002

Trace gases	
9. Krypton	0.0001
10. Nitrous oxide	0.000025
11. Hydrogen	0.000050
12. Ozone	0.000002

Most of the above values remain practically unchanged with resport to time. However, the concentration of CO_2 is increasing at the rate of 1.5 ppm per year as a result of deforestation and increased air pollution from industries and automobiles.

The atmosphere extends for approximately **500 kms** from Earth's surface, becoming less dense with increasing altitude. With increasing altitude the air simply gets thinner but there is not a distinct altitude at which the atmosphere ends and outer space begins.

More than 99% of the mass of the atmosphere is found within approximately **30 km** of the Earth's surface. Such an altitude is extremely small compared to earth's diameter. Hence, it is known as **tissue thin** protective layer.

Although, the total mass of the global atmosphere is approximately 5.14×10^{15} tons, it is still only approximately one millionth of the Earth's total mass.

3.3 STRUCTURE OF ATMOSPHERE :

[April 2010]

The atmosphere can be sub-divided into five regions as given below :

i. Troposphere
ii. Stratosphere
iii. Mesosphere
iv. Thermosphere
v. Exosphere

(i) Troposphere :

It is the lower most layer of atmosphere in which most living organisms exist. It extends up to **8** km at the poles and **16 km** at equator.

It contains **70%** of the atmosphere's mass. The density of the troposhere decreases with altitude. The air near the ground level is heated by the radiation from the earth, but the temperature decreases uniformly with altitude. This decreases of temperature with altitude is known as **lapse rate.**

The cold layer (–56°C) at the top of the troposphere, which shows a temperature inversion, that is, a negative to positive lapse rate, is known as **tropopause.**

(ii) Stratosphere :

A stable layer of atmosphere above troposphere is called stratosphere. It extends about **50 - 55 km** above the surface of the earth.

Stratosphere is known for the presence of **ozone** which is found at around 20 km from ground. This layer of ozone is called **ozonosphere** and acts as a protective layer against the harmful effects of ultra violet radiations on living organisms.

The layer separting **stratosphere** from mesosphere is called **stratopause.**

(iii) Mesosphere :

It exists over stratosphere and in this layer, temperature decreases with altitude (negative lapse rate) because of low levels of ozone that absorbs ultraviolet radiation. The mesopause separates the **mesosphere** from the thermosphere.

This layer is very special as all sound waves as well as short radio waves coming from earth are reflected from this layer.

(iv) Thermosphere :

After mesosphere, thermosphere starts and extends up to **500 km** above earth's surface. Tempefature rises in this zone with altitude and this trend continues further.

Ionisation of elements like oxygen and nitric oxide take place in the upper most portion of layer. Therefore, the upper layer of thermosphere is also called **ionosphere.**

(v) Exosphere :

The uppermost layer of the atmosphere is called **exosphere.** This extends up to a height of about 1600 km and gives way to interplanetary space. In this layer very high temperature (> 1200 °C) is found.

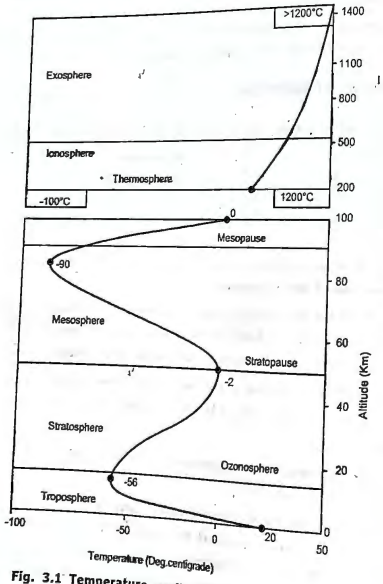


Fig. 3.1 Temperature profile of Atmosphere

3.4 NATIONAL AMBIENT AIR QUALITY STANDARDS : [June 2010, May 2015]

Table 3.2 National Ambient Air Quality Standards

Central Pollution Control Board

Notification, New Delhi, 18th November-2009

National Ambient Air Quality Standards (NAAQS)

Sr. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial Other Area	Ecologically Residential, Rural and by Central Government)	Sensitive Area (notified
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), µg/m³	Annual*	50	20	– Improved West and Gaeke
		24 hours**	80	80	– Ultraviolet fluorescence
2	Nitrogen Dioxide (NO_2), µg/m³	Annual*	40	30	– Modified Jacob & Hochhieser (Na–Arsenite)
		24 hours**	80	80	– Chemiluminescence
3	Particulate Matter (size less than 10 µm) or PM_{10} µg/m³	Annual*	60	60	– Gravimetric
		24 hours**	100	100	– TOBM
					– Beta attenuation
4	Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ µg/m³	Annual*	40	40	– Gravimetric
		24 hours**	60	60	– TOBM
					– Beta attenuation
5	Ozone (O_3) µg/m³	8 hours**	100	100	– UV photometric
		1 hour**	180	180	– Chemiluminescence
					– Chemical Method
6	Lead (Pb) µg/m³	Annual*	0.50	0.50	– AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
		24 hours**	1.0	1.0	– ED–XRF using Teflon filter
7	Carbon Monoxide (CO) mg/m³	8 hours**	02	02	– Non Dispersive Infra Red Red (NDIR) spectroscopy
		1 hour**	04	04	
8	Ammonia (NH_3) µg/m³	Annual*	100	100	– Chemiluminescence
		24 hours**	400	400	– Indephenol blue method
9	Benzene (C_6H_6) µg/m³	Annual*	05	05	– Gas Chromatography based continuous analyzer
					– Adsoption and Desorption followed by GC analysis

10	Benzo(a)Pyrene (BaP) – particulate phase only, mg/m³	Annual*	01	01	– Solvent extraction followed by HPLC/ GC analysis
11	Arsenic (AS), mg/m³	Annual*	06	06	– AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni) mg/m³	Annual*	20	20	– AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

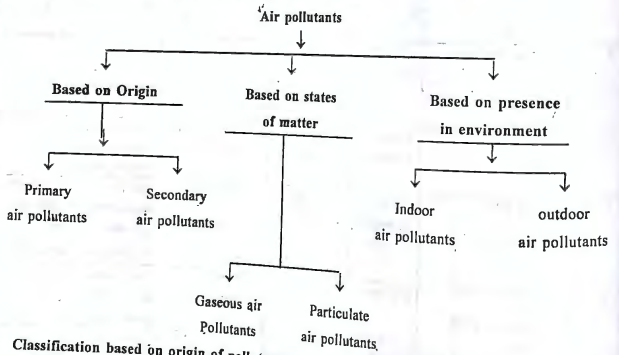
* *Annual arithematic mean of minimum 104 measurement in a year at a particular site taken twice a week 24 hourly at uniform intervals.*

** *24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year, 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

3.5 CLASSIFICATION OF AIR POLLUTANTS : [Jan. 2010, Jan. 2013, May 2015]

Air pollutant may be defined as any substance (solid, liquid or gaseous) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment.

The air pollutants can be classified on the following basis :



(a) Classification based on origin of pollutants :

According to the origin of pollutants, the air pollutants are classified as :

1. **Primary air pollutants**
2. Secondary air pollutants

1. Primary air pollutants : [June 2011, Jan. 2016, June 2017]

Primary air pollutants are those which are directly emitted from the source into the atmosphere, and remains in the same form in the atmosphere.

For example,

- Sulphur oxides (SOx)
- Nitrogen oxides (NO_x)
- Carbon monoxide
- Hydrocarbons
- Radioactive materials
- Particulate matter - ash, smoke, dust, fumes, mist, sprays, etc.

These air pollutants are emitted by man made sources like,

- transportation
- fuel combustion
- industrial operations
- solid waste disposals, etc.

2. Secondary air pollutants : [June 2011, Jan. 2016, June 2017]

Secondary air pollutants are those which are formed by chemical reactions among primary pollutants and atmospheric chemical species.

For example,

- Ozone
- Sulphur trioxide
- Petroxyacyl nitrate (PAN)
- ketones
- Photo-chemical smog, etc.

(b) Classification based on states of matter :

According to the state in which air pollutants are found in atmosphere, they are classified as :

1. Gaseous air pollutants
2. Particulate air pollutants

1. Gaseous air pollutants : [May 2012]

Gaseous air pollutants are those air pollutants which are found in the gaseous state at normal temperature and pressure in the atmosphere.

The most common gaseous air pollutants are :

- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Nitrogen oxides (NO_x)
- Sulphur Oxides (SO_x)
- Hydrocarbons
- Photochemical oxidants, etc.

2. Particulate air pollutants : [May 2012]

Particulates are finely divided, air borne, solid and liquid particles (droplets), which remain for very long time in air, in suspension. Depending upon their size and mode of formation, particulate air pollutants are further classified as below :

Aerosols :

These are air borne suspensions of solid or liquid particles smaller than 1 mm size. e.g. dust, smoke, fume, mist, etc. are aerosols.

Dust :

It consists of small solid particles (size 1 to 200 μm) and are generated by material crushing, grinding or blasting.

They remain in suspension but finally settle under influence of gravity.

Fumes :

They are fine solid particles of size around 0.1 to 1 μm formed by the condensation of vapours of solid matter.

They are odourless vapours which may or may not be visible.

Smoke :

They are also fine solid particles of size around 0.1 to 1 μm, formed by the incomplete combustion of organic matter like coal and wood.

Depending upon the nature of the material burnt, smoke may have different odours.

Mist :

It consist of liquid droplets of size around 0.1 to 10 μm and formed by the condensation of vapours in the atmosphere.

Fog : **[June 2010, Jan. 2013]**

If the mist is made up of water droplets at high concentration so as to obscure vision then mist is called fog.

Flayash :

These are inorganic substances released after the burning of organic part from coal or wood. These are finely divided non-combustible light paraticles present in the gases.

Soot : **[June 2013]**

These are the carbon particles impregnated with tar, and released by the incomplete combustion of carbonaceous materials.

Photochemical smog : **[June 2016]**

Atmospheric pollution formed by chemical reactions among hydrocarbons, ozone and other pollutants in the presence of sunlight is referred as photochemical smog.

(c) Classification based on presence in environment :

According to the presence of pollutants in the environment, they are classified as :

1. Indoor air pollutants
2. Outdoor air pollutants

1. Indoor air pollutants :

The air pollutants which are generated from households are called indoor air pollutants.

e.g.
- Cleaning agents
- mosquito repellents
- Pesticides
- Paints, glues, varnishes

- Cigarette smoke
- gases from stoves
- Microbes like bacteria, viruses, fungi, etc.

2. Outdoor air pollutants :

The air pollutants which are generated outside the buildings are called outdoor air pollutants.

e.g.
- Automobile pollutants
- Industrial pollutants
- Mining pollutants
- Natural emissions from decaying organic matter and animals etc.

→ **Units of measurement of Air pollutants :**

The concentration of air pollutant in the air may be expressed in units of :

1. $\mu g/m^3$ = micrograms per cubic meter
2. ppm = parts per million

These two units are used to indicate the concentration of gaseous pollutant.

However, the concentration of particulate matter is usually expressed only as $\mu g/m^3$.

The ppm unit, is a volume to volume ratio.

Note that the usage of ppm here is different than that in water and waste water, which is mass to volume ratio, i.e. mg/L.

3.6 SOURCES OF AIR POLLUTION : [June 2009, April 2010, Jan. 2011]

The sources of air pollution may be classified into two groups :

1. Natural sources
2. Man made sources

1. Natural sources :

The following are the different forms of natural sources :

(i) Atmospheric reactions :

In the atmosphere, different types of chemical reactions are always going on. In the lower atmosphere, the gases or vapours are converted in solids and liquids by condensation or oxidation.

In the upper atmosphere, the photochemical reactions are going on by the absorption of ultra-violet solar radiation. It breaks the complex molecules of organic matters.

The products of atmospheric reactions come down to earth by rain, snowfall, etc.

(ii) Gases and ash released from **volcanic eruptions.**

(iii) Smoke and green house gases released by **forest fires.**

(iv) Harmful gases, particulates and chemicals from **dust storms, electric storms** etc.

(v) Marsh gases due to decay of vegetable matter **in marshy places.**

(vi) **Pollen.** These may enter the atmosphere from the flowers of trees, grasses and weeds and may be transported from place to place by wind.

(vii) **Salt spray from oceans.**

(viii) **Microorganisms :**

These are in the form of algae, fungi, bacteria, yeast, etc. These organisms can be transported by wind to far distances and can affect plants, animals and human beings.

(ix) **Radioactive substances :**

The radioactive substances like uranium, radium, thorium, etc. present in the earth crust are responsible for imparting the radioactivity of air.

2. **Man-made sources :**

The following are the man made sources of air pollution :

(i) **Combustion of fuel :**

In domestic areas, the burning of coal, wood, oil, LPG. etc. forms harmful gases which pollute the air.

(ii) **Automobile exhaust :**

Automobiles like truck, buses, cars, two wheelers, autorickshows, etc. exhaust carbon monoxide (CO) which is dangerous to human health

(iii) **Industries :**

The industries like iron and steel manufacturing oil refinery, chemical factories, petro-chemical plants, pulp and paper, etc. cause serious air pollution.

(iv) **Thermal and Nuclear power plants :**

The thermal power plants contribute sulphur dioxide (SO_2) and nuclear power plants contribute radioactive fly ashes to the atmospheric air.

(v) **Agricultural activities :**

Use of pesticides for growing crops may cause air pollution.

(vi) **Construction materials :**

The manufacture of bircks, cement, stone chips, etc. pollute the atmosphere by discharging smoke, gases and dusts.

(vii) **System of sanitation :**

The unscientific disposal of garbage produces foul gases, bad odour and insanitary condition.

In towns where the conservancy system is followed, the system of disposal of night soil produces foul gases and fly nuisance.

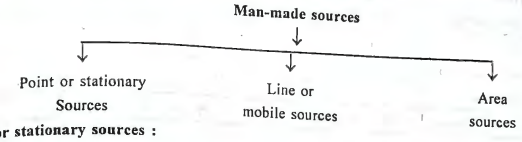
(viii) **Mining**

(ix) **Nuclear explosions**

(x) **Air crafts**

(xi) **Waste water treatment plants**

The man-made sources of air pollution can be classified as :



Point or stationary sources :

These are the sources which add pollutants to air from one or more controllable points.

e.g. Chimneys of different industries

Pollutants from point sources affect only restricted areas.

Line or mobile sources :

The line or mobile sources of air pollution are the sources like automobiles, trains, ships aeroplanes, etc. which emit exhaust into air along a narrow belt over long distance.

Area sources :

Area sources are locations from which air pollutants are emitted from a well defined area.

e.g.

release of air pollutants from industrial area of town or city which affects particular area.

