(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.**

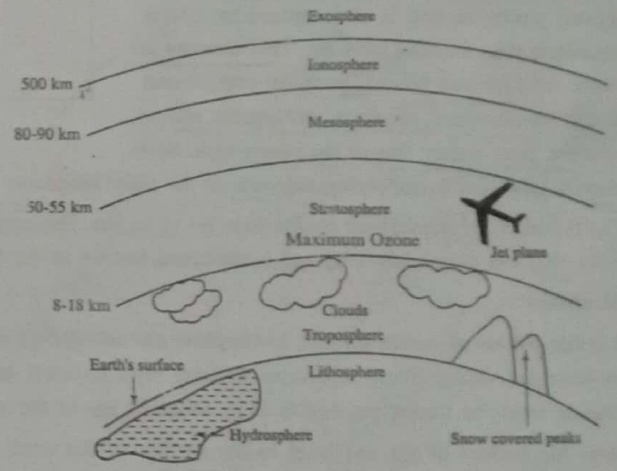


Fig. 1.3 Layer of atmosphere

(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.

3. Lithosphere : **[Jan. 2010]**

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.

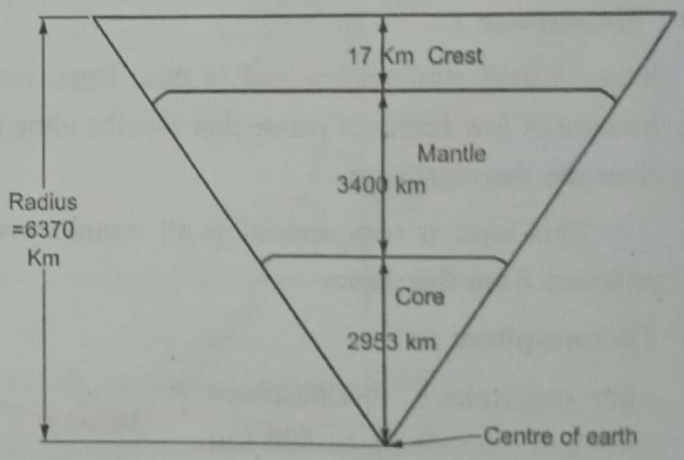


Fig. 1.4 Lithosphere

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.

Environment

- Abiotic component
  - Atmosphere
  - Lithosphere
  - Hydrosphere
- Biotic component
  - Biosphere

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,

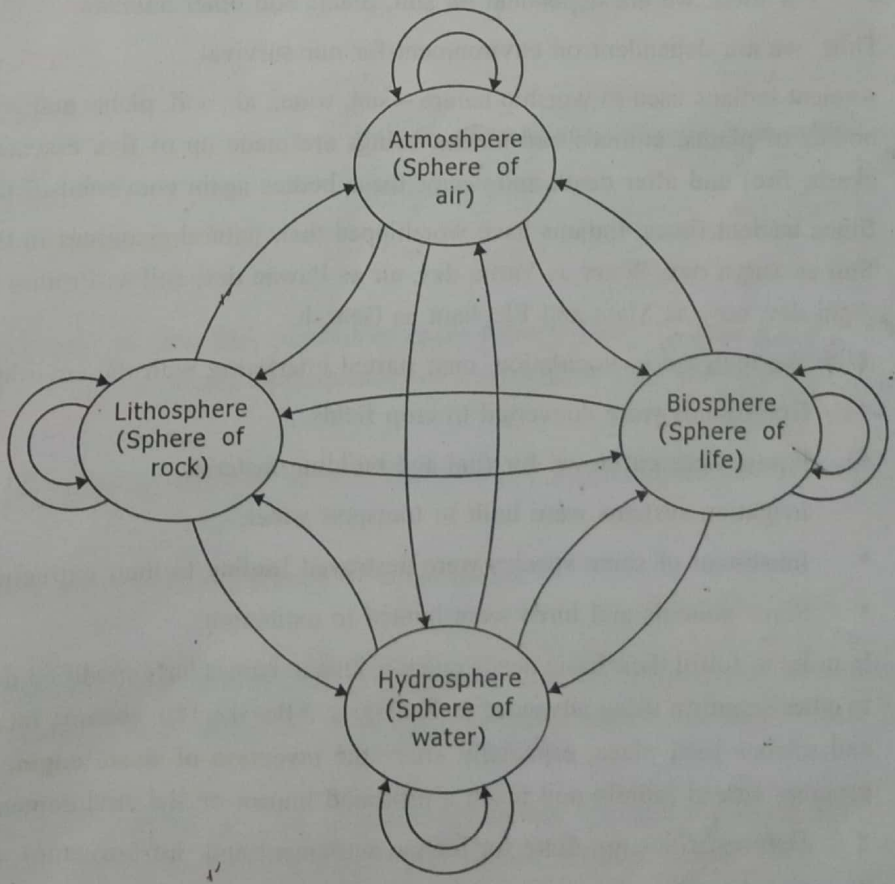


Fig. 1.5 Relationship between different components of environment

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

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

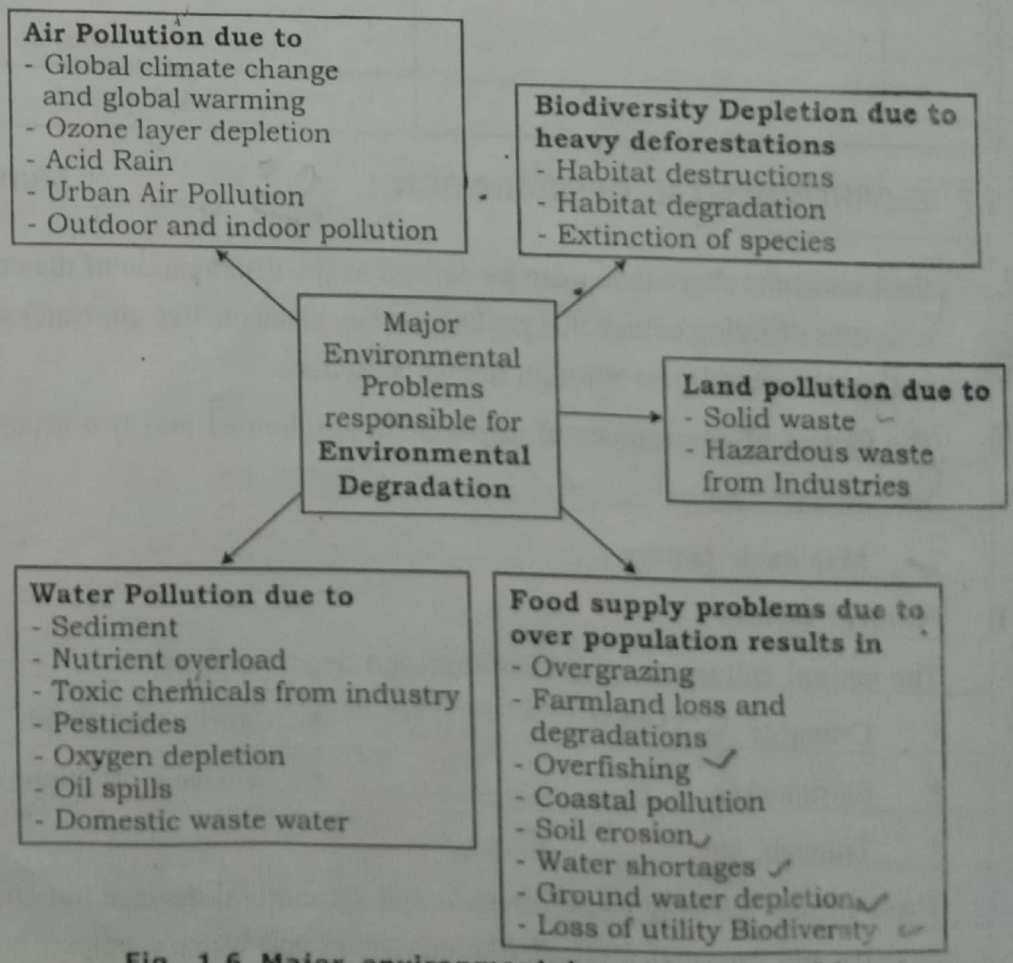


Fig. 1.6 Major environmental problems resulting in environment degradation

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.

→ **Objectives of Environmental Education :** **[Jan. 2010, June 2013, May 2015]**

- 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

SHORT ANSWER QUESTIONS

1. Define the term 'environment'. **[Jan. 2010, April 2010, June 2010, Jan. 2011]**

It 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.

2. What is biome envirement ?

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

Biotic components → Plants, animals, birds, micro-organisms

Abiotic components → light, water, air, temperature, humidity, etc.

3. Define 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.

4. Define 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.

5. What are the different components of the environment ?

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

6. Define the term 'biomes'. **[Jan. 2013]**

Within the biosphere, living organisms form ecological communities based on the physical surrounding of that area, these communities are referred as biomes.

Examples of biomes are,

grasslands, deserts, tropical rainforest, etc.

7. What is biosphere ? **[Jan. 2011]**

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.

8. What is lapse rate ?

The density of the troposphere 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.

9. What is ozone layer ? **[June 2010]**

Stratosphere is known for the presence of ozone which is found at around 20 km from ground. This layer of ozone is called ozonesphere and acts as a protective layer against the harmful effects of ultraviolet radiations on living orgapisms.

10. What are the different spheres of atmosphere ?

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

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

11. What are the constituents of atmosphere ?

Nitrogen	= 78%	by volume
Oxygen	= 21%	by volume
CO_2	= 0.032 %	by volume

12. How water is distributed on the earth ?

97 %	.....	oceans and seas
2.3%	.....	in ice caps at polar regions
0.67 %	.....	as ground water
0.03%	.....	lakes, ponds, rivers, streams

13. Define 'environmental degradation'.

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.

14. What is anthropogenic environment ?

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

Anthropogenic activities :

- Agricultural activities
- Construction activities
- Transport activities
- Mining activities
- Industrial activities, etc.

15. What is IPAT equation ?

It is an equation to assess the impact (I) on the environment of three factors, viz Population (P), Affluence (A) and Technology (T).

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

16. Define 'sustainable development'.

Sustainable development is defined as a form of development or progress that meets the needs of the present without compromising the ability of future generations to meet their own needs.

17. **Environmental education is** essential for engineers, why ? **[Dec. 2011]**

Because the engineers do the design, construction and operation of

- Municipal water supply system
- Sewage treatment plants
- Sewage and strom water drainage network
- Solid waste management system, etc.

MULTIPLE CHOICE QUESTIONS

1. The 'world environment day' is celebrated on **[June 2010, Dec. 2014, Jan. 2017]**
   (a) 15th June (b) 5th June (c) 5th January (d) 15th February
2. Short term properties of the atmosphere at a given place and time is referred as, **[Jan. 2013]**
   (a) Climate (b) Microclimate (c) Season (d) Weather
3. Which of the following is an example of impact of the development activities on hydrosphere ? **[Jan. 2013, Jan. 2017]**
   (a) air pollution (b) soil pollution (c) noise pollution (d) water pollution
4. Study of trends in human population growth and prediction of future growth is called **[Jan. 2013]**
   (a) Demography (b) Biography (c) Paleography (d) Psychology
5. Ozone present in 'ozonosphere' protect us from
   (a) Infrared radiations (b) Ultraviolet radiations (c) Visiable radiations (d) None of these
6. Environmental degradation is due to
   (a) rapid industrialization (b)Urbanization (c) developmental works (d) all of the above
7. Atmosphere has major constituents of
   (a) Nitrogen , Oxygen, Argon (b) Carbon dioxide, Nitrogen
   (c) Ozone, Methane, Nitrogen (d) Nitrogen, Oxygen, Ozone
8. The range of temperature variations in troposphere is
   (a) 20°C to – 56°C (b) – 56°C to – 2°C (c) – 2°C to – 90°C (d) –90°C to 1200°C
9. The layer in which Ozone is found is **[June 2017]**
   (a) Stratosphere (b) Troposphere (c) Ionosphere (d) Exosphere
10. The biggest pollutant receptor or sink on the earth is
    (a) Biosphere (b) Atmosphere (c) Lithosphere (d) Hydrosphere
11. The least pollutant receptor or sink on the earth is **[June 2017]**
    (a) Hydrosphere (b) Atmosphere (c) Lithosphere (d) None of these
12. The ambient lapse rate is
    (a) – 5°C per km (b) –9.8°C per km (c) – 6.5°C per km (d) None of these
13. The range of temperature variations in stratosphere is
    (a) 20°C to – 56°C (b) –56°C to – 2°C (c) –2°C to – 90°C (d) –90°C to 1200°C

14. Lithosphere consists of
(a) Crust (b) Mantle (c) Core (d) All of these

15. The layer of atmosphere which provides the ideal site for flying of jet planes is
(a) Thermosphere (b) Stratosphere (c) Mesosphere (d) Troposphere

16. The outer soil crust of the earth is known as **[Dec. 2013]**
(a) Hydrosphere (b) Exosphere (c) Lithosphere (d) Mesosphere

17. Earth day is celebrated on ..... **[June 2014]**
(a) 5th June (b) 12th May (c) 22nd April (d) 22nd May

18. A zone consisting of land, water and air which supports life on earth is **[June 2014]**
(a) Biosphere (b) Atmosphere (c) Lithosphere (d) Hydrosphere

19. Stratosphere contains an important spices which protects life on Earth is ..... **[June 2014]**
(a) Oxygen (b) Ozone (c) Nitrogen (d) Hydrogen

20. Which is not true ? **[Dec. 2014]**
(a) Lithosphere includes the crust and the uppermost mantle
(b) Lithosphere is underlain by the stratosphere
(c) Lithosphere provides timber
(d) Lithosphere is broken into tectonic plates

21. The Equitable use of resources is necessary for ..... **[Dec. 2014]**
(a) sustainable development (b) better Life Style for man
(c) Sustain natural wealth (d) All of the above

22. The range of temperature variation in mesosphere is ..... **[May 2015]**
(a) 20°C to –56°C (b) –2°C to -90°C (c) –56°C to -2°C (d) –90°C to 1200°C

23. Stratosphere contains an important species which protects life on earth is **[Jan. 2016]**
(a) Oxygen (b) Ozone (c) Nitrogen (d) Hydrogen

24. Environmental degradation is due to **[Jan. 2016]**
(a) Rapid industrialization (b) onset of different development work
(c) Fast urbanization leading of deforestation (d) All of the above

25. In the atmosphere the layer above the troposhere is **[June 2016]**
(a) Stratosphere (b) Exosphere (c) Mesosphere (d) Thermosphere

26. The layer in which presence of ozone is treated as pollutant is **[Jan. 2017]**
(a) Stratosphere (b) Troposphere (c) Ionosphere (d) Exosphere

27. Percentage of total water found as fresh water is **[Dec. 2014, June 2017]**
(a) 87.5 % (b) 2.5 % (c) 97.5 % (d) 75 %

28. The study of interaction between living organisms and their physical and biological environment is called
(a) biology (b) ecosystem (c) ecology (d) zoology

29. The outer soil crust of the earth is known as **[Dec. 2013]**
(a) Hydrosphere (b) Lithosphere (c) Exosphere (d) Mesosphere

30. Earth day is celebrated on
(a) 5th June (b) 22nd March (c) 22nd April (d) 16th September

ANSWERS

1.	(b)	2.	(d)	3.	(d)	4.	(a)	5.	(b)	6.	(d)	7.	(a)
8.	(a)	9.	(a)	10.	(d)	11.	(b)	12.	(c)	13.	(b)	14.	(d)
15.	(b)	16.	(c)	17.	(c)	18.	(a)	19.	(b)	20.	(b)	21.	(d)
22.	(b)	23.	(b)	24.	(d)	25.	(a)	26.	(b)	27.	(b)	28.	(c)
29.	(b)	30.	(c)										

REVIEW QUESTIONS

1. What are the components of environment ? Explain by drawing sketch. **[Jan. 2009, Nov. 2010, May 2012, Jan. 2016]**
2. Explain the impact of technology and development on environment. **[Jan. 2011, June 2011, May 2012, June 2016, Jan. 2017, June 2017]**
3. Explain interrelationship between various components of the environment. **[Sept. 2009, June 2010, June 2014, Jan. 2016]**
4. Give the composition of atmosphere. **[Jan. 2010, June 2011, Dec. 2014, June 2016, June 2017]**
5. Explain the importance of environmental education. Discuss the impact of human on environment. **[Dec. 2011, May 2012, Dec. 2013, May 2016, June 2017]**
6. What is relationship between man and environment ? Do you think that man has protected environment ? **[April 2010, Dec. 2011, May 2012]**
7. Write a short note on : 'environmental degradation'. **[June 2010, Jan. 2013, Jan. 2016]**
8. Define the terms :
   (i) Environment **[Jan. 2010, April 2010, June 2010, Jan. 2016]**
   (ii) Biosphere **[Jan. 2011]**
   (iii) Biomes **[Jan. 2013]**
   (iv) Atmosphere **[Jan. 2010]**
   (v) Lithosphere **[Jan. 2010]**
   (vi) Ozone layer **[June 2010]**
   (vii) Biotic and abiotic components. **[Jan. 2011, May 2012]**
9. What is the role of an environmental engineer ? **[June 2011]**
10. Explain the IPAT equation. **[March 2009]**
11. What is sustainable development ? How it can be achieved ? **[Dec. 2014, June 2016]**
12. Why is environmental education provided to engineeris **[Dec. 2014, June 2017]**

❖ ❖ ❖

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

- Volcanic eruptions
- Earthquakes
- Storms and dust
- UV radiations
- Decay of organic matter (release of H_2S and mecroplans)

Man-made causes

- Commercial activities
- Industrial activities
- Over Population
- Urbanisation
- 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
- Urbanisation
- deforestation
- Explosions in wars
- mining
- 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 $= 10^{-7}$

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

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

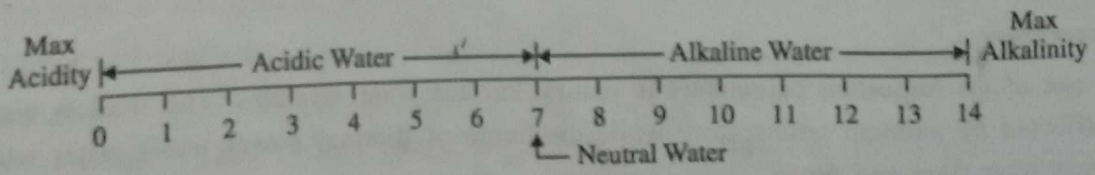


Fig. 2.1 pH scale

$\therefore$ 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.

$$\text{MPN Per 100 ml} = \frac{\text{Number of Positive tubes}}{\sqrt{\begin{pmatrix}\text{ml of sample in}\\ \text{negative tubes}\end{pmatrix} \times \begin{pmatrix}\text{ml of sample}\\ \text{in all tubes}\end{pmatrix}}}$$

(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.

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	

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/m*l*	–	10^{-7}		10^{-9}
Beta–emitters mi/m*l*	–	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.

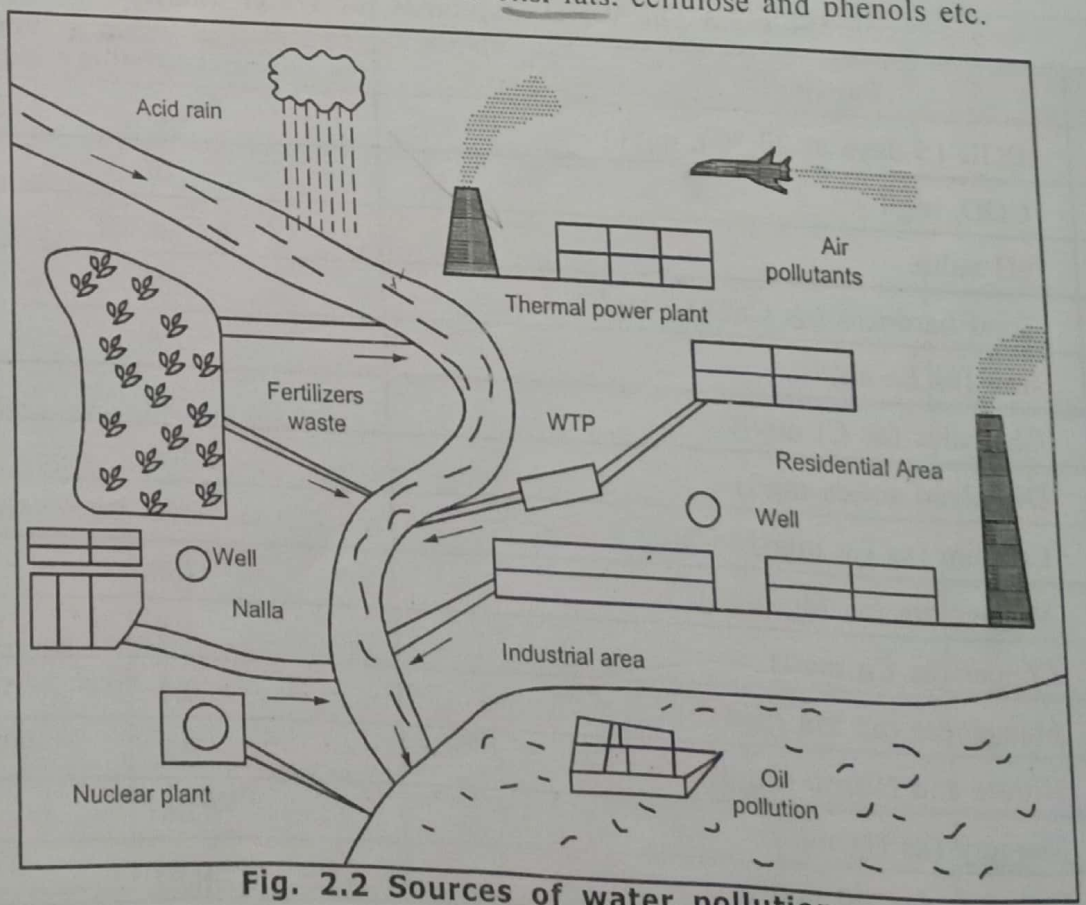


Fig. 2.2 Sources of water pollution

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.

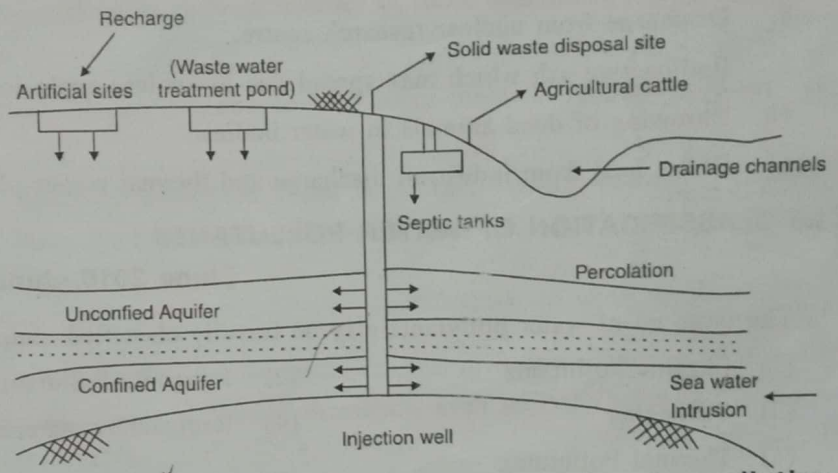


Fig. 2.3 Potential sources of ground water pollution

→ **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 :

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

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.

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

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 then 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.

→ **Control of eutrophication :** **[May 2015]**

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.g. phosphorus can be removed by precipitation and nitrogen by nitrification or denitrification, electrodialysis, osmosis and ion 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.

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
   - glass
   - E–waste, etc.
   - Plastic
   - polythene bags

4. Define 'potable water'. **[Jan. 2013]**

   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

Parameter	Permissible limit
Colour	25 (Hazen units)
turbidity	10 ppm
temperature	20°C
pH	6.5 – 8.5
taste	aggreable

6. Give permissible limits for the following parameters in drinking water as per BIS. Total hardness, iron, chlorides, fluorides, calcium, magnesium, mercury, arcenic

Parameter	Permissible limit
Total hardness	600 mg/*l*
iron	1.0 mg/*l*
chlorides	1000 mg/*l*
Fluorides	1.5 mg/*l*
Calcium	200 mg/*l*
Magnesium	100 mg/*l*
Mercury	0.001 mg/*l*
arcenic	0.05 mg/*l*

7. Define pH of water.

It is defined as the negative logarithm of hydrogen ion (H^+) concentration in water.

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

pH = 7 ..... neutral water

pH = 0 to 7 ..... acidic water

pH = 7 to 14 ..... alkaline water

8. What is temporary hardness of water ? How it can be removed ?

The temporary hardness of water is due to the presence of carbonates and bicarbonates of calcium and magnesium.

It can be removed by either boiling of water or adding lime to the water.

9. Given environmental significance of hardness.

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

10. What is B–coil ?

The combined group of the two bacteria (pathogenic and non–pathogenic) is termed as B–coil group.

11. What is MPN ?

MPN = Most Probable Number

The E–coli (B – coli) test determines the MPN of coliform bacteria in 100 ml of water sample.r

12. What is 'Eutrophication' ? [Dec. 2011]

'eu' means 'well'

'trophes' means 'feed'.

Thus, eutrophication means 'well fed' or 'well nourished'.

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

13. What is BOD and COD ?

BOD is called biochemical oxygen demand. It is defined as oxygen demand created by the aerobic bacteria to decompose the biodegradable organic matter aerobically.

COD is called chemical oxygen demand. It is defined as requirement of equivalent oxygen to degrade biodegradable and non–biodegradable organic matter by oxidising agents like potassium dischromate under controlled conditions.

