Environmental Chemistry

7.1 Introduction

As we know that environment means everything which exists around us. The aggregation of social, biological, physical and chemical factors existing around us is called environment. Environmental chemistry means scientific study of chemical and biochemical processes occurring in environment. Thus, **the study of the sources, reactions, transport, effects and fates of chemical species in the air, soil and water environment and the effect of human activity on these is called environmental chemistry.** Environmental chemistry is an interdisciplinary science that includes disciplines like atomospheric, aquatic, soil and analytical chemistry. Analytical chemistry includes study of different methods and techniques used for analysis of chemical compounds.

The incidents and changes occurring in environment creates a number of questions like why do our eyes suffer irritation when we pass through specific areas ? Why the temperature of earth is increasing ? What is the reason for erosion of historical buildings ? Why does soil become dry ? What type of water is safe for drinking ? Why does a person working in a factory become deaf earlier than a normal one ? To answer these questions, we have to take help of environmental chemistry. It gives importance to the study of air, water, soil and noise pollution. In this unit we will discuss mainly the causes and the effects of air, water and soil pollution and also the remedies for its removal and how to control it.

7.2 Environmental Pollution

The pollution of environment is called environmental pollution. This pollution occurs due to harmful wastes produced by natural and

human activities. The substances which produce or spread the pollution are known as pollutants. Pollutants are found in solid, liquid or gaseous forms. Different time durations are required for natural degradation of pollutants. **Pollutants which degrade rapidly are known as rapidly degradable pollutants.** e.g. discarded vegetables naturally degrade within 7-10 days. **Pollutants which degrade slowly are known as slowly degradable pollutants.** e.g. agricultural wastes require 3 to 5 months for their natural degradation. For this reason, the farmers remove dungheaps maximum twice in a year. **Some pollutants remain for decades in their original form without degradation. They are known as non-degradable pollutants. e.g.** dichlordiphenyltrichloroethane (DDT), plastic materials, heavy metals, radioactive wastes etc. These compounds are not degraded naturally so it is difficult to remove them from the environment. These pollutants are proved to be more harmful to living beings. As we know that our environment consists of lithosphere (soil), hydrosphere (water) and atomsphere (air, gas), so, study of environmental pollution requires to know pollution that occurs in these three spheres. We will study them sequentially in this unit.

7.3 Atmospheric Pollution

The gaseous coverage surrounding the earth is known as atmosphere which is extended upto 500 km above sea level. **The lowest region of atmosphere is called troposphere in which all living beings including human beings reside.** It is extended upto 10 km above sea level. **The region which is above the troposphere and between 10 to 50 km from the sea level is known as stratosphere.** Dinitrogen (N_2), dioxygen (O_2), carbon dioxide (CO_2), water vapour (H_2O) and argon (Ar) are present in troposphere. Dintrogen (N_2), dioxygen (O_2) and ozone (O_2) are present in stratosphere. Troposphere and stratosphere greatly affect the biosphere of earth due to which study of pollution, in these two regions, is very important for the study of pollution in environment. So we will study the air pollution in troposphere and stratosphere.

7.3.1 Tropospheric Pollution :

Tropospheric pollution occurs due to the presence of undesirable solid or gaseous particles in the air. The gaseous pollutants - SO_x, NO_x, CO, CO_2, H_2S, O_3, hydrocarbons and particulate pollutants dust, mist, fumes, smoke and smog are to a great extent present in the troposphere.

7.3.1.1 Gaseous Air Pollutants :

(1) Oxides of sulphur (SO_x) : When sulphur containing fossil fuel is burnt, then oxides of sulphur are produced. Sulphur dioxide is the most common gaseous species which is poisonous to both animals and plants. Even low concentration of sulphur dioxide causes respiratory diseases like asthma, swelling and irritation of respiratory tract in human beings. Sulphur dioxide also causes irritation to eyes and turn them into reddish and tearful. High concentration of sulphur dioxide leads to stiffness of flower buds which eventually fall off from plants. The oxidation of sulphur dioxide without catalyst is slow, but the particulate matter present in polluted air acts as catalyst and converts sulphur dioxide into sulphur trioxide.