Table 3.3 Classification of Anthropogenic Air pollution sources

Source type	Category	Important Sources	Typical Pollutants
Combustion	Stationary	Power plants, Industrial boilers Diesel generators Municipal or industrial Incineration Reuse burning	SO_x NO_x CO Smoke Fly ash Trace metal oxides
	Mobile	Motor vehicles Air craft	CO, HC, NO_x, SO_x, Particulates
Roasting and heating	Non ferrous metallurgical	Roasting, smelting and refining operations sulphur	Dust, smoke, metal fumes (Cu, Zn and Pb) oxides of
	Ferrous metallurgical	Material handling, ore siutering and pelletizing, coke ovens, blast furnaces, steel furnaces	Smoke, fumes, CO, odours, H_2S, organic vapour, fluorides
	Non-metallic minerals	Crushed stone, cement, glass, refracteries, ceramic manufacture, coal cleaning.	Mineral and organic particulates

Food and agriculture.	Food processing	Drying, preserving, packaging	Vapour, odour, dust
	Crop spraying and dusting	Pest and weed control	Organic phosphates, chlorinated HC, organic, lead.
	Field burning	Refuse burning	Smoke, fly-ash and soot.
Chemicals, petroleum, pulp and paper	Petroleum refining	Boilers, process heaters, catalyst regenerators, flares, storage tanks, compressor engines.	SO_x, HC, NO_x, particulate matter, CO, aldehyde, ammonia, odours.
	Inorganic chemical	Sulphuric acid plants, fertilizer manufacturers, nitric acid and ammonia plants, phosphoric acid manufacture.	SO_x, HF, H_2S, NO_x, NH_3, particulate matter, H_3PO_4, etc.
	Organic chemicals	Plastics, paint and varnish manufactures, synthetic rubbers, rayon, insecticides, soap and detergent manufacture, methanol, phenol, etc.	Particulate matter, odours, SO_2, CO, organic intermediates, solvent vapours
	Pulp and paper (Kraft process)	Digester blow system, pulp washers, recovery furnace, evaporators, oxidation towers	Particulate matter, H_2S, methyl mercaptans, dimethyl sulfide, SO_2

3.7 MAJOR AIR POLLUTANTS - SOURCES AND EFFECTS :

[April 2010, June 2010, May 2012, Dec. 2013, June 2014]

The major air pollutants are :

1. Carbon monoxide (CO)
2. Carbon dioxide (CO_2)
3. Oxides of Nitrogen (NO_x)
4. Oxides of Sulphur (SO_x)
5. Hydrocarbons (HC)
6. Photochemical Oxidants
7. Particulate matter (PM)
8. Ground level ozone

1. Carbon monoxide (CO):

[Jan. 2011, July 2011]

Carbon monoxide is a colourless, odourless, tasteless gas, chemically inert under normal conditions of temperature and pressure. It is not soluable in water.

At normal concentration (less than 0.1 ppm) it is not harmful, but if its concentration exceed 0.1 ppm in atmosphere it seriously affect the human metabolism.

Sources :

1. Natural processes like volcanic eruptions, natural gas emissions, electric discharge during storms, seed germination, marsh gas production, etc, contribute a small amount of CO in the atmosphere.
2. Transportation sources contribute about 65% of CO in air.
3. Solid waste disposal.
4. Forest fires
5. Coal mines
6. Industrial processes such as electric furnaces and blast furnaces in iron and steel industry, petroleum refining, paper industry, etc.

Effects :

1. CO has strong affinity with haemoglobin and it combines with blood haemoglobin to form Carboxyhaemoglobin (COHb) which reduces the oxygen carrying capacity of blood.
2. It reduces vision, causes headache.
3. It affects the nervous system and imparts laziness.
4. It causes cardiovascular disorders.
5. It may cause coma, respiratory failure and even death.

2. Carbon dioxide (CO_2) :

Carbon dioxide is ideally not considered as an air pollutant if its presence does not exceed the concentration ideally present in atmosphere.

The content of CO_2 in the air has increased by approximately 15% during the last century inspite of the fact that photosynthesis process of green plants balance the $CO_2 - O_2$ ratio to a large extent.

Sources :

1. Fossil fuel combusiton.
2. Jet planes use O_2 and release CO_2
3. Respiration process
4. Forest fires
5. Decay of organic matter, etc.

Effects :

1. It is the main green house gas responsible for rise in average temperature of atmosphere.
2. CO_2 is less dangerous than CO and causes nausea and headache.
3. It disturbs atmospheric stability and thus plays an important role in climate changes in atmosphere.

3. Oxides of Nitrogen (NO_x) :

[Dec. 2014]

Among the six different oxides of nitrogen [NO, NO_2, N_2O, N_2O_3, N_2O_4, N_2O_5] nitric oxide (NO) and nitrogen oxide (NO_2) are very important pollutants.

NO is colourless, odourless gas but NO_2 is reddish brown and have suffocating odour.

NO and NO_2 are formed as under :

$$N_2 + O_2 \xrightleftharpoons{1210\text{-}1265^{\circ}C} 2\,NO$$

$$2NO + O_2 \rightleftharpoons 2NO_2$$

Sources :

1. Fuel combustion in automobiles and industries
2. Light thundering
3. Forest fires
4. Bacterial decomposition of organic matter
5. Natural ionizing radiations

Effects :

1. Like CO, nitric oxide (NO) can also combine with haemoglobin and reduces the oxygen carrying capacity of blood.
2. NO_2 is more toxic then NO and may affect lungs and cause bronchitis.
3. NO_2 absorbs light and thus reduce the visibility.
4. NO_2 reacts with atmospheric moisture to form nitric acid causes acid rain and affects vegetables and metals.

4. Oxides of Sulphur (SO_x) : **[Dec. 2014]**

Sulphur oxides are called SOx. Among the six oxides of sulphur [SO, SO_2, SO_3, SO_4, S_2O_3, S_2O_7] sulphur dioxide (SO_2) and sulphur trioxide (SO_3) are very important pollutants.

SO_2 is colourless, nonflammable and nonexplosive gas which may impart suffocation. SO_2 and SO_3 form H_2SO_3 (sulfurous acid) and H_2SO_4 (Sulfuric acid) in the air.

Sources :

Natural processes like volcanic eruptions contribute to 67% of SOx pollution, whereas 33% comes from anthropogenic sources as mentioned below :

1. Burning of fossil fuels
2. Emissions from vehicles
3. Emissions from industries - thermal power plants, oil
4. Solid waste disposal

Effects :

1. It causes cardiac diseases, asthma, bronchitis, eye irritation, throat troubles, etc.
2. Long term exposures to high levels of SO_2 gas causes respiratory illness and heart diseases.
3. Oxides of sulphur attacks building materials especially marbles and lime stone.
   e.g. **Taj Mahal** at **Agra**
4. SO_2 react with moisture in atmosphere to form sulphuric acid which causes acid rain and affects vegetables and metals.
5. Oxides of sulphur may affect clothes, leather, paper and plants.

5. Hydrocarbons (HC) :

The main hydrocarbons which may be gaseous and/or volatile air pollutants are methane (CH_4), ethane, acetylene and ethylene.

Sources :

1. Incomplete combustion of fossil fuels.
2. Emissions from vehicles.
3. Refineries and industries
4. Forest fires.
5. Agricultural burning
6. Emissions from trees

Effects :

1. Unburned hydrocarbons with oxides of nitrogen in the presence of sunlight form photochemical smog which can have adverse effects on humans and plants.
2. Ethylene may inhibit the growth of plants.
3. Some aromatic hydrocarbons may cause cancer.

6. Photochemical Oxidants :

The major photochemical oxidant is ozone (O_3).

Ozone is produced in the upper atmosphere by solar radiation. Small concentrations of this gas diffuse downwards and become the major concern in air pollution.

Formation :

In the presence of sunlight, the oxides of nitrogen react with the unburned hydrocarbons released by the exhausts of automobiles (fuel combustion) and following a series of complex reactions produce secondary pollutants like peroxyacylnitrate (PAN), Ozone (O_3), aldehydes and ketones etc.

Unburnt Hydrocarbon + $NO_x \xrightarrow{\text{Abundant Sunlight}}$ Photochemical Smog

Sources :

(1) Automobile exhausts

Health Effects :

(1) Photochemical oxidants cause irritation of eye, nose and throat, headache etc. in man.

(2) Ozone damage chromozomes.

(3) O_3 and PAN cause damage to plants by interfering with plant cell metabolism especially in leafy vegetables.

(4) Premature fall and Yellowing of leaves are due to this pollutant.

(5) Photochemical oxidants also effect the materials like rubber plants, textile fibers etc.

7. Particulate Matter (PM) : **[Jan. 2011, May 2012]**

Particulate matter are finely divided air borne, solid and liquid particles (droplets) which remain for very long time in air, in suspension.

The size of particulate ranges from 0 02 μ to 500 μ.

The examples of particulate matter are dust, fume, smokes, fog, mist, etc.

The more general classification of particulates is

(i) TSPM :- Total suspended particular matter

(ii) RSPM - Respirable suspended particulate matter, popularly known as PM_{10}.

PM_{10} are particulates of equivalent spherical diameter of 10 μm or less. PM_{10} directly affect health and not the whole range of sizes of particulates.

Sources :

1. Volcanic eruptions
2. Dust storms
3. Spraying of salts by oceans.
4. Fly ash from combustion of fossil fuels.
5. Smoke from vehicles.
6. Mining
7. Agricultural burning.

Effects :

1. Fly ash and soot discharged by burning of coal causes respiratory diseases.
2. Atmospheric dust causes allergic and respiratory diseases in man. If dust contains silica, it leads to silicosis.
3. Metal dust containing heavy metals and cotton dust may also cause respiratory diseases.
4. Air borne asbestos and toxic metals are carcinogenic.
5. Vehicular particulates containing lead affects haemoglobin formation.
6. Aerosols released from aeroplanes may affect ozone layer.
7. Mist and fog reduce visibility.
8. Flyash reduces pH balance and potability of water.
9. Particulates cause damage to buildings, sculptures and plants.

→ **Black Carbon :**

It is a particulate air pollutant produced from incomplete combustion of fuels. It is a solid particle.

It is also called soot or aerosol.

Brown carbon is referred for green house gas.

Sources of black carbon :

- diesel exhaust
- cooking with solid fuels
- biomass burning

Black carbon warms the earth by absorbing heat in the atmosphere.

It reduces albedo (the ability to reflect sunlight) when deposited on snow and ice.

25 to 35 % of black carbon in the global atmosphere comes from China and India.

In India, 'Project Surya' has been launched by the Government of India to reduce black carbon in the atmosphere by introducing efficient stoves, solar cooker, solar lamps and biogas plants.

8. **Ground level Ozone :**

Ground level ozone is the ozone present in the earths lower atmosphere. It is produced by a complex chemical reaction when nitrogen oxides (NO_x), Carbon monoxide (CO) and volatile organic compounds (VOC's) such as xylene, react in the presence of sunlight. These chemicals are produced

from cars, trucks, electric power plants, paint fumes and industrial process. Ground level ozone is the primary constituent of smog. Ground level ozone, though less concentrated than ozone in the stratosphere, is more of a problem because of its health effects :

The major health effects are —

1. Irritation of the respiratory system causing coughing, throat irritation and an uncomfortable sensation in the chest.
2. Aggravations of asthma. The reason is that ozone makes people more sensitive to allergies, which in turn triggers asthma attacks.
3. Increases susceptibility to respiratory infections.
4. Inflammation and damage of the lining of lungs.

3.8 EFFECTS OF AIR POLLUTION :

(a) Effects of Air pollution on Human health :

[Jan. 2010, April 2010, June 2013, June 2014, Jan. 2017]

The general health effects of air pollution are :

1. Carbon monoxide (CO) and nitric oxide (NO) combine with haemoglobin to form carboxy haemoglobin (COHb) which reduces oxygen carrying capacity of blood.
2. Oxides of nitrogen (NO_x) and oxides of sulphur (SO_x) cause irritation to eye, throat and nose. They also cause diseases like asthama and bronchitis, etc.
3. Secondary pollutant (PAN) produced by hydrocarbons and NO_x, results in the formation of photochemical smog, which causes irritation of eyes, nose, throat and respiratory diseases.
4. Some aromatic hydrocarbons may cause cancer.

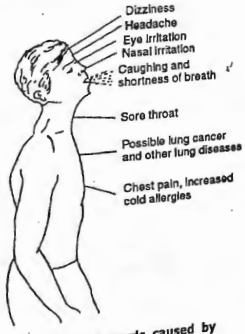


Fig. 3.2 Health hazards caused by air pollution

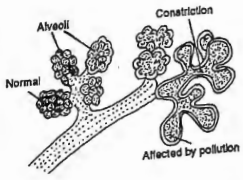


Fig. 3.3 Effects of polluted air on bronchial tubes

5. Exposure to dust, smoke, smog and soot may induce several respiratory diseases like asthama, bronchitis and lung cancer.
6. Atmospheric dust containing slilica may cause silicosis.
7. Air borne asbestos and toxic metals are carcinogenic.
8. Heavy metals like lead may cause poisoning effects on nervous system, damage to kidney and vision problems.
9. Pollens initiate asthamatic attacks.
10. Mercury from combustion of fossil fuels, plants result in nerve brain and kidney damage.
11. Nickel particulates in tobacoo smoke result in respiratory damage.
12. Radioactive substances cause lung diseases and affect kidney, liver, brain and sometimes may cause cancer.

Table 3.4 Effect of Air pollutants on Human beings

Sr. No.	Name of pollutant	Effect on human being
1.	Carbon monoxide (CO)	Reduction in oxygen carrying capacity of blood, affects nervous system, imparts laziness, reduces vision, causes headache.
2.	Carbon dioxide (CO_2)	Causes nausen and headache.
3.	Nitrogen Oxide (NO_2)	Irritation to eye and nose, affect lungs and cause bronchitis.
4.	Sulphur dioxide (SO_2)	Irritation in eye and throat, respiratory diseases, heart diseases.
5.	Hydrocarbons (HC)	Effects respiratory system, may cause cancer
6.	Photochemical oxidants	Asthama, bronchitis, effects on lungs.
7.	Particulate matter (PM)	Respiratory diseases, silicosis
8.	Heavy metals like lead	Poisoning effects on nervous system, damage to kidney, vision problems.
9.	Hydrogen fluoride	Bone diseases, mottling of teeth, respiratory diseases.
10.	Hydrogn sulphide	Irritation in eye and nose, nausea, bad smell.
11.	Aldehydes, Ketones,	Irritation in respiratory tract, long term exposure Ammonia may cause lukemia.

(b) Effects of Air pollution on plants and vegetations : **[June 2017]**

- Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis. During the day time the stomata are wide open to facilitate photosynthesis. Air pollutants during day time affect plants by entering the leaf through these stomata more than night.
- Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought and frost. Damage to leaf structure causes dropping of leaves.
- Paticulates like dust, fog, soot deposit on plant leaves, block stomata and affect the rate of transpiration.

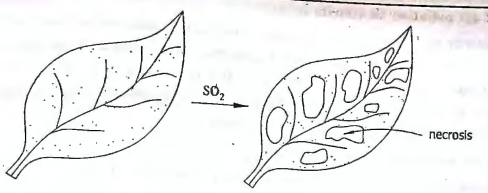


Fig. 3.4 Effect of SO_2 on Leaf [It causes Necrosis]

Following are some of the effects of air pollutants on plants and vegetations.