The value of COD is mostly more than the BOD.

[Jan. 2013]

14. What is 'Minamata' ?

It is a disease caused by eating fishes inhabiting mercury contaminated water.

MULTIPLE CHOICE QUESTIONS

1. Water is acidic if its pH is
(a) 7 (b) greater than 7 (c) less than 7 (d) None of these

2. Which of the following is an example of impact of the development activities or hydrosphere ? [Jan. 2013]
(a) Air pollution (b) Soil pollution (c) Noise pollution (d) Water pollution

3. Disease caused by eating fish inhabiting mercury contaminated water is
(a) Bright's disease (b) Minimata disease
(c) Hashimoto disease (d) Osteosclerosis

[Jan. 2017]

4. Nitrate pollution causes
(a) Skin diseases (b) Typhoid (c) Blue baby disease (d) None of these

[June 2016]

5. Fluoride pollution mainly affects
(a) kidney (b) Brain (c) Heart (d) Teeth

6. The main pathogen present in contaminated water is
(a) Bacteria (b) Algae (c) Protozoa (d) All the above

7. BOD measures
(a) Pathogens (b) Inorganic matter
(c) Organic matter from domestic waste waters (d) None of these

8. COD is a measure of
   (a) Pathogens
   (b) Only biodegradable organic matter
   (c) Only non–biodegradable organic matter
   (d) both (b) and (c)

9. For potable water which of the following statement is not correct ?
   (a) It should be odourless and colourless (b) Turbidity less than 10 ppm
   (c) Temperature maximum 20°C. (d) All of the above

10. Fishes may start dying if DO in water body is
   (a) Less than 4 mg/*l* (b) More than 4 mg/*l*
   (c) 7 mg/*l* (d) None of these

11. Water will be considered saline if the TDS value is
   (a) < 1500 mg/*l* (b) > 5000 mg/*l* (c) < 500 mg/*l* (d) None of these

12. Potable water is [June 2017]
   (a) Polluted water (b) Conaminated water
   (c) Safe drinking water (d) Pure form of water

13. The biggest pollutant receptor or sink on the earth is
   (a) Biosphere (b) Hydrosphere (c) Atmosphere (d) Lithosphere

14. Lakes which are rich in nutrient are called [Jan. 2017]
   (a) Oligotrphic (b) Mesotrohic (c) Eutrophic (d) All of these

15. Lakes which are poor in nutrient are called
   (a) Oligotrphic (b) Mesotrophic (c) Eutrophic (d) All of these

16. Which disease occurs due to consumption of methyl mercury by bacterial action ? [Dec. 2013]
   (a) Minamata (b) Fluoropyrosis (c) Cholera (d) None of these

17. Which of these is not a physical quality parameter for determining quality of water ? [Dec. 2013]
   (a) Turbidity (b) Odour (c) Hardness (d) temperature

18. ..... gives an empirical value of water quality and is a parameter for organic mater present in water. [June 2014]
   (a) BOD (b) COD (c) DO (d) All of the above

19. Discharge of organic waste water into river will [Dec. 2014]
   (a) reduce dissolved oxygen (b) Reduce pH
   (c) increase total dissolved solids (d) Toxic to humans

20. Which of the group of diseases is spread through contaminated food or water..... [Dec. 2014]
   (a) Typhoid, claolera & dysentery (b) Tetauns, Hepatitis & AIDS
   (c) Measles, influenza & small pox (d) Rabies, Malaria & encephalitis

21. Minimata disease is due to [Dec. 2014, June 2016]

(a) Hg (mercury) (b) Pb (lead) (c) Zn (Zinc) (d) Mg (Magnesium)

22. Eutrophication is caused due to the nutrients like .....& ..... . [May 2015]

(a) Calcium and sodium (b) Phosphorous and nitrogen

(c) Carbon and Oxygen (d) None of the above

23. Fluorosis is ..... [May 2015, Dec. 2017]

(a) decolorisation of teeth (b) reduction of fluids in body

(c) a respiratory disease (d) None of the above

24. Eutrophication is [Jan. 2016]

(a) An improved water quality status of lakes

(b) The result of accumulation of plant nutrients in water bodies.

(c) A process in the carbon cycle.

(d) None of the above

25. BOD stands for

(a) Biochemical oxygen demand (b) Basic oxygen demand

(c) Biological Oxygen decomposition (d) Biological organic demand

26. Which of the following is a biodegradable substance ? [May 2016]

(a) Plastic (b) Oil (c) Pesticide (d) Garbage

27. Eutrophication is caused in water bodies due to [May 2017]

(a) poor nutrients (b) Excess nutrients (c) Poor BOD (d) Excess BOD

28. Safe drinking water is also called. [May 2017]

(a) Rain water (b) potable water (c) well water (d) distilled water

29. Blue baby diseases is caused by [May 2017]

(a) Sodium (b) Chlorides (c) Fluoride (d) Nitrate

30. Discharge of organic waste water into river will [Dec. 2017]

(a) Reduced dissolved oxygen (b) Reduce pH

(c) Increases TDS (d) Toxic to humans

ANSWERS

1. (c)	2. (d)	3. (b)	4. (c)	5. (d)	6. (a)	7. (c)
8. (d)	9. (d)	10. (a)	11. (b)	12. (c)	13. (b)	14. (c)
15. (a)	16. (a)	17. (c)	18. (a)	19. (a)	20. (a)	21. (a)
22. (b)	23. (a)	24. (b)	25. (a)	26. (d)	27. (b)	28. (b)
29. (d)	30. (a)					

REVIEW QUESTIONS

1. Enlist types of environmental pollution. What are effect of water pollutants on environment and human. **[April 2010]**
2. Write short note on : 'Indian drinking water standards'. **[Sept. 2009, Jan. 2010, April 2010]**
3. Explain Eutrophication. Highlight causes and effects of eutrofication on lake. **[Dec. 2010, Jan. 2011, June 2011, May 2015, June 2016]**
4. Write short note on : 'Eutrophication'. **[Sept. 2009 Jan. 2013]**
5. What is potable water ? Describe the different water pollutants which make water unfit for drinking. **[June 2010, June 2017]**
6. What is pollutant ? Give classification of pollutants. **[May 2015]**
7. What are the causes of environmental pollution ? List all environmental pollution and their sources in detail. **[Dec. 2011]**
8. Discuss various water quality parameters for safe drinking water. **[May 2012, Dec. 2013]**
9. Enlist major sources of surface water pollution. **[June 2014, June 2016]**

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

3.1 AIR POLLUTION : [Jan. 2013, Jan. 2017]

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.

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

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.

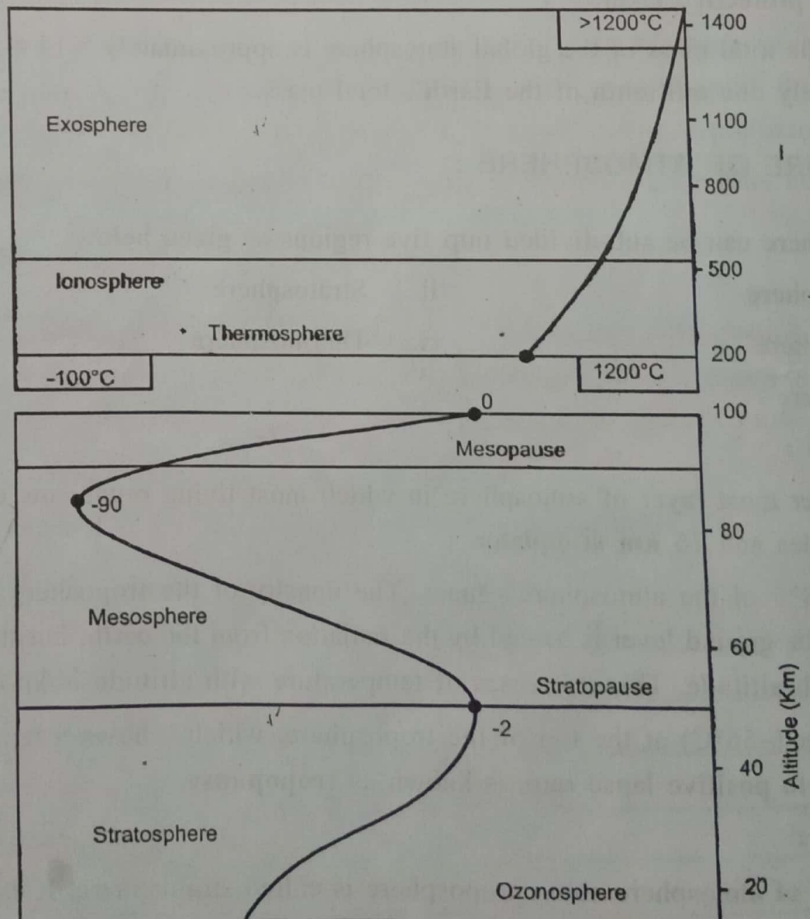


Table 3.2 National Ambient Air Quality Standards

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		Methods of Measurement
		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

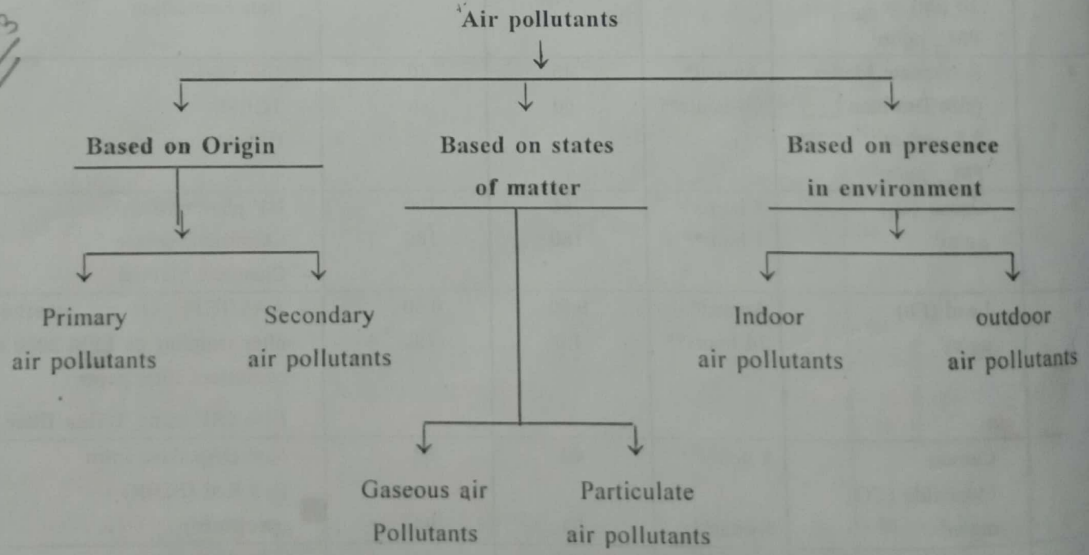
* *Annual arithematic mean of minimum 104 measurement in a year at a particular site taken twice a week 24 hourly at uniform intervals.*

** *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

[May 2012]

1. **Gaseous air pollutants :**

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.

[May 2012]

2. **Particulate air pollutants :**

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.

[June 2010, Jan. 2013]

Fog :

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.

[June 2013]

Soot :

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.

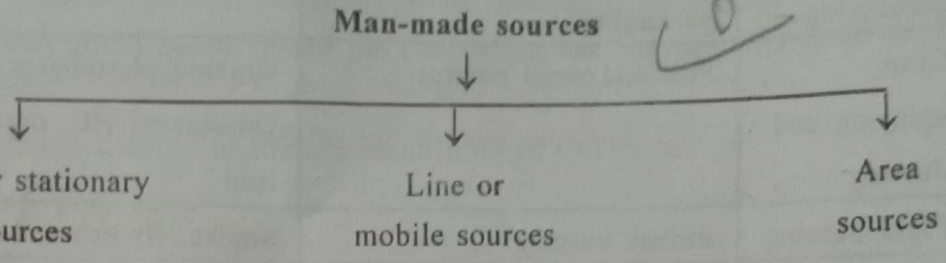
(viii) **Mining**

(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 :

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

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

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.

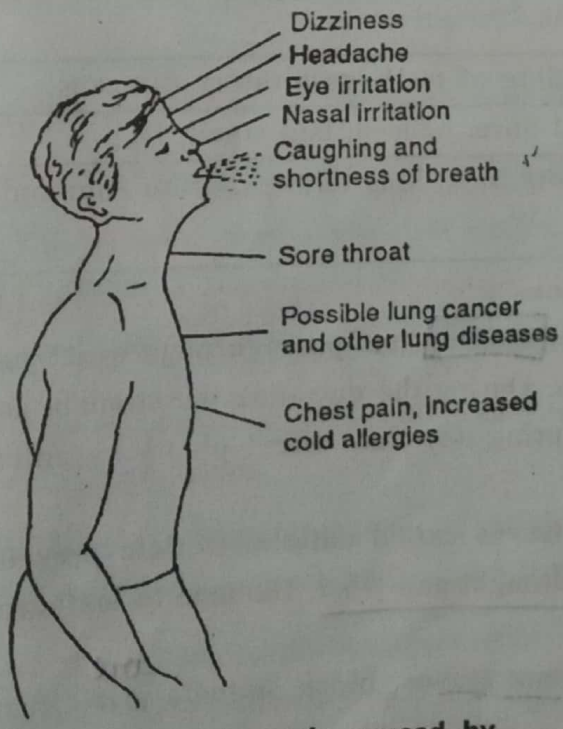


Fig. 3.2 Health hazards caused by air pollution

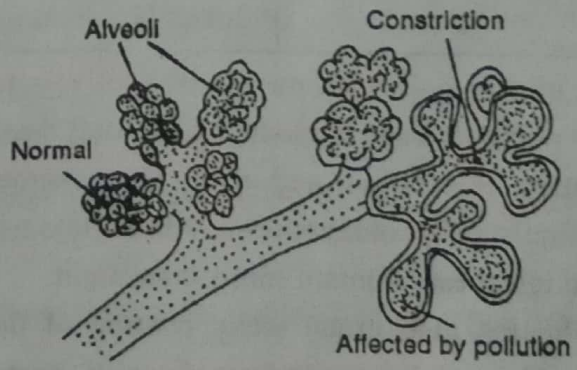


Fig. 3.3 Effects of polluted air on bronchial tubes

5. Exposure to dust, smoke, smog and soot may induce several respiratory diseases like asthama, bronchitis and lung cancer.
6. Atmospheric dust containing silica 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 nausea 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.

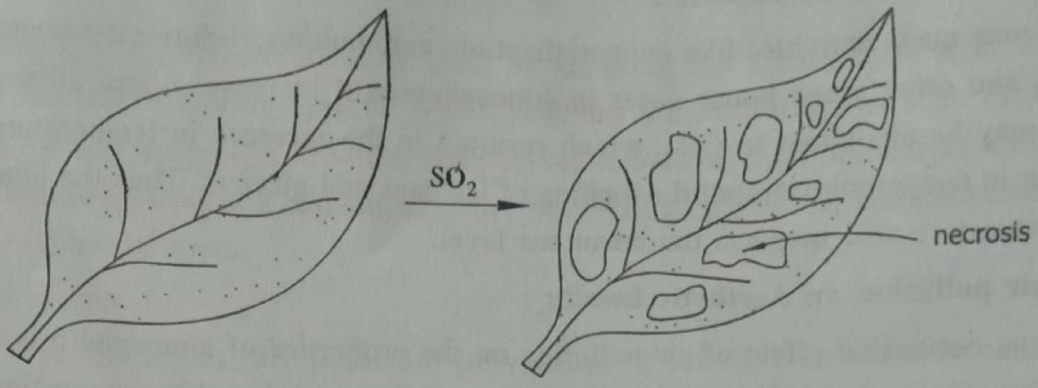


Fig. 3.4 Effect of SO_2 on Leaf [It causes Necrosis]

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 for 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_2 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.

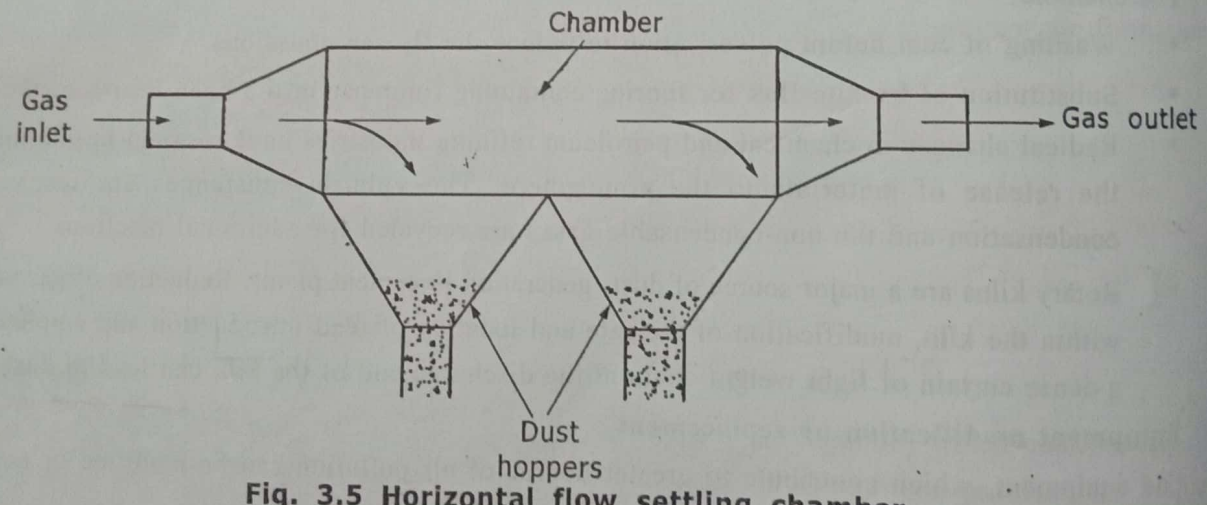


Fig. 3.5 Horizontal flow settling chamber

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 :

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

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

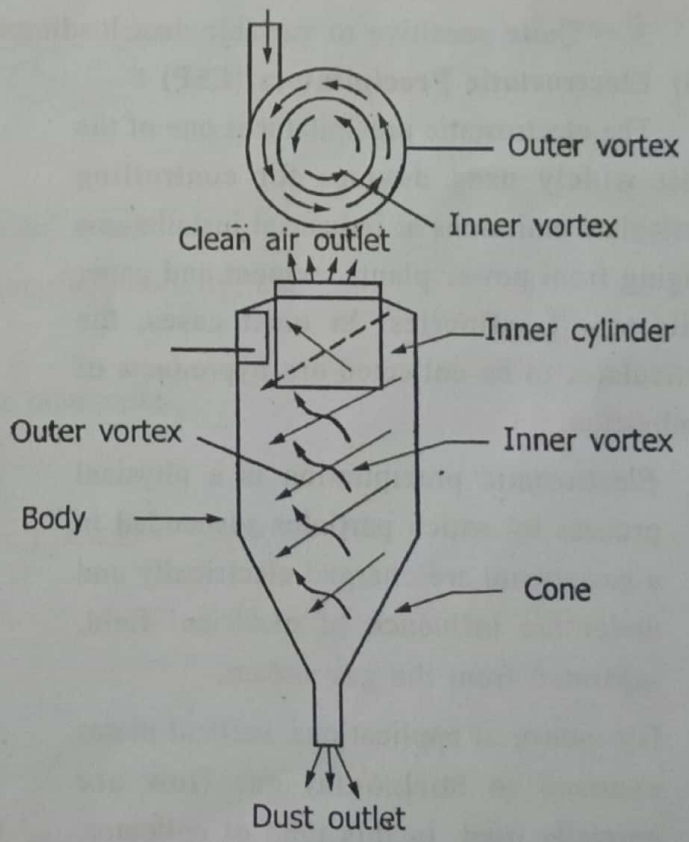


Fig. 3.6 Reverse flow cyclone separator

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

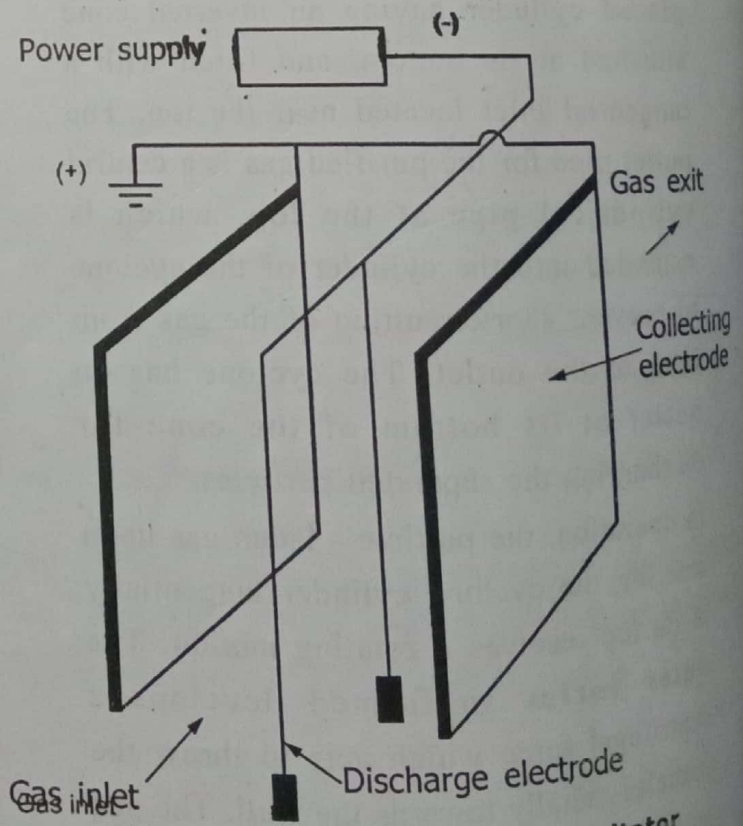


Fig. 3.7 Parallel plate precipitator

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]

Q-5

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.

MULTIPLE CHOICE QUESTIONS

1. Damaging effect on Taj Mahal is due to **[Jan. 2017, May 2017]**
   (a) CO (b) SO_2 (c) CFCs (d) Hydrogen
2. The atmosphere of big cities is polluted by
   (a) Household waste (b) Radioactive fallout
   (c) Automobile exhaust (d) Pesticides
3. Air pollutant which reduces oxygen carrying capacity of haemoglobin is
   (a) Ammonia (b) Hydrogen sulphide
   (c) Carbon monoxide (d) Sulphur dioxide
4. Chemical reaction of nitrogen oxides and hydrocarbons in the presence of sunlight form
   (a) SO_2 (b) Benzene (c) CO (d) PAN
5. Coal is the main contributor of
   (a) CO_2 (b) CO (c) SO_2 (d) N_2
6. Bhopal gas tragedy was due to leakage of **[Jan. 2016, Jan. 2017]**
   (a) methyl iso cynate (b) Carbon monoxide (c) Chlore benzane (d) None of these

7. Asthama, bronchitis and silicosis disease are : [Jan. 2017]
(a) Water borne (b) air borne (c) both (a) and (b) (d) none of these

8. The main product of photochemical smog is
(a) PAN (b) O_2 (c) H_2SO_4 (d) NH_4Cl

9. The main important indoor air pollutant is
(a) SO_2 (b) CO_2 (c) NO_2 (d) Radon gas

10. Which one is a primary pollutant ?
(a) smoke (b) CO_2 (c) PAN (d) CO

11. Which air pollutant reduces the oxygen carrying capacity of the blood by combining with hemoglobin forming carboxyl hemoglobin ? [Dec. 2013, June 2016]
(a) CO (b) SO_2 (c) CO_2 (d) N_2O

12. In cyclone separators which force is utilized to separate the particulate matter from the gas. [Dec. 2013]
(a) Electrostatic force (b) Centrifugal force
(c) Gravitational force (d) Hydrostatic force

13. PAN is a secondary pollutant that ..... [June 2014]
(a) Forms when hydrocarbon radical reacts with nitrogen dioxide.
(b) Cause photochemical smog
(c) May cause respiratory diseases in human
(d) All of the above

14. Automobile exhaust consists of ..... [June 2014]
(a) Hydrocarbons, carbon monoxide and nitric oxide
(b) Lead vapour (c) Sulphur dioxide (d) Carbon dioxide

15. Solid or liquid particle in the air smaller than 2 μm is known as [May 2015]
(a) Flyash (b) Aerosol (c) Soot (d) Mist

16. The removal of carbon dioxide from the earth's atmosphere and the provision of long term storage of carbon in the terrestrial biosphere is called..... [June 2016]
(a) carbon sequestration (b) carbon dating
(c) carbon fixing (d) photosynthesis

17. Soot particles come in air by [May 2017]
(a) photochemical reaction (b) volcanic eruption
(c) Acid rain (d) Fuel combustion

18. Least pollution fuel in automobiles is
(a) Petrol (b) Diesel (c) LPG (d) CNG

19. Nercosis in plant leaf is caused due to
(a) SO_2 (b) CO_2 (c) N_2O (d) CO

20. The most important indoor air pollutant is
(a) SO_2 (b) CO_2 (c) N_2O (d) Radon gas

ANSWERS

1. (b)	2. (c)	3. (c)	4. (d)	5. (a)	6. (a)	7. (b)	8. (a)	9. (a)
10. (d)	11. (a)	12. (b)	13. (d)	14. (a)	15. (b)	16. (c)	17.(d)	18. (d)
19. (a)	20. (b)							

REVIEW QUESTIONS

1. Define air pollution. Give the classification of air pollutants. **[Jan. 2010, Jan. 2013, May 2015]**
2. Explain the effects of air pollution on climate and aesthetic beauty. **[Jan. 2013]**
3. Discuss various gaseous and particulate air pollutants with their sources. **[May 2012]**
4. Define : (i) Fog (ii) Soot **[June 2010, Jan. 2013]**
5. Enlist the common air pollutants stating their permissible limits as per ambient air quality standards. Discuss the effect of high carbon monoxide presence in atmosphere upon human beings. **[June 2010]**
6. Enumerate different primary and secondary air pollutants and explain the effect of carbon monoxide on human beings. **[June 2011, Jan. 2016, June 2017]**
7. What are the effects of carbon monoxide and particulate matter in air on human health ? **[Jan. 2011]**
8. Describe structure of atmospheric air. Give types and effects of common air pollutants in detail. **[Aprll 2010]**
9. Give classification of air pollutants based on source. **[Jan. 2011]**
10. Enlist the important factors affecting air pollution and explain any one. **[Jan. 2011]**
11. Explain effect of air pollution on human beings and animals. **[Jan. 2009, June 2013, Jan. 2017]**
12. Describe different air pollutants. **[Jan. 2009, Sept. 2009, June 2014]**
13. Give types and effects of common air pollutants in detail. **[Dec. 2013]**
14. Discuss the controlling measures of air pollution. **[June 2013]**
15. Discuss the air pollution caused by oxides of nitrogen and sulphur. **[Dec. 2014]**
16. Discuss ambient air quality standards of important air pollutants. **[May 2015]**

• KNOW THE FACTS •

1. ***Carbon Dioxide (CO_2) is powerful cerebral dilator. At concentration between 2 to 10% CO_2 can cause nausea, dizziness, headache, mental confusion, increased blood pressure and respiratory rate. Above 10%, suffocation and death can occur within minutes.***
2. ***Shipping by sea produces 1/60 the emission of shipping by air and about 1/5 that of trucking.*** *– Daniel Goleman*
3. ***It takes 27 to 54 barrels of oil to build a car. A barrel of oil that sells for $ 100 costs only $1 to extract from the ground in Iraq. – Mathew David***
4. ***More than 60% of carbon monoxide (CO) is contributed into the atmosphere by vehicular emissions caused by the transportation services.***

[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 = 1 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

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.