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$$

This reaction can also be possible in presence of oxidising agents like ozone and hydrogen peroxide.

$$SO_{2(g)} + O_{3(g)} \rightarrow SO_{3(g)} + O_{2(g)}$$

$$SO_{2(g)} + H_2O_{2(l)} \rightarrow H_2SO_{4(aq)}$$

(2) Oxides of Nitrogen (NO_x) : Nitrous oxide (N_2O), nitric oxide (NO) and nitrogen dioxide (NO_2) are present greatly in atmosphere as oxides of nitrogen. Generally these oxides of nitrogen are known as NO_x. We know that dioxygen (21%) and dinitrogen (78%) are the main constituents of air. In specific conditions, they react with each other and form oxides of nitrogen. NO_2 is oxidised to NO_3^- which, when

enters into soil, acts as a fertilizer. In an automobile engine, when fossil fuel is burnt at high temperature, then significant quantities of nitric oxide and nitrogen dioxide are produced due to the combination of dinitrogen and dioxygen.

$$N_{2(g)} + O_{2(g)} \xrightarrow{1483\ K} 2NO_{(g)}$$

NO reacts instantly with dioxygen to give NO_2

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

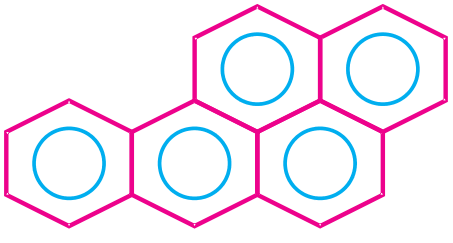
In stratosphere the rate of production of NO_2 becomes faster when nitric oxide reacts with ozone.

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$

Thus, forest fires, vehicle smokes, mineral oil, coal and natural gas burning, smokes generated by supersonic jet etc. are the sources of NO_x. In heavy traffic and congested areas, the irritant red-hazy environment is produced due to oxides of nitrogen. Higher concentration of NO_2 damage the leaves of plants and decrease the rate of photosynthesis. NO_2 is lung irritant. It causes an acute respiratory diseases in children. It is highly toxic to living tissues. Moreover, it is also harmful to metals and textile fibres.

(3) Hydrocarbons : The compounds of hydrogen and carbon only are called hydrocarbons. The hydrocarbons such as 3, 4- benzpyrene are present in smoke which is produced from incomplete combustion of fuel of vehicles and smoking of cigarettes. They are carcinogens, which means they cause cancer. They break the tissues of plant. Moreover, causes shedding of leaves, flowers and twigs. Benzene is also a carcinogen.

Benzene



3, 4- Benzpyrene

(4) Oxides of Carbon :

(i) Carbon monoxide (CO) : Carbon monoxide is the most severe air pollutant. It is colourless, odourless and highly poisonous gas. It is being produced from incomplete combustion of carbon.

$$2C_{(s)} + O_{2(g)} \xrightarrow[\text{Combustion}]{\text{Incomplete}} 2CO_{(g)}$$

Carbon monoxide is present as a major constituent in smoke produced by vehicles. Moreover, it is also produced by incomplete combustion of firewood, coal and petroleum products. The number of vehicles in the world is increasing day-by-day and so higher and higher CO is released from these vehicles due to inadequate pollution control equipments and lack of their regular service. Carbon monoxide enters into our body and binds with haemoglobin to form carboxyhaemoglobin complex, which is about 300 times more stable than the oxygen-haemoglobin complex. When the concentration of carboxyhaemoglobin reaches to about 3 to 4 % in blood, the oxygen carrying capacity of blood reduces. It causes headache, weak eyesight and cardiovascular disorder. Carbon monoxide gas produced during smoking enters our body through lungs and causes harmful effects. Due to this people are advised not to smoke. **That is why on cigarette cases the statutory warning- "Smoking Kills" is printed.** Smoking by pregnant woman results in increased level of CO in her blood which may increase the possibility of premature birth, spontaneous abortion and a deformed baby.

(ii) Carbon dioxide (CO_2) : CO_2 is natural constituent of air which is necessary for every vegetation. Its level in normal atmosphere is 0.03 %. Carbon dioxide is released by respiration, by burning of fossil fules for energy and by decomposition of limestone during the manufacturing of cement. So the level of carbon dioxide increases in the atmosphere. Plants use the carbon dioxide from the atmosphere for the photosynthesis. In this manner plants decrease the level of carbon dioxide in atmosphere. But due to increased use of fossil fuel and

deforestation, by growing human population to satisfy their greed, CO_2 level is increasing in atmosphere. The increased amount of carbon dioxide is responsible for global warming. Pollution effect due to gaseous pollutants in troposphere results in increased temperature of earth and also causes acid rains. Now, we will study in detail the effects of gaseous pollutants.

Global Warming and Green House Effect : The simple meaning of green house is 'plant growing house'. Plants can be grown at expected temperature in glass houses made from insulated walls and transparent ceiling. During day time the sunlight passes through transparent ceiling and transfer heat to soil, vegetation and other materials. The surplus absorbed heat by these constituents is reflected during night, but due to decreased penetration ability of this heat, it cannot escape from the walls or ceiling of glass house. So this heat stays in plant growing house and results in warm environment. Due to this, summer plant can grow in green house when the temperature of outside environment is quite low. Nature also has such wonderful arrangement to keep the earth warm. In 1882, French Mathematician Jean Fourier, first of all, compared the environment of earth with green house. Later on, in 1886, Swedish chemist Swante Arrhenius and American scientist Chamberlin explained that green house and atmosphere of earth are working in the same way. This means that sun rays enter but do not escape. **This process of warming of the earth is known as Green house effect or Global Warming and the gases actively involved in it are called Green house gases.** Carbon dioxide, methane, ozone, chlorofluorocarbons (CFCs), nitrous oxide and water vapour present in atmosphere act as green house gases. Actually these green house gases act as blanket of earth. In absence of green house effect the temperature of earth would be 30 ^{0}C lesser than the present temperature. Can we imagine how a living being can sustain in this coolest environment ?