Table 3.5 Effects of Air pollutants on Plants and vegetations

Sr. No.	Name of pollutant	Effect on plants and vegetations
1.	Sulphur dioxide (SO_2)	Loss of chlorophyll, bleached spots on leaves, necrosis (Killing of tissues).
2.	Nitrogen dioxide (NO_2)	Suppressed growth, premature leaf fall (abscission), reduction in productivity.
3.	Ozone (O_3)	Premature ageing, bleaching of leaves, necrosis, destruction of vegetation.
4.	Fluorides	Necrosis at leaf tip
5.	Ethylene	Leaf fall, flower dropping
6.	PAN	Bronzing of leafs, damage to small plants

(c) Effects of air pollution on Materials and Buildings :

- Sulphur dioxide effects marble, limestone, roofing, paper, building, textile and monuments.
- NO_x fades away textile dyes like cotton, rayon etc. Higher level of NO_x causes 10% loss of fibre strength in cotton and rayon.
- Leather also has afinity far SO_2 which affects its strength and causes it to disintegrate.
- Low concentration of ozone induces chemical alteration in natural synthetic textiles, paper, rubber and polymers.
- Particulates accelerate corrosion of metals. Dust, soot, mist, aerosols bring about severe damage to soil, building, sulpture and monuments.
- H_2S and organic sulphides react with lead paints to form lead sulphide thereby producing brown to black discoloration.
- Hydrocarbons (HC) pollutants damage long chains of carbon atoms loosing tensile strength of polymers..

(d) Effects of air pollution on climate : **[Jan. 2013]**

- Due to man made activities like industrialization, automobiles, deforestations etc., concentration of CO_1 and other green house gases in atmosphere will increase. About 50% of Green House Effect may be attributed to CO_2, which resulted in the increase in temperature of earth. This increase in temperature caused the melting of ice caps and glaciers. Thus the increase in ambient air temperature will increase the mean sea level.

(e) Effect of air pollution on Aesthetic beauty : **[Jan. 2013]**

- The most noticeable effect of air pollution on the properties of atmosphere is the reduction in visibility, which may lead to safety hazards. Visibility is reduced by absorption and scattering of light. The aesthetic beauty of nature is not visible due to scattering of light by air borne particles (0.1 to 1 mm size). Industrial and automobiles emissions, sewage and garbage emit foul odours causing loss of aestetic beauty.

(f) Effects of air pollution on Animals : **[Jan. 2009, June 2017]**

Animals are indirectly affected by air pollution mainly by eating contaminated vegetation.

- Lead poisoning occurs in animals grazing near smelters and lead mines. It causes paralysis and difficulty in breathing. It also leads to loss of appetite and diarrhoea.
- Arsenic poisoning in animals causes severe salivation, thirst, vomiting irregular pulse and respiration, abnormal body temperature and death.
- Farm animals like cattle and sheep are quite susceptible to fluorine toxicity. It affects to lack of apetite, periodic diarrhoea, muscular, weakness loss of weight and death.

3.9 CONTROL OF AIR POLLUTION : **[June 2013]**

The most effective means dealing with the problem of air pollution is to prevent the formation of the pollutants or minimise their emissions at the source itself.

Following measures can be taken to control air pollution :

1. Dilution
2. Zoning
3. Control at source
4. By using controlling equipments

1. Dilution :

The atmosphere, like natural stream, possesses self cleansing properties which continuously clean and remove the pollutants from the atmosphere under natural conditions, provided the pollutants are discharged in the atmosphere judiciously so that effective dispersion take place.

If the pollutants are carried away to some distance or taken to high altitudes, they are reduced in concentration by diffusion and dilution. The pollutants are taken to high altitudes by means of tall stacks. i.e. high rise chimneys. The height of the stack should be such that the maximum ground level concentration, which varies inversely with the square of the stack height, is within the permissible limits.

2. Zoning :

Air pollution can be effectively controlled by adopting the zoning system at the planning stage itself. The **'exclusive zoning system'** which provides for compatible uses for each zone, excluding other uses. In this system, a separate zone (area) is set aside for industries known as **industrial** zone, located away from the residential zone. This will result in low concentration of pollutants in the air of residential area.

3. Control at source :

This method is known as **'air pollution prevention at source'**. This can be achieved through :

i. Raw material changes

ii. Process changes

iii. Equipment modification or replaement

(i) Raw material changes :

If a particular raw material is responsible for causing air pollution, use of a purer grade of raw material is often beneficial and may reduce the formation of undesirable impurities and byproducts.

For example,

- use of low sulphur fuel in place of high sulphur fuel
- use of natural gas in place of coal for power generation.
- use of LPG/CNG instead of diesel/petrol in automobiles.

(ii) Process Changes :

Process changes involving new or modified techniques offer important ways of lowering atmospheric pollutant emissions.

For example,

- Washing of coal before pulverization to reduce the fly ash emissions.
- Substitution of bauxite flux for fuorine containing fluorspar in the open hearth method.
- Radical changes in chemical and petroleum refining industries have resulted in minimising of the release of materials to the atmosphere. The volatile substances are recovered by condensation and the non-condensable gases are recycled for additional reactions.
- Rotary kilns are a major source of dust generation in cement plants. Reduction of gas velocities within the kiln, modification of the rate and location of feed introduction and employment of a dense curtain of light weight chain at the discharge end of the kiln can lead to dust control.

(iii) Equipment modification or replacement':

Old equipment, which contribute to greater degree of air pollution can be modified or completely replaced.

For example,

- Replacing open hearth furnaces, with controlled basic oxygen furnaces or electric furnaces in steel industry can reduce smoke, carbon monoxide and metal fumes and conserving energy.
- Newer type of equipments in paper and pulp industry also cut down the quantity of pollutants emitted.

Unburnt carbon monoxide and hydrocarbons in the cylinders of an automobile engine, which are otherwise emitted into the atmosphere through the tail pipe, can be burnt by injecting air into the hot exhaust manifold of the engine.

4. **By using controlling equipments :**

Certain mechanical devices can be installed in the industrial processes, which may help in reducing the emission of pollutants.

Following equipments or devices are used to control the emission of particulate pollutants :

i. Gravitational settling chambers
ii. Cyclone separators or centrifugal collectors
iii. Electrostatic Precipitators
iv. Fabric Filters
v. Wet Scrubbers

(i) **Gravitational Settling Chambers :**

Gravitational settling chambers are generally used to remove large abrasive particles (usually > 50 μm) from gas streams.

A gravitational settling chamber consists of a large circular/rectangular expansion chamber in which dust is separated from the gas by reducing the velocity of the gas. Due to this the dust particles settle down under gravity, in the bottom of the chamber. Gravity settling chambers are set horizontally, often on the ground and can be constructed in brick or concrete. In order to reduce the size of the chamber, the gas velocity is kept between 0.5 m/s to 3 m/s. to prevent re-entrainment of settled particles.

The simplest form of horizontal type settling chamber is shown in Fig. 3.5.

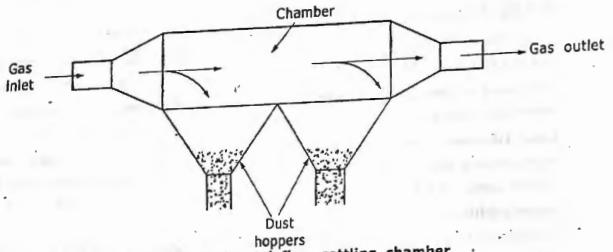


Fig. 3.5 Horizontal flow settling chamber

The emitted smokes, when made to pass through a settling chamber, drop some of their larger sized particles in the chamber, under Stoke's law. The largest size particle (d) that be removed with 100 % efficiency in a chamber of length (L), height (H) is given by the equation :

$$d = C\sqrt{\frac{18\mu \times V_h \times H}{g \times L \times \rho_P}}$$

where,

V_h = horizontal velocity of gas (0.5 to 2.5 m/s)
μ = Viscosity of air, in kg/m.sec
ρ_p = density of particles removed
C = correction factor for existing non-quiescent conditions in the gas flow, generally taken as 2.

Advantages :

1. Low initial cost
2. Simple to design
3. Low pressure drop
4. Low maintenance cost
5. Dry and continuous disposal of solid particulates

Disadvantages :

1. Requires large space
2. Less collection efficiency
3. Only large sized particles (> 50 μm) can be separated out.

(ii) **Cyclone separators or centrifugal collectors :**

Cyclone separators utilise a centrifugal force generated by a spinning gas stream to separate the particulate matter from the carrier gas. The centrifugal force on particles in a spinning gas stream is much greater than gravity; therefore cyclones are much effective in removing much smaller particles (10 to 50 μm) than gravitational settling chambers.

A simple reverse flow type cyclone is shown in Fig. 3.6. It consists of a vertically placed cylinder having an inverted cone attached at its bottom, and fitted with a tangential inlet located near the top. The outlet pipe for the purified gas is a central cylindrical pipe at the top, which is extended into the cylinder of the cyclone to prevent shortcircuiting of the gas from inlet to the outlet. The cyclone has an outlet at its bottom of the cone for discharging the separated particles.

In operation, the particle - laden gas upon entering the cyclone cylinder tangentially at its top receives a rotating motion. The **outer vortex** so formed develops a centrifugal force which acts to throw the particles radially towards the wall. The gas spirals downwards to the bottom of the

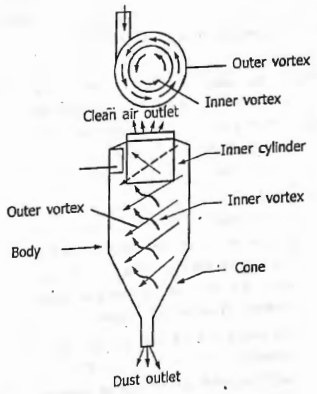


Fig. 3.6 Reverse flow cyclone separator

cone, and at the bottom, the gas flow reverses to form an inner vortex which leaves through the outlet pipe situated at the top of the cyclone. Due to their inertia, the dust particles tend to concentrate on the surface of the cycle from where they are led to the receiver.

The centrifugal force generated can be expressed by,

$$F_c = \frac{m_p \times V_i^2}{r}$$

where,

F_c = Centrifugal force

m_p = mass of the particles

r = radius of cyclone

V_i = inlet gas velocity

Cyclones are widely used in industries producing larger quantities of gas containing large sized particles like cement and fertilizer plants, petroleum refineries, asphalt mixing plants, grain mills, cotton gins, etc.

Advantages :

1. low initial cost
2. Simple to design and maintain
3. requires less floor area
4. ensures dry continuous disposal of collected dusts
5. Low to medium pressure loss (2.5 to 20 cm)
6. Can handle large volumes of gases at temperatures up to 90°C.

Disadvantages :

1. Requires much headroom
2. Collection efficiency is low for smaller particles
3. Quite sensitive to variable dust loadings and flow rates

(iii) Electrostatic Precipitators (ESP) :

The electrostatic precipitator is one of the most widely used devices for controlling particulate emissions at industrial installations ranging from power plants, cement and paper mills to oil refineries. In most cases, the particulates to be collected are byproducts of combustion.

Electrostatic precipitation is a physical process by which particles suspended in a gas stream are charged electrically and under the influence of electrical field, separated from the gas stream.

For industrial applications, vertical plates exposed to horizontal gas flow are normally used. In this type of collector, the gas flows between two parallel plates

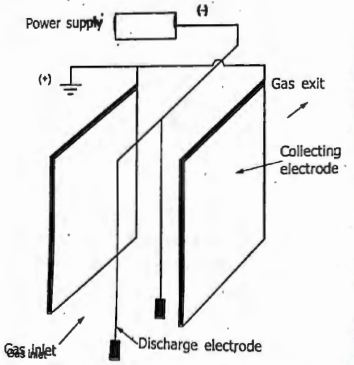


Fig. 3.7 Parallel plate precipitator

between which are suspended a number of vertical wires held in place by weights attached at the bottom. These wires form the discharge electrodes, while the vertical plates form the collection electrode.

Advantages :

1. Particles as small as 0.1 μm can be removed.
2. High collection efficiency
3. Power requirement is less
4. Large gas columns can be handled
5. Pressure drop is less (0.25 – 1.25 cm of water)
6. Can remove tar and acid mists
7. ability to operate over a wide range of conditions, temperature up to 800°C and pressures of 50 atmosphere.
8. treatment time is negligible (0.1 to 10 seconds)

Disadvantages :

1. High initial cost
2. Large space is required
3. high voltage equipment necessitates special safety precautions
4. There are possible explosion hazards during collection of combustible particulates or gases.
5. Collection efficiency raduces with time
6. Sensitive to variable dust loadings and flow rates

3.10 FACTORS AFFECTING AIR POLLUTION : [Jan. 2011]

The major factors affecting air pollution are :

1. **Meteorological characteristics :**
   - Wind direction
   - Wind speed
   - Atmospheric lapse rate
   - Relative humidity, etc.
2. **Topographical features :**
   - Unevenness of land forms and barriers like mountains
   - Valleys
3. **Characteristics of pollutants :**
   - Type and size of pollutants
   - Interaction among pollutants
4. **Mode of release of pollutants :**
   - Intermittent, continuous, cyclic
   - From single source or multiple source
   - From point source or area source

3.11 AIR POLLUTION EPISODES :

Air pollution episode means air Pollution disasters.

The major air pollution disasters of the world are :

1. **Bhopal (India) :**
   - 3rd December, 1984
   - Union Carbide Company, Bhopal.
   - 30 tonnes of deadly **methyl isocynate** (MIC) gas was leaked from storage tank.
   - More than 2500 people died and about 1 lakh people severely affected with coughing, conjuctivities, suffocation and cardiac failure.
2. **Donora (USA) :**
   - October 1948
   - Donora, Pennsylvania 45 km north of Pittsburgh
   - anticyclone weather condition characterized by little or no air movement occured over a period of 4 days.
   - Temperature inversion and fog resulted in the death of 20 people and 6000 people become ill.
3. **London (England) :**
   - December 1952
   - Anticyclone weather created a subsidence inversion and fog formed over the london area.
   - Due to low temperature inversion, stagnant air, smoke and sulphur dioxide, 4000 people died, and several thousands hospitalized for respiratory troubles.

CHAPTER

4. Noise Pollution

Natural processes can take more than 500 years to form one inch of top soil.

[June 2011]

4.1 NOISE AND SOUND :

Sound :

Sound is what we hear.

Noise :

Noise is unpleasant and unwanted sound.

The difference between sound and noise depends upon the listener and the circumstances.

e.g.

rock music can be pleasant sound to one person and an annoying noise to another. Sound can be hazardous to a person's hearing if it is loud and if a person is frequently exposed for a long time.

→ **Difference between Sound and Noise :**

Sound	Noise
(i) It is pleasant to hear.	(i) It is unpleasant to hear.
(ii) Sound waves have periodic motion.	(ii) Noise waves have non-periodic mation.
(iii) Pitch of waves is constant.	(iii) Pitch of waves is varying.
(iv) It produces meaningful communication.	(iv) It produces no meaningful communication.
(v) Its unit is Hertz (H_z). Hz = cycles / second	(v) Its unit is decibel (dB)

4.2 CHARACTERISTICS OF SOUND :

1. **Frequency (f) : (Pitch)**

Number of vibrations (cycles) made in one second is called frequency of sond.