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.

5. **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.

[June 2013]

4.3 NOISE RATING SYSTEM :

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.

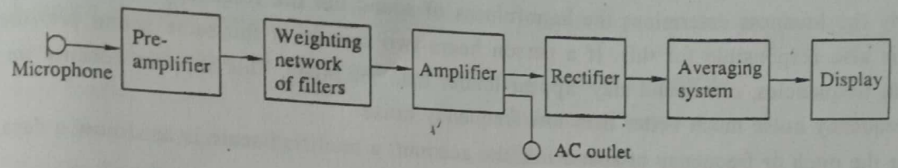


Fig. 4.1 Sound Level Meter Block Diagram

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 : Q.3 [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)
- Mental stress
- Effects on performance
- Depression, fatigue
- Speech interference
- 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.

1. Which one is the intensity level of noise ? [Dec. 2017]

(a) Newton (b) Decibel (c) Pascal (d) Watt

2. Sound becomes hazardous noise pollution at

(a) above 30 dBA (b) above 80 dBA (c) above 100 dBA (d) above 120 dBA

3. Sound wave is an example of

(a) Transverse wave (b) Electromagnetic wave

(c) Longitudinal wave (d) None of these

4. The night time hours considered for permissible noise levels in India are

(a) 6 p.m. to 6 a.m. (b) 8 p.m. to 6 p.m.

(c) 9 p.m. to 6 p.m. (d) 10 p.m. to 6 p.m.

5. up to what distance from hospitals and educational institutions is considered as silent zone

(a) 100 m (b) 150 m (c) 200 m (d) 250 m

6. Major effects of noise pollution includes

(a) Interference in communication

(b) Loss of hearing

(c) Annoyance

(d) All of above

7. Noise is [Dec. 2014]

(a) Loud sound (b) Sound of high frequency

(c) unwanted sound (d) Constant sound

8. Noise is expressed in

(a) Lux (b) dB (c) Pasal (d) km

9. Ambient noise level for residential area during day time is

(a) 75 dBA (b) 65 dBA (c) 55 dBA (d) 45 dBA

ANSWERS

1. (b)	2. (d)	3. (c)	4. (c)	5. (a)	6. (d)	7. (c)	8. (b)	9. (c)

REVIEW QUESTIONS

1. Describe the unit of sound measurement. Discuss the ways to control noise pollution. **[June 2010, June 2011, May 2012]**
2. What are the effects of noise pollution ? **[June 2009, Dec. 2010, Dec. 2013]**
3. What do you understand by acceptable noise level ? Briefly describe the sources and effects of noise pollution. **[Dec. 2010, Jan. 2016]**
4. Discuss about effects of noise pollution and its control. **[Dec. 2013, June 2014, June 2017]**
5. Explain measurement of noise.
6. Explain sources of noise pollution.

• KNOW THE FACTS •

1. ***An average soil sample consists of 45% minerals, 25% water, 25% air and 5% organic matter.***
2. ***Mineral particles of different sizes, such as sand, silt and clay give soil its texture.***
3. ***Bacteria and fungi help break down organic matter in the soil.***
4. ***A modern glass bottle takes 4000 years or more to decompose.***

❖❖❖

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

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-putrescrible 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

This includes
- Vegetable and animal waste matter
- rubbish
- ashes
- cinders
- debris from demolition of structures

Street refuse

This includes
- empty packets and bottles
- empty matches and cigarette boxes
- Polythene bags
- fruit peels
- tree leaves
- Street sweepings

Trade refuse

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 discarbed 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.

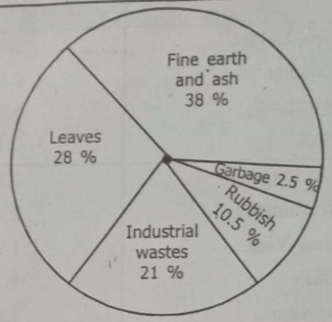


Fig. 5.1 Average composition of refuse by weight (Indian city)

→ **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 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.

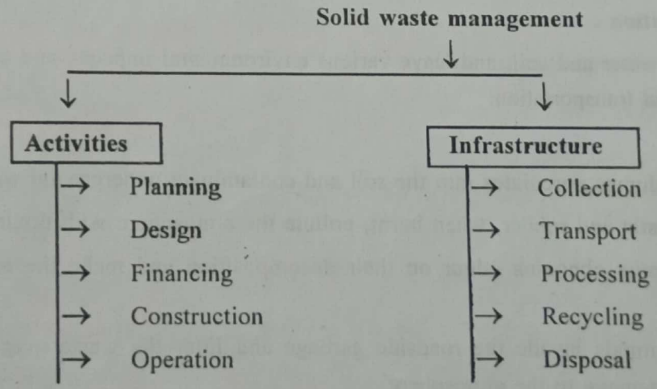


Fig. 5.2 Solid waste management activities and facilities

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:

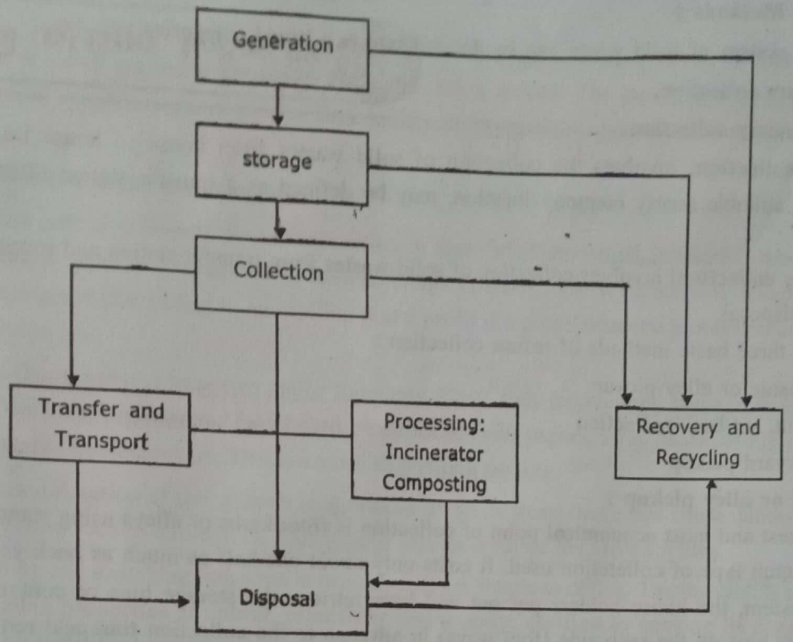


Figure 5.3 Typical SWM system: Functional Elements

→ **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.

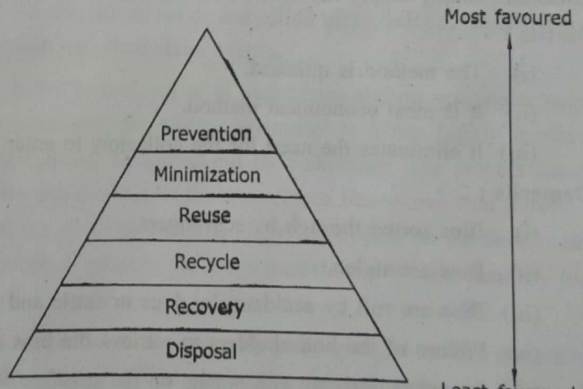


Fig. 5.4 Hierarchy of solid waste Management

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 eneration to a suitable nearly common location, may be defined as a transfer station (dust bins, garbage ats, etc).

Secondary collection, involves collection of solid wastes from transfer station and transportation to the oint 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

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.

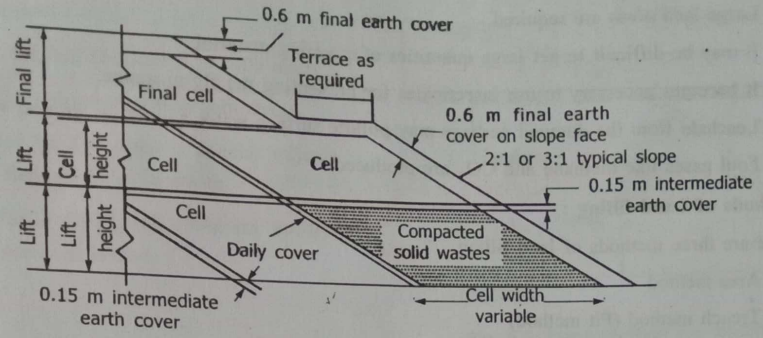


Fig. 5.5 Sectional view of a sanitary land fill

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.

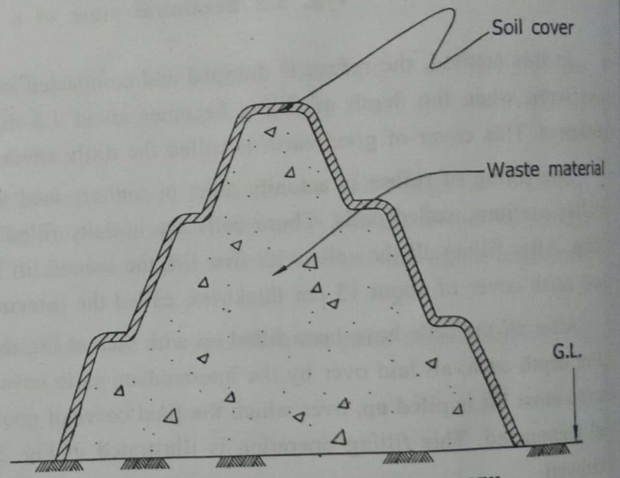


Fig. 5.6 Area method for landfill

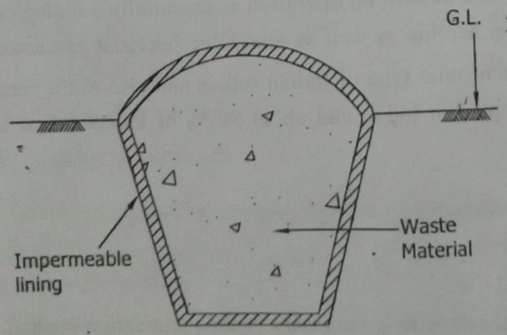


Fig. 5.7 Trench method for Land fill

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.

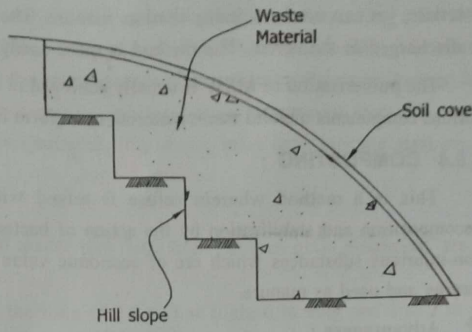


Fig. 5.8 Ramp method for landfill

→ **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

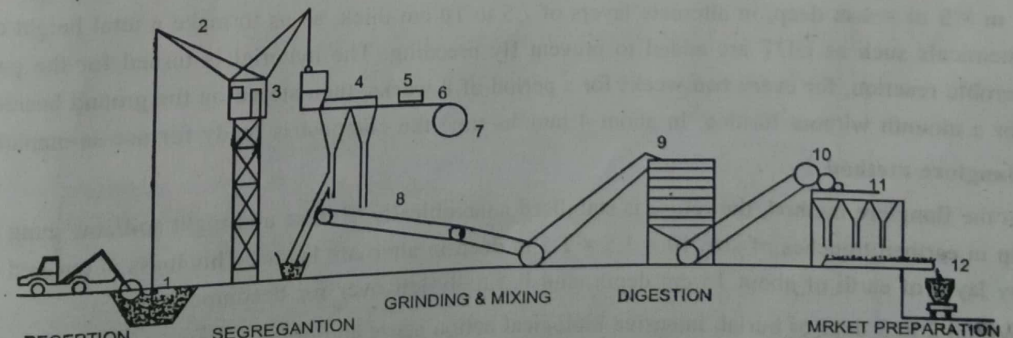


Fig. 5.9 Processing of Refuse of Mechanical Composting

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 shreded 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 :

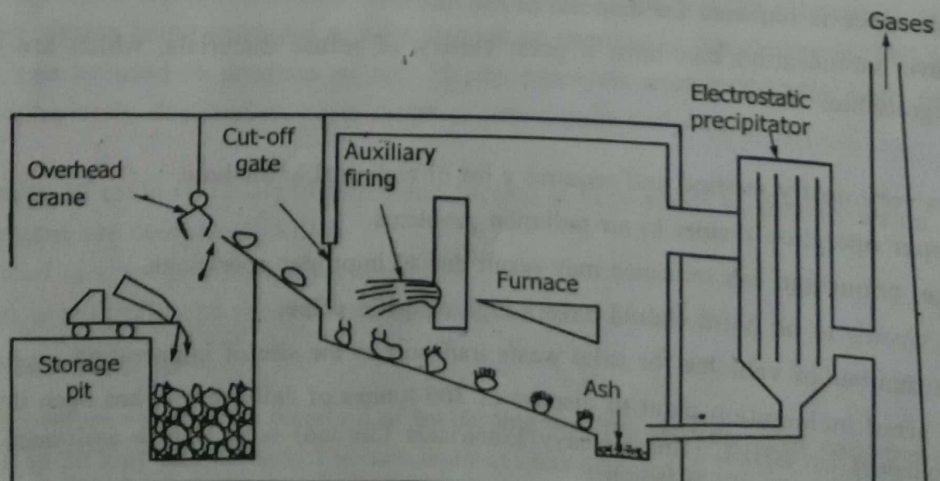
i. Dig a small pit about 0.5 m × 0.5 m and 1 m deep.
ii. Line the pit with straw or dried leaves and grass.
iii. Organise the disposal of organic domestic waste (such as vegetable wastes) into the pit as and when generated.
iv. Introduce a culture of worms.
v. Cover the pit contents daily, by sprinkling 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



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 plastic and rubber waste disposal ?
   (a) composting (b) incineration (c) sanitary landfill (d) pyrolysis
5. The daily cover of MSW landfills consists of which one of the following ?
   (a) compacted soil (b) Geomembrane (c) Geotextile (d) Geocomposite
6. Two biodegradable components of Municipal solid waste are
   (a) Plastics and wood (b) cardboard and glass
   (c) Leather and tin cans (d) food waste and garden trimming
7. The main gases formed from solid waste at landfill site are
   (a) carbon dioxide and oxygen (b) carbon dioxide and methane
   (c) Nitrogen and carbon dioxide (d) sulphur dioxide and methane
8. Which of the following solid waste require maximum degeneration time
   (a) cloth (b) Aluminium (c) plastic bags (d) wood
9. The calorific value of municipal solid waste is about
   (a) 400-500 kcal/kg (b) 500-700 kcal/kg
   (c) 800-1000 kcal/kg (d) 1000-1200 kcal/kg
10. The method most suitable for disposal of hazardous and biomedical wastes is
    (a) sanitary landfilling (b) incineration
    (c) composting (d) plasma pyrolysis
11. The average generation rate of solid waste for Indian cities is :
    (a) 0.1 - 0.3 kg/day (b) 0.2 - 0.5 kg/day (c) 0.5 - 0.8 kg/day (d)1.0 - 1.2 kg/day
12. Which of the following is not the method of sanitary land filling ?
    (a) Trench method (b) Area method (c) Pit method (d) Open dumping
13. In pyrolysis method of solid waste disposal the waste is burnt in a control environment
    (a) in the absence of oxygen (b) in the presence of oxygen
    (c) both 'a' and 'b' above (d) None of the above

14. Which of the following is not the part of MSW ?
(a) Garbage (b) Rubbish (c) Human excreta (d) Ashes

15. Which method of disposal of solid waste produces end product that can be used as fertilizer
(a) sanitary land filling (b) composting
(c) Incineration (d) Pyrolysis

16. Which of the following is the functional element of SWM ?
(a) collection (b) Disposal (c) Recycling (d) All the above

17. Which of the following method of solid waste disposal requires large land area ?
(a) Land filling (b) Composting (c) Pyrolysis (d) Incineration

18. Indore method of composting is a
(a) Trench method (b) Pit method (c) area method (d) None of these

19. The size of trench in Banglore method is
(a) 10 × 1.5 × 1.5 m (b) 10 × 2.0 × 2.0 m
(c) 15 × 1.5 × 1.5 m (d) 15 × 2.0 × 2.0 m

ANSWERS

1. (c)	2. (c)	3. (d)	4. (b)	5. (b)	6. (d)	7. (b)
8. (c)	9. (c)	10. (d)	11. (c)	12. (d)	13. (a)	14. (c)
15. (b)	16. (d)	17. (a)	18. (b)	19. (a)		

REVIEW QUESTIONS

1. What is solid waste management ? State the composition and characteristics of the municipal solid waste.
2. Describe briefly various methods of collection of solid waste.
3. Write short note on :
(i) Physical composition of solid waste
(ii) Composting
4. What are the sources of municipal solid waste ? Give the classification of materials found in municipal solid waste.
5. What is solid waste management ? Describe it with flow diagram indicating its all functional elements.
6. What is sanitary land filling ? Describe the different factors to be considered for the site selection of sanitary land filling.
7. Explain the difference between pyrolysis and incineration.
8. Classify the solid waste and describe in detail mechanical composting.
9. Discuss briefly : Incineration
10. Discuss the merits and demerits of sanitary landfilling and method of composting of solid waste disposal.
11. Give biomedical waste characterization.
12. What is solid waste management ? Enlist its objectives.
13. Define : (i) Rubbish (ii) Garbage
14. Discuss different chemical characteristics of solid waste.

Ch-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

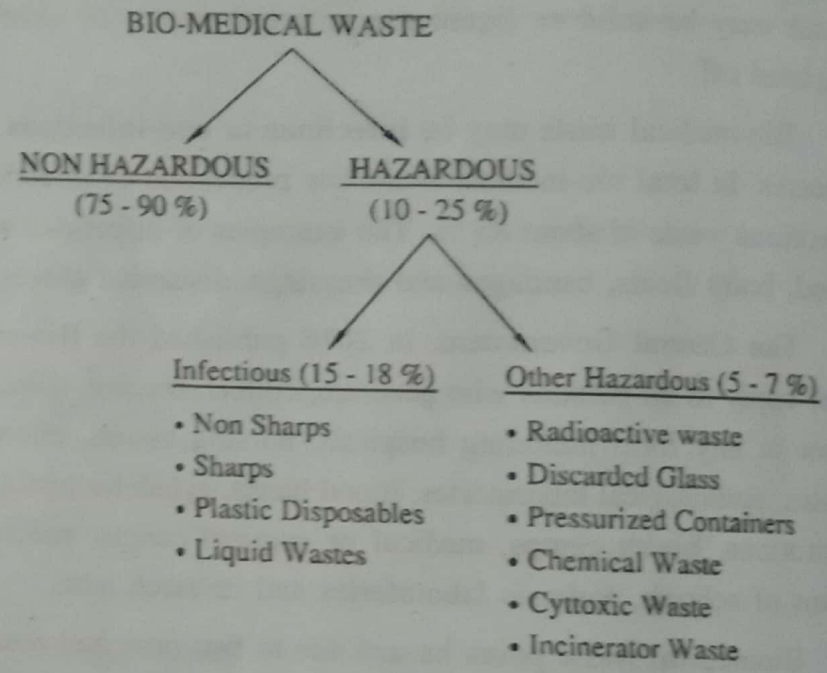


Fig. 6.1 Classification of Bio-medical waste

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 1 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?

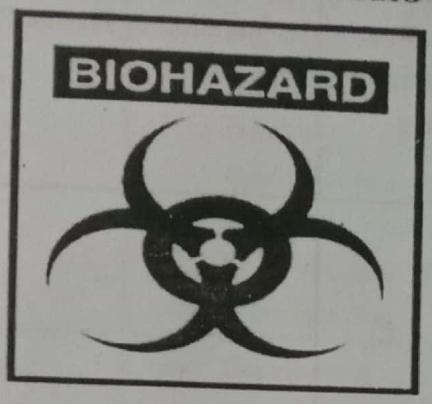
- Segregation reduces the amount of waste needs special handling and treatment.
- Effective segregation process prevents the mixture of medical waste like sharps with the general municipal waste.
- Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics.
- 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 labeling 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 :

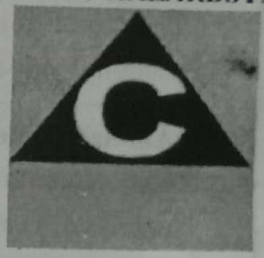
LABEL FOR BIO-MEDICAL WASTE CONTAINERS or BAGS



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 material	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.

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^o 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.

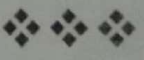
1. Bio-medical waste should not be stored for more than
   (a) 12 hours (b) 24 hours (c) 48 hours (d) 72 hours
2. Non -infectious waste forms about ..... of the total bio-medical waste.
   (a) 15 % (b) 25 % (c) 50 % (d) 85 %
3. The colour of plastic bag used for storing human anatomical waste is
   (a) Yellow (b) Red (c) Blue (d) White
4. Syringes without needles should be stored in which coloured bag ?
   (a) Yellow (b) Red (c) Blue (d) White
5. As per the Bio-medical (Management and Handling) Rules, 2016, the minimum stack height of incinerator should be :
   (a) 15 m (b) 20 m (c) 30 m (d) 40 m
6. The combustion efficiency of incinerator used for treating bio-medical waste should be minimum.
   (a) 75 % (b) 90 % (c) 95 % (d) 99 %
7. The combustion efficiency of plasma pyrolysis for treating bio-medical waste should be minimum :
   (a) 90 % (b) 95 % (c) 99 % (d) 99.99 %
8. Indian hospitals generate approximately .....kg of biomedical waste per patient per day.
   (a) 1.0 (b) 1.5 (c) 2.0 (d) 2.5
9. The thermal method used for disinfection of bio-medical waste is
   (a) Plasma pyrolysis (b) Autoclaving (c) incineration (d) microwaving

ANSWERS

1.	(c)	2.	(d)	3.	(a)	4.	(b)	5.	(c)	6.	(d)
7.	(d)	8.	(b)	9.	(b)						

REVIEW QUESTIONS

1. What is bio-medical waste ? Also explain infectious waste and non-infectious waste.
2. Give classification of bio-medical waste.
3. Enlist sources of biomedical waste.
4. Give importance of biomedical waste.
5. Explain segregation of biomedical waste before disposal.
6. Enlist various methods of treatment and disposal of biomedical waste and describe incineration.
7. Write short note on 'autoclaving'.
8. Explain various steps in bio-medical waste management process.
9. Give scenario of bio-medical waste generation in India. What are the factors affecting generation rate of biomedical waste ?



Ch-7 E-Waste : Generation and Management

7.1 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.

E-waste (Management) Rules, 2016, were published by the Government of India, Ministry of Environment, Forest and Climate Change. [Amended in 2018].

7.2 CLASSIFICATION OF E-WASTE [SOURCES OF E-WASTE] :

E-waste composed of discarded electrical and electronic appliances which have reached the end of their life and no longer serve the purpose they were intended for.

Categories of electrical and electronic equipment covered under the e-waste management rules,2016 are:

(I) Information technology and telecommunication equipment :

Centralized data processing: Mainframes, Minicomputers

Personal Computing: Personal Computers (Central Processing Unit with input and output devices)

Personal Computing: Laptop Computers (Central Processing Unit with input and output devices)

Personal Computing: Notebook Computers

Personal Computing: Notepad Computers

Printers including cartridges

Copying equipment

Electrical and electronic typewriters

User terminals and systems

Facsimile

Telex

Telephones

Pay telephones

Cordless telephones

Cellular telephones

Answering systems

(II) Consumer electrical and electronics:

Television sets (including sets based on (Liquid Crystal Display and Light Emitting Diode technology)

Refrigerator

Washing Machine

Air-conditioners excluding centralized air conditioning plants

Fluorescent and other Mercury containing lamps.