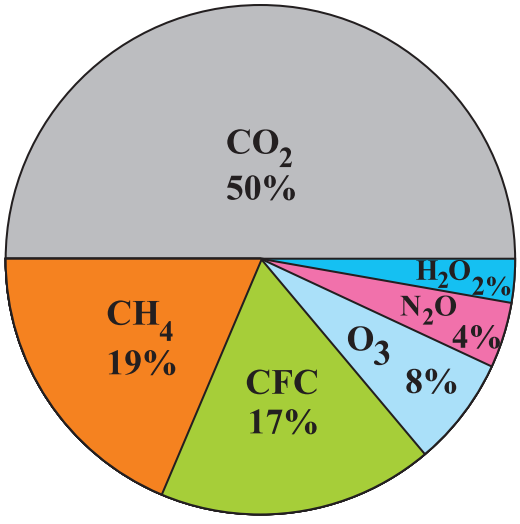


Fig. 7.1 Contribution of green house gases in global warming

Fig 7.1 shows the contribution of green house gases like CO_2, CH_4, CFC, O_3, N_2O and H_2O is 50%, 19%, 17%, 8%, 4% and 2% respectively in global warming. United Nations Intergovernmental Panel on Climate Change has given the word **'Global Warming Potential' (GWP)** for heat retaining capacity of green house gases. The GWP based sequence of green house gases is as

$$CFC \overset{10000\text{ times}}{>} N_2O \overset{150\text{ times}}{>} CH_4 \overset{25\text{ times}}{>} CO_2$$

This suggests that methane is 25 times stronger than carbon dioxide; nitrous oxide is 150 times stronger than methane and chlorofluorocarbon is 10,000 times stronger than nitrous oxide in terms of Global Warming Potential. In other words, compared to carbon dioxide, methane has 25 times, nitrous oxide has 3800 times and chlorofluorocarbon has 380 lakh times stronger Global Warming Potential.

If the amount of carbon dioxide in atmosphere is increased from 0.03 %, then, due to disturbance in balance of natural green house, the temperature of earth will be increased. Digestion of dung heap, paper, kitchen waste and organic materials, in absence of oxygen, produce methane. Generally, chlorofluorocarbons are used in aerosols, foam plastic cup, refrigerator, airconditioner, production of electronic circuits,

oil paints and foams used in fire extinguisher that ultimately enter into atmosphere. Burning of coal and petroleum products at higher temperature in power plants and automobiles release nitrous oxide. Moreover, this gas also enters into atmosphere by use of nitrogen containing fertilizers. In this manner, the increasing amount of green house gases in atmosphere results in increased temperature of earth. This will result in increased water level of sea due to melting of ice on the poles; increase in frequency and intensity of floods in rivers and damages to the areas of sea shores and also erosion of soil. Increase in average temperature of earth may increase the possibilities of contagious diseases and also diseases like malaria, dengue and yellow fever. That is why it is essential to think about the remedies to control the increasing temperature of earth.

Remedies to Control the Increasing Temperature of Earth :

(i) To protect forests and grow more trees, because trees utilize carbon dioxide for photosynthesis and release oxygen. According to one estimate photosynthesis utilizes 2200 crore tons of CO_2 annually from atmosphere and releases 1600 crore tons of oxygen.

(ii) To take proper care of vehicles we should insist on regular service to keep engine in good condition.

(iii) Renewable energy sources should be used more. Complete dependence on coal and petroleum products should be reduced.

(iv) To control the amount of NO_x in atmosphere use of chemical fertilizers should be stopped or reduced and to opt for organic farming.

(v) Devices or instruments free from chloro-fluorocarbons should be used.

(vi) To stop the release of methane gas in atmosphere. We have to increase efforts in the direction towards production of biogas and best fertilizer from agricultural wastes and excreta of animals by avoiding the preparation of heap in open ground.