Unit of frequency is Hertz.

1 Hz = I cycle per second.

The sound of human speech is in the range of 300 Hz to 3000 Hz.

2. **Time period (T) :**

The time taken by the vibrating particle to complete one vibration (forth and back) is called time period.

It is the time period between successive peaks or troughs of the oscillations.

$$T = \frac{1}{f}$$

3. **Intensity (I) :**

Amount of sound energy received per second from the source of sound per unit area perpendicular to the direction of wave is called intensity of sound.

$$I = \frac{W}{A} = \frac{\text{Sound power}}{\text{Unit area perpendicular}^{\,2} \text{ to the direction of wave motion}}$$

Unit is watt/m^2

4. **Wavelength (λ) :**

The distance travelled by the sound wave during one time period is known as wavelength.

It is the distance between two adjacent crests or troughs of pressure.

5. **Sound pressure :**

It is the amount of air pressure fluctuation created by the source.

We hear sound pressure as 'loudness' e.g. if the drum is hit very lightly, the drum surface moves only a very short distane and produces weak pressure fluctuations and a sound is faint. However, if the drum is hit very hard, the drum surface moves farther from its mean position and produces stronger pressure fluctuations resulting in louder sound.

Sound pressure is expressed in pascals (Pa).

1 Pa = 1 N/m^2 (in SI unit)

In absolute system, unit of sound pressure is dynes/cm^2.

A healthy young person can hear sound pressures as low as 2×10^{-5} Pa.

6. **Sound power :**

It is the sound energy transferred per second from the source to the air.

It is expressed in watts (W).

7. **Sound pressure level (SPL) :**

Sound pressure converted to the decibel scale is called sound pressure level.

$$SPL = 20 \log_{10}\left(\frac{P}{P_0}\right) \text{ decibel}$$

where,

P = Pressure variation measured in N/m^2 (Pa)

P_0 = standard reference pressure

$= 2 \times 10^{-5}$ Pa

8. **Amplitude of wave (A) :**

The amplitude of wave is the height of the peak or depth of the trough measured from zero pressure line.

4.3 NOISE RATING SYSTEM :

[June 2013]

A noise may consists of different types of sound, i.e. continuous, intermittent, and impulse with different pressure levels operating for different time periods. Hence, the frequency of this sound may vary. The combined resultant impact of different sound pressures lasting for different periods is worked out by using some statistical measures as L_N and Leq system.

(i) **L_N system :** The parameter L_N is a statistical measure indicating how frequently a particular sound pressure level is exceeded. The value of L_N will represent the sound pressure level that will exceed for N % of the gauging time.

For example, the given 80 dB value of L_{50} will means that the sound level will exceed 80 dB for 50 % of time.

(ii) Leq system : Leq is defined as the constant noise level, which over a given time, expands the same amount of energy, as is expanded by fluctuating levels over the same time.

L_{eq} is expressed as under :

$$L_{eq} = 10 \log \sum_{i=1}^{n} (10)^{Li/10} \times t_i$$

where,

n = total number of sound samples

t_i = time duration of ith sample, expressed as fraction of total sample time.

L_i = The noise level of the ith sample.

4.4 NOISE MEASURING INSTRUMENTS :

Many types of measuring systems can be used for the measurement of sound depending on the purpose of the study, the characteristics of sound and the extent of information that is desired about the sound.

Various noise measuring instruments used in practice are:

1. Sound level meter
2. Microphones
3. Frequency Analyzers
4. Noise Dosimeters

The various elements in a measuring system are:

a. the transducer; that is, the microphone;
b. the electronic amplifier and calibrated attenuator for gain control;
c. the frequency weighting or analyzing possibilities;
d. the data storage facilities;
e. the display.

1. Sound Level Meter [SLM] :

The electrical signal from the transducer is fed to the pre-amplifier of the sound level meter and, if needed, a weighted filter over a specified range of frequencies. Further amplification prepares the signal either for output to other instruments such as a tape recorder or for rectification and direct reading on the meter.

The rectifier gives the RMS value of the signal. The RMS signal is then exponentially averaged using a time constant of 0.1 s ("FAST") or 1 s ("SLOW") and the result is displayed digitally or on an analog meter.

In some cases, the sound level meter does not include a logarithmic converter. The scale on the indicating device is then exponential so that the linear signal may be read in dB. In this case, the dynamic range of the display is usually restricted to 10 to 16 dB and the precision of the reading is rather poor. In the case of

intermittent noise, the user must constantly adjust the amplifier to adapt the output signal to the dynamic range of the display.

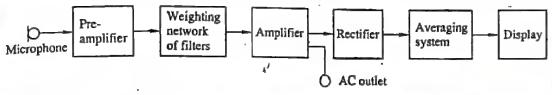


Fig. 4.1 Sound Level Meter Block Diagram

Steps for using Sound Level Meter:

(i) Batteries must be checked before use and during long measuring sessions.

(ii) A wind shield must be used if the air velocity is noticeable. It should anyway be used all the time as a dust shield.

(iii) The microphone should be oriented as described previously.

(iv) All intruding objects such as the body of the sound level meter (SLM) or the operator itself will degrade the frequency response of the microphone at high frequencies and directivity effects will appear at much smaller frequencies. Therefore, the SLM should be, whenever possible, installed on a stable and sturdy tripod equipped with resilient blocks to isolate the sound level meter from vibration and consequent spurious readings. The operator should be at a reasonable distance (2-3 m) behind the sound level meter. Extension cables should be used if possible when measurements are to be made in a restricted area. When the instrument makes it possible, an extension rod should be used for the microphone.

(v) The SLM must be calibrated before any measuring session using a calibrator.

(vi) Nowadays, it is much more advantageous to use an integrating sound level meter to determine the LAeq,T over a representative period of time T than to use a simple SLM on fast or slow giving an instantaneous value.

4.5 MEASUREMENT OF SOUND / NOISE : [June 2011, May 2012, June 2013]

The amount of sound energy received per second from the source of sound, per unit area perpendicular to the direction of wave is called intensity of sound.

The intensity of sound is expressed in watt/m^2.

The value of reference intensity is 10^{-12} watt/m^2.

Sound is measured in decibel (dB) which measures how much intense is the sound compared to reference quantity. [June 2017]

$$\text{decibel (dB)} = 10 \log_{10} \left(\frac{\text{measured intensity}}{\text{reference intensity}} \right)$$

$$\therefore \quad dB = 10 \log_{10} \left(\frac{I}{I_o} \right)$$

where,

I = measured intensity

I_o = reference intensity = 10^{-12} W/m^2

Not only the loudness determines the harmfulness of sound but the frequency or the pitch of the sound is also responsible for this. If a person hears two sounds of the same sound pressure but different frequencies, one sound may appear louder than the other. This happens because we hear high frequency noise much better than low frequency noise.

To take the pitch or frequency of sound into the account, a modified scale is used now a days that is decibel-A, expressed as dBA.

Permissible noise levels, ambient and work place are normally given in dBA.

Table 4.1 gives typical noise levels for different sources.

Table 4.1 Noise levels for different sources

	Source of noise	Noise level (dBA)
1.	Hearing threshould	0
2.	Normal breathing	10
3.	Whisperings	30
4.	Normal conversation	60
5.	Television	70
6.	Passenger car –60 km/hr at 20 m	65
7.	Diesel truck –5 km/hr at 20 m	85
8.	Shouting	75
9.	Motorcycle	75
10.	Rock music	120
11.	Jet plane	130

As per the Ministry of Environment and Forest, Government of India (1989) , the permissible noise levels are given below :

Table 4.2 Permissible ambient noise levels in India

Zone	Noise limits, dBA	
	Day time	Night time
A - Industrial	75	65
B - Commercial	65	55
C - Residential	55	45
D - Silence zone	50	40

day time = 6 a.m. to 9 p.m.

Night time = 9 p.m. to 6 a.m.

Silence zone = up to 100 m around hospitals, educational institutions and courts. Use of vehicle horns, loud speakers, and bursting of crakers shall be banned in these zones.

4.6 SOURCES OF NOISE POLLUTION : [March 2009, June 2013, June 2014]

The presence of unwanted and unpleasant sound in the atmosphere, which may cause discomfort is called noise pollution.

Sources of noise pollution : [Dec. 2010, Jan. 2016]

The sources of noise pollution can be classified into three categories :

1. Traffic sources
2. Industrical sources
3. Constructional sources
4. Other sources

1. Traffic Sources :

Noise created by various means of transport like trucks, tractors, buses, autorickows, trains, aeroplanes, etc. are the traffic related source of noise pollution.

It may be in the form of :

- horn of vehicles
- Raise of accelerator
- Vehicle with damaged silencer
- Noise produced by a diesel car will be more than that produced by a petrol car.
- A jet aircraft will produce more noise than a propeller type of aircraft.

2. Industrial sources :

Industrial noises are usually produced by :

- reciprocating or rotating machinery
- Cutting of materials, grinding
- Blow hammers
- Generators
- High pressure and high velocity gases, etc.

3. Constructional sources :

Noise produced by various constructional activities are :

- rock crushers for production of aggregate
- Pile driving equipments
- boring and drilling equipments
- road rollers
- Materials handling by belt conveyors, chute, hoist
- Rock blasting

4. Other sources :

- In residential area - loud voice of T.V., music systems, radio, etc.
- Public address systems - Public functions, Navratry festival etc.
- Sirens - Police van, industries
- Use of crackers during Diwali and other celebrations.
- Shouting of hawkers at market places
- Playing of children at play ground

4.7 EFFECTS OF NOISE POLLUTION :

[June 2009, Dec. 2010, Dec. 2013, June 2014, Jan. 2016]

The major effects of noise pollution are :

1. Physical effects
2. Physiological effects
3. Psychological effects

1. Physical effects :

- Loss of hearing - long time exposure of loud sound (80 -90 dBa) for more than 8 hours a day, may cause loss in hearing.
- Total deafness (acoustic trauma).
- Sudden loudness particularly from crackers and explosions may affect the ear drum and sensitive ear membrances.

2. Physiological effects :

- Headache, nausea
- Dizziness, gastric ulcers
- High rate of heart beat
- Fluctuations in blood pressure and sugar

3. Psychological effects :

These includes,

- Annoyence, sleep interference (insomnia)
- Depression, fatigue
- Mental stress
- Speech interference
- Effects on performance
- Decrease in efficiency

Effects on animals:

- hearing loss, resulting from noise levels of 85 db or greater;
- masking, which is the inability to hear important environmental cues and animal signals;
- non-auditory physiological effects, such as increased heart rate and respiration and general stress reaction;
- behavioral effects, which vary greatly between species and noise characteristics, resulting in, for example, abandonment of territory and lost reproduction.

Effects on plants;

- Noise pollution is altering the landscape of plants and trees, which depend on noise-affected animals to pollinate them and spread their seeds.
- In cases where noise has ripple effects on long-lived plants like trees, the consequences could last for decades, even after the source of the noise goes away.

4.8 CONTROL OF NOISE POLLUTION : [Jan. 2010, May 2012, Dec. 2013, May 2017]

Noise is a serious Environmental problem and a health hazard. Noise pollution can be effectively controlled by taking the following measures :

(1) Control at Receiver's End :

People working in a noisy installations, ear-protection aid like ear-plugs, ear-muffs, noise helmets, headphones etc. must be provided to reduce occupational exposure.

(2) Supression of Noise at source :

If working methods are improved by :

(a) Installing noisy meachines in sound proof chambers.

(b) Proper maintenance and lubrications of machine.

(c) Use of sound absorbing materials for covering noise-producing machines.

(d) Using silencers to control noise from automobiles, ducts, exhausts etc.

(e) designing, fabricating and using quieter machines to replace the noisy ones.

(f) reducing noise from vibrating machine by vibration damping. i.e. damping materials e.g. rubber, neoprene, cork and plastic beneath the machine.

(3) Acoustic Zoning :

- Silence zones near the educational, hospitals and residential area should require.
- Increasing distance between source and receiver of noisy industrial areas, bus terminals and railway stations, aerodromes etc. away from the residential areas would go a long way in minimising noise pollution.

(4) Planting Trees :

Planting green trees along the roadside, near hospitals, schools, educational institutions etc. help in noise reduction.

(5) Sound Insulation at construction stages :

(a) Gap between the door and wall should be packed with sound absorbing material.

(b) In sound proof recording rooms, acoustical tiles, perforated plywood etc can be fixed on walls and ceilings etc.

(6) Legislative Measures :

Strict legislative measures need to be enforced to reduce noise pollution.

(a) Framing a separate Noise Pollution Act.

(b) Minimum use of loud speakers and amplifiers especially near silence zones.

CHAPTER

5. Solid Waste : Generation And Management

5.1 INTRODUCTION :

The term **'solid waste'** includes all those solid and semi-solid materials that are discarded by a community. Solid wastes are arising from the human and animal activities. It includes both homogeneous and heterogeneous mass of throwaways from residential, industrial and commercial activities.

The solid waste generated through domestic and commercial activities is classified as **'Municipal Solid Waste (MSW)'** and is also called **'refuse'**. It includes garbage, rubbish, ashes, dust, demolition and construction wastes, dead animals, etc.

With increase in population, urbanization and industrialization, most of the cities are facing the issue of solid waste management. Rising incomes, unplanned urbanization and changing lifestyles have resulted in increased volumes and changing composition of municipal solid waste in India.

Presently, India generates about 65 million tons of MSW per year which requires about 1250 hectares of land per year, if this waste remains untreated. The volume of waste is projected to increase from 65 million tons at present to about 125 million tons by 2031. Untreated waste from Indian cities lies for months and years at dumpsites, causing land, water and air pollution. Hence, there is acute need to develop proper solid waste management system in India.

5.2 DEFINITION OF IMPORTANT TERMS :

1. Refuse :

Refuse is a general term used to indicate what is rejected or leftout as worthless.

All sorts of solid wastes from a community may be termed as refuse.

Refuse includes all putrescible and non-putrescible solid wastes.

For example,

- garbage
- rubbish
- ashes
- dead animals
- industrial wastes, etc.

Body waste (excreta) is not included in refuse.

2. Garbage :

This consists of all sorts of putrescible organic waste from kitchens, hotels, restaurents, in the form of waste food products, vegetable and fruit peelings.

It is organic in nature and decomposes quickly. Its density varies from 450 to 900 kg/m^3.

3. Rubbish :

It consists of all non-putrescible wastes, excluding ashes.

For example,

- Paper pieces, paper packets
- rags
- glass and plastic bottles
- broken pieces of glass

- Broken crockery
- Broken furniture, card boards, etc.

The density of rubbish varies between 50 to 400 kg/m^3.

4. Ashes :

Ashes are incombustible waste products from houses, industries, hearths (chulhas) and furnaces. It's density vary between 700 to 850 kg/m^3.

5. Putrefaction :

Anaerobic decomposition of organic matter caused by the anaerobic bacteria and facultative bacteria in absence of oxygen is called putrefaction.