7.3 CONSTITUENT MATERIALS OF E-WASTE :

Various elements and substances contained in e-waste are as under:

1. Useful metals like-iron, steel, copper, aluminum.
2. Precious metals like-platinum, gold, silver.
3. Hazardous materials like- mercury, lithium, barium, radioactive isotopes.
4. Toxic substances like- Dioxins, polychlorinated biphenyls (PCBs), Lead, Zinc, Cadmium.
5. Plastics like- High Impact Polystyrene (HIPS), Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC).
6. Glass materials like- Cathode Ray Tube (consists of glasses such as SiO, CaO, NaO).

E-waste mainly consists of Ferrous & Non-ferrous Metals, Plastics, Glass, Wood etc.

Iron & Steel	- 50%
Plastics	- 21%
Non-ferrous metal	
Mercury, Arsenic, Lead etc.	- 13%

7.4 E-WASTE GENERATION IN INDIA:

India has emerged as fourth largest electronic waste producer in the world. Computer devices account for nearly 70% of e-waste, with the contribution of telecom sector being 12%, medical equipment being 8%, and electric equipments being 7% of the annual e-waste production.

Projection by International Association of Electronic Recycler (IAER).

- 3 billion electronic and electrical appliances became e-waste in 2010.
- Globally about to 20 – 50 million tons of E-Waste is disposed of each year.
- Which accounts for 5% of all Municipal Solid Waste.

According to Comptroller and Auditor-General's (CAG) Report, over 7.2 MT of Industrial Hazardous Waste, 4 lakh Tones of electronic waste, 1.5 MT of Plastic waste, 1.7 MT of medical waste and 48 MT of municipal waste are generated in the country annually.

- CPCB has estimated that E-Waste exceeded 8 lakh tones mark in 2012.
- Annual growth rate of E-Waste generation – 10%
- There are 10 states that contribute to 70% of the total E-Waste generated in the country.
- 65 cities generate more than 60% of the total E-Waste in India.
- Among the top ten cities generating E-Waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pane, Surat & Nagpur.
- Maharashtra ranks first in generation of e-waste followed by Tamil Nadu and U.P.

- Main source of electronic waste in India are the government, public and private (Industrial) sectors – 70%.
- Contribution of individual house hold – 15%
- Rest being contributed by manufacturers.

Out of total E-Waste volume in India :

Computer devices	.....	70 %
Telecom sector	.....	12 %
Medical equipment	.....	8 %
Electrical equipment	.....	7 %

Despite 23 units currently registered with Govt. of India, Ministry of Environment and Forest / Central Pollution Control Board, as E-Waste recyclers / preprocessors, the entire recycling process more or less still exists in the unorganized sector.

Electronics waste in the Global context :

- It is estimated that more than 50MT E-Waste is generated globally every year.
- A report of the United Nations predicted that by 2020, E-Waste from old computers would jump by 400% on 2007 levels in China and by 500% in India.
- Additionally E-Waste from discarded mobile phones would be about seven times higher than 2007 levels in China and in India 18 timers higher by 2020.
- China already produces about 2.3 million tons of E-Waste domestically second only to the US with about 3 million tons.

According to the Global E-waste Monitor Report, 2017, the top 5 e-waste producing countries are as under:

Table 7.1 E- Waste generation- Top 5 Countries

Sr. No.	Country	E-waste generated (million metric tons)	E-waste Per capita (kg)
1.	China	7.2	5.2
2.	United States	6.3	19.4
3.	Japan	2.2	16.9
4.	India	2.0	1.5
5.	Germany	1.9	22.8

7.5 IMPACT OF E-WASTE ON ENVIRONMENT AND HUMAN HEALTH :

Electronic waste or e-waste is one of the rapidly growing problems of the world. E-waste comprises of a multitude of components, some containing toxic substances that can have an adverse impact on human health and the environment if not handled properly. In India, e-waste management assumes greater significance not only due to the generation of its own e-waste but also because of the dumping of e-waste from developed

countries. This is coupled with India's lack of appropriate infrastructure and procedures for its disposal and recycling.

The predictions highlight the urgent need to address the problem of E-Waste in developing countries like India where the collection and management of E-Waste and the recycling process is yet to be properly regulated. It may cause rising environmental damage and health problems if E-Waste recycling is left to the vagaries of the informal sector.

1. **Effect on Human Health :**

(i) The impact is found to be worse in developing countries like India where people engaged in recycling E-Waste are mostly in the unorganized sector, living in close proximity to dumps or landfills of untreated E-Waste and working without any protection or safe guards.

(ii) E-waste is much more hazardous than many other municipal wastes because electronic gadgets contain thousands of components made of deadly chemicals and metals like lead, cadmium, chromium, mercury, polyvinyl chlorides (PVC), brominated flame retardants, beryllium, antimony and phthalates. Long-term exposure to these substances damages the nervous systems, kidney, bones, reproductive and endocrine systems. Some of them are carcinogenic and neurotoxic.

Children are especially vulnerable to the health risks that may result from e-waste exposure and, therefore, need more specific protection. Children may be exposed through dump sites located close to their homes, schools and play areas.

2. **Effect on Environment :**

(i) Disposal of e-wastes is a critical problem faced and poses a threat to both health and vital components of the ecosystem. There are number of channels through which e-waste goes to the environment. E-waste that is land filled produces contaminated leachates, which eventually pollute the groundwater.

(ii) Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil, leading to contamination of water resources.

(iii) Due to dumping of e-waste in to the land filling site, many toxic heavy metals and chemicals from e-waste enter the soils and then it follows the ' soil-crop-food pathway', which is one of the most significant routes for heavy metals exposure to humans.

(iv) Incineration of e-wastes can emit toxic fumes and gases, thereby polluting the surrounding air.

(v) Improper recycling and recovery methods can have major impacts on the environment. Crude forms of dismantling can often lead to toxic emissions, which pollute the air and thereby also expose the workers to the harmful materials.

(vi) The most dangerous form of recycling and recovery from e-waste is the open air burning of circuit boards (made of plastic) in order to recover copper,aluminum,silver and other metals. This will cause air pollution.

(vii) Extraction of metals through acid bath method or through mercury amalgamation also contributes to environmental degradation.

(vii) Burning of plastic casing of e-waste leads to liberation of toxic air pollutants.

(viii) Burning of computer monitors and other electronics produces dioxins causing cancer.

(vii) Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. Not only does the leaching of mercury pose problems, the vaporization of metallic mercury and dimethylene mercury is also of concern.

Table 7.2 Pollutants and their occurrence in waste electrical and electronic equipment

Pollutant	Occurrence	Environmental and Health relevance
Liquid crystal	Displays	
Lithium	Mobile telephones, Photographic equipments, video equipments, batteries	may develop explosive gases (hydrogen) if wetted
Mercury	Components of Copper machines and steam irons, batteries in clocks and pocket calculators, switches, LCDs	acutely poisonous and injurious to health
Nickel	Alloys, batteries, relays, semiconductors, pigments	may cause allergic reactions
PCBs (poly chlorinated biphenyls)	Transformers, capacitors, softening agents for paints, glue, plastic	
Selenium	Photoelectric cells, pigments, photo copiers, fax machines	
Silver	Capacitors, Switches (contacts) batteries, resistors	
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances	toxic when inhaled
Arsenic	Semiconductors, diodes, microwaves, LEDs (light emitting diodes), solar cells	acutely poisonous and on a long-term perspective injurious to health
Barium	Electron tubes, filler of plastic and rubber, lubricant additives	may develop explosive gases (hydrogen) if wetted
Brominated flame proofing agent	Casings, circuit boards (plastic), cables and PVC cables	
Cadmium	Batteries, pigments, solders, alloys, circuit boards, computer batteries, monitor, cathode ray tubes (CRTs)	acutely poisonous and injurious to health
Chrome	Dyes/ Pigments, Switches, Solar	
Cobalt	Insulator	
Copper	Conductor Cables, copper ribbons, coils, circuitry, Pigments	
Lead	Lead reachable batteries, solar, transistors, lithium batteries, PVC (polyvinyl chloride), stabilizers lasers, LEDs, thermo electrical elements, circuit boards	causes damage to the nervous system, circulatory system

7.6 MANAGEMENT OF E-WASTE :

Role of Government :

The responsibility of the Government in e-waste management is to provide adequate system of laws, controls and administration. The Government should set up administrative agency to implement the set rules.

E-waste (Management) Rules, 2016, were published by the Government of India, the Ministry of Environment, Forest and Climate Change.

These rules shall apply to every manufacturer, producer, consumer, bulk consumer, collection centers, dealers, e-retailer, refurbisher, dismantler and recycler involved in manufacture, sale, transfer, purchase, collection, storage and processing of e-waste or electrical and electronic equipment listed in Schedule I, including their components, consumables, parts and spares. Central Pollution Control Board (CPCB), New Delhi, is the agency responsible for implementation of these rules.

These rules also includes Extended Producer Responsibility (EPR) in which a manufacturer of the product is responsible for post consumer stage of the product's life cycle, including its final disposal.

At present 90 % of recycling of e-waste in India is carried out by the informal sector. This practice should be stopped and e-waste recycling by certified recyclers should be ensured.

Responsibilities of the manufacturer :

'Manufacturer' means a person or an entity or a company which has facilities for manufacture of electrical and electronic equipment.

(1) Collect e-waste generated during the manufacture of any electrical and electronic equipment and channelize it for recycling or disposal.

(2) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

(4) Maintain records of the e-waste generated, handled and disposed in Form-2.

Responsibilities of the producer :

'Producer' means any person who, irrespective of the selling technique used such as dealer, retailer, e-retailer, etc, manufactures and offers to sell electrical and electronic equipment and their components or consumables or parts or spares.

(1) Implementing the Extended Producers Responsibility with the following frameworks, namely, - collection and channelization of e-waste generated from the 'end-of-life' of their products or 'end-of-life' products.

- For disposal in Treatment, Storage and Disposal Facility, a pre-treatment is necessary to immobilize the mercury and reduce the volume of waste to be disposed off.
- Creating awareness through media, publications, advertisements, posters, or by any other means of Communication with regard to information on hazards of improper handling, disposal, accidental breakage, damage or improper recycling of e-waste.

Responsibilities of collection centres :

(1) Collect e-waste on behalf of producer or dismantler or recycler or refurbisher including those arising from orphaned products.

(2) Ensure that the facilities are in accordance with the standards or guidelines issued by Central Pollution Control Board from time to time.

(3) Ensure that the e-waste collected by them is stored in a secured manner till it is sent to authorized dismantler or recycler as the case may be.

(4) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

Responsibilities of dealers :

(1) In the case the dealer has been given the responsibility of collection on behalf of the producer, the dealer shall collect the e-waste by providing the consumer a box, bin or a demarcated area to deposit e-waste, or through take back system and send the e-waste so collected to collection centre or dismantler or recycler as designated by producer.

(2) The dealer or retailer or e-retailer shall refund the amount as per take back system or Deposit Refund Scheme of the producer to the depositor of e-waste.

(3) Every dealer shall ensure that the e-waste thus generated is safely transported to authorized dismantlers or recyclers.

(4) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

Responsibilities of the recycler :

(1) Shall ensure that the facility and recycling processes are in accordance with the standards or guidelines prescribed by the Central Pollution Control Board from time to time.

(2) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

(3) Ensure that the recycling processes do not have any adverse effect on the health and the environment.

(4) Make available all records to the Central Pollution Control Board or the concerned State Pollution Control Board for inspection.

(5) Ensure that the fractions or material not recycled in its facility is sent to the respective authorised recyclers.

(6) Ensure that residue generated during recycling process is disposed of in an authorised treatment storage disposal facility.

7.7 RECYCLING OF E-WASTE :

E-waste recycling is the reuse and reprocessing of electrical and electronic equipment of any type that has been discarded or regarded as obsolete. Recycling of e-waste is a growing trend and was initiated to protect human and environmental health mainly due to the widespread environmental pollution impacts of e-waste.

Recycling process of electronic waste is quite hazardous. Printed circuit boards are scrapped by acid bath and de-soldering. Plastics used to make keyboards and other components are outmoded by chemical stripping using nitric and hydrochloric acid. Copper wires used in computers are burnt and stripped in the open to obtain copper, thus resulting in severe air pollution.

Step-by Step Process of E-waste Recycling :

The e-waste recycling process is highly labor intensive and goes through several steps. Below is the step-by-step process of how e-waste is recycled,

1. **Picking Shed :**

When the e-waste items arrive at the recycling plants, the first step involves sorting all the items manually Batteries are removed for quality check.

2. **Disassembly :**

After sorting by hand, the second step involves a serious labor intensive process of manual dismantling. The e-waste items are taken apart to retrieve all the parts and then categorized into core materials and components. The dismantled items are then separated into various categories into parts that can be re-used or still continue the recycling processes.

3. **First size reduction process :**

Here, items that cannot be dismantled efficiently are shredded together with the other dismantled parts to pieces less than 2 inches in diameter. It is done in preparation for further categorization of the finer e-waste pieces.

4. **Second size reduction process :**

The finer e-waste particles are then evenly spread out through an automated shaking process on a conveyor belt. The well spread out e-waste pieces are then broken down further. At this stage, any dust is extracted and discarded in a way that does not degrade the environmentally.

5. **Over-band Magnet :**

At this step, over-band magnet is used to remove all the magnetic materials including steel and iron from the e-waste debris.

6. **Non-metallic and metallic components separation :**

The sixth step is the separation of metals and non-metallic components. Copper, aluminum, and brass are separated from the debris to only leave behind non-metallic materials. The metals are either sold as raw materials or re-used for fresh manufacture.

7. **Water Separation :**

As the last step, plastic content is separated from glass by use of water. One separated, all the materials retrieved can then be resold as raw materials for re-use. The products sold include plastic, glass, copper, iron, steel, shredded circuit boards, and valuable metal mix.

→ **Benefits of e-waste recycling :**

* Recycling Helps Protect The Environment
* Recycling Helps Conserve Limited Resources
* Recycling Promotes Energy Efficiency
* Recycling Helps Build A Strong Economy
* Recycling Creates Jobs
* Recycling Builds Community
* Recycling Can Be Financially Rewarding

E-waste recycling companies in India :

Some of the well known e-waste recycling companies are listed below :

Attero, a Roorkee-based e-waste management company, handles almost 500 tonnes of e-waste per month. Founded by Rohan and Nitin Gupta in 2007, the company currently provides its service to nearly 100 cities

across 22 states in the country. India's electronic industry is growing by 20% annually and one can expect 800,000 tons of e-waste generated every by 2020.

Bangalore-based **E-Parisaraa Pvt Ltd** is India's first government authorized electronic waste recycle company. Started in 2005, it extracts waste such as gold and silver and converts them into industrial raw materials.

Delhi-based **Karma Recycling** has launched an e-portal to offer a simple online electronics trade-in service, which makes it easy for commoners to resell or recycle their used electronic devices. Karma Recycling is also a government-authorized electronic waste collector and segregator that puts efforts on systematic electronics reuse and responsible recycling.

→ **Reuse of recycled e-waste :**

1. **Plastic.** All the plastic materials retrieved are sent to recyclers who use them to manufacture items such as fence posts, plastic sleepers, plastic trays, vineyard stakes, and equipment holders or insulators among other plastic products.
2. **Metal**. Scrap metals materials retrieved are sent to recyclers to manufacture new steel and other metallic materials.
3. **Glass**. Glass is retrieved from the Cathode Ray Tubes (CRTs) mostly found in televisions and computer monitors. Extracting glass for recycling from CRTs is a more complicated task since CRTs are composed of several hazardous materials.
4. **Mercury**. Mercury containing devices are sent to mercury recycling facilities that uses a specialized technology for elimination for use in dental amalgams and metric instruments, and for fluorescent lighting. Other components such as glass and plastics are re-used for manufacture of their respective products.
5. **Printed Circuit Boards**. Circuit boards are sent to specialized and accredited companies where they are smelted to recover non-renewable resources such as silver, tin, gold, palladium, copper and other valuable metals.
6. **Hard Drives**. Hard drives are shredded in whole and processed into aluminum ingots for use in automotive industry.
7. **Ink and Toner Cartridges**. Ink and toner cartridges are taken back to respective manufacturing industries for recycling. They are remanufactured while those that can't are separated into metal and plastic for re-use as raw materials.
8. **Batteries.** Batteries are taken to specialized recyclers where they are hulled to take out plastic. The metals are smelted is specialized conditions to recover nickel, steel, cadmium and cobalt that are re-used for new battery production and fabrication of stainless steel.

MULTIPLE CHOICE QUESTIONS

1. The per capita per year generation of e-waste in India is about
   (a) 0.5 kg (b) 1.0 kg (c) 1.5 kg (d) 2.5 kg
2. The e-waste management rules in India has been last amended in the year
   (a) 2015 (b) 2016 (c) 2017 (d) 2018
3. 'EPR' stands for
   (a) Extended producer Rules (b) Extended producer Responsibility
   (c) Exclusive producer Rules (d) Extra primary Responsibility
4. Major portion of e-waste in India consists of
   (a) computer devices (b) Telecom devices (c) Medical equipment (d) electrical equipment
5. In terms of e-waste generation, India ranks in the world
   (a) First (b) third (c) Fourth (d) fifth
6. Which state ranks first in e-waste generation in India ?
   (a) Karnataka (b) Maharashtra (c) Gujarat (d) Tamilnadu
7. Which city ranks first in e-waste generation in India ?
   (a) Mumbai (b) Delhi (c) Bengaluru (d) Chennai

ANSWERS

1. (c) 2. (d) 3. (b) 4. (a) 5. (c) 6. (b) 7. (a)

REVIEW QUESTIONS

1. What is e-waste ? What are the reasons for faster e-waste generation rate in the world ?
2. Give classification of e-waste.
3. What are the constituent materials of e-waste ?
4. Give present scenaria of e-waste generation in India and in the world.
5. Explain impact of e-waste on environment and on human health.
6. Explain role of government in e-waste management.
7. Explain the responsibilities of manufacturer and producer in e-waste management.
8. Explain recycling of e-waste. Give advantages of recycling e-waste.

Ch-8 Global Environmental Issues

8.1 INTRODUCTION :

In the present day scenario, the world community has realised the importance of environment. Significant changes has taken place in the global ecosystem.

The factors disturbing the global ecosystem are :

1. Population explosion
2. Rapid industrialization
3. Urbanization
4. Modern life style, etc.

1. Population explosion has created an imbalance in demand and supply by creating huge demands for shelter, food, water and other natural and man-made resources.
2. Rapid industrialization has resulted in more consumption of natural resources and more degradation of environment due to pollution.
3. Urbanization has resulted in an imbalance in villages and cities by the migration of people towards urban areas, which has deteriorated the quality of air, water and land of urban areas.
4. Modern life style of the people has contributed a lot in degrading our environment.

All these factors are responsible for the following global environmental problems :

(June 2014)

1. Climate change
2. Global warming and Green house effect
3. Acid rain
4. Ozone layer depletion

8.2 SUSTAINABLE DEVELOPMENT :

[Dec. 2014, June 2016]

Sustainable development is defined as a form of development or progress that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable development is a process of betterment of life in all the sectors like economic, social, educational, health, sanitation, food and housing, national security, etc. It means, every generation should leave air, water and soil, pure and unpolluted as possible, so that the next future generation is not jeopardize of their needs. Although, it is difficult thing, it can be achieved through proper environmental management,

In 1987, the **'World Commission on Environment and Development'** made sustainable development on the theme of its report **"our common future"**. The three important components highlighted in this report are :

1. **Economic development :**

This includes,

- Utilisation of natural resources
- Industrialisation
- raising quality of life
- Agricultural developments
- Creating job opportunities

2. **Social development :**

This includes,

- Providing the basic needs of life like, food, drinking water, shelter, fresh air, clothes, education, health and sanitation.

3. **Environmental development :** [Jan. 2017]

This includes providing safe environment by means of providing clean air, water and soil.

The idea of sustainable development was strongly supported by the **Earth Summit 1992,** held at Rio de Janerio, Brazil. It was the largest environmental conference ever held attracting 30,000 people and more than 100 heads of states. UN general assembly asked for a report on progress made towards sustainable development.

Sustainable development should be a part and parcel of national development plan of each country. It can be achieved by keeping the following points in consideration :

1. Controlling population explosion.
2. Reducting the over exploitation of resources.
3. Enhancing the conservation of natural resources like water, soil, forest and energy.
4. Minimising waste production by performing recycling and reuse.
5. Enhancing the use of non-conventional energy sources like solar, wind, wave and biomass energy.
6. Use of clean production technologies.
7. Providing housing, education and health care to poor people, particularly in rural areas.
8. Encouraging the empowerment and education of women.
9. Development of industrial pollution control methods to reduce level of pollution.
10. By marking strategies for eradication of poverty.
11. Arranging tree plantation programs.

8.3 CLIMATE CHANGE :

Climate change refers to any significant change in climatic factors such as temperature, wind, precipitation, lasting for an unexpected period.

The term **climate change** is very often used inter changeably with the **global warming**. But, the term global warming refers to rise in temperature of earth, while climate change refers to other changes in addition to global warming.

→ **Causes of climate change :**

1. Change in the sun's intensity.
2. Slow changes in the Earth's orbit around the sun.
3. Change in ocean circulation.
4. Human activities that change the composition of atmosphere and land e.g..
   - burning fossil fuels
   - deforestation
   - desertification
   - urbanization
   - industrialization, etc.

→ **Effects of climate change :**

- extreme hot and cold spells of temperature
- wet or dry spells of rainfall
- cyclones
- Floods
- rise in sea level
- global warming

→ **Key signs of climate change :**

The reports published by Intergovernmental Panel on Climat Change (IPCC) and data published by NAOO, US provides clear evidence of the climate change and key signs of climate change.

(1) **Increase in global concentration of CO_2 and other green house gases :**

The concentration of CO_2 and other green house gases (CH_4, N_2O) has increased tremendously during the last few decades. The industrial revolution has resulted in an increase in the concentration of CO_2 in the atmosphere of about 30%, from 280 ppmv around the year 1700 to a value of over 360 ppmv in year 2011.

(2) **Increase in global temperature :**

The earth's average surface temperature has risen about 0.90°C since the late 19th century. The main reason for this rise is increased CO_2 and other man-made emissions into the atmosphere. Year 2016 was the warmest year on record.

The oceans have absorbed much of this increased heat with the top 700 m of ocean showing warming of 0.30°C since 1969.

(3) **Sinking of ice sheets :**

The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's report show Greenland lost an average of 281 billion tons of ice per year between 1993 and 2016, while Antarctica lost about 119 billion tons of ice during the same period. The rate of Antarctica ice mass loss has tripled in the last decade.

(4) **Sea level rise :**

Over the period 1901 to 2010, global sea level rose by 0.19 m (about 8 inch). It is nearly double that of the last century.

8.4 GLOBAL WARMING AND GREEN HOUSE EFFECT : Q-3

[Dec. 2010, June 2011, Jan. 2013, Dec. 2014, May 2015, Jan. 2016]

The increase in the average temperature of global atmosphere is called **global warming.**

The average temperature of the global atmosphere has increased by about 1°C in the last century. The main cause of this temperature rise is the abnormal increase in the concentration of green house gases in the atmosphere.

[Jan. 2017]

→ **Green House Effect :**

Green House is a house made of glass to have higher temperature inside compared to outside temperature. It is used particularly in cold countries to grow tender (delicate) crops. Higher growth of plants inside the house is maintained by controlling the temperature, humidity and carbon dioxide (CO_2).

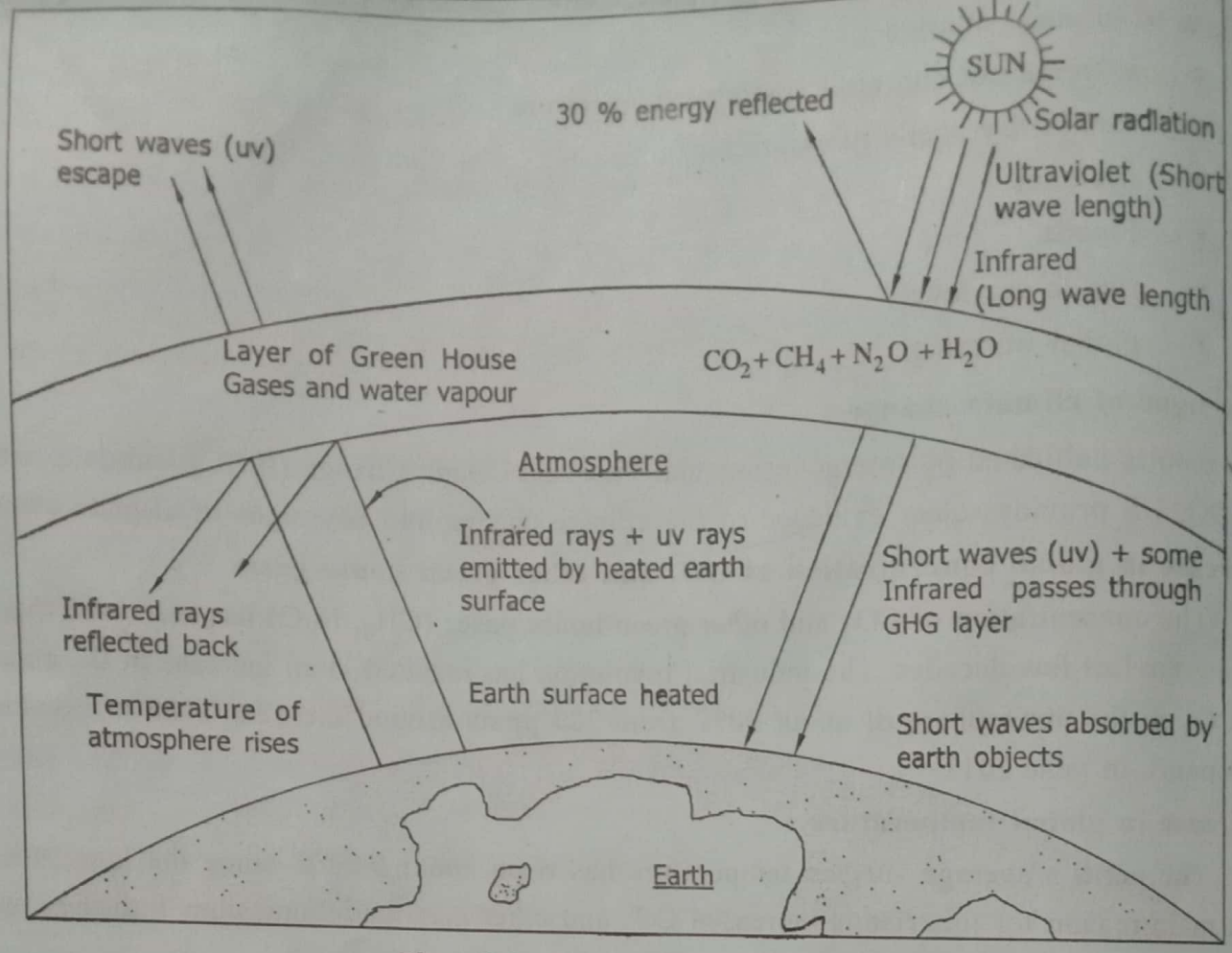


Fig. 8.1 Green house effect

Solar energy (light rays) from sun travels in the form of electro-magnetic waves as ultroviolet (short wavelength) radiations and infrared (long wavelength) radiations.