Acid Rain : As we know, the pH of rain water is about 5.6 because water reacts with CO_2 of atmosphere and produces carbonic acid (H_2CO_3).

$$H_2O_{(l)} + CO_{2(g)} \rightleftharpoons H_2CO_{3(aq)}$$

$$H_2CO_{3(aq)} \rightleftharpoons H^+_{(aq)} + HCO_3^-{}_{(aq)}$$

When the pH of rain water becomes lower than 5.6 then it is called acid rain. SO_2 and NO_2 released from burning of fossil fuels like coal and petroleum products in power plants and from combustion of petrol and diesel in vehicles, react with moisture of air and are converted into sulphuric acid and nitric acid. These acidic clouds move with wind and under suitable condition it rains.

$$2SO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 2H_2SO_{4(aq)}$$

$$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 4HNO_{3(aq)}$$

The acid rain in water reservoirs like rivers, ponds adversely affect fish, micro organisms and plants, in aquatic world. Acid rain has proved harmful to agriculture because this water results in increased erosion of nutrients essential for plant growth. Large amount of acidic rain decreases soil fertility. The buildings made up of stones and metals are affected adversely due to acid rain. Taj Mahal, the historical monument of our country is also being affected by acid rain. The harmful gases released from nearby refineries are responsible for this. Implementation of Clean Air Law against industries producing SO_x and NO_x, may protect from the adverse effect of acid rain.

7.3.1.2 Particulate Pollutants : Particulate pollutants are the minute solid particles or liquid droplets in air. They are present in vehicle exhausts, smoke particles from fires, dust, ash from units generating electricity and industries. Particulate pollutants can be classified in two types viable and non-viable. Bacteria, fungi and

algae etc. microorganisms spread in atmosphere are viable particulate pollutants. Non-viable pollutants are classified on the basis of their characteristics and size.

(1) Smoke : It is solid or mixture of solid and liquid produced during burning of organic materials. e.g. smoke from bidi-cigarette, smoke produced by burning of fossil fuels, dried leaves and garbage.

(2) Dust : It is a fine solid particle (more than 1 μ (micron) in diameter, 1μ = 1micro m = 10^{-6} meter). These particles are produced by crushing or grinding of solid materials. Sand from sand blasting, sawdust from wood works and fly ash from industries are examples of such pollutants.

(3) Mist : Natural spray of liquid produced by condensation of vapours present in air, is called mist e.g. sulphuric acid mist. Furthermore, herbicides and insecticides produce mist after spreading in the air.

(4) Fumes : They are produced by condensation of vapour released during distillation, boiling and some other chemical reactions of organic solvents, metals and oxides of metals.

Spreading of smoke, dust, mist and fumes through air causes a great danger to human health. Effect of particulate pollutants is based on size of particles. Particulates of one micron (10^{-6} meter) size reaches easily to lungs and causes diseases related to lungs. Particulates having the size more than 5 microns lodge in nasal passage and harm human health.

Smog : Smog is a word derived from combination of smoke and fog which are common air pollutants present in urban areas. Smog can be divided into two parts.

(1) Classical Smog : Classical smog occurs in cool humid climate. It is a mixture of smoke, fog and sulphur dioxide gas. Chemically it is a reducing mixture so it is called the **reducing smog.** In nineteenth century, classical smog was found in heavily populated industrial cities such as London and other cities in England. In these cities high sulphur coal was used as the energy sources both at domestic places and in the industries. At that time, the smoke produced was released near the ground level due to unawareness about pollution control. Due to this, the smog episodes were frequent in these cities depending on prolonged periods of climatic conditions. In 1952, such severe smog remained for several weeks in London. More than 4000 people died due to inhalation of the smog. As this classical smog was responsible for the accident in London, it is conventionally known as **'London smog'.**

(2) Photochemical Smog : Photochemical smog is produced in warm, dry and sunny climate. It is produced by sunlight on nitrogen oxide and hydrocarbons produced by vehicles and industrial units. Photochemical smog is known as oxidising smog because it possesses high concentration of **oxidising agent**. This type of smog is found frequently in the automobile rich city – Los Angeles of America. So it is known as **'Los Angeles Smog'.**

When fossil fuels are burnt, different types of pollutants are emitted into the troposphere of earth. Out of these, when nitrous oxide and hydrocarbons are present at sufficiently high level then in presence of sunlight a chain reaction occurs between them and NO_2 is produced. This NO_2 is converted into nitric oxide and free oxygen after absorbing the energy from sunlight.

$$NO_{2(g)} \xrightarrow{h\nu} NO_{(g)} + O_{(g)} \quad \ldots\ldots \quad 7.1$$

Due to high reactivity, free oxygen reacts with oxygen gas of air and produces ozone.

$$O_{(g)} + O_{2(g)} \rightleftharpoons O_{3(g)} \quad 7.2$$

$O_{3(g)}$ formed according to reaction(7.2) reacts rapidly with $NO_{(g)}$ formed according to reaction (7.1) and produces $NO_{2(g)}$ again. It results in hazy atmosphere.

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)} \quad \ldots\ldots\ 7.3$$

NO_2 and O_3 are strong oxidising agents. They react with unburnt hydrocarbons