6. Leachate :

Liquid that has travelled through solid waste or other medium and has extracted, dissolved or suspended materials from it.

When dumped refuse contains non-biodegradable and carcinogenic substances, such as plastics, unused medicines, paints, pesticides, sanitary napkins, etc. which may start troubling on coming in contact with rain water **seeping through it, producing a coloured liquid called leachate.**

7. Biodegradable (Putrescible) :

A substance that can be broken down (decomposed) by microorganism is called biodegradable.

5.3 CLASSIFICATION OF SOLID WASTE :

The term **'solid waste'** includes all those solid and semi-solid materials that are discarded by a community. Solid wastes are arising from the human and animal activities. It includes both homogeneous and heterogeneous mass of throwaways from residential, industrial and commercial activities.

Various types of solid waste are :

1. Minicipal solid waste (MSW)
2. Industrial solid waste
3. Hazardous solid waste
4. Agricultural waste
5. Biomedical waste
6. E-waste

1. Municipal Solid Waste (MSW) :

The solid waste generated through domestic and commercial activities is called **'Municipal Solid Waste (MSW)'**. It is also called **'refuse'**.

The MSW consists of :

(i) Garbage
(ii) Rubbish
(iii) Ashes
(iv) Dust
(v) Demolition and construction wastes
(vi) Dead animals, etc.

Municipal Solid Waste (Refuse)

House refuse	Street refuse	Trade refuse
This includes • Vegetable and animal waste matter • rubbish • ashes • cinders • debris from demolition of structures	This includes • empty packets and bottles • empty matches and cigarette boxes • Polythene bags • fruit peels • tree leaves • Street sweepings	This includes solid wastes from • factories • Commercial centres • business centres • slaughter houses, etc.

The average composition of MSW in India is :

Garbage (organic material)	..... 45-50 %
Ash, dust, sand, demotion waste, etc (Inert material)	..... 20-30 %
Paper, glass, plastics, rags, metals etc. (Recyclable material)	..... 20-25 %

Human excreta and **Animal excreta** are not included in MSW.

2. Industrial Solid Waste :

The solid waste generated by industries is known as **'industrial solid waste'.**

It includes, chemical solvents, sludge, ash, metals, paints, sandpaper, flyash, slag, radioactive waste etc.

3. Hazardous Solid Waste :

Any discarded material, liquid or solid, that contains substances known to be fatal to humans, animals and plants are called **hazardous waste.**

A waste is called hazardous if it exhibits any of the following characteristics :

(i) Radioactivity
(ii) Reactivity
(iii) Ignitability
(iv) Toxicity
(v) Corrosivity

Typical examples of hazardous wastes are :

- radioactive substances
- exposives
- flammable wastes
- Chemical wastes

The main sources of hazardous wastes are :

- Nuclear power plants
- Hospitals, laboratories
- Research institutions
- Industries, etc.

4. **Agricultural waste :**

Agricultural wastes are generated from agricultural activities like planting, harvesting, animal farm, poultry farm etc.

The examples of agricultural waste are : crop residue, dead plants manure, animal waste, etc.

5. **Bio-medical waste :**

The wastes from hospitals, nursing homes, clinics, research laboratories, etc. are bio-medical wastes. It is generated during diagnosis, treatment or immunization of human beings or animals. The bio-medical waste which may be solid or liquid are potential source of health hazard and need to be specially treated and disposed off.

6. **E-waste :**

'e-waste' means electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes.

Rapid growth of technology, upgradation of technical innovations, and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world which consist of end of life electrical and electronic equipment product such as : Refrigerator, Washing machines, Computers and Printers, Televisions, Mobiles, Ipods etc. Many of which contain toxic materials.

5.4 QUANTITY AND COMPOSITION OF SOLID WASTE :

The quantity and quality of solid waste varies from place to place and also varies from season to season.

The factors affecting solid waste generation are :

i. the season
ii. climatic conditions
iii. geographic location
iv. habits of people
v. standards of living, etc.
vi. locality - whether residential, commercial or industrial

Ashes increase in winter and in northern latitudes while these are less in summer and in hot tropical countries. In India, average summer refuse is about 25 % higher than the yearly average.

The average per capita per day solid waste generation in India ranges from about 0.1 kg in small towns to about 0.5 kg in large cities. The density of Indian refuse varies from 400 to 600 kg/m^3.

The degree of commercialisation, urbanisation and industrialisation, has resulted in a vast increase in the amount of refuse generation per person. For example, the average per capita daily refuse production in U.S.A. is as high as about 2.8 kg; where as the figure is only about 0.5 kg in India.

Table 5.1 shows the quantity of refuse produced in some important cities in India and in U.S.A.

Table 5.1 Refuse production of some important cities.

Country	City	Refuse quantity (kg/capita/day)
India	New Delhi	1.0
	Calcutta	0.51
	Nagpur	0.40
	Pune	0.30
U.S.A.	Los Angeles	3.20
	Washington	2.20
	New York	1.90
	Ohio	1.70
	Mexico	1.00

→ **New Delhi** – Population about 15 million – Municipal solid waste (MSW) production about 6,000 tonnes/day

→ New York – Population about 20 million – MSW production about 50,000 tonnes/day

Table 5.2 gives an average composition of refuse (by weight) for an average Indian city and an American city, at the disposal site.

Table 5.2 Average composition and properties of MSW (Refuse)

Sr. No.	Constituent	Average composition (% by weight at disposal site)	
		Typical Indian city	Typical city of U.S.A.
1.	Garbage	45 %	20 %
2.	Rubbish (Paper, glass, rags, etc.)	15 %	50 %
3.	Ashes	15 %	15 %
4.	Fine dust, silt, Sand	25 %	15 %
(a)	density	400 to 600 kg/m^3	100 to 250 kg/m^3
(b)	Calorific value (Kilo. joule/kg)	5000 – 6600	15,000

Calorific Value :

Number of heat units obtained by complete combustion of unit mass of fuel.

It's unit of measurement is kilo. Joule/kg or kilo cal/kg.

1 kJ/kg = 0.243 KC/kg.

The average composition of refuse by weight for Indian city is shown in Fig. 5.1.

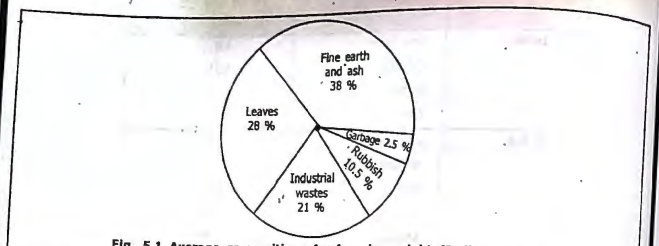


Fig. 5.1 Average composition of refuse by weight (Indian city)

→ **Physical characteristics of Solid waste :**

The physical characteristics of solid waste include the determination of percent contents of various ingredients of the solid waste (i.e. paper, rubber, glass, metal, etc.)

As per manual on SWM, NEERI-1996 : Physical characteristics of solid waste for Indian cities are :

- The paper content generally varies from 2.9 to 6.5 % and increases as population increases.
- The plastics, rubber and leather contents are generally less than 1 %
- The metal content is also less than 1 %.
- The glass content is about 0.3 to 0.8 %.
- Total compostable matter is about 30 to 55 %.
- Fine dust, silt, sand content is about 25 %.
- Density of solid waste is about 400- 600 kg/m^3.

→ **Chemical characteristics of solid waste :**

The chemical content of solid waste includes study of percent contents of various chemical elements like Nitrogen, phosphorous, Potassium, carbon, etc. It also include study of moisture content and calorific value of the solid waste.

- The moisture content of solid waste varies from 20% to 40%.
- The organic matter content also varies from 25% to 40%.
- Nitrogen content is 0.6 to 0.7 %.
- Phosphorous content is 0.5 to 0.8 %.
- Potassium content is about 0.5 to 0.8 %
- Carbon content is about 12%..
- Calorific value is about 800 to 1000 kcal/kg.

5.5 CAUSES AND EFFECTS OF SOLID WASTE POLLUTION :

→ **Causes of solid waste pollution :**

The main causes of rapid growth in the generation of solid wastes are :

1. **Over population :** The quantity of solid waste generated increases with increase in population. Thus solid waste pollution also increases.
2. **Urbanization :** Solid waste is an urban problem where people have the habit of using variety of commodities and discarding them afterwards. With increase in urbanization, solid waste pollution increases.
3. **Technology :** Technology has changed the culture of using things. There is a shift in technology from the returnable packaging to non-returnable packaging. For example, the returnable glass container or bottles are being replaced by non-returnable cans, plastic containers, plastic bottles, etc.

   Since packaging materials like those made from plastic and non-biodegradable, they are largely responsible for causing solid waste pollution.
4. **Affluence :** Affluence means increase in wealth and associated material comfort. In an affluent society, the per capita consumption is very high and people discard many things regularly, which increase solid waste to a large extent.

→ **Effects of solid waste pollution :**

Solid waste can pollute air, water and soil, and leave various environmental impacts, and cause health hazards, due improper handing and transportation.

Environmental impacts :

(i) Leachates from refuge dumps percolates into the soil and contaminate underground water.

(ii) Waste products like plastic and rubber, when burnt, pollute the atmosphere with noxious fumes.

(iii) Organic solid wastes emits obnoxios odour on their decomposition and make the environment polluted.

(iv) Scavengers and stray animals invade the roadside garbage and litter the waste over large area causing much aesthetic damage to the atmosphere.

Health hazards :

(i) Rats and insects invade refuse dumps and spread various diseases, like plague, salmonellosis, trichinosis, etc.

(ii) Water and food contamination through flies causes various diseases like dysentery, diarrhea, etc.

(iii) Water supply, if gets contaminated with pathogens present in solid waste, may result in cholera, jaundice, hepatitis, etc.

(iv) During handling and transportation of hospital wastes, disease transmission may take place.

5.6 SOLID WASTE MANAGEMENT :

Uncontrolled pollution will destroy the ecosystem and the process is irrecoverable. Hence the goal of solid waste management is to minimise hazards to environment due to indiscriminate disposal of solid wastes. Based on the knowledge of solid waste generation, characteristics and treatment methods, certain materials can be recovered or re-used and electrical energy can be generated.

In ensuring better sanitary environments for the people and promoting their general health, the proper collection of refuse (solid waste), its haulage, treatment and disposal with minimum possible nuisance or risk to public health are fundamental to **'solid waste management'.**

Objectives of solid waste management :

1. To remove discarded materials from inhabited places in a timely manner.
2. To prevent the spread of disease.
3. To minimise the likelihood of fires.
4. To reduce aesthetic insults arising from putrifying organic matter.
5. To dispose the refuse in such a manner so as to minimise hazards to environment.

→ **Solid waste management activities :**

The solid waste management encompasses the planning, design, financing, construction and operation of facilities for the collecting, transporting, processing, recycling and final disposal as shown in Fig. 5.2.

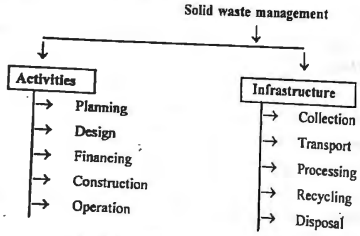


Fig. 5.2 Solid waste management activities and facilities

The three basic functional elements of solid waste management (SWM) are :

1. Collection
2. Disposal
3. Recycling or Reutilization

In figure 5.3 below, we show you a typical SWM system with its functional elements and linkages:

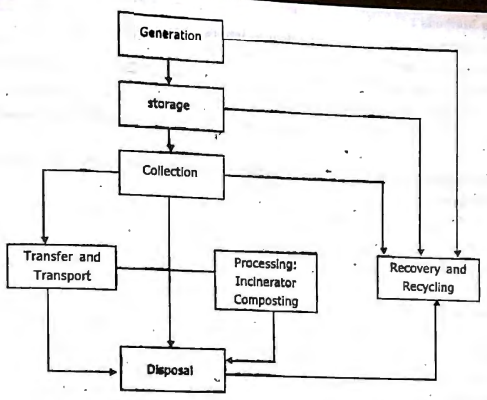


Figure 5.3 Typical SWM system: Functional Elements

→ **Hierarchy of Solid Waste Management :**

The hierarchy of solid waste management shown below indicates an order of preference for action to reduce waste. The main aim of waste hierarchy is to extract the maximum practical benefit from products and generate minimum amount of waste.

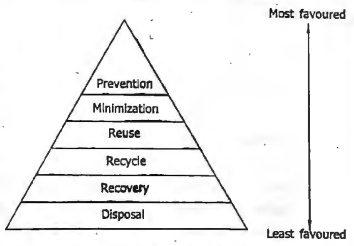


Fig. 5.4 Hierarchy of solid waste Management

5.7 COLLECTION AND CONVEYANCE OF MSW :

The solid waste collection policies of a city begin with decisions made by elected representatives about whether collection is to be made by :

1. City employees (municipal collection)
2. Private firms that contract with city government (Contract collection)
3. Private firms that contract with private residents (private collection)

Many communities have moved away from exclusive municipal collection and towards a combined system. More and more communities are moving towards mandatory recycling of materials such as paper, plastic and glass. In these situations, separation of waste is required.

→ **Collection Methods :**

Collection system of solid waste can be divided into two broad categories :

(i) Primary collection

(ii) Secondary collection

Primary collection, involves the collection of solid wastes from house to house i.e. the points of generation to a suitable nearly common location, may be defined as a transfer station (dust bins, garbage vats, etc).

Secondary collection, involves collection of solid wastes from transfer station and transportation to the point of final disposal.

There are three basic methods of refuse collection :

1. Curbside or alley pickup
2. Setout, set-back collection
3. Backyard pickup

1. Curbside or alley pickup :

The quickest and most economical point of collection is from kerbs or alleys using standard containers. It is most common type of colletction used. It costs only about one-half as much as back-yard collection.

In this system, the house holders put out and later retrieve the storage bins or containers. Residents must place their bins on the kerb side (foot ways) in advance to the collection time and remove them after they have been emptied. A typical crew consists of a driver with vehicle and two or four collectors. The collectors simply empty the bins into the collection vehicles.

Merits :

(i) The method is quickest.

(ii) It is most economical method.

(iii) It eliminates the need for the collectors to enter private property.

Demerits :

(i) Bins sorted through by scavangers.

(ii) Bins are stolen.

(iii) Bins are roll by accident, by dogs or cattle and interfere with the traffic.

(iv) Failure of the householders to retrieve the bins quickly.

(v) It creates unsighty appearance on the streets.

2. Set out-set back collection (Door to door collection) :

In this system the collector (set out crew) enters the garden or courtyard, carries the loaded bins to the vehicle, empties it, and returns it to its usual place. Householders are not involved in the collection process.

It is really a satisfactory system, but is a costly system. It is more time consuming than curbside system.

→ **Backyard Pickup :**

Backyard pickup is usually accomplished by the use of tote barrels (wheel barrow). In this method, the collector enters the resident's property, dumps the container into a tote barrel, carries it to the truck, and dumps it. The collector may collect refuse from more than one house before returning to the truck to dump.