The short wave length radiations passes through the glass and are absorbed by the objects. In being thus absorbed, it is converted into heat energy, which is given off in the form of infrared radiations. Unlike short wave length radiations, infrared radiations (long wavelength) are prevented by glass walls from escaping. The trapped heat energy causes the inside air temperature to rise and keeps it warmer than the surroundings. This phenomenon is known as **green house effect.**

e.g. The heating of the car sitting in the sun is an example of green house effect.

In absence of green house effect, the average, temperature of earth surface would be (– 19°C) instead of present 15°C.

→ **Earth as green house :**

Almost similar phenomenon takes place in the atmosphere where green house gases like carbon dioxide, methane, nitrous oxide, chloro fluoro carbons (CFC), ozone and water vapours act like a glass in the green house. Solar radiations in the form of long wave and in the short wave are absorbed by the earth's surface and converted to heat energy and emitted into the space as long wave radiation. The green house gases present in the atmosphere absorbs re-radiated long wave radiation and send them back and heat the earth's surface to maintain the temperature.

Most of the incoming short wave solar radiations are of 0.2 to 4 μm range which becomes long wave radiations (range 4 to 100 μm) after getting reflected by the earth. It is found that between the wavelengths of around 7 to 12 μm, absorption of reflected radiations is almost nil which is called **atmospheric window.**

Thus, a maximum of radiations absorbed by green house gases heat the atmosphere and a very little is passed to escape into space. Therefore, if the atmosphere had been free from green house gases then the earth would have been very cold because of complete radiation lost from atmosphere to space.

Green House Gases (GHG) : **[Jan. 2010, May 2015, June 2017]**

The green house effect is caused by gases in the atmosphere which have the ability to absorb the sun's energy that is usually radiated back into space from the earth. These gases are popularly known as the **green house gases.**

The major green house gases are :

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous Oxide (N_2O)
4. Chloro Fluoro Carbon (CFC)
5. Ozone (O_3)
6. Water vapour

1. Carbon dioxide (CO_2) :

Carbon dioxide contribute about 55 - 60% to global warming. It is released to the atmosphere by burning of fossil fuels (oil, natural gas and coal), respiration process of animals and plants, deforestation, decay of organic matter, etc.

The level of CO_2 has increased from 280 ppm to 370 ppm in the last five decades. It's residence time in the atmosphere is 100 years. The weighting assigned to it is unity, that is 1.

2. Methane (CH_4) :

Methane is second important gas responsible for global warming. It's contribution is about 18-20% to global warming. It is produced by the anaerobic decomposition of organic waste water and sludge by anaerobic bacteria called methanogens.

It is produced from dumped garbage, wetlands, biomass burning, petroleum exploration sites, agricultural rice fields, organic municipal wastes etc.

The concentration of methane in air is less than 2 ppm. However, its potential of global warming is very high and its weighting is 21, i.e. it is 25 times more powerful as compared to CO_2. It's residence time in the atmosphere is 12 years.

3. Nitrous Oxide (N_2O) :

Nitrous oxide is also known as laughing gas. Contribution of this gas towards global warming is about 6%.

Its main resources are agricultural activities, industrial activities, combustion of solid waste and combussion of fossil fuels. It is produced by the breakdown of nitrogen rich fertilizers in the soil and nitrate contaminated ground water, burning of nitrogen rich fuels, live stock waste and during nylon production.

The atmospheric concentration of nitrous oxide is 0.3 ppm. The residence time in the atmosphere is 120 years. The GWP of N_2O is 230.

4. **Chloro Fluoro Carbon (CFCs) :**

CFCs are highly stable, non-flammable man-made gaseous compounds of carbon and halogens. Major sources of CFCs are leaking of air conditioners, refrigeration units, cleaning of electronic components, production of plastic foams, spraying paints, etc.

CFC is a combination of carbon, hydrogen fluorine and chlorine. CFC-11 and CFC-12 are the most commonly used CFCs.

They have tremendous potential of global warming, some 12,000 to 16,000 times as compared to carbon dioxide. The atmospheric concentration of CFCs is 0.00225 ppm and is increasing at the rate of 0.5% annually.

5. **Ozone (O_3) :**

In the troposphere, ozone is a secondary pollutant. It is formed by the reaction of atomic oxygen with oxygen gas in the presence of nitrogen.

Ozone has strong absorption band at 9 µm and is quite unstable in troposphere. The contribution of ozone towards global warming is about 8%.

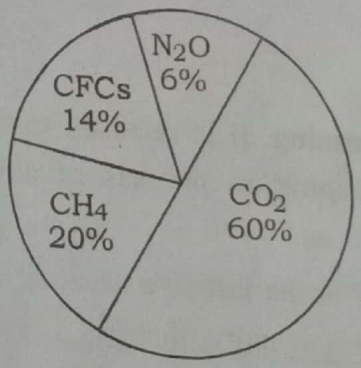


Fig. 8.2 Relative contribution of different greenhouse gases to global warming

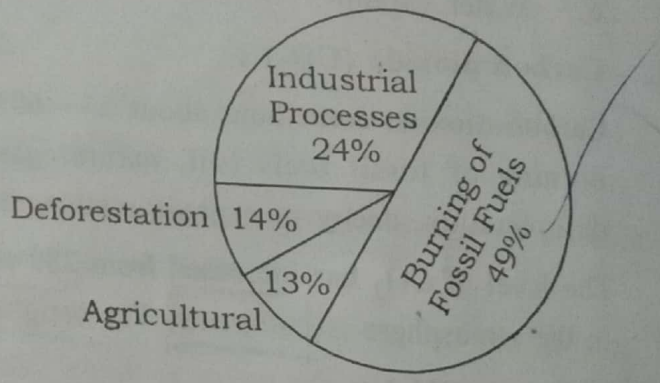


Fig. 8.3 Relative contribution of various human activities to the increase of greenhouse gases in the atmosphere from different sources

→ **Effects of Global warming :**

1. **Change in climate :** **[June 2013]**

Rising temperatures have a pronounced effect on the global climate regime.

Change in climate bring in following problems :

- Change in rainfall pattern
- Drying of surface water bodies
- Conversion of fertile land into deserts
- Serious water shortage
- Fall in ground water table
- Change in crop pattern
- Growth of micro-organisms and spread of diseases
- Change in vegetation pattern, etc.

2. **Rise in Sea level :**

High temperature on earth will melt polar ice caps and glaciers causing rise in the sea water leve Over the period of 1901 to 2010 global sea level rose by 0.19 m (about 8 inch). This rise is mor than half of the rise in the preceeding 2000 years. It is estimated that if there is an increase in sea level by 1m, the costline moves inland by 1.5 kilometers.

- rising sea level will inundate coastal areas.
- Submergance of islands.

For example, Tuvalu country between Australia and Hawaii.

3. **Effect on human health :**

Human health may be adversely affected in hot climate. Climate changes and rise in average temperature of atmosphere has led to occurance of different new diseases.

Change in climate may generate drinking water problems at global level.

4. **Other effects :**

- Decrease in food production
- Adverse effect on flora and fauna.
- Adverse effect on many ecosystems.

→ **Control of Global warming :** **[June 2013]**

Some of the measures to control global warming are as follows :

1. Reduction in the use of fossil fuel for energy generation.
2. Promoting non-conventional energy sources like wind energy, solar energy, nuclear energy, etc.
3. Hydrogen as an energy source of the future is another proposal.
4. Reduction in N_2O emission by minimising the use of nitrogen fertilizers in agriculture.
5. Increase of the vegetation cover, particularly forest as it is sink for CO_2 absorpiton.
6. There is vast scope for energy conservation such as through introduction of mass transporation in cities, development of energy efficient devices, economic use of energy, etc.
7. By using the substitutes like HCFCs in place of CFCs.
8. Traping and use of methane as fuel.
9. Stabilize population growth.
10. Industrial processes have to be upgraded to release as little green house gases as possible.

Global Warming Potential (GWP) :

Global warming potential is the ratio of the warming caused by a substance compared to the warming caused by a similar mass of CO_2.

The GWP of CO_2 is 1.0

Green House Gas	GWP	Life (years)
(i) CO_2	1	100
(ii) Methane (CH4)	25	12
(iii) N_2O	230	120
(iv) CFC	12000-16000	800-50,000

5 ACID RAIN :

[Jan. 2010, April 2010, Jan. 2011, Jan. 2013, Jan. 2016, June 2016, Jan. 2017]

When the pH of rain water is less than 5.6, it is called **acid rain.**

Theoretically speaking, rain water (natural water) as it falls should be neither acidic nor alkaline. It should be neutral, i.e. pH = 7. But, in reality it is not so because of the dissolution of atmospheric CO_2 in rainwater to yield carbonic acid which imparts slight acidity to rainwater.

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

The adverse impacts of acid rain will be experienced only if the pH of rain water is about 4.5 and less. Europe, Netherland, Sweden, USA and other industrialized countries faced problem of acid rain with pH of 5.0 to 2.2. The phenomenon of acid rain has also been observed in cities like Kanpur and Mumbai.

The reduction in pH of rainwater is basically due to the dissolution of oxides of nitrogen and sulphur present in the atmosphere which forms nitric acid (HNO_3) and sulphuric acid (H_2SO_4) as shown below.

(1) $2SO_2 + O_2 \longrightarrow 2SO_3$

$SO_3 + H_2O \longrightarrow H_2SO_4$ (Sulphuric acid)

(2) $2NO + O_2 \longrightarrow 2NO_2$

$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$ (Nitric acid)

(3) HCl gas $\xrightarrow{\text{dissolved in water}}$ HCl (Hydrocloric acid)

It is estimated that acid rain contribution of H_2SO_4 is 60-70% and that of HNO_3 is 30 - 40% Acidity contributed by HCl is very small.

Causes of acid rain :

[June 2014, June 2016]

1. Dissolution of SO_2 and NO_2 formed by the burning of fossil fuels into rain water.
2. Dissolution of oxides of sulphur and nitrogen emitted from automobile exhaust into rain water.
3. Dissolution of oxides of sulphur and nitrogen released from the chimneys of smelting industries.
4. Industrial plants using sulphuric acid and nitric acid.

Effects of acid rain :

[June 2014, June 2016]

Effect on human health :

Skin irritation and aggravation of respiratory diseases are frequently observed in acid rain affected areas.

Effects on aquatic life :

Acidification of lakes and streams due to acid rain may cause disapperence of aquatic species and killing of bacteria, algae and small fishes. It is reported that due to acidity there are thousands of lakes in Norway and Sweden that do not contain any fish.

Effects on Vegetation :

Acid rain may decolourise the leaves of plants and reduces chlorophyll content. In highly industrialized regious forests are virtually killed.

4. **Effect on water resources :**

Acidification of water resources, both surface and underground sources is a very critical outfall of acid rain. pH of water drastically reduces, which has a deleterious effect on fish population.

Water treatment costs increase. Water storage structures are damaged.

5. **Damage to structures and property :**

Acid rain can damage the structural materials like marble and limestone. Monuments especially those structured that of marble such as the Taj Mahal in India are disfigured.

Vehicle finishes are also affected.

6. **Reduction in soil pH :**

Low soil pH diminishes the bacterial activity in soil, which has a serious repercussion on nutrient fixation. Also, the uptake of nutrients by plants is hindered due to leaching out of aluminium at low pH conditions.

7. **Effect on ecosystem :**

Acid rain affects the ecosystem as it breaks the food chain and food web and thereby reduces the bio-diversity.

Control of acid rain :

Remedial and control measures of acid rain are :

1. Decreasing the emissions of sulphur dioxide (SO_2) and nitrogen oxide (NO_2).
2. Adopting energy conservation measures.
3. Using less coal in power plants and utilizing non-polluting energy sources.
4. Lakes and soil that are extremely acidified can be treated with lime to rejuvenate them.
5. Release of SO_2 can be controlled by adopting suitable SO_2 reducing equipments in industries and thermal power plants.
6. Natural gas can be used in place of high-sulphur coal for producing electricity in thermal power plants.
7. Considering nuclear energy as an option for the future fuel.

8.6 OZONE LAYER DEPLETION :

[Dec. 2010, June 2011, May 2012, Dec. 2013, Dec. 2014, Jan. 2017]

The layer in the upper atmosphere (stratosphere), some 15 to 30 km above the earth's surfae, in which most of the atmospheric ozone (about 90%) is concentrated is called the **ozone layer.**

The ozone layer, absorbs most of the sun's ultra violet (uv) radiation and protects various life form on the earth. It acts like a natural sunscreen for the earth. Therefore, the ozone layer is often called the **ozone shield or earth's protective umbrella.**

Formation of ozone :

In the stratosphere, the formataion and destruction of ozone is a continuous phenomenon. In the stratosphere, UV radiation splits oxygen molecule into oxygen atoms, which combine with other oxygen molecules to form ozone.

The UV radiation splits oxygen molecule into oxygen atoms.

$$O_2 + hv \longrightarrow O + O$$

The atomic oxygen react with molecular oxygen to form ozone.

$$O + O_2 + M \longrightarrow O_3 + M$$

(M is third body necessary to carry away the energy released in the reaction)

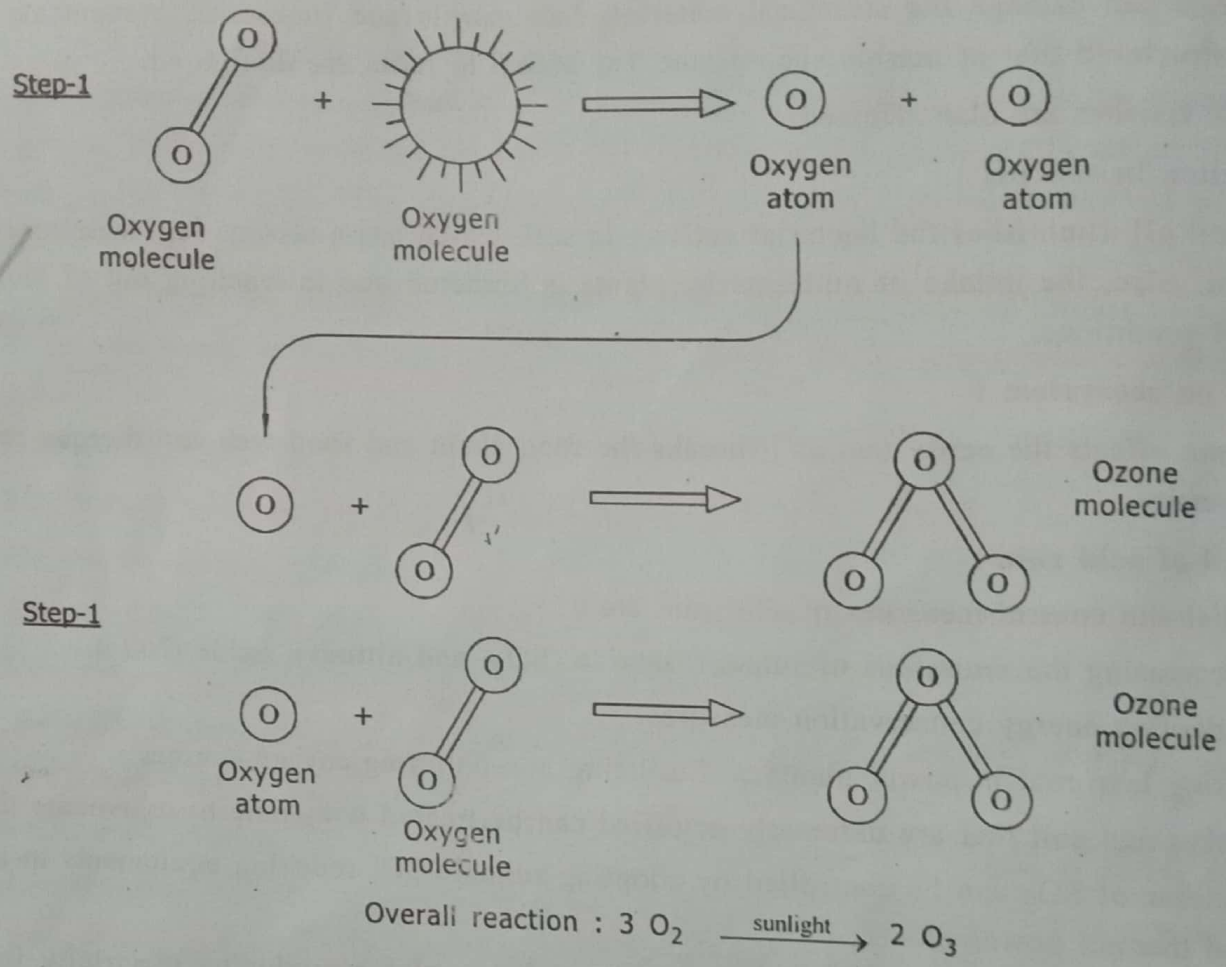


Fig. 8.4 Ozone Formation

Ozone thus formed distributes itself in the atmosphere and absorb harmful ultraviolet radiation (200 - 320 nm) and it continuously converted back to molecular oxygen.

$$O_3 + hv \longrightarrow .O_2 + O$$

➜ **Destruction of ozone layer :**

The main chemicals responsible for ozone layer depletion are chloro fluoro carbons (CFCs) and chlorofluoro bromines (CF_3 Br).

Among the CFCs, the main chemicals responsible for ozone depletion are referred to by trade names such as

Feron - 11 (C Cl_3 F)

Feron - 12 (C Cl_2 F_2)

They are largely used, and subsequently released into the atmosphere, by the following activities :

(i) Refrigeration
(ii) Air conditioning
(iii) Extinguishing fires
(iv) Cleaning solvents in industries
(v) Solvent in paint industry
(vi) Blowing agents in plastic industries

CFCs are destroyed by UV radiation in the atmosphere and releases atomic Cl which destroys the ozone layer as under.

$$C\,Cl_2\,F_2 \xrightarrow{uv} Cl + C\,Cl\,F_2$$

(Chlorine atom released from CFCs)

$$Cl + O_3 \longrightarrow ClO + O_2$$

(O_3 : Ozone; ClO : Chlorine monoxide; O_2 : Oxygen molecule)

The ClO so formed then react with another oxygen atom to form new oxygen molecule and a chlorine atom :

$$ClO + O \longrightarrow Cl + O_2$$

These chlorine atoms so formed break apart the ozone molecules in a drastic way leading to large scale ozone depletion.

In above reaction Cl just acts acts as a catalyst and reappears. It is estimated that one Cl atom can destroy 1,00,000 Ozone molecules in 1 to 2 years.

Other ozone depleting substances :

(i) Carbo tetra chloride (CTC)

(ii) Halon

(iii) Methyl bromide

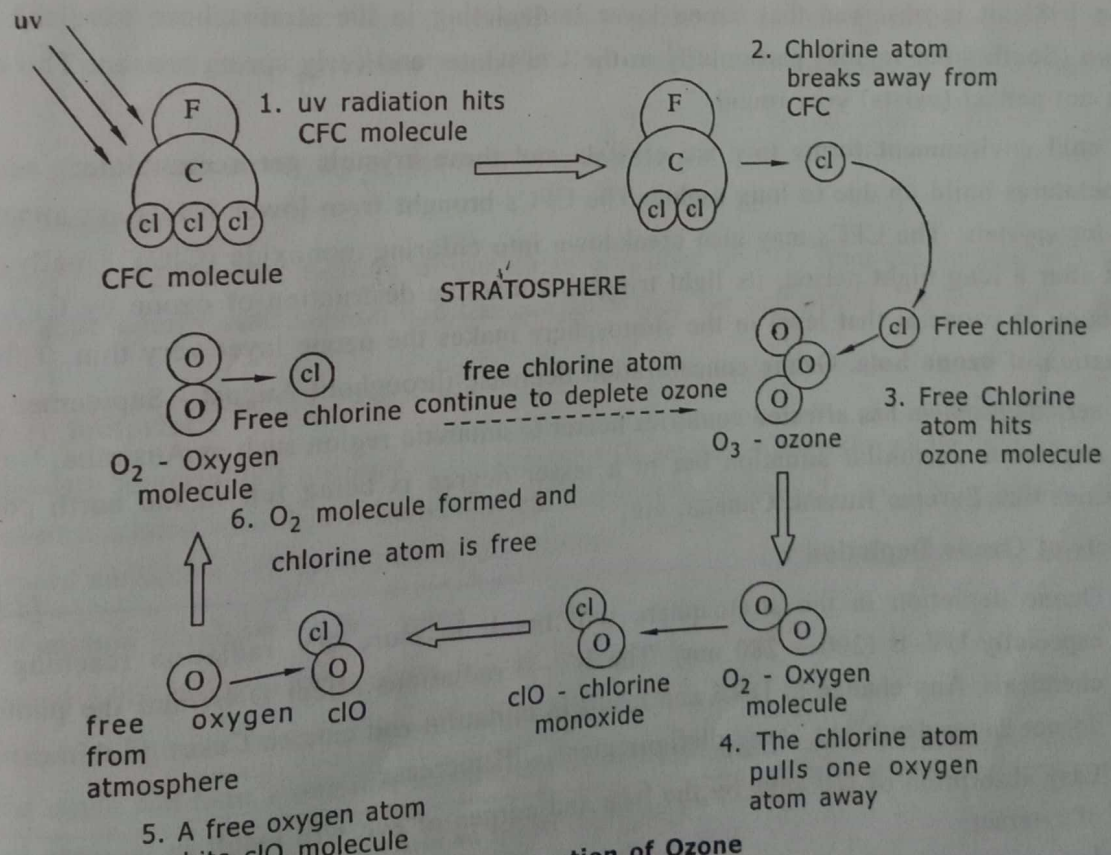


Fig. 8.5 Destruction of Ozone

→ **Dobson unit (DU) :**

Unit of measurement of ozone in atmosphere is **Dobson unit (DU).**

1 Dobson unit is equivalent to a concentration of 1 ppb (parts per billion) O_3.

1 Dobson unit (DU) is defined as 0.01 mm thick ozone layer at STP (i.e 0°C and 1 atm)

Under normal conditions, earth atmosphere contains about 300 DU i.e. 3 mm thick slab of ozone layer which is reduced to 100 DU, i.e. 1 mm thick ozone slab at **'Ozone holes'.**

Ozone Depleting Potential (ODP) :

It is the ratio of the impact on Ozone caused by a chemical compared to the impact of a similar mass of CFC-11.

The ODP of CFC-11 is 1.0.

→ **Ozone hole :**

The ozone hole is an area of the stratosphere where the concentration of ozone drops drastically. The average amount of ozone in the atmosphere is roughly 300 DU, i.e. 3 mm thick slab of ozone layer. Any place where the ozone concentration drops below 220 DU, it is considered as part of the ozone hole. Average concentrations in the ozone hole are around 100 DU (i.e. 1 mm thick slab).

Since 1985, it is observed that ozone layer is depleting in the stratosphere over the **Antarctic region** (South polar region) particularly in the late winter and early spring season. The ozone hole does not persist (exists) year round.

The cold environment forms tiny ice crystals and these crystals get accumulated, as very cold temperatures build up due to long nights. The CFCs brought from lower levels get attached to the tiny ice crystals. The CFCs may also breakdown into chlorine monoxide (ClO). Finally, when sun rises after a long night period, its light triggers a massive destruction of ozone by ClO. This vast depletion of ozone at that level in the stratosphere makes the ozone layer very thin. This is called formation of **ozone hole.** Ozone concentration decrease throughout August - September - October.

This serious problem has affected countries nearer to antarctic region such as Australia, New Zealand and Argentina. A similar situation but to a lesser degree is being felt in the north polar region countries like Europe, Russia, Canada, etc.