The primary advantage of this system is in the convenience to the homeowner. The major disadvantage is the high cost. Many homeowners object to having the collectors enter their private property.

4. Block collection :

In this, system the homeowners deliver the waste to the vehicles at the time of collection, the time and route of the vehicles are made known to each area being served. The performance of the system depends upon the proper synchronization, precise time table and co-operation between the municipal authorities and the public.

→ **Separation of materials from waste :**

The most primitive method for the separation of materials from waste, is **hand sorting** or **picking**. Ever since civilization began, scavengers have been an integral part of society. Selectively accepting other people's waste, collecting and processing it, and selling it at a profit is a time - honored profession and, in recent times, quite a profitable one.

Pickers (hand sorters) have two major functions. First, they recover any items of value that need not be processed. Commonly, **corrugated card boards**, bundles of news papers, large pieces of metal (reinforcing bars etc.) are recovered by the pickers. This is known as **positive sorting.**

The second function of the pickers is to remove all those items that could cause damage to the rest of the processing system, such as explosives. This type of sorting is called **negative sorting.**

The coding and switching functions in hand sorting are simple to define. The material is recognized visually (coding) by such properties as colour, relectivity and opacity, verified by sensing its density; and removed (separated) by hand picking. Hand sorting is usually done on the conveyor belt after the bags have been mechanically opened in a trommel or a bag-opening flail mill.

Materials recovery facilities (MRFs) that process mixed waste are called **dirty MRFs,** while those that process partially separated material (the recyclables) are called **clean MRFs.**

At a clean MRF the material may arrive in the loose form or in paper bags and no opening is needed. At some facilities, no such preprocessing is used, and the sorting operation is hence highly inefficient. Typically, the conveyor belt is loaded, and the material is leveled out by a skimmer. The pickers stand on either side of the conveyor belt and remove the selected materials. Experience has shown that pickers can salvage up to about 1000 lb/h/person. However, the quantity sorted is highly dependent on the density of the material. For example, the picker removing carboard removes far more material by weight than the picker removing **film** plastic.

The picking belt should be no more than 60 cm wide for one side picking or 90 to 120 cm wide for pickers on both sides, and should not move faster than 9 m/min, depending on the number of pickers. If at all possible, the picking operation should be done in daylight.

Recycling materials include :

- Paper
- Plastic
- Wood
- IT and telephone equipment
- Printer cartridges
- Aluminium
- Card board
- Metal
- Electrical and electronic equipment
- Fluorescent tubes
- Glass
- Steel, etc.

→ **Transport of solid waste :**

The refuse collected in the public dust bins located by the sides of roads, is transported to the disposal site by means of following vehicles :

(i) Auto-rickshaws (ii) Trailers (iii) Trucks

(i) Auto-rickshaws :

These having three or four wheels, have covered bodies. Since their capacity is limited to $\frac{1}{2}$ to $\frac{1}{4}$ tonnes, these are used only for those narrow localities where other heavy vehicles can not go.

(ii) Trailers :

Trailers have slightly larger capacity (2 to 3 tonnes). They are also used for localities where trucks can not go. Loading of trailors is done manually. However, they are of tilting - tipping type and hence their unloading is done automatically with the help of hydraulically operated jacks.

(iii) Trucks :

Trucks have larger capacity (5 – 10 tonnes). They are generally of tilting - tipping type so that unloading is automatic special types of trucks, capable of bodily lifting covered with skip boxes are now available, and should be used so as to avoid nuisance of flies.

The vehicles employed for the transport of refuse should be of such pattern and design that collected garbage does not fall once again on the road during the transport. The transport vehicle should be strong, durable and water tight. They should be made of steel with smooth interior surface and round edges and corners, so that they can be kept clean.

The flowchart in Fig. 5.2 illustrate the decisions that must be made from the point of generation to the ultimate disposal of residential solid waste.

5.8 DISPOSAL OF SOLID WASTE :

Refuse or solid waste can be finally disposed off by the following methods :

1. Open Dumping
2. Sanitary Land filling
3. Shredding and Pulverisation
4. Composting
5. Incineration
6. Pyrolysis
7. Dumping into sea

5.8.1 OPEN DUMPING :

This is a very crude and insanitary method of refuse disposal. It consists of dumping the solid wastes in some selected areas. Some components of refuse are suitable for open dumping. These include street sweepings, ashes and some rubbish. However, this will create a serious problem if garbage is disposed in this manner.

The dumped garbage can become a potential breeding ground for flies and rats and the health of the community around will be in danger. Garbage should be dumped far from residential areas.

5.8.2 SANITARY LAND FILLING OR CONTROLLED TIPPING METHOD :

In this method of refuse disposal, refuse is carried and dumped into the low lying area under an engineered operation, designed and operated in an environmentally sound manner.

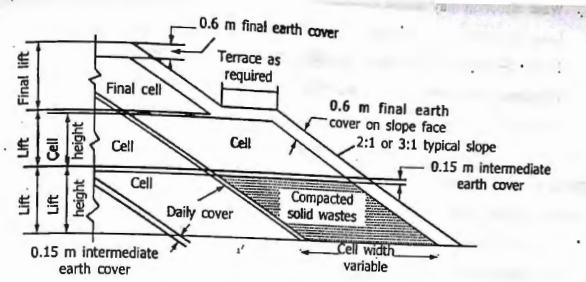


Fig. 5.5 Sectional view of a sanitary land fill

In this method, the refuse is dumped and compacted in layers of about 0.5 m thickness, and after the days work when the depth of filling becomes about 1.5 m, it is covered by good earth of about 15 cm thickness. This cover of good earth is called the **daily cover.**

The filling of refuse is actually done in sanitary land filling by dividing the entire land fill area into smaller portions, called cells. These cells are initially filled with compacted refuse of about 1.5 m depth, inturn. After filling all the cells with first lift, the second lift is laid in about 1.5 m height, and covered with good earth cover of about 15 cm thickness, called the **intermediate cover.**

After all the cells have been filled up with second lift, the third and more lifts can be piled up in about 1.5 m depth each, all laid over by the intermediate earth covers, turn by turn. The process will continue till the top most lift is piled up, over which the final cover of good earth of about 0.6 m depth shall be laid, and well compacted. This filling operation is illustrated in Fig. 5.5. The sides are kept sloping at 45° to the horizontal.

With the passage of time, the filled up refuse will get stabilised due to the decomposition of organic matter and subsequent conversion into stable compounds. The landfilling operation is essentially a biological method of waste treatment, since the waste is stabilised by aerobic as well as anaerobic bacterial processes.

This method of refuse disposal is very suitable to the heavier type of Indian refuse and also to the rural communities, hostels, camps, etc. Hence, it is widely adopted in India, and about 90 % of Indian refuse is disposed of in this manner.

(i) Advantages :

i. It is simple and economical
ii. No plant/equipment is required.
iii. It does not require separation of different kinds of refuse as is necessary in the incineration method.
iv. There are no byproducts and hence there is no problem of the disposal of the by-products.
v. The low lying areas can be reclaimed and put to better use by this method.

(ii) Disadvantages :

i. Proper dumping site may not be available nearby.

ii. Wind direction may not be favourable.
iii. Large land areas are required.
iv. It may be difficult to get large quantities of covering material.
v. It becomes necessary to use insecticides for preventing the fly nuisance.
vi. Leachate from the dumped garbage may pollute surface water as well as ground water.
vii. Foul gases like methane and CO_2 are produced.

→ **Methods of Land-filling :**

There are three methods of land filling.

1. Area method
2. Trench method (Pit method)
3. Ramp method

1. Area method :

- In this method waste materials are disposed off on the ground.
- This method is adopted when natural depressions are not available and it is very difficult to excavate land.
- Waste material is covered with soil.

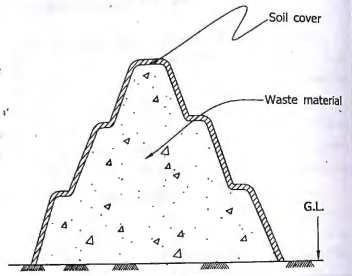


Fig. 5.6 Area method for landfill

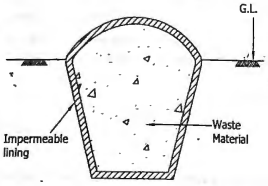


Fig. 5.7 Trench method for Land fill

2. Trench method : (Pit method)

- In this method soil is excavated and trenches are made below natural ground level.
- Trenches / depressions are made where ground water table is very deep.
- The trenches are lined with impermeable material to prevent leachate.

3. Ramp method :

- This method is adopted in hilly areas.
- The hill slope is given tooth shape.
- About 30–35° slope is considered safe for disposal of solid waste.
- Suitable liner and leachate control system is provided.

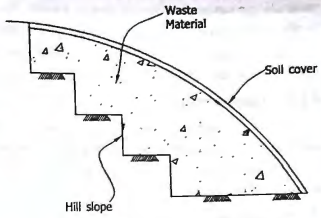


Fig. 5.8 Ramp method for landfill

→ **Site selection for landfill :**

Site selection is perhaps the most difficult obstacle to overcome in the development of a MSW landfill. Opposition by local citizens eliminates many potential sites. In choosing a location for a landfill, following points should be considered.

i. Public opposition
ii. Proximity of major roadways
iii. Speed limits
iv. Load limits on roadways
v. Bridge capacities
vi. Underpass limitations
vii. Traffic patterns and congestion
viii. Haul distance
ix. Detours
x. Hydrology
xi. Availability of cover material
xii. Climate (flood, mud slide, snow, etc.)
xiii. Buffer areas around the site (For example, high trees on the site periphery)
xiv. Historic buildings, endangered species, wetlands, etc.

5.8.3 SHREDDING AND PULVERIZATION [MECHANICAL VOLUME REDUCTION] :

The size and volume reduction of Municipal Solid Waste (MSW) is accomplished by the physical process of shredding and pulverisation.

Shredding refers to the actions of cutting and tearing; where as **pulverisation** refers to the actions of crushing and grinding. Shredding and pulverisation may help in reducing the overall volume of the MSW, by as much as 40 %. It also helps in changing the physical character of the waste, which becomes practically odourless and unattractive to the insects.

The pulverised refuse, though contains fertilizing elements like potash, phosphorous and nitrogenous materials, yet can not be suitably used as manure. The pulverised refuse can be disposed off by land filling or discharged in the sewer. The method is quite costly and hence not commonly used in India.

The pulverisation of MSW is usually achieved in a hammer mill. A hammer mill, reduce the size of the various components of solid waste material, to uniform fragments of size 25 to 50 mm.

5.8.4 COMPOSTING :

This is a method wherein refuse is mixed with sludge and night soil and allowed to undergo decomposition and stabilization by the action of bacteria. The organic matter gets decomposed into stable, non-injurious substances which are of economic value to the soil. The final product is called **compost** or **humus** and used as manure.

→ **Advantagaes :**

(i) It produces manure which can be used for increasing crop yield.

(ii) It improves soil aeration.

(iii) It prevents soil erosion.

(iv) It is the most easy method for disposal of solid waste.

→ **Limitations :**

(i) This method is suitable for small and medium sized towns.

(ii) Suitable for disposal of organic wastes only.

(iii) For controlling moisture content, extra care has to be taken.

→ **Factors affecting composting :**

(i) **Particle size :** Smaller particle size increases the rate of composting.

(ii) **Moisture content :** Moisture content around 55 - 60 % gives higher rate of composting.

(iii) **pH :** If pH value decreases, it reduces biological conversion rate.

(iv) **Temperature :** If temperature increases above 60°C the microorganisms die out and biological conversion rate decreases.

(v) **Air circulation :** Air is necessary for aerobic composting.

There are three methods of composting.

1. Composting by trenching
2. Open window composting
3. Mechanical composting

1. Composting by trenching :

In this method, trenches to 4 to 10 m long, 2 to 3 m wide and 0.7 to 1 m deep are excavated with a clear spacing of 2 m. The trenches are then filled with refuse/garbage in layers of 15 cm. On the top of each layer, 5 cm thick sandwiching layer of night soil/animal dung is spread in semi-liquid form. On the top layer, protruding 0.3 m above the original ground surface, a 10 cm layer of good earth is spread so that flies do not get access to the refuse.

Within 2 - 3 days intensive biological action starts to destroy/reduce organic matter present in the refuse. In this process, considerable heat is generated and the temperature of the composting mass rises to about 75° C. Due to this reason breeding of flies does not take place. The refuse gets stabilised in about 4 - 5 months period, and gets changed into a brown coloured odourless powdery form, known as humus, which has high manure value because of its nitrogen content. The stabilised mass is removed from the trenches, sieved through 12.5 mm sieve to exclude coarse inert materials like stones, brick bats, brocken glass etc. The sieved material is sold out as a manure.

2. Open window composting :

In this method, a large proportion of mineral matter like dust, stone, broken glass pieces etc. are first removed from the refuse.

The refuse is then dumped on the ground in the form of 0.6 to 1 m high, 6 m long and 1 to 2 m wide piles at about 60 % moisture content. The pile is then covered with night soil, cow dung etc. through which the organisms or germs that are necessary for fermentation are added.

Due to biological activity through aerobic bacteria, heat starts developing up to about 75°C in the refuse piles. Due to this, the microbial reaction shifts from mesophilic to thermophilic stage. After this, the pile is turned up for cooling and aeration to avoid anaerobic reactions. The process of turning and cooling is repeated. The complete process take about 4 - 6 weeks, after which the compost is ready for use as manure.

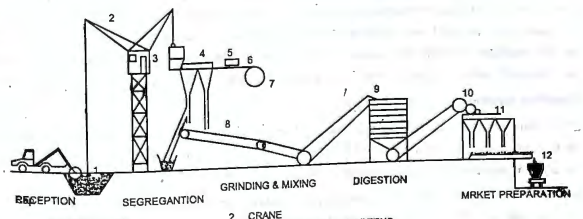
3. Mechanical Composting :

The open window method of composting is very laborious and time consuming process. Also, it requires large area of land which may not be available in big cities. These difficulties are overcome by adopting mechanical composting.

In this method, the process of stabilisation is expedited by mechanical devices turning the compost. By this method, the refuse is stabilised only within 3 - 6 days. The operations involved in a large scale composting plant shown in Fig. 5.9 are as follows :

i. Reception of refuse

ii. Segregation



1. RECEIVING PITS
2. CRANE
3. HOPPER
4. ROTARY/VIBRATING SCREENS
5. MAGNETIC SEPARATOR
6. SORTING BELT/TABLE
8. MIXING OF SLUDGE
9. WINDOW PITS
10. ROLLERS
11. SCREENS
12. MARKET PREPARATION OF FINE, INTERMEDIATE AND COARSE HUMUS

Fig. 5.9 Processing of Refuse of Mechanical Composting

iii. Shredding and pulverisation

iv. Stabilisation

v. Marketing the humus

- The refuse is received at the plant site in quantities of 2 to 6 tonnes per vehicle. Hence the plant site should have a storage capacity of about 25 to 50 % of total daily arrival.
- Segregation is done by hand picking on smaller plants and by mechanical devices on large plants, to remove paper, rags, non-ferrous metals and large objects. Ferrous metals are removed by magnetic separators. Finer material such as ash, particles of garbage etc. are removed by passing the refuse over shaker - screens.
- The remaining refuse is then shredded and pulverised mechanically.
- The prepared refuse is then decomposed or stabilised under controlled conditions of temperature and moisture content. The refuse is digested in mechanical digestors and converted into humus and stable mineral compounds. The digestion period vary between 2 - 5 days.

  Various types of mechanical digestors are :

  (i) Pits or cells

  (ii) Windows or stacks

  (iii) Vertical cylinder, horizontal cylinder or silo type closed digestors
- The stabilised brown mass (humus) is collected, sieved and sold in packets. Sometimes, the stabilised mass is enriched by adding chemical nutrients like phosphorous, nitrogen.

  In India composting is practised in rural areas on the mixture of night soil and refuse. The following two methods are adopted :

(i) Indore method

(ii) Banglore method

(i) Indore Method :

In the Indore method, refuse, night soil and animal dung etc. are placed in a shallow open masonry pits, 3 m × 3 m × 1 m deep, in alternate layers of 7.5 to 10 cm thick, so as to make a total height of 1.5 m. chemicals such as DDT are added to prevent fly breeding. The material is turned for the purpose of aerobic reaction, for every two weeks for a period of 8 weeks, then stored on the ground beside the pits for a mounth without turning. In about 4 months time the compost is ready for use as manure.

(ii) Banglore method :

In the Banglore method, the refuse is stabilised anaerobically. Refuse and night soil/cow dung are filled up in earthen trenches of size 10 × 1.5 × 1.5 m deep in alternate layers. This mass is covered at its top by layer of earth of about 15 cm depth, and is finally left over for decomposition.

Within 2 to 3 days of burial, intensive biological action starts and organic matter begins to be destroyed. The temperature of the mixture rises to about 75° C. This heat prevents the breeding of flies. After 4 to 5 months, the refuse gets fully stabilised and changes into a brown coloured odourless powdery mass called humus. This humas is removed from the trenches, sieved on 12.5 mm sieve to remove stones, broken glass, brickbats, etc. and then sold out in the market as manure. The empty trenches can again be used for receiving further batches of refuse.

→ Vermi Composting :

Vemi composting uses the natural composting process of decomposition of bio-degradable organic matter by the soil bacteria - as in ordinary composting technique, but takes the assistance of **cultured earth worms,** that are now produced commercially. These earth worms do help in quicker decomposition of the organic matter.

Various steps of vermi composting technique are :

i. Dig a small pit about 0.5 m × 0.5 m and 1 m deep.

ii. Line the pit with straw or dried leaves and grass.

iii. Organise the disposal of organic domestic waste (such as vegetable wastes) into the pit as and when generated.

iv. Introduce a culture of worms.

v. Cover the pit contents daily, by sprinkling of dried leaves and soil every day.

vi. Water the pit once or twice a week to keep it moist.

vii. Turn over the contents of the pit every 15 days.

viii. In about 45 days, the waste will be decomposed by the action of the microorganisms.

ix. The produced humus (soil) in the pit is fertile and can be used as manure in the garden.

5.8.5 INCINERATION :

This consists of burning the refuse in the incinerator plant. This is commonly used in disposing of garbage from hospitals and industrial plants. Before incineration, non-combustible and inert material like earth, broken glass, chinaware, metal etc. are separated so as to reduce the load on the hearth. The byproduct of this method is ash and clinker which can be easily disposed of by land filling. The heat generated by burning the dry refuse may be utilised for raising steam power.

The basic arrangement of a conventional incinerator, which is widely used for incinerating municipal solid waste is shown in Fig. 5.10.

Since the solid wastes reaching the incinerator plant are generally quite wet, inspite of their high calorific

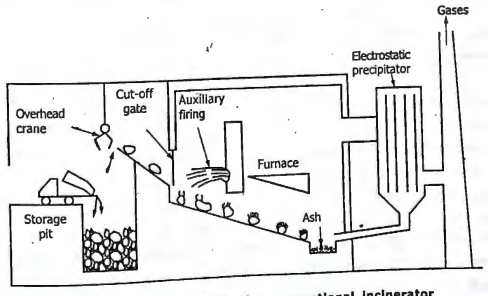


Fig. 5.10 Schematic sketch of a conventional incinerator

value, it is generally found necessary to dry them out before burning. Conventionally, auxiliary fuel is used for initial drying of these wastes. Electrostatic precipitators are also installed in the incineration plant to reduce air pollution, caused by the escaping furnace gases. Still however, large scale air pollution, particularly due the emissions of **dioxins**, remain a serious problem with the incinerators. Moreover, the produced fly ash from the incinerators is often found to be highly contaminated with substances like lead, and hence, has to be treated as a hazardous waste.

Due to air pollution problems, the incineration plants should generally be located in sparsely populated area and on the leeward side of the city, so that foul gases or combustible gases may not adversely affect the residents on a large scale.

Large size incinerators are called **destructors** and they can burn 100 to 150 tonnes of refuse per hour. A destructor consists of a furnace chamber, combustion chamber, expansion chamber and a tall chimney (25 m or 50 in height). The ancilliary works consists of ash pit, charging apparatus, forced draft apparatus, pre-heating arrangements, steam generating apparatus, etc.

The following points should be carefully observed during incineration :

1. The refuse charging should be through, rapid and continuous.
2. Each batch of refuse entering furnance should be well mixed.
3. Auxiliary burners should be installed above the refuse to ignite it and to establish the draft at the begining of the cycle.
4. minimum temperature in the combustion chamber should be sufficient (> 670°C) so that all the organic matter is incinerated and foul smelling gases are oxidised.

Merits :

1. This is most hygienic method of refuse disposal.
2. There is no odour trouble or dust nuisance.
3. The heat generated can be used for raising steam power.
4. Clinkers produced can be used for road purposes.
5. The disposal site can be located at a convenient distance.
6. Lesser space is required for disposal of residue.
7. Modern incinerators can burn a great variety of refuse materials, which are otherwise not biodegradable.

Demerits :

1. It is a very costly method and requires a lot of technical know-how.
2. Improper operation results in air pollution problems.
3. Smoke, odour and ash nuisance may result due to improper operations.
4. Solid wastes to be burnt should have a high calorific value.
5. Large number of vehicles for solid waste transport to the site of incineration.

A medium sized incineration plant to dispose of 300 tonnes of daily refuse, has been installed in New Delhi (near Timarpur) by BHEL (Bhart Heavy Electricals Limited) with Danish assistance. The plant is designed to produce 3.75 MW of electricity.

5.8.6 PYROLYSIS [THERMAL VOLUME REDUCTION]

Upon heating in closed containers in oxygen free atmosphere, most of the organic substances of solid waste can be split through combination of thermal cracking and condensation reactions into gasesous, liquid and solid fractions. This process is known as '**pyrolysis**' or '**thermal pyrolysis**'.

In contrast to the combustion process which is highly **exothermic** (releasing heat on burning in the presence of oxygen), the pyrolysis is highly **endothermic** (Consuming heat). That is why, this process is also known as **destructive distillation.**

The pyrolysis of organic solid waste, produces the following products at different temperatures.

i. **a gas stream :**
The generation of a gas fraction containing primarily hydrogen, methane, carbon monoxide, carbon dioxide and various other gases.

ii. **a liquid fraction :**
The generation of a liquid fraction consisting of a tar/or oil, steam containing acetic acid, acetone and methanol.

iii. **a solid fraction :**
The generation of a solid fraction consisting of almost pure carbon with other inert materials that have entered the process.

Plasma Pyrolysis :

Plasma pyrolysis is an environmental friendly technology for safe disposal of solid waste. In this method organic matter is converted into commercially useful by-products. The intense heat generated by the plasma enables it to dispose of all types of wastes including municipal solid waste, biomedical wastes and hazardous wastes in a safe and reliable manner. Medical waste is pyrolyzed into CO, H_2 and hydrocarbons when it comes in contact with the plasma-arc.

The plasma pyrolysis technology has been indigenously developed at the facilitation centre for Industrial plasma Technologies, Institute for plasma Research, Gandhinagar. In plasma pyrolysis process, the hot gases are quenched from 500°C to 700°C to avoid recombination reactions of gaseous molecules that inhibit the formation of dioxins and furans.

In plasma-pyrolysis technique plasma tourch is used. Plasma torches are electrical discharge plasma sources with the plasma being extracted as a jet through an opening in the electrode. DC and microwave power sources can be used to produce an arc. Plasma pyrolysis uses extremely high temperatures of plasma arc to completely decompose waste material into simple molecules.

Advantages :

- Quantity of toxic residuals (dioxius and furans) is very small in treated waste.
- Pathogens are completely killed.
- No need to segregate hazardous waste.
- There is possibility to recover energy from the treated waste.

5.8.7 DUMPING INTO SEA :

Solid waste/ refuse can also be disposed of by barging out into the sea, after carrying it at reasonable distance (say 15 to 20 km) into the sea. The sea depth at such disposal point should not be less than 30 m or so, and the direction of the currents should be such as not to bring it back towards the shore.

Radioactive substanes are packed in containers and taken deep into the sea and then dumped. These containers reach the bottom of the sea. In due course they lose their radioactivity.

This method is quite cheap and simple, but possesses the following **disadvantages :**

1. Bulky and lighter matter may float, spread out and tend to return to the shores during high tides.
2. During stormy weather and monsoons, it is not possible to send barges out into the sea.
3. Inspite of best care, some portion of refuse may return the shores and spoil them.
4. The method is suitable only in case of coastal cities.

MULTIPLE CHOICE QUESTIONS

1. Heating solid waste at a very high temperature in absence of air is called
(a) Composting (b) incineration (c) pyrolysis (d) land filling

2. Maximum percentage by weight of refuse for a typical Indian city is
(a) ashes (b) rubbish (c) garbage (d) None of the above

3. Collection routes of Municipal waste is decided based on
(a) vehicle type (b) crew size (c) pickup points (d) All of the above

4. Which one of the following methods can be employed for plas
(a) composting (b) incine

CHAPTER

6. Biomedical waste : Generation And Management

6.1 BIO MEDICAL WASTE-GENERATION :

"Bio-medical waste" means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps. It is also known as **" Health care waste"**.

The wastes from hospitals, nursing homes, clinics, research laboratories, etc. are bio-medical wastes. It is generated during diagnosis, treatment or immunization of human beings or animals. The bio-medical waste which may be solid or liquid are potential source of health hazard and need to be specially treated and disposed off.

Bio-medical waste may be **infectious** or **non-infectious waste**. Infectious waste may transmit infectious diseases. In total bio-medical waste the proportion of infectious waste may be about 15 % and that of non-infectious waste is about 85 %. The examples of infectious wastes are: Human tissues and organs, discarded blood, body fluids, bandages and dressings, discarded gloves, laboratory waste, etc.

The Central Government, in 2016 published the Bio-medical Waste Management Rules, 2016. These rules apply to all persons who generate, collect, receive, store, transport, treat, dispose, or handle bio medical waste in any form including hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks, ayush hospitals, clinical establishments, research or educational institutions, health camps, medical or surgical camps, vaccination camps, blood donation camps, first aid rooms of schools, forensic laboratories and research labs.

Biomedical waste poses hazard due to two principal reasons – the first is infectivity and other toxicity.

Indian hospitals generate approximately 1.50 kg of bio-medical waste per patient per day. According to WHO report about 85% of the bio-medical wastes are non-hazardous, 10% are infectious and about 5% are non-infectious but hazardous.

The quantity of the bio-medical wastes generated in some countries are given below :

Country	Quantity of Bio-medical waste (kg/bed/day)
USA	4.5
Netherlands	2.7
France	2.5
India	1.5

Bio Medical waste consists of :

- Human anatomical waste like tissues, organs and body parts
- Animal wastes generated during research from veterinary hospitals
- Microbiology and biotechnology wastes
- Waste sharps like hypodermic needles, syringes, scalpels and broken glass
- Discarded medicines and cytotoxic drugs
- Soiled waste such as dressing, bandages, plaster casts, material contaminated with blood, tubes and catheters

- Liquid waste from any of the infected areas
- Incineration ash and other chemical wastes

6.2 CLASSIFICATION OF BIO-MEDICAL WASTE :

The World Health Organization (WHO) has classified medical waste into eight categories:

- General Waste
- Pathological
- Radioactive
- Chemical
- Infectious to potentially infectious waste
- Sharps
- Pharmaceuticals
- Pressurized containers

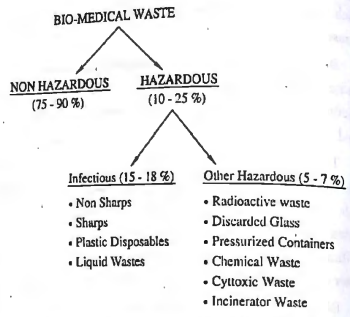


Fig. 6.1 Classification of Bio-medical waste

Sources of Biomedical Waste :

Hospitals produce waste, which is increasing over the years in its amount and type. The hospital waste, in addition to the risk for patients and personnel who handle them also poses a threat to public health and environment.

Major Sources :

- Govt. hospitals/private hospitals/nursing homes/ dispensaries.
- Primary health centers.
- Medical colleges and research centers/ paramedic services.
- Veterinary colleges and animal research centers.
- Blood banks/mortuaries/autopsy centers.
- Biotechnology institutions.
- Production units.

Minor Sources :

- Physicians/ dentists' clinics
- Animal houses/slaughter houses.
- Blood donation camps.
- Vaccination centers.
- Acupuncturists/psychiatric clinics/cosmetic piercing.
- Funeral services.
- Institutions for disabled persons

6.3 IMPORTANCE OF MANAGEMENT OF BIO-MEDICAL WASTE :

Need of Biomedical waste Management in Hospitals

The reasons due to which there is great need of management of hospitals waste are:

1. Injuries from sharps leading to infection to all categories of hospital personnel and waste handler.
2. Nosocomial infections in patients from poor infection control practices and poor waste management.
3. Risk of infection outside hospital for waste handlers and scavengers and at time general public living in the vicinity of hospitals.
4. Risk associated with hazardous chemicals, drugs to persons handling wastes at all levels.
5. "Disposable" being repacked and sold by unscrupulous elements without even being washed.
6. Drugs which have been disposed of, being repacked and sold off to unsuspecting buyers.
7. Risk of air, water and soil pollution directly due to waste, or due to defective incineration emissions and ash.

Problems relating to biomedical waste :

A major issue related to current Bio-Medical waste management in many hospitals is that the implementation of Bio-Waste regulation is unsatisfactory as some hospitals are disposing of waste in a haphazard, improper and indiscriminate manner. Lack of segregation practices, results in mixing of hospital wastes with general waste making the whole waste stream hazardous. Inappropriate segregation ultimately results in an incorrect method of waste disposal.

Inadequate Bio-Medical waste management,thus will cause environmental pollution, unpleasant smell, growth and multiplication of vectors like insects, rodents and worms and may lead to the transmission of diseases like typhoid, cholera, hepatitis and AIDS through injuries from syringes and needles contaminated with human.