→ **Effects of Ozone Depletion :**

[Jan. 2017]

- Ozone depletion in the stratosphere will result in more UV radiation reaching the earth especially UV–B (200 – 280 nm). The UV–B radiations affect DNA and the photosynthetic chemicals. Any change in DNA can result in mutation and cancer. Cases of skin cancer which do not cause death but cause disfigurement will increase.
- Easy absorption of UV rays by the lens and cornea of eye will result in increase in incidents of cataract.
- Melanin producing cells of the epidermis will be destroyed by UV–rays resulting in immuno-suppression. Fair people (can't produce enough melanin) will be at a greater risk of UV exposure.

- Phytoplankton are sensitive to UV exposure Ozone depletion will result in decrease in their population thereby affecting the population of Zooplankton, fish, marine animals, in fact the whole aquatic food chain.
- Yield of vital crops like corn, rice, soyabean, cotton, bean, pea and wheat will decrease.
- Degradation of paints, plastics and other polymer material will result in economic loss due to effects of UV radiation resulting from Ozone depletion.

8.7 CARBON FOOTPRINT : Q-10

The carbon footprint is a measure of the total amount of Carbon Dioxide (CO_2) and other greenhouse gas emissions that are directly or indirectly caused by an activity, or which are accumulated over the life span of a product, person, an organization, or even a city or state. Carbon foot printing is a measure by which a company or individual can calculate how much carbon emissions they have produced during a project or time period.

A carbon footprint is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day–to–day lives through burning fossil fuels for electricity, heating and transportation etc.

The carbon footprint is a measurement of all greenhouse gases we individually produce and has units of tones (or kg) of carbon dioxide equivalent.

Carbon footprint can sometimes also expressed in kg carbon rather than kg carbon dioxide. Kg carbon dioxide can be converted into kg carbon by multiplying with a factor 0.27. (1000 kg CO_2 equal 270 kg carbon)

A carbon footprint is made up of the sum of two parts:

(1) Primary footprint :

The primary footprint is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation (e.g. car and plane). We have direct control of these.

(2) Secondary footprint :

The secondary footprint is a measure of the indirect CO_2 emissions from the whole lifecycle of products we use – those associated with their manufacture and eventual breakdown. To put it very simply – the more we buy the more emissions will be caused on our behalf.

A ton of carbon is released when you :

- Travel 5,000 miles in an airplane
- Drive 2,500 miles in a medium–sized car
- Cut down and burn a tree that was about one foot in diameter and 40 feet tall.

Why are individual carbon footprints so alarmingly high?

- We cause huge amounts of air, water and land pollution;
- We are incredibly lazy in our home and work habits;
- We produce enormous and completely unjustifiable amounts of waste materials;

- We have been resistant to embrace alternative energy sources.
- We gorge ourselves on animal-based diets that not only destroy our health, but also cause unparalleled amounts of deforestation and shrink our fresh water supplies to nothing.

There are different types of carbon footprint, e.g. for organizations, individuals, products, services, and events. Different types of footprint have different methods and boundaries.

The full carbon footprint of an organization encompasses a wide range of emissions sources from direct use of fuels to indirect impacts such as employee travel or emissions from other organizations up and down the supply chain.

Three main types of emissions exist:

1. **Direct emissions that result from activities that the organization controls.** The majority of direct emissions will result from combustion of fuels which produce CO_2 emissions, e.g. the gas used to provide heating for a building. Some organizations will also directly emit other greenhouse gases e.g. the burning and production of cement.

2. **Emissions from the use of electricity.** Workplaces generally use electricity for lighting and equipment. Electricity generation comes from a range of sources, including renewable. In the UK however, around 75% is produced through the combustion of fossil fuels such as coal and gas. Although not directly in control of the emissions, by purchasing the electricity the organization is indirectly responsible for the release of CO_2.

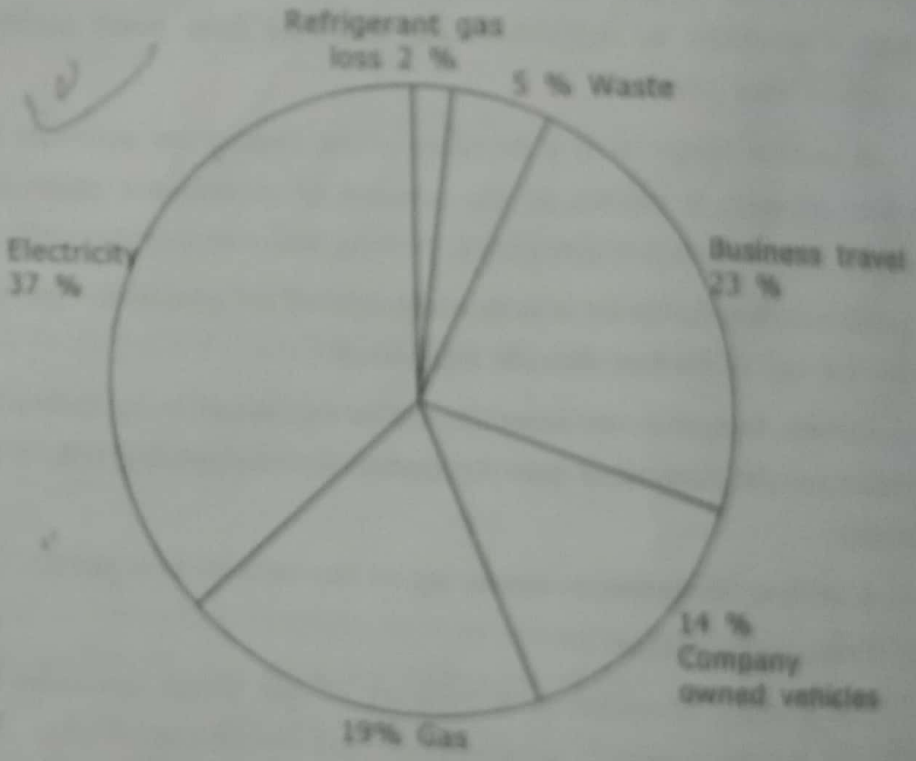


Fig. 8.6 Example of the breakdown of an organizational carbon footprint

3. **Indirect emissions from products and services.** Each product or service purchased by an organization contributes towards emissions. The way the organization uses products and services therefore affects its carbon footprint, e.g. a manufacturing company is indirectly responsible for the CO_2 that is emitted in the transport of the raw materials, as well as emissions from the distribution, use and disposal of its finished products.

CO_2 Equivalence :

CO_2 equivalence (or CO2e) is used to express a carbon footprint, which is made up of a number of different greenhouse gases, in a single figure. It is the quantity of CO2 which would have the equivalent global warming impact as the mixture of greenhouse gases in question.

A complete carbon footprint may include a number of types of greenhouse gas, e.g. all those controlled under the Kyoto Protocol. The Kyoto gases are listed in the table below with their global warming potential

Carbon dioxide (CO2)	1
Methane (CH4)	25
Nitrous oxide (N2O)	230
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,500 – 12,200
Sulphur hexafluoride (SF6)	22,800

A quantity of greenhouse gas is converted into CO2e by multiplying its mass by its global warming potential, e.g. 1 kg of methane is equal to 25 kg of CO2e.

→ **Benefits of carbon footprint :**

Calculating carbon footprint and taking measures to reduce it yields many environmental, social and economic benefits. Some of the benefits are:

(i) Calculating an organization's carbon footprint can be an effective tool for ongoing energy and environmental management. It helps in reducing emissions over time.

(ii) A carbon footprint helps to identify the inefficiencies or waste within a company in terms of energy and raw material consumption. It helps in reducing waste thus reducing cost of materials.

(iii) It helps to determine what quantity of emissions they need to offset for them to become 'carbon neutral'.

(iv) It helps to identify which activities contribute the most to a footprint (in order to identify the important areas for reduction efforts), typically including gas, electricity and transport.

(v) It can be used to report the footprint accurately to a third party.

(vi) It helps in measuring changes in emissions over time, and monitoring the effectiveness of reduction activities.

(vii) Organizations are also increasingly wanting to calculate their carbon footprint in detail for public disclosure e.g. for marketing purposes, to fulfill requests from customers or investors. It has positive impact on brand of business.

→ **Methods of Minimizing the Carbon Footprint :**

Several methods exist for reducing an individuals or an organizations carbon footprint.

1. Planting trees is one of the most common and simplest forms of carbon footprint reduction. Trees absorb CO_2 from the atmosphere and hence can be used to offset carbon emissions.
2. Recycling waste materials such as household, industrial and construction waste can be a valuable method of carbon footprint reduction as the carbon content of the new materials which would have otherwise been used can be offset.
3. Many energy saving technologies exist which can contribute towards carbon footprint reduction, from cheap and simple measures such as installing low energy light bulbs to more expensive measures such as using electric vehicles.

4. Renewable energy generation can also be used for offsetting a carbon footprint, such as wind turbines and solar panels.
5. Inflate your tires. If you own a car, it will get better gas mileage when the tires are fully inflated, so it will burn less gas and emit less carbon.
6. Walk or bike instead of driving a car. Cars and trucks run on fossil fuels, which release carbon dioxide into the atmosphere.
7. Teleconference instead of flying. For office meetings, if you can telephone or videoconference, you will save time, money, and carbon emissions.
8. Turn down the heat or air conditioning when you leave the house or go to bed. You can easily install a programmable thermostat that can save up money and carbon.
9. Purchase a solar powered, biofuel–driven or hybrid vehicle. Purchase a solar energy system for your home. Purchase solar powered hot water heaters.

8.8 CLEANER DEVELOPMENT MECHANISM [CDM] :

The UN's Kyoto protocol [Japan-1997]established binding greenhouse gas emissions reduction targets for 37 industrialized countries and the European community. To help achieve these targets, the protocol introduced three "flexible mechanisms" – international emissions trading (IET), joint implementation (JI), and the clean development Mechanism (CDM).

To date the CDM has arguably been the most successful of the three flexible mechanisms. **It has two main goals:**

(1) To assist countries without emissions targets (i.e. developing countries-Annex B) in achieving sustainable development.

(2) Help those countries with emission reduction targets under Kyoto (i.e. developed countries-Annex I) in achieving compliance by allowing them to purchase offsets created by CDM projects.

The ***CDM*** allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets.

A broad range of projects are eligible for CDM accreditation, with the notable exceptions of nuclear power and avoided deforestation projects. They vary from hydropower and wind energy projects, to fuel switching and industrial efficiency improvements. Crucially, to qualify for accreditation the project developers must prove 'additionality', defined as emissions reductions that are additional to what would have otherwise occurred. This is calculated by using an approved methodology to subtract the estimated emissions of a given project from a hypothetical 'business-as-usual' emissions baseline.

Once registered, projects are then issued **Certified Emissions Reductions (CER)**, with each CER unit equal to a reduction of one tonne of carbon dioxide equivalent. CER is also known as **carbon credit.** These CERs, or offsets, can be bought and used by developed countries to meet their Kyoto commitments. Companies can also purchase CERs to contribute towards their own emission reduction targets under mandatory emissions trading schemes (such as the EU Emissions Trading Scheme, ETS) or voluntary schemes.

A carbon credit or CER is a tradable certificate or permit representing the right to emit 1 tonne of carbon or carbon dioxide equivalent.

1 CER = 1 carbon credit = 1 tonne CO_2 equivalent gases

or 1 tonne carbon

An organization which produces 1 tonne less carbon or carbon dioxide equivalent than the standard level of carbon emissions allowed, earns 1 carbon credit.

India and China are the biggest sellers of carbon credits and Europe is the largest buyer of carbon credits. Carbon credit trading is done globally.

Under the **'cap-and-trade'** or emissions program, a company, emitting less than its capped limit, may sell unused credits to a company exceeding its limit. For example, Company A has a cap of 10 tons but produces 12 tons of emissions. Company B also has an emission cap of 10 tons but emits only 8 tons resulting in a surplus of two credits. Company A may purchase the additional credits from Company B to remain in compliance. Without the purchased carbon credits, Company A would face penalties.

CDM Projects :

Because of their project-based character, CDM can assist project developers in enhancing the economics of their project by selling the resulting emission reductions. Not every project is eligible as a CDM project; this is subject to a number of activities and approvals.

Below is a list of some typical projects that may be eligible as CDM projects:

- The implementation of a renewable energy project, e.g. wind, or biomass;
- Demand-side energy efficiency improvement, e.g. implementation of energy saving light bulbs;
- Solar power
- Hydro power
- The reduction of methane emissions from a landfill site;
- Reduction of industrial process emissions;
- Forestry practices to store carbon.

Between 2004 and 2012, there was a steady increase in the number of registered CDM projects after which there has been a drastic decline. This could be a result of the crash in CER prices in the recent times. The price of CER, which was around $ 20 a tonne in 2008, fell to below $ 5 a tonne in 2012. This may be attributed to the lack of demand from the European Union (EU), which was the major market for CERs. Due to the industrial slowdown in EU as a result of Euro crisis as well as over-allocation of carbon quotas in EU's Emission Trading System there was slack demand for CERs. In july 2018 the CER prices were$ 16 a tonne.

Most of the CDM projects in India are concentrated in a few sectors, namely, those related to the renewable energy sector. The maximum number is in the wind energy sector. This sector accounts for 42 per cent of all CDM projects in India. Biomass energy projects come second with 15 per cent.

CER Markets in the world :

There are four markets in the world dealing with CER trading:

(i) Kyoto Protocol

(ii) EU Emission Trading Scheme.

(iii) Canada Green house gas Offset System

(iv) Japan (Voluntary Trading System)

The Project Cycle in CDM :

Every CDM project has to go through a cycle before it is registered and CERs are issued to the project. There are seven steps in the project cycle:

(1) ***Project design***: the first step is the preparation of a project design document by the project participant detailing the project, the baseline and methodology and other details relevant to the project;

(2) ***National Approval***: the second step is securing the letter of approval from the Designated National Entity of the host party;

(3) ***Validation:*** the project is independently evaluated by a designated operating entity on whether it meets the requirements of CDM.

(4) ***Registration:*** validated projects are submitted to the CDM executive board for formal approval, which is called registration;

(5) ***Monitoring:*** Measurement of actual emissions is done by the project participant according to the approved methodology;

(6) ***Verification:*** Is the independent review of the emission reductions claimed by the project participant by a designated operating entity.

(7) ***CER issuance:*** Once the verification of the claimed emission reduction is done, the designated operating entity submits the verification report to the CDM board for the issuance of CERs.

Benefits of CDM :

The main benefits of CDM are :

- Sustainable development
- Conservation of environment- reduction of GNG emissions.
- Reduction in climate change phenomenon
- CDM projects include investment in climate change mitigation projects in developing countries,
- Transfer of technology in the host countries,
- Improvement in the livelihood of communities through the creation of employment or increased economic activity.
- Social and economic development in the host country.
- Development of environment friendly projects in Annex B countries.
- Increase in foreign direct investment in CDM projects in the country.
- Image enhancement at local level of the company developing CDM project.
- Development of new GNG emission reducing technologies.

Challenges for CDM :

- DNA (Designated National Authority) approval capacities.
- High methodology rejection rates.

- Annex I companies may only be interested in buying CER, not in investing CDM projects.
- Gap between CER and EU allowance prices.
- Interpretation of national policies in baseline methodologies.
- Availability of reliable and authentic data for establishing baselines.

8.9 INTERNATIONAL STEPS FOR MITIGATING GLOBAL CHANGE : 0-12

A list of Un Conferences & Protocols on Environment, Sustainable Development, Climate Change is as under:

- United Nations Framework Convention on Climate Change (1992)
- Vienna Convention (1985) (Protection of Ozone Layer)
- Montreal Protocol (1989) (Total Elimination of Ozone Depleting Substances)
- Basal Convention (1989) (Control of Trans-boundary Movements of Hazardous waste)
- Geneva Convention (1990) (Technology and financial help to Developing Countries)
- UN Convention on Climate Change, New York (1992) Economic Development and Environmental Protection.
- UN Conference on Environment and Development (Earth Summit) Rio de Janeiro, Brazil (1992) (Environment and Sustainable Development)
- Kyoto Protocol (1997) (Stabilization of Green House Gases)
- Copenhagen Summit (2009) (Road map for Post-Kyoto treaties)
- United Nations Climate Change Conference, Doha, Qatar (2012) (The Doha Climate Gateway)
- Paris Agreement (2016) (Targets for everyone)

Some important agreements/protocols are discussed below.

(1) **Paris agreement (2015) :**

The **Paris Agreement** is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with mitigation, adaptation, and finance, starting in the year 2020. The agreement's language was negotiated by representatives of 196 state parties at Paris, France on 12 December 2015.

The Paris Agreement's long-term goal is to keep the increase in global average temperature to well below 2 °C above pre-industrial levels; and to limit the increase to 1.5 °C, since this would substantially reduce the risks and effects of climate change.

Additionally, the agreement aims to strengthen the ability to deal with the impacts of climate change.

The Paris deal is the world's first comprehensive climate agreement.

The Paris Agreement and the outcomes of the UN climate conference (COP21) cover all the crucial areas identified as essential for a landmark conclusion:

- Mitigation – reducing emissions fast enough to achieve the temperature goal
- A transparency system and global stock-take – accounting for climate action
- Adaptation – strengthening ability of countries to deal with climate impacts
- Loss and damage – strengthening ability to recover from climate impacts
- Support – including finance, for nations to build clean, resilient futures.

(2) Montreal Protocol :

In 1987, twenty seven industrialized countries signed an international agreement to protect the ozone layer in the stratosphere. This agreement is known as Montreal Protocol.

The main points of the agreement are :

(i) To limit the production and use of ozone depleting substances.

(ii) To freeze production of CFCs at 1986 levels and to reduce production by 50% by 1999.

(iii) To help the developing countries to implement use of alternatives to CFCs.

Up till now, more than 175 countries have signed the Montreal protocol.

Due to this protocol, ozone layer is likely to return to normal level by 2050.

(3) Earth summit :

The United Nations conference on Environment and Development, the Earth summit, held at Rio de Janeiro, Brazil in 1992, established principles to reduce green house gases.

Objectives of the summit were :

- to secure renewed political commitment to sustainable development.
- to address new and emerging challenges.
- green economy and poverty eradication
- sustainable development.

(4) Kyoto protocol :

In December 1997, an international conference was held at Kyoto, Japan to discuss climate change. The conference was attended by 37 industrialised countries and the European community for reducing green house gases.

It was decided that the countries will reduce the green house emission by 5% compared to 1990 level up to 2012.

(5) Copenhagen International Conference :

During 7-19 December 2009, an international conference was held at Copenhegan (Denmark) after United Nations Climate change conference took place in Dec. 2007 at Bali to prevent Climate changes and carbon emissions.

Governmental representatives from 192 nations, NGO's, journalists and other representatives attended the conference. United Nations Framework convention on climate change (UNFCCC) has received submissions of national pledges to cut or limit emissions of green house gases by 2020 from 75 parties which togeter account for more than 80% of global emissions.

(6) Vienna Convention :

- Convention for the ***Protection of the Ozone Layer***.
- Often called a framework convention, because it served as a framework for efforts to protect the globe's ozone layer.
- The Vienna Convention was adopted in 1985 and entered into force on 22 September, 1988.
- The objectives of the Convention were for Parties to promote cooperation by means of systematic observations, research and information exchange on the effects of human activities on the ozone layer and to adopt legislative or administrative measures against activities likely to have adverse effects on the ozone layer.

- The Vienna Convention did not require countries to take concrete actions to control ozone depleting substances. Instead, in accordance with the provisions of the Convention, the countries of the world agreed the Montreal Protocol on Substances that Deplete the Ozone Layer under the Convention to advance that goal.
- The Parties to the Vienna Convention meet once every three years, back to back with the Parties to the Montreal Protocol, in order to take decisions designed to administer the Convention.
- In 2009, the Vienna Convention became the first Convention of any kind to achieve universal ratification.

(7) **Doha Climate Change Conference (2012) :**

- The 18th session of the COP to the UNFCCC, that started on 26 November and concluded on 8 December 2012 in Doha, Qatar has resulted in a set of decisions (clubbed together as 'Doha Climate Gateway') aimed at advancing the implementation of the UNFCCC and its Kyoto Protocol (KP).
- Key issues for the Doha conference were:
- Amending the KP to implement the second commitment period under the Protocol
- Successfully concluding the work of the Bali Action Plan (BAP) within which there was urgent need for a clear path to climate finance.
- planning the work under the Durban Platform (DP) for enhanced action.

→ Key **Doha Outcome**:

- It has been agreed that the Kyoto Protocol (KP), as the only existing and binding agreement under which developed countries commit to cutting emissions of GHGs, will enter a second commitment period that will run for eight years.
- Governments have agreed to speedily work toward a climate change agreement under Doha Protocol (DP) applicable to all countries from 2020, to be adopted by 2015. Further governments have decided to find ways to scale up efforts before 2020 to meet the gap in global ambition for emissions reduction.
- Governments have launched a robust process to review the long-term temperature goal. This will start in 2013 and conclude by 2015 and is a reality check on the advance of the climate change threat and the possible need to mobilize further action.

MULTIPLE CHOICE QUESTIONS

1. Ozone layer depletion is mainly due to
   (a) CFCs (b) SO_2 (c) CO (d) None of these
2. Acid rain is due to high concentration of
   (a) N_2 and O_2 (b) CO_2 and CO (c) SO_2 and NO_2 (d) None of these
3. Type of radiations absorbed by green house gases are
   (a) Infra red radiations (b) UV radiations
   (c) Visible radiations (d) None of these
4. Atmospheric window is between wave lengths.
   (a) 2 - 20 μm (b) 7 - 12 μm (c) 20 - 30 μm (d) None of these
5. Ozone absorbs
   (a) IR radiations (b) UV radiations
   (c) Visiable radiation (d) All of the above
6. Which one is a green house gas
   (a) Oxygen (b) Nitrogen (c) carbon dioxide (d) Sulphur dioxide
7. Which is not a green house gas
   (a) Carbon dioxide (b) Methane (c) CFC (d) Carbon monoxide
8. Chlorofluorocarbon (CFC) used as coolants in refrigerators contains **[Dec. 2013]**
   (a) Carbon (b) Hydrogen
   (c) Chlorine and fluorine (d) all of these
9. A green house has higher temperature inside than outside which is due to **[Dec. 2013]**
   (a) Glass walls (b) High CO_2 content
   (c) High water vapour of air (d) All of these
10. Which one is not greenhouse gas ? **[Dec. 2014]**
    (a) CO_2 (b) Ozone (c) CH_4 (d) CFC
11. ..... is a green house gas. **[May 2015]**
    (a) Nitrogen (b) Oxygen (c) Argon (d) Water vapour
12. Acid rain contains **[Jan. 2016]**
    (a) Sulphuric acid (b) Hydrochloric acid
    (c) Oxalic acid (d) Acetic acid
13. Chernobyl disaster is related to **[Jan. 2016]**
    (a) Nuclear power plant (b) Coal based power plant
    (c) Gas based power plant (d) None of these
14. Which of the following gases has the maximum contribution to enhanced green house effect. **[Jan. 2016]**
    (a) CFCs (b) CH_4 (c) CO_2 (d) N_2O

15. Rise in sea level is due to .....
(a) ozone depletion (b) smog
(c) Global warming (d) Acid rain

16. Maximum depletion of ozone occurs at
(a) Equator (b) North pole (c) South pole (d) Tropics

17. Rain in classified as 'acid rain' if its pH is less than
(a) 4.5 (b) 5.6 (c) 6.5 (d) 7.0

18. Montreal protocol - 1987 was signed to control
(a) Global warming (b) Acid rain
(c) Ozone depletion (d) All the above

19. Kyoto protocol was signed in 1997 to control
(a) Acid rain (b) Green house emissions
(c) ozone depletion (d) All the above

20. Earth summit, 1992 was held at
(a) Kyoto (b) Montreal (c) Paris (d) Rio de Janero

21. The Paris agreement's long term goal is to keep the increase in global temperature to well below
(a) 1.0°C (b) 1.5°C (c) 2.0°C (d) 2.5°C

22. The type of radiation absorbed by CO_2 are
(a) UV radiation (b) Infrared radiation (c) Nuclear radiation (d) Visible radiation

23. Global worming potential of CO_2 is
(a) 1 (b) 25 (c) 230 (d) 100

24. Global warming potential of methane (CH_4) is
(a) 1 (b) 21 (c) 230 (d) 1000

25. Life of CO_2 in the atmosphere is
(a) 12 years (b) 100 years (c) 120 years (d) 800 years

26. Ozone depleting potential of CFC-11 is
(a) 0.75 (b) 1.0 (c) 1.5 (d) 2.0

27. Carbon footprintof the electricity consumed by an organization is classified as
(a) direct emission (b) Indirect emission (c) both of the above
(d) None of the above

28. The country having highest carbon footprint in the world is
(a) India (b) China (c) US (d) Germany

29. Unit of measurement of Ozone in atmosphere is
(a) Decibel unit (b) Dobson unit (c) kg (d) All the above

30. 'CDM' stands for
(a) Carbon free development Mechanism (b) Clean Development Mechanism
(c) Cleaner Development Mechanism (d) Carbon Destructive Mechanism

31. 'CER' stands for

(a) Carbon Emissions Reductions (b) Carbon Emissions Reserve

(c) Certified Emissions Reductions (d) Certified Emissions Right

32. Cattle, termite, rice fields are responsible for the release of the following gas

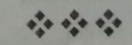
(a) Carbon dioxide (b) Methane (c) Nitrous oxide (d) All the above

ANSWERS

1. (a)	2. (c)	3. (a)	4. (b)	5. (b)	6. (c)
7. (d)	8. (d)	9. (a)	10. (b)	11. (d)	12. (a)
13. (a)	14. (c)	15. (c)	16. (c)	17. (b)	18. (c)
19. (b)	20. (d)	21. (c)	22. (b)	23. (a)	24. (b)
25. (b)	26. (b)	27. (b)	28. (b)	29. (b)	30. (c)
31. (c)	32. (b)				

REVIEW QUESTIONS

1. Explain by drawing sketch : Green house effect . **[Jan. 2009, June 2010, Jan. 2013, Jan. 2017]**
2. Enlist Global Environmental pollution problems. Describe one in detail and suggest remedial measures to reduce them. **[June 2009, Jan. 2010, Dec. 2011]**
3. Write down the causes and environmental effect of acid rain. **[Jan. 2013, June 2014, June 2016]**
4. Explain causes of ozone layer depletion. Why "Montreal protocol' is called a successful international step ? **[May 2012]**
5. Explain the green house effect with schematic diagram and compare the effect of different green house gases in global warming. **[June 2010, May 2015]**
6. Write short note on : Acid rain **[Jan. 2010, Jan. 2016, Jan. 2017]**
7. How is acid rain formed ? What are its effects on atmosphere ? **[Jan. 2009]**
8. Explain : Ozone layer depletion. **[June 2011, May 2012, Dec. 2013, Dec. 2014, Jan. 2017]**
9. What is global warming ? What are the impacts of global warming ? Which are the measures to reduce global warming ? **[June 2013, Jan. 2016]**
10. What is carbon footprint ? Why organizations calculate their carbon footprint.
11. Give methods of minimizing carbon footprint.
12. What is CDM ? Give its benefits.
13. Discuss International steps for mitigating global change.
14. Write short note on : Sustainable development.
15. What is climate change ? Give its causes and effects.