Various communicable diseases, which spread through water, sweat, blood, body fluids and contaminated organs, are important to be prevented. The Bio Medical Waste scattered in and around the hospitals invites flies, insects, rodents, cats and dogs that are responsible for the spread of communication disease like plague and rabies.

Rag pickers in the hospital, sorting out the garbage are at a risk of getting tetanus and HIV infections. The recycling of disposable syringes, needles, IV sets and other article like glass bottles without proper sterilization are responsible for Hepatitis, HIV, and other viral diseases. It becomes primary responsibility of Health administrators to manage hospital waste in most safe and eco-friendly manner.

The problem of bio-medical waste disposal in the hospitals and other healthcare establishments has become an issue of increasing concern, prompting hospital administration to seek new ways of scientific, safe and cost effective management of the waste, and keeping their personnel informed about the advances in this area. The need of proper hospital waste management system is of prime importance and is an essential component of quality assurance in hospitals.

6.4 BIOMEDICAL WASTE MANAGEMENT PROCESS :

"Management" includes all steps required to ensure that bio- medical waste is managed in such a manner as to protect health and environment against any adverse effects due to handling of such waste.

There is a big network of Health Care Institutions in India. The hospital waste like body parts, organs, tissues, blood and body fluids along with soiled linen, cotton, bandage and plaster casts from infected and contaminated areas are very essential to be properly collected, segregated, stored, transported, treated and disposed of in safe manner to prevent nosocomial or hospital acquired infection.

Various steps in the Bio-medical waste management process are:

1. Segregation of waste
2. Collection
3. Storage
4. Transportation
5. Treatment
6. Disposal

1. Segregation of Bio-medical Waste :

Segregation refers to the basic separation of different categories of waste generated at source and thereby reducing the risks as well as cost of handling and disposal. Segregation is the most crucial step in bio-medical waste management. Effective segregation alone can ensure effective bio-medical waste management. The BMWs must be segregated in accordance to guidelines laid down under schedule I of BMW Rules, 2016.

The color coding and types of containers are as follows:

(i) **Yellow bag:** Human anatomical waste- body parts, organs, tissues, dressings, plaster casts, discarded medicines, liquid waste from laboratory, discarded linen, mattresses, beddings, micro biology and biotechnology laboratory waste, etc.

(ii) **Red bag** : Contaminated waste (recyclable)-disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles) and gloves.

(iii) **White bag** : Waste sharps, needles, blades, etc. are disposed of in a white translucent puncture proof container.

(iv) **Blue bag** : Glassware- broken and discarded glass, medicine vials, ampoules, etc.

How does segregation help?

- Segregation reduces the amount of waste needs special handling and treatment.
- Effective segregation process prevents the mixture of medical waste like sharps with the general municipal waste.
- Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics.
- Provides an opportunity for recycling certain components of medical waste like plastics after proper and thorough disinfection.
- Recycled plastic material can be used for non-food grade applications.

Proper labelling of bins :

The bins and bags should carry the biohazard symbol indicating the nature of waste to the patients and public. Label shall be non-washable and prominently visible.

Schedule III (Rule 6) of Bio-medical Waste (Management and Handling) Rules, 1998 specifies the Label for Bio-Medical Waste Containers / Bags as :

LABEL FOR BIO-MEDICAL WASTE CONTAINERS or BAGS

HANDLE WITH CARE

(a) Bio Hazard Symbol

CYTOTOXIC HAZARDSYMBOL

HANDLE WITH CARE

(b) Cytotoxic Hazard Symbol

Fig. 6.2 Label for Bio-medical waste containers or Bags

2. Collection :

The collection of biomedical waste involves use of different types of container from various sources of biomedical wastes like Operation Theatre, laboratory, wards, kitchen, corridor etc. The containers/ bins should be placed in such a way that 100 % collection is achieved. Sharps must always be kept in puncture-proof containers to avoid injuries and infection to the workers handling them.

The system of using different coloured bins and bags to collect different types of solid medical wastes is known as **colour coding.**

3. Storage :

Once collection occurs then biomedical waste is stored in a proper place. Segregated wastes of different categories need to be collected in identifiable containers. Each container may be clearly labeled to show the ward or room where it is kept. The reason for this labeling is that it may be necessary to trace the waste back to its source. Besides this, storage area should be marked with a caution sign.

The bio-medical waste should not be stored for more than **48 hours.**

4. Transportation :

The waste should be transported for treatment either in trolleys or in covered wheelbarrow. Manual loading should be avoided as far as for as possible. The bags / Container containing BMWs should be tied/ lidded before transportation. Before transporting the bag containing BMWs, it should be accompanied with a signed document by Nurse/ Doctor mentioning date, shift, quantity and destination.

Special vehicles must be used so as to prevent access to, and direct contact with, the waste by the transportation operators, the scavengers and the public. The transport containers should be properly enclosed. The effects of traffic accidents should be considered in the design, and the driver must be trained in the procedures he must follow in case of an accidental spillage. It should also be possible to wash the interior of the containers thoroughly.

Table 6.1 Biomedical wastes categories and their segregation, collection, treatment, processing and disposal options [Schedule-I]

Category	Type of Waste	Type of Bag or Container to be used	Treatment and Disposal options
(1)	(2)	(3)	(4)
1. Yellow	(a) **Human Anatomical Waste:** Human tissues, organs, body parts and fetus below the viability period	Yellow coloured non-chlorinated plastic bags	Incineration or Plasma Pyrolysis or deep burial
	(b) **Animal Anatomical Waste :** Experimental animal carcasses, body parts, organs, tissues, including the waste generated from animals used in experiments or testing in veterinary hospitals or colleges or animal houses.		
	(c) **Soiled Waste:** Items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs and bags containing residual or discarded blood and blood components.		Incineration or Plasma Pyrolysis or deep burial* In absence of above facilities, autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery
	(d) **Expired or Discarded Medicines:** Pharmaceutical waste like antibiotics, cytotoxic drugs including all items contaminated with cytotoxic drugs along with glass or plastic ampoules, vials etc.	Yellow coloured non-chlorinated plastic bags or containers	Expired 'cytotoxic drugs and items contaminated with cytotoxic drugs to be returned back to the manufacturer or supplier for incineration at temperature >1200 0C or to common bio-medical waste treatment facility or hazardous waste treatment
	(e) **Chemical Waste:** Chemicals used in production of biological and used or discarded disinfectants.	Yellow coloured containers or non-chlorinated plastic bags	Disposed of by incineration or Plasma Pyrolysis or Encapsulation in hazardous waste treatment, storage and disposal facility.

	(f) **Chemical Liquid Waste :** Liquid waste generated due to use of chemicals in production of biological and used or discarded disinfectants, Silver X-ray film developing liquid, discarded Formalin, infected secretions, aspirated body fluids, liquid from laboratories and floor washings, cleaning, house-keeping and disinfecting activities etc.	Separate collection system leading to effluent treatment system	After resource recovery, the chemical liquid waste shall be pre-treated before mixing with other wastewater.
	(g) **Discarded linen, mattresses,** beddings contaminated with blood or body fluid.	Non-chlorinated yellow plastic bags or suitable packing materia	Non- chlorinated chemical disinfection followed by incineration or Plazma Pyrolysis or for energy recovery.
	(h) **Microbiology, Biotechnology and other clinical laboratory waste:** Blood bags, Laboratory cultures, stocks or specimens of microorganisms, live or attenuated vaccines, human and animal cell cultures used in research, industrial laboratories,	Autoclave safe plastic bags or containers	Pre-treat to sterilize with nonchlorinated chemicals on-site as per National AIDS Control Organisation or World Health Organisation guidelines thereafter for Incineration.
2. Red	**Contaminated Waste (Recyclable):** Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles and fixed needle syringes) and gloves.	Red coloured non-chlorinated plastic bags or containers	Autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent to registered or authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making.Plastic waste should not be sent to landfill sites.

3. White (Translucent)	**Waste sharps including Metals:** Needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades	Puncture proof, Leak proof, tamper proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete
4. Blue	(a) **Glassware:** Broken or discarded and contaminated glass including medicine vials and ampoules except those contaminated with cytotoxic wastes.	Cardboard boxes with blue colored marking	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling.
	(b). **Metallic Body Implants**	Cardboard boxes with blue colored marking	

*Disposal by deep burial is permitted only in rural or remote areas where there is no access to common bio-medical waste treatment facility.

Source: CPCB

"biological" means any preparation made from organisms or micro-organisms or product of metabolism and biochemical reactions intended for use in the diagnosis, immunization or the treatment of human beings or animals or in research activities.

"handling" in relation to bio-medical waste includes the generation, sorting, segregation, collection, use, storage, packaging, loading, transportation, unloading, processing, treatment, destruction, conversion, or offering for sale, transfer, disposal of such waste.

"management" includes all steps required to ensure that bio- medical waste is managed in such a manner as to protect health and environment against any adverse effects due to handling of such waste.

"Occupier" means a person having administrative control over the institution and the premises generating bio-medical waste, which includes a hospital, nursing home, clinic, dispensary, veterinary institution, animal house, pathological laboratory, blood bank, health care facility.

"Operator of a common bio-medical waste treatment facility" means a person who owns or controls a Common Bio-medical Waste Treatment Facility (CBMWTF) for the collection, reception, storage, transport, treatment, disposal or any other form of handling of bio-medical waste.

"Prescribed authority" means the State Pollution Control Board in respect of a State and Pollution Control Committees in respect of an Union territory.

Standards For Liquid Waste:

The effluent generated from the hospitals must confirm to the following:

Parameter	Permissible limits
PH	6.5-9.0
Suspended solids	100mg/l
Oil and Grease	10 mg/l
BOD	30 mg/l
COD	250 mg/l
Bio assay test	90% survival of fish after 96 hours in 100% effluent

6.5 TREATMENT AND DISPOSAL OF BIO-MEDICALWASTES :

The various methods used for disposing of the hazardous bio-medical wastes are:

1. Incineration
2. Plasma Pyrolysis or Gasification
3. Autoclaving
4. Microwaving
5. Deep burial
6. Chemical disinfection
7. Heat Sterilization

1 Incineration :

Incineration is a high-temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight. This process is usually selected to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. Incinerator, if operated properly, eliminate pathogens from waste and reduce the waste to ashes.

Three basic kinds of incineration technology are of interest for treating health-care waste:

- **double-chamber pyrolytic incinerators**, which may be especially designed to burn infectious health-care waste;
- **single-chamber furnaces** with static grate, which should be used only if pyrolytic incinerators are not affordable;
- **rotary kilns** operating at high temperature, capable of causing decomposition of genotoxic substances and heat-resistant chemicals.

Characteristics of waste suitable for incineration:

Incineration of waste is affordable and feasible only if the "heating value" of the waste reaches at least 2000kcal/kg.

Content of combustible matter above 60%.

Content of non-combustible solids below 5%.

Moisture content below 30%.

Waste types not to be incinerated

- Pressurized gas containers.
- Large amounts of reactive chemical waste.
- Silver salts and photographic or radiographic wastes.
- Halogenated plastics such as polyvinyl chloride (PVC).
- Waste with high mercury or cadmium content, such as broken thermometers, used batteries, and lead-lined wooden panels.

STANDARDS FOR INCINERATION :

All incinerators shall meet the following operating and emission standards

A. Operating Standards

(i) Combustion efficiency (CE) shall be at least **99.00%.**

(ii) The Combustion efficiency is computed as follows:

C.E. = %C02/(% C02 + % CO) 100 %

(iii) The temperature of the primary chamber shall be a minimum of 800^0C and the secondary chamber shall be minimum of 1050^0C + or - 50^0C.

(iv) The secondary chamber gas residence time shall be at least two seconds.

(v) The stack height should be minimum of 30 m above ground level.

2. Plasma Pyrolysis or Gasification :

This system uses plasma torch or burner for heating the waste to super-high temperatures. The furnace temperature may be as high as 10,000^{0}C. The plasma fired chambers operate in an oxygen deficient mode. The residue produced is a glass-like substance, rather than a particulate ash typical of incinerators.

All the operators of the Plasma Pyrolysis or Gasification shall meet the following operating and emission standards:

(i) Combustion efficiency (CE) shall be at least **99.99%.**

(ii) The Combustion efficiency is computed as follows:

C.E. = %C02/(% C02 + % CO) 100 %

(iii) The temperature of the combustion chamber after plasma gasification shall be 1050 ± 50° C with gas residence time of at least 2(two) second, with minimum 3 % Oxygen in the stack gas.

(iv) The Stack height should be minimum of **30 m** above ground level.

3. Autoclaving :

Autoclaving is a low heat thermal process and it uses steam for disinfection of waste. Autoclaves are of two types depending on the method they use for removal of air pockets are gravity flow autoclave and vacuum autoclave.

When operating a gravity flow autoclave, medical waste shall be subjected to:

- A temperature of not less than 121°C and pressure of about 15 pounds per square inch (psi) for an autoclave residence time of not less than 60 minutes; or

- A temperature of not less than 135°C and a pressure of 31 psi for an autoclave residence time of not less than 45 minutes; or
- A temperature of not less than 149°C and a pressure of 52 psi for an autoclave residence time of not less than 30 minutes.

4. Microwaving :

Microwave treatment shall not be used for cytotoxic, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items.

The microwave system shall comply with the efficacy tests/routine tests

The microwave should completely and consistently kill bacteria and other pathogenic organism that is ensured by the approved biological indicator at the maximum design capacity of each microwave unit.

5. Deep Burial :

A pit or trench should be dug about 2 m deep. It should be half filled with waste, and then covered with lime within 50 cm of the surface, before filling the rest of the pit with soil.

It must be ensured that animals do not have access to burial sites.

Covers of galvanized iron/wire meshes may be used.

On each occasion, when wastes are added to the pit, a layer of 10cm of soil be added to cover the wastes. Ground water table shall be a minimum of 6m below the lower level of pit.

Burial must be performed under close and dedicated supervision.

The site should be relatively impermeable and no shallow well should be close to the site.

The pits should be distant from habitation, and sited so as to ensure that no contamination occurs of any surface water or ground water.

The area should not be prone to flooding or erosion.

No shallow well shall be close to the site.

6. Chemical Disinfection :

Chemical disinfection, used routinely in health care to kill microorganisms on medical equipment and on floors and walls, is now being extended to the treatment of health-care waste. Chemicals are added to waste to kill or inactivate the pathogens it contains; this treatment usually results in disinfection rather than sterilization. Chemical disinfection is most suitable for treating liquid waste such as blood, urine, stools, or hospital sewage. However, solid—and even highly hazardous— health-care wastes, including microbiological cultures, sharps, etc., may also be disinfected chemically.

The types of chemicals used for disinfection of health-care waste are mostly aldehydes, chlorine compounds, ammonium salts, and phenolic compounds.

7. Heat Sterilization :

Waste sharps can be treated by dry heat sterilization at a temperature not less than 185^{0}C, at least for a residence period of 150 minutes in each cycle, which sterilization period of 90 minutes. There should be automatic recording system to monitor operating parameters.