Ch-9 Basic Concept of Green Building & Smart Cities

9.1 THE GREEN BUILDING CONCEPT :

Our ancestors worshipped the five elements of nature -

Earth as **'Prithvi'**

Water as **'Jal'**

Agni as **'Energy'**

Air as **'Vayu'**

Sky as **'Akash'.**

A **green building** or **environmental building** or **sustainable building** is a building which seek to harness all these natural elements in its design and construction to an optimum level so as to have an eco-friendly, low energy & low water consumption building and at the same time providing fresh and healthy environment to its occupants.

The term 'green building' apply not just to products, but building design, orientation, construction strategies, landscaping, building operations, maintenance, and more. The less impact a building has on human health and the environment, the more green it is.

The concept of green building incorporates and integrates a variety of strategies during its planning, design, construction and maintenance of building projects. Common goal of green building is achieving aesthetic harmony between a structure and its surrounding environment and use those resources that help in environmental protection or disturbs least to the environment compared to other alternatives available. Green building movement is infact the result of contribution from architects and engineers in maintaining the ecological balance, thus, a step forward by architects and engineers to work as an environmentalist.

As regards the cost impact in the design of a green building, the cost could be slightly higher than a conventional building. However green buildings, on account of their design features, consume less energy and less water vis-a-vis a conventional building. Thus this extra cost gets paid back in 3-5 years time.

9.2 OBJECTIVES OF GREEN BUILDING :

The design, construction and maintenance of buildings have a tremendous impact on our environment and our natural resources. Traditional building practices often overlook the interrelationships between a building, its components, its surroundings, and its occupants; and consume more of our resources than necessary, negatively impacting the environment. The basic resources like ground cover, water, forests and energy are depleted to construct and operate buildings. This is where green buildings step in with an aim to address all these issues in an integrated and scientific manner.

The main objective of green building is to reduce the overall impact of building on environment and on human health by minimising the usage of natural resources (like ground cover, water, forests, energy) and to maximize the benefits.

1. To minimise the use of natural resources like ground cover, water, forests, energy, etc.
2. To reduce overall impact of building on environment and human health.
3. To reduce waste, pollution and environmental degradation.
4. To select proper building materials and use recycled and scrap materials having low energy requirement.

5. To boost renewable energy usage, i.e. solar energy and wind energy.
6. To enhance interior lighting quality by increased use of natural day lighting to reduce energy demand.
7. To make efficient use of water in a building, reduce wastage and water pollution.
8. To improve human health and comfort.
9. To reduce global warming.

9.3 FEATURES (PRINCIPLES) OF GREEN BUILDING :

The different elements of a green building are as follows :

1. Sustainable site selection
2. Energy efficiency
3. Water efficiency
4. Materials efficiency
5. Design efficiency
6. Occupant Health and safety

1. Sustainable site selection :

Site selection, its development and construction process are basic considerations for any project. The mpact of project should be minimum on the ecology, so that the nature adjusts itself within a short period. Therefore, the first objective of site selection is to select a site that does not disturb ecological balance of he area. The natural landscaping and natural features not be destructed as far as possible.

Architects and engineers including administrators have to consider the factors like

- Number of industries / buildings existing and proposed
- Surface and ground water quality
- Air quality
- Eco-system
- Land use
- Services existing near such development
- Flora/fauna conservation, etc.

during site selection process.

Energy efficiency :

Building consumes energy mainly for cooling, heating and lighting. The design of a building should be ch that it can use maximum available energy of the nature and this type of design is termed as **passive sign of a building.** Passive design of a building can dramatically change the energy use pattern of a ilding. The measures include building shape and orientation, passive solar design, and the use of natural hting.

Some of the energy saving measures are :

- Use a properly sized and energy efficient heating /cooling system in a building.
- Use solar energy for lighting, water heating.
- Maximum use of natural lighting and air.

- Maximize light colours for roofing and wall finishing materials.
- Use minimam glass on east and west exposures.
- Insulate the walls. The options for insulation materials can be - Extruded polystyrene, Expanded polystyrene (thermocol), glass wool, etc.
- Brick wall with air cavity can also significantly reduce the heat ingress.
- Hollow blocks, fly ash bricks, Autoclaved Aerated concrete (AAC) blocks are also good insulators.
- Bureau of Energy efficiency (BEE) star rated lamps and tubelights should be used.

3. Water efficiency :

Water is going to be a scare natural commodity, leading to clashes between users and even between governments. Thus neither it can be wasted nor it can be polluted. Thus water efficiency can be achieved only if water is efficiently used without wastage, reused to the maximum extent and water pollution is stopped.

Avoiding wastage is considered better than production. To achieve this an integrated and holistic approach is to be adopted for water management.

→ **Measures to improve water efficiency :**

- Potable water should not be used for the purposes other than essential requirements.
- For other uses waste water is to be recycled. Waste water treatment plant should be installed at the project site.
- In buildings water saving materials are to be used like low capacity cisterns, showers, waterless urinals, etc.
- Water meters should be installed.
- Use waste water for floor washing and gardening.
- Instead of continuous supply of water adopt intermittent system of supply.

4. Materials efficiency :

Selection of new construction materials and use of recycled and scrap materials are the two important factors for the construction of green buildings. Such products promote resource conservation and efficiency. Using recycled materials also helps in solid waste management system.

Building materials consume a considerable energy and affect ecological balance due to extraction from the nature. Building material is to be examined for being a green material based on its energy requirement from raw stage to the providing and fixing stage in a building. These stages may be extraction, manufacturing, transportation, fixing, maintenance and disposal.

Green building materials offer the following benefits :

- Energy conservation
- Lower costs
- Greater design flexibility
- Reduced maintenance costs
- Improved occupant health and productivity

→ **Criteria to identify green materials :**

(i) Local availability of materials.

(ii) Embodied energy - i.e. energy required for extraction, manufacturing, transportation, fixing, maintenance, disposal of materials.

(iii) % of recycled / waste materials used.

(iv) Contribution in energy efficiency of buildings.

(v) Recyclability of materials.

(vi) Durability

(vii) Environmental impact.

→ **Various Green materials :**

(i) **Fly ash :**

Fly ash, a waste product from thermal power plant is a resource material now. Its use in cement as a substitute of cementitious material in manufacturing PPC, part replacement of cement and producing number of building products like fly ash cement concrete, fly ash bricks, fly ash hollow/solid blocks, fly ash concrete tiles, etc. has been well established. Pond ash and fly ash is also used in filling under floors and in embankments.

(ii) **Green concrete :**

Green concrete as the name suggests is eco-friendly and saves the environment by using waste products generated by industries in various forms like rice husk ash, micro silica and fly ash, etc. Use of green concrete helps in saving energy, reduces emissions, cheaper, has better strength and durability than the normal concrete.

(iii) Use of scrap and recycled aggregate in concrete.

(iv) Other waste materials such as

- Blast furance slag
- Silica fume
- red mud
- Marble dust
- cinder
- rice husk
- coconut husk
- waste glass
- Jute fibres
- rubber from automobile tires
- Bamboo strips

have also been demonstrated by research.

(v) Wood salvaged from old buildings has been used for doors and windows.

(vi) Wood substitutes like

- Particle boards
- Medium density fibre boards
- Block boards
- Rubber wood
- Glass fibre reinforced products

- PVC
- Gypsum boards, gypsum building blocks

Steel requires 3 times as much energy as compared to wood to extract, transport, manufacture and construct.

Aluminimum framing requires 10 times as much energy as compared to wood.

5. Design efficiency :

Design of a building is very important as it plays a vital role in reducing the energy requirement of a building during its life.

Design has to consider the following :

(i) Optimum use of solar energy.

(ii) Optimum use of renewable energy.

(iii) Selection of energy efficient fittings, plants and equipment.

(iv) Adoption of environment friendly and energy efficient materials.

(v) Adopting energy efficient design and technologies.

A good architectural design will take full advantage of sun, wind and trees around the building. The location of door, windows and walls will be designed in a way to have maximum advantage of nature to minimize energy requirements. While deciding the specifications of materials and adoption of technologies for execution of the work, civil engineer plays an important role.

6. Occupant health and safety :

Research findings reported in different literatures revealed that buildings with good overall environmental quality can reduce the rate of respiratory disease, allergy, asthma, and enhance worker performance. Choose construction materials and interior finish products with zero or low emissions to improve indoor air quality. Many building materials and cleaning/maintenance products emit toxic gases, such as volatile organic compounds (voc) and formaldehyde. These gases can have a detrimental impact on occupant's health and productivity .

Provide adequate ventilation and a high-efficiency, in-duct filtration system. Heating and cooling systems that ensure adequate ventilation and proper filtration can have a dramatic and positive impact on indoor air quality. Provide effective drainage from the roof and surrounding landscape.

9.4 BENEFITS OF GREEN BUILDINGS :

(a) Economic benefit (tangible benefits) :

1. **Energy efficiency :** Green buildings are around 25-30% more energy efficient, with gold-rated buildings as much as 37% efficient.
2. **Water efficiency :** Green buildings use 20-30% less water compared with similar conventional buildings. This reduces operating water costs.
3. **Waste reduction :** Green buildings emphasise waste reduction. Construction wastes and demolition debris are the main wastes produced during the construction process, which degrade the quality of environment.

- The reuse and minimisation of construction wastes and debris and diverting them to recycling units.
- The increased use of recycled content in construction materials.

4. Improve employee productivity and satisfaction.
5. Enhance asset value and profits.
6. Optimize life-cycle economic performance.
7. Incorporate latest techniques and technologies.

(b) **Environmental benefits :**

1. Enhance and protect ecosystems and biodiversity.
2. Improve air and water quality
3. Reduce solid waste
4. Conserve natural resources
5. Reduced water consumption

(c) **Health and community benefits :**

1. Improve air, thermal and acoustic environment.
2. Enhance occupant comfort and health.
3. Contribute to overall quality of life.
4. Enhanced image and marketability

9.5 GREEN BUILDING RATING SYSTEMS :

There have been buildings which adopt one or more green features. To recognize the extent of features that a building adopts, rating system have been evolved. The Green building rating systems are the qualitative and quantitative measures of sustainability and the actual benefits of green design.

Government body and policy guidelines responsible for assessing sustainability in buildings sector in India are :

- NBC (National Building Code),
- ECBC (Energy Conservation Building Code), 2007
- Local byelaws

The Indian Green Building Council (IGBC), 2009 is actively promoting green buildings in India.

The India has currently two green rating systems :

(a) LEED

(b). GRIHA

(a) **LEED (Leadership in Energy and Environmental Design) :**

LEED was developed by the US Green Building Council (USGBC), and it is the most widely used Green Building Rating System used in North America.

The Indian Green Building Council (IGBC) has taken steps to promote the green building concept in India. Currently IGBC is facilitating the LEED rating in India.

The first LEED India rating programme, referred to as LEED India Version 1.0, was launched during the Green Building Congress Conference in October 2006. The latest rating system is now called the LEED 2011 for India - New Commercial Construction and Major Renovations or LEED 2011 for India - NC.

LEED India for 2011 is a measurement system designed for rating new and existing commercial and institutional and residential buildings. It is based on accepted energy and environmental principles and strikes a balance between known established practices and emerging concepts.

LEED 2011 for India - NC addresses :

1. Sustainable Sites
2. Water Efficiency
3. Energy & Atmosphere
4. Materials & Resources
5. Indoor Environmental Quality
6. Innovation in Design
7. Regional Priority

LEED 2011 has adopted several benchmarks for building performance. The buildings are given ratings of **'Platinum', 'Gold', 'Silver'**, and **'Certified'** based on green building attributes.

Table 9.1 LEED 2011 Green Building Rating System

Rating	Points
Certified	40 - 49
Silver	50 - 59
Gold	60 - 79
Platinum	80 and above

Table 9.2 Examples of LEED rated Buildings in India

Green Building	Rating Received
1. ABN Amro Bank N.V., Ahmedabad	Platinum
2. Infinity Benchmark, Kolkata	Platinum
3. CRISIL House, Mumbai	Platinum
4. Biodiversity Conservation India Ltd. (BICL), Banglore	Platinum
5. Patni (i-Gate) Knowledge Centre, Noida	Platinum
6. CII-Sohrabji Godrej Green Business Centre, Hyderabad	Platinum
7. ITC-Green Centre, Gurgaon	Platinum
8. Indira Paryavaran Bhavan, New Delhi	Platinum
9. Suzlon Energy Limited, Pune	Platinum
10. Birla International School, Jaipur	Gold
11. American Embassy School, Delhi	Gold
12. Anna Centenary Library Building, Chennai	Gold

b) GRIHA RATING SYSTEM :

GRIHA-Green Rating for Integrated Habitat Assessment, is the national rating system of India aunched in 2008. It has been conceived by The Energy and Resources Institute (TERI).

ADARSH (Association for Development and Research of Sustainable Habitats) founded jointly by TERI nd MNRE (Ministry of New and Renewable Energy, Government of India) promotes GRIHA as a design of valuation tool for Green Buildings and Habitats.

All GRIHA Rating variants undergo periodical technical revisions under the supervision of GRIHA echnical Advisory Committee (TAC). The latest version of GRIHA, GRIHA version 2015 (GRIHA V2015), vas introduced in January 2015.

The GRIHA V 2015 rating system consists of 31 criteria categorized under various sections such as ite Planning, Construction Management, Occupant Comfort and Wellbeing, Sustainable Building Materials, erformance Monitoring and Validation, and Innovation.

Eligibility :

All buildings, which are in the design stage and have built up area more than 2,500 m^2, are eligible for ertification under GRIHA. Building types include, but are not limited to offices, retail spaces, institutional uildings, hotels, hospital buildings, healthcare facilities, residences, and multi-family high-rise buildings.

Criteria and their weightage :

GRIHA is a performance-oriented system where points are earned for meeting the design and performance ntent of the criteria. Each criterion has certain points assigned to it. It means that a project demonstrating compliance with a criterion would achieve the associated points.

GRIHA is a 100-point system consisting of some core points, which are mandatory, while the rest are optional. Different levels of certification (one star to five stars) are awarded based on the number of points earned. The minimum points required for certification are 25.

The scores for achieving GRIHA rating have been revised. The new thresholds for achieving GRIHA rating are mentioned below:

Table 9.3 GRIHA Rating System

GRIHA V 2015 Rating Thresholds	GRIHA Rating
25-40	★
41-55	★★
56-70	★★★
71-85	★★★★
86 or more	★★★★★

Table 9.4 Set of 31 Criteria for GRIHA 2015 Rating System

Criterion 1	Site Selection
Criterion 2	Low-impact design
Criterion 3	Design to mitigate UHIE
Criterion 4	Site Imperviousness Factor
Criterion 5	Air and water pollution control
Criterion 6	Preserve and protect landscape during construction
Criterion 7	Construction Management Practices
Criterion 8	Energy efficiency
Criterion 9	Renewable energy utilization
Criterion 10	Zero ODP materials
Criterion 11	Achieving indoor comfort requirements (visual/thermal/acoustic)
Criterion 12	Maintaining good IAQ
Criterion 13	Use of low-VOC paints and other compounds in building interiors
Criterion 14	Use of low-flow fixtures and systems
Criterion 15	Reducing landscape water demand
Criterion 16	Water Quality
Criterion 17	On-site water reuse
Criterion 18	Rainwater Recharge
Criterion 19	Utilization of BIS recommended waste materials in building structure
Criterion 20	Reduction in embodied energy of building structure
Criterion 21	Use of low-environmental impact materials in building interiors
Criterion 22	Avoided post-construction landfill
Criterion 23	Treat organic waste on site
Criterion 24	Labour safety and sanitation
Criterion 25	Design for Universal Accessibility
Criterion 26	Dedicated facilities for service staff
Criterion 27	Increase in environmental awareness
Criterion 28	Smart metering and monitoring
Criterion 29	Operation, Maintenance Protocols
Criterion 30	Performance Assessment for Final Rating
Criterion 31	Innovation

9.6 CONCEPT OF SMART CITY :

A smart city is the integration of technology into a strategic approach to sustainability. Although there is no clear definition to define smart city but broadly **"a city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water supply, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens is known as smart city."**

The concept of a smart city is relatively new one. Smart cities are those which have smart (intelligent) physical, social, institutional and economic infrastructure. It is expected that such a smart city will generate options for all residents to pursue their livelihoods and interests meaningfully and with joy.

Smart cities are meant as virtual reconstructions of cities or virtual cities. The term 'smart city' has been broadly used as an equivalent to 'intelligent city', 'digital city', 'information city', 'knowledge based city', 'wired city', 'telecity', 'teletopia', 'cyberville, etc.

Apart from employment, it is also important for a Smart City to offer decent living options to every resident. This would mean that it will have to provide a very high quality of life (comparable with any developed Europen City) i.e. good quality but offordable housing, cost efficient physical infrastructure such as 24 × 7 water supply, sanitation, 24 × 7 electric supply, clean air, quality education, health care, security, entertainment, sports, robust and high speed interconnectivity, fast & efficient urban mobility etc.

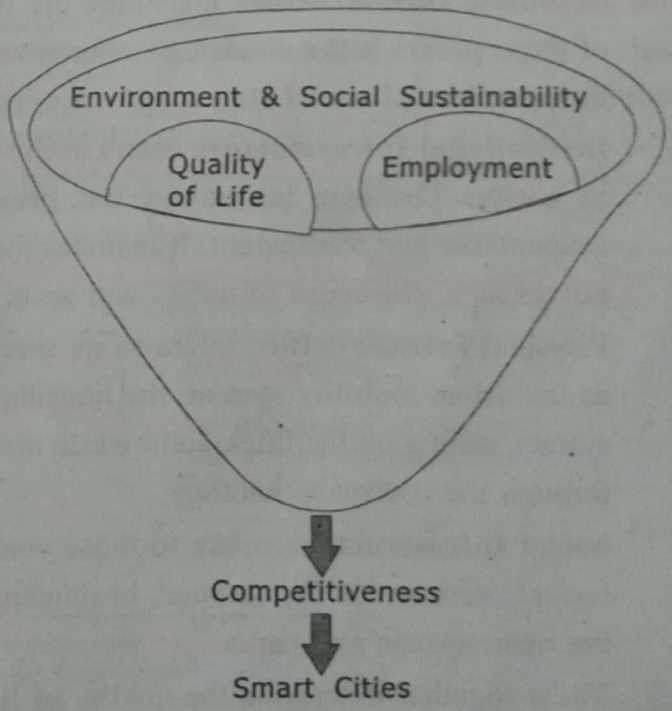


Fig. 9.1 What is a Smart City

In this context :

- **Competitiveness** refers to a city's ability to create employment opportunities, attract investments, experts, professionals and people. The ease of being able to do business and the quality of life it offer determines its competitiveness.
- **Sustainability** includes social sustainability, environmental sustainability and financial sustainability.
- **Quality of Life** includes safety and security, inclusiveness, entertainment, ease of seeking and obtaining public services, cost efficient healthcare, quality education, transparency, accountability and opportunities for participation in governance.

→ **Factors required to become a smart city :**

1. It should provide holistic urban environment embedded with the fundamental values along with the options to grow and prosper.
2. It should provide an opportunity to the new generations to participate in the City's management.
3. It should provide satisfactory lifestyle to the people.
4. It has to be a living city with respiratory system supported by its citizens and technology for its governance, management and functioning.
5. It should be technologically sound and efficient city.
6. It should have smart grids in infrastructure, transportation and energy.
7. It should offer quality water supply, sanitation, electrical supply, cost effective health care, quality education, communication network, clean environment, solid waste management, better public transport, safety, etc.

9.7 PILLARS OF A SMART CITY [REQUIREMENTS] :

Institutional Infrastructure (including Governance), **Physical Infrastructure, Social Infrastructure and Economic Infrastructure** constitute the four pillars on which a city rests. The centre of attention for each of these pillars is the citizen. In other words a Smart City works towards ensuring the best for its entire people, regardless of social status, age, income, levels, gender, etc.

- **Institutional Infrastructure** refers to the activities that relate to the planning and management systems in a city. The new technology has provided a new dimension to this system making it efficient, accountable and transparent. It includes the participatory systems of governance, e-governance, inclusive governance, the sense of safety and security and the opportunities for creativity.
- **Physical Infrastructure** refers to its stock of cost-efficient and intelligent physical infrastructure such as the urban mobility system, the housing stock, the energy system, the water supply system, sewerage system, sanitation facilities, solid waste management system, drainage system, etc. which are all integrated through the use of technology.
- **Social Infrastructure** relate to those components that work towards developing the human and social capital, such as the educational, healthcare, entertainment, etc. It also includes entertainment and sports, the open spaces and parks.

These together determine the quality of life of citizens in a city. It is also necessary that city promotes inclusiveness and city has structures which proactively bring disadvantageous sections i.e. SCs, STs, socially and financially backwards, minorities, disabled and women into the mainstream of development.

Economic Infrastructure :

For a city to attract investments and to create the appropriate economic infrastructure for employment opportunities, it has to first identify its core competence, comparative advantages and analyse its potential be determined. This would generally comprise the following :

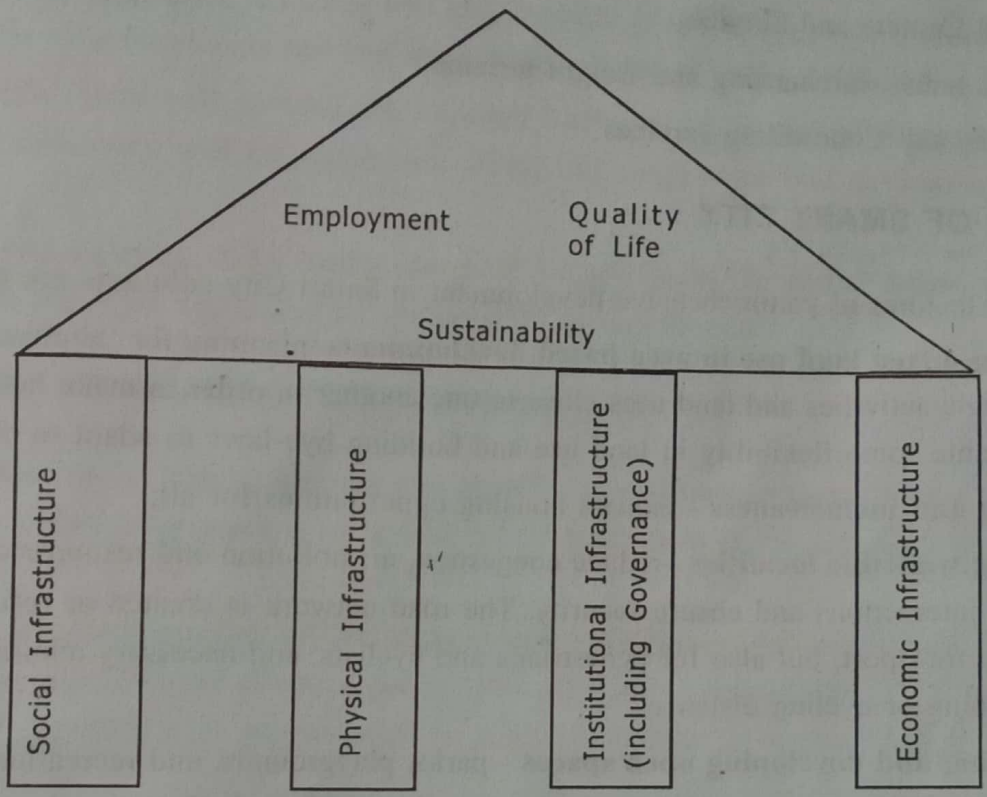


Fig. 9.2 Pillars of a smart city

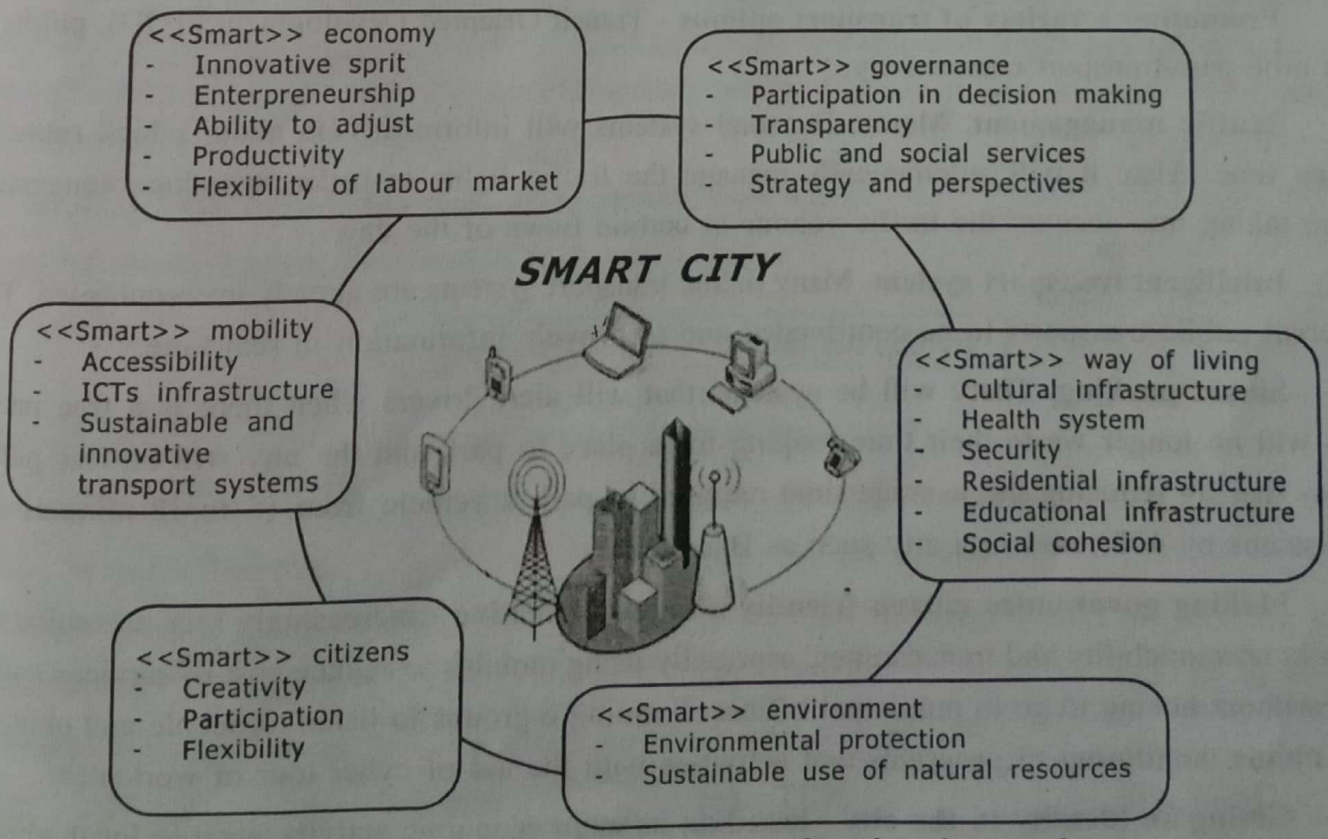


Fig. 9.3 Dimensions of smart city development

- Industrial parks and Export Processing Zones
- IT/BT Parks
- Trade centers
- Service Centers
- Skill Development Centres
- Financial Centers and Services
- Logistics hubs, warehousing and freight terminals
- Mentoring and Counselling services

9.8 FEATURES OF SMART CITY :

Some typical features of comprehensive development in Smart City solutions are described below.

1. **Promoting mixed land use in area based developments**–planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The States will enable some flexibility in land use and building bye-laws to adapt to change;

2. **Housing and inclusiveness** - expand housing opportunities for all;

3. **Creating walkable localities** –reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;

4. **Preserving and developing open spaces** - parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;

5. **Promoting a variety of transport options** - Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;

6. **Traffic management**. Monitoring road systems will inform drivers about which route is best at any given time. Also, it will automatically manage the traffic lights in order to reduce congestion to the minimum taking into account the traffic volume at certain times of the day.

7. **Intelligent transport system**. Many public transport systems are already interconnected. This allows for different public transports to be coordinated and to provide information in real time.

8. **Smart parking**. There will be systems that will alert drivers when there is a free parking spot. Citizens will no longer waste their time looking for a place to park and the city will be less polluted. Did you know that by reducing the average time required to park a vehicle from 15 to 12 minutes can reduce CO_2 emissions by 400 tones in a city such as Barcelona?

9. **Making governance citizen-friendly and cost effective** - increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices. Forming e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

10. **Giving an identity to the city** - based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc;

11. ... providers to **infrastructure and services** in area-based develop... in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resource... and providing cheaper services.

12. **Waste management**. Not all places generate the same kind or the same amount of waste. Wit... smart containers and a good fleet management system, the routes can be tailored to any situation. Thanks to this kind of solution, the efforts in waste collection will be much more efficient.

13. **Smart city maintenance**. Citizens will now be able to rely on systems to notify the City Council of any damages in the urban elements through their smart phones. This way things will be repaired faster.

14. **Smart grids**. They will provide the necessary amount of electricity depending on the demand. This way the power efficiency will be maximized. There are some cities that are testing these systems, as Malaga, for instance.

15. **Smart urban lighting**. Why waste energy if nobody is on the street? Smart urban lighting will adjust the intensity of the light depending on the people who are around.

9.9 DEVELOPMENT OF SMART CITIES IN INDIA :

Smart City mission is an Urban renewal and retrofitting programme launched by the Government of India, in the year 2015. The programme is to be rum in collaboration with the state governments of respective cities.

It is a five year programme where all the states except West Bangal would participate by nominating at least one city from the state, for the development as a Smart City. In August 2015, the list of **98 Cities** was published by the ministry of Urban development. In June 2018 shilong (Meghalaya) got the smart city tag with total smart cities 100.

The required financial aid would be provided by the Central Government of India and by their respective state governments between the period 2017 and 2022. Each of the selected city, would create a special purpose vehicle (SPV) which will be headed by a full time CEO to implement the smart city mission. A joint company will be formed with Public Private Partnership (PPP). The centre and the state Government will provide Rs. 1000 crore to this company.

Cities selected from Gujarat for smart cities development are :

Ahmedabad, Surat, Rajkot, Vadodara, Gandhinagar, Dahod.

MULTIPLE CHOICE QUESTIONS

1. Which of the following is an element of a green building ?
   (a) Material efficiency (b) energy efficiency
   (c) Water efficiency (d) All the above
2. As per GRIHA rating system, for 4 star rating, a green building should score ..... points.
   (a) 41-55 (b) 71-85 (c) 56-30 (d) 86 or more
3. Which of the following is not a green building rating system ?
   (a) LEED (b) GRIHA (c) TERI (d) IGBC

4. As per LEED 2011 rating system for 'Gold' rating points to be scored are
   (a) 40-49 (b) 50-59 (c) 60-79 (d) 80 and above
5. 'GRIHA' stands for
   (a) Green Rating for Integrated Habitat Assessment
   (b) Green Rating for Indian Habitat Assessment
   (c) Green Rating for Indian Housing Assessment
   (d) Green Rating for Integrated Housing Assessment

ANSWERS

1. (d)	2. (b)	3. (c)	4. (c)	5. (a)

REVIEW QUESTIONS

1. What is green building ? Explain concept of green building.
2. What is need for green buildings ?
3. Describe important features of Green Building.
4. What are the benefits of Green Building ?
5. Describe rating systems for Green Building.
6. Write short note on :
   (i) LEED - India rating system
   (ii) GRIHA - rating system
7. Explain various green mateials.
8. Explain about principle and construction of green building.
9. Give full form of : LEED, GRIHA, IGBC, TERI
10. Define 'Smart City'. Give concept of smart city.
11. List any 10 Green Buildings in India.
12. Discuss four basic pillars of a smart city.
13. Describe various characteristics of a smart city.

Ch-10 Concept of 4R's

10.1 PRINCIPLES OF 4R'S:

4R's refers to:

1. Reduce
2. Reuse
3. Recycle
4. Recovery.

(1) Reduce : Reduce means Prevent waste in the first place; by eliminating waste at source through better planning and design.

Reducing the amount you buy is the most significant of all the options to manage waste. The key is to only purchase goods that we need and in the right amount. If we never generate products in the first place, we do not have to extract raw resources, manufacture goods from scratch, come up with shipping materials, utilize additional resources for shipping, and then devise ways to dispose of them.

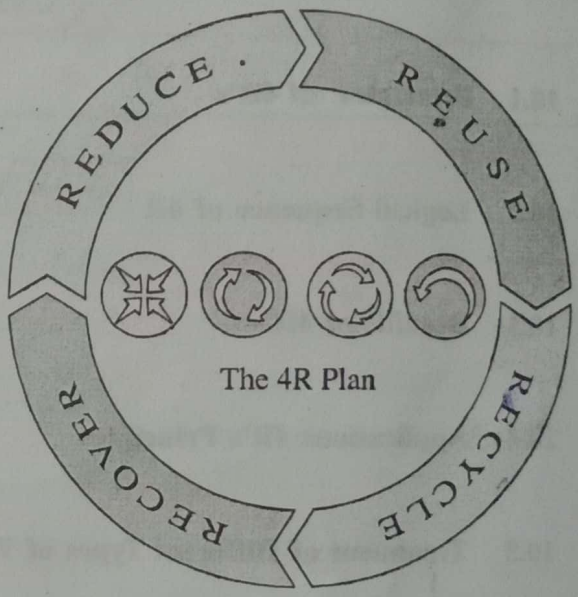


Fig. 10.1 4R Concept

We live in an era of over-consumption. Everything can be bought. Everything is monetized. Durable products are rare. And this consumption—goods production, transportation, packaging and waste management—is all too often at the expense of the environment. At the expense of life. At our children's and grandchildren's expense.

We must reduce waste production at the source. This means reducing the quantity of waste during production, distribution, purchasing, use and elimination.

Table below lays out how long it takes to decompose typical waste products.

Table 10.1 How Long Does It Take to Decompose

Paper towel 2–4 weeks	Plastic bag 10–20 years
Newspaper 6 weeks	Plastic film container 20–30 years
Apple core 2 months	Tin can 50 years
Plywood 1–3 years	Rubber boot sole 50–80 years
Wool sock 1–5 years	Aluminum can 80–200 years
Cigarette butt 1–5 years	Disposable diaper 450 years
	Plastic beverage bottle 450 years
	Glass bottle 1 million years

(2) **Reuse :** Reuse means to use things again that would be normally thrown away. Reuse increases creativity on site. Reuse materials waste whenever possible; this is both cost-effective and reduces waste to landfill.

We are conditioned to think of things that are old, empty, worn, broken, ugly, or marred as useless, so we throw them away without much thought about the consequences. The process of reusing starts with the assumption that the used materials that flow through our lives can be a resource rather than refuse.

Waste, after all, is in the eye of the beholder. One person's trash is another person's treasure. If we really look at things we are throwing away, we can learn to see them as materials that can be reused to solve everyday problems and satisfy everyday needs. Most of us, however, haven't even begun to exploit the resources in our trash. Once you have made up your mind to use trash for positive uses, you can begin to brainstorm and generate ideas. Reusing saves money, conserves resources, and satisfies the human urge to be creative.

(3) **Recycle :** Recycle means the material/product goes through a mechanical process to change its original form.

Recycling ensure a good separation of waste into "one-material fractions" that can be more easily recycled. It enables segregation of at least 6 fractions: Wood, Concrete, Gypsum/Plasterboard, Metal, Plastic -soft and hard, Paper/Cardboard.

The main benefits of recycling are:

- Recycling generates industry
- Recycling creates jobs
- Recycling should be thought of as a cost-effective disposal option. It usually requires fewer government subsidies than land filling or incineration. It saves natural resources and helps protect the environment. Lower taxes, energy savings, and a cleaner environment are the real "bottom lines" in favor of recycling.

(4) **Recover :** Recovery means convert waste into resources like heat, electricity, fuel, compost, etc. Energy Recovery can be an alternative, if recycling is not available.

10.2 LOGICAL SEQUENCE OF 4R :

The 4Rs principles provides an ecologically sound and environmentally friendly approach for minimizing and managing wastes. The logical sequence of 4R is **Reduce- Reuse - Recycle - Recover.**

The waste management hierarchy (sequence) is as follows:

1. Wherever possible, waste prevention is the most preferable option.
2. The second option is the waste minimization.
3. If waste is produced, every effort should be made to reuse it if practicable.
4. Recycling is the third option in the waste management hierarchy. Although recycling does help to conserve resources and reduce wastes, it is important to remember that there are economic and environmental costs associated with waste collection and recycling. For this reason, recycling should only be considered for waste which cannot be reduced or reused.

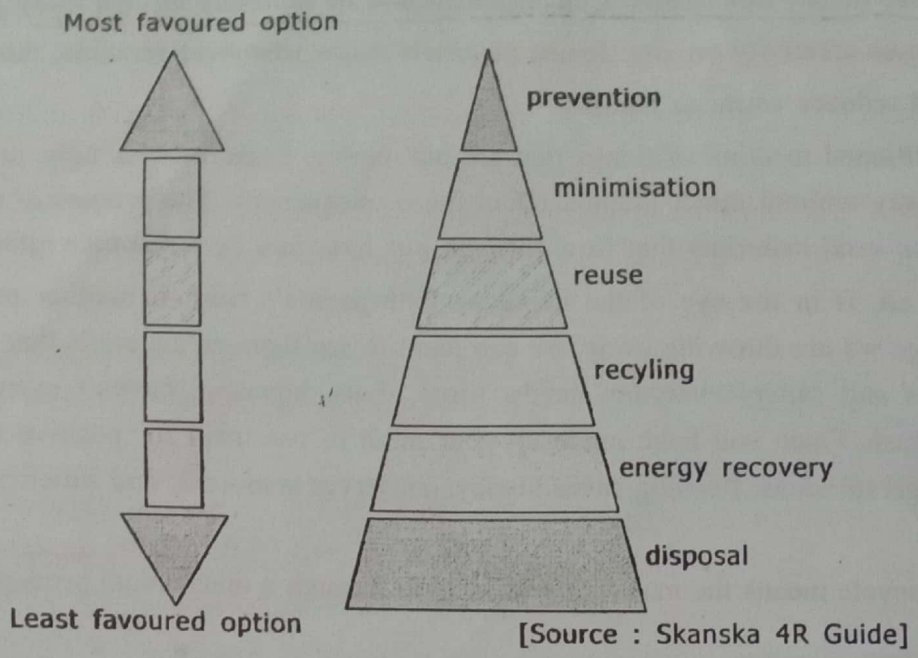


Fig. 10.2 Logical Sequence of 4R

5. Finally, it may be possible to recover materials or energy from waste which cannot be reduced, reused or recycled.

.3 BENEFITS OF 4R :

The benefits derived from exercising 4R principles are :

- Less waste leads to fewer disposal facilities, which leads to less environmental issues .
- Reducing, reusing, and recycling C&D reduces greenhouse gas emissions.
- Deconstruction and selective demolition methods divert large amounts of materials from disposal and provide business opportunities within the local community.
- Recovered materials can be donated to qualified charities; results in tax benefit.
- Allows you to avoid disposal and purchasing costs.
- Generates revenue from the sale of materials.
- Creates opportunities for tax breaks through material donations.

Empirical evidence suggests that by practicing waste prevention, reusing products, recycling, and making vironmentally conscious purchases, businesses can cut costs and increase profits. Cost savings take the m of:

- Lower waste disposal costs;
- Lower waste treatment costs;
- Lower energy costs;
- Savings on materials and supplies;
- A reduction in regulatory compliance costs;
- Lower storage costs;

- Cost recovery through the sale of recyclable materials;
- Cost recovery through sales of 4Rs technologies.

For example, in China, organic waste from thousands of small straw pulp mills is used as agricultura fertilizer.

In Kalundborg, Denmark, a coal-fired power station, an oil refinery, a plasterboard factory, a pharmaceutical plant and the municipality have created an *'industrial symbiosis'* by exploiting each other's waste streams.

10.4 APPLICATIONS 4R'S PRINCIPLES :

1. REDUCE :

We can reduce our consumption, our production of waste and our impact on the environment by practicing responsible consumption. All it takes is using our buying power carefully and respectfully in order to contribute positively to society, the environment and the world. Buying something means guaranteeing the waste and greenhouse gases that were caused in its production, transportation, packaging and future removal.

(i) Buying :

- Replace your consumption of disposable objects and products by reusable ones.
- Buy recyclable products; Buy products that contain recycled materials.
- Buy local products.
- Buy products that aren't over-packaged.
- Buy bulk whenever possible. Your supermarket should have a bulk section. Packaging is less present and often reusable. Some stores even sell household products in refillable containers.
- Avoid everything that's disposable.
- Reduce purchases of toxic products to a minimum.

(ii) Reducing use of Plastic :

- Find alternatives to plastic bags like cloth or paper bags for shopping.
- you can do shopping in markets and supermarkets that give paper or plastic bags.
- reduce use of plastic water bottles-you can carry water to work or school in your own bottle.
- In the case where water dispensers provide disposable plastic cups-you can help reduce plastic waste by carrying own bottle or cup.
- you can carry your cup or coffee mug around in case you will feel like having coffee at work or in school.
- when making purchases be conscious of the things you buy, ensuring that no unnecessary plastic is carried back home.
- Instead of using plastic containers to store water at home, you can go for an alternative like water pots that have been used for ages.
- Instead of having pre-packaged meals, you can opt for a more healthy homemade meals.
- you can make your own toys at very low cost.

(iii) Use Alternate Transportation :

- Avoid using car for travel.
- Use public transport like bus, train, auto, etc.
- practice walking and bicycling instead of using car or bike.

(iv) Reduce consumption of petrol or gas of your vehicle :

- Avoid abrupt stops and starts. Not only will you save the wear and tear on your breaks and tires, you could save up to 40% on every tank of gas.
- Don't drive too fast: Going from 90km/h to 100km/h increases your gas use by 10%; from 100km/h to 120km/h = 20% more! Gas consumption is optimal at 60-70 km/h.
- Turn off your engine as soon as you are parked or stopped for more than 10 seconds.
- Keep tire pressure up. Just one under-inflated tired could increase your gas consumption by 4%.
- Do regular oil and filter changes. Do preventive tune-ups. Poor maintenance can increase your gas consumption.
- Air conditioning can increase your gas consumption by 20%!.
- Before turning off your car, turn off all energy-consuming accessories: radio, telephone battery chargers, conditioning systems, etc.

(v) Reduce water use :

- Avoid flushing system in toilet, alternatively use bucket.
- A low-flow shower head can cut your water use in half.
- Take showers more frequently than baths: a shower takes 25-100 litres of water while baths require 250 litres.
- Avoid lawn sprinkling by fresh clean water, use grey water for it.
- Avoid pumping out ground water, store rain water in house tanks for daily use.

2. REUSE :

Reuse is thus about extending the life or giving a second life to something that we previously considered as "garbage".

- Use a reusable plastic or cotton bag for your purchases.
- Use and reuse cloth diapers instead of disposable ones.
- Reuse grey water from kitchen and bathroom for lawn sprinkling.
- Use one side printed waste paper for printing on other side.
- Donate your old clothes to needy persons or charitable trusts.
- Reuse your family-pack containers to buy in bulk.
- Reuse wrapping paper, plastic bags, boxes, and lumber.
- Buy beverages in returnable containers.
- Books and magazines can be donated to schools, public libraries, or nursing homes.
- Old tires can be used in the garden and in the play yard.

- Cement, bricks and other materials can be crushed and used as filling material.
- Demolition waste can be used as aggregate in concrete.
- Use Cloth napkins (thus washable) and washable rags instead of paper napkins and paper towels (single-use).
- Use Electric razor instead of disposable razors;
- Use rechargeable batteries instead of regular batteries.

3. **RECYCLE :**

(i) Paper and cardboard :

- Instead of using virgin fiber paper, use recycled papers. A sheet of paper can only be recycled about seven times, since the fibers become shorter and more fragile during the recycling process.

Universal Recycling Symbol
(used as a generic symbol for recycling or to indicate the material is recyclable)

Black Universal Recycling Symbol

Recycled Paper Symbol
(used to indicate 100% recycled paper content).

Partially - Recycled Paper Symbol

Fig: 10.3 Recycling Symbols

(ii) Plastics :

- Various plastic bottles (bottled water, soft drinks, juice), cables, clothing can be recycled in to T-shirts, carpets, binders, pillow fillings, etc.
- Polyvinyl chloride Containers for household cleaning or personal care products (bleach, shampoo), mineral water, food boxes, blinds, cheese and meat packaging, credit cards, bottles, etc. can be recycled in to Coating, pipes, car parts, road cones, signs, construction materials, etc.
- Low density polyethylene Flexible containers (mustard, sauces), expandable bags and wrappings (bread bags), bags (garbage, grocery, freezer), tarps,etc. can be recycled in to Grocery bags, garbage bags, plastic lumber, etc.

(iii) Glass :

- Glass Like plastic, glass is an inert material, so it does not move or change. A buried glass bottle takes 4,000 years to decompose. This is why it's a good idea to recycle glass.
- Glass can be recycled indefinitely without losing its properties and quality. It is brought back to life as bottles, containers and jars of all sorts. It is also used :
- In glass-insulated wool ;
- As an aggregate for road sub bases, concrete blocks, asphalt and ceramic tiles;
- In reflective road paint (glass microbeads) ;
- As abrasive ;
- To replace fine sand for jetting.

For the time being, these products cannot be recycled: • Ceramic ; • Mirrors and window glass ; • Porcelain and pottery ; • Pyrex glass ; • Cups, dishes, drinking glasses ; • Crystal ; • Light bulbs and neon lights.

(iv) **Metal :**

Recycling metals preserves the environment in many ways. On the top of that list is mining, which is a very destructive and polluting activity. By recycling metal, we avoid extracting, refining, transporting—all activities requiring a lot of energy and water. In consequence, that keeps us from producing considerable greenhouse gases.

- 1 tonne of recycled aluminium saves 6 tonnes of greenhouse gases.
- Recycled aluminium is transformed into cans, wrapping paper, garden furniture and car parts.
- Presently, 65% of steel products are made from recycled steel. Recycled steel is used for making engine parts, steel structures and cans.
- What you can recycle : • Tin cans ; • Cans ; • Beer caps ; • Aluminum paper, foil and plates ; • Metal lids. - Getting Copper wires from old electrical equipment.

(v) **Debris from construction, renovation and demolition :**

- Cement, bricks and other materials can be crushed and used as filling material.
- Demolition waste can be used as aggregate in concrete.
- Reinforcement steel bars can be sent to steel recyclers or it can be used in flooring concrete.
- Old Timber can be used for doors, windows , furniture, etc.

4. RECOVER :

Most of the materials thrown in the garbage can be used and processed in ways other than being destroyed. This is what is called recovering. Reusing, recycling and composting are the most frequently used methods for recovering waste. When it's not possible to reuse or recycle objects—such as dead batteries, ink cartridges or cell phones, which all contain toxic elements labeled hazardous household waste—there is one last option before throwing them away: scrap dealers, recycling workers and recoverers.

Another alternative is recovering the energy stored in residual material. That means turning waste into a fuel for manufacturing processes or equipment designed to produce energy. Various mechanical, biological and caloric systems and technologies can convert, reprocess or break up wastes into new materials or energy. For example, the methane caused by rotting materials in dump sites can be recycled. This gas is converted into power, and thus eliminates its harmful effects on the environment.

For example,

- Use kitchen waste (organic waste) in manufacturing compost.
- Production of compost from municipal waste.
- Methane gas produced during decomposition of waste can be used as a fuel.
- Generation of electricity from waste (energy recovery).

10.5 TREATMENT OF DIFFERENT TYPES OF WASTE USING CONCEPT OF 4R :

Examples of different types of waste and how it can best be treated at end of life, using the 4R Best Practice are given below:

Table 10.2 Treatment of Different Types of Waste Using Concept of 4R

	Examples of Waste	4R Best Practice
[I] Construction waste:		
(i) Construction Waste	Concrete	Reuse
	Plasterboard/Gypsum	Recycle
	Paper	Recycle
	Metal	Recycle
Office Waste	Paper	Recycle
	Cardboard	Recycle
	Plastic (hard/soft)	Recycle or Recover
	Toners	Recycle
Waste from Manufacturing plants	Asphalt	Reuse
	Concrete	Reuse or Recycle
(II) Demolition Waste :	Concrete	Reuse
	Steel	Recycle
	Cabling	Recycle or Recover
	Glass	Recycle
	Timber	Reuse or Recycle
	Other materials	Reuse or Recycle

MULTIPLE CHOICE QUESTIONS

1. Which of the following R is not included in the 4R principles ?
   (a) Reduce (b) Reuse (c) Restrict (d) Recycle
2. Using one side printed papers for printing on other side, which 4R principle is used ?
   (a) Reduce (b) Reuse (c) Recover (d) Recycle
3. Using kitchen waste (organic waste) in manufacturing compost, which 4R principle is used ?
   (a) Reduce (b) Reuse (c) Recover (d) Recycle
4. The concept of 4R can be used for which type of waste ?
   (a) Solid waste (b) Liquid waste (c) Gaseous waste (d) All the above
5. Getting Copper wires from old electrical equipment, which 4R principle is used ?
   (a) Reduce (b) Reuse (c) Recover (d) Recycle

ANSWERS

1. (c) 2. (b) 3. (c) 4. (d) 5. (d)

REVIEW QUESTIONS

1. Explain principles of 4R's.
2. Give various applications of 4R's.
3. Explain Reduce, Reuse, Recycle and Recover.
4. Give benefits of using 4R.
5. Explain how concept of 4R can be used for developing effective solid waste management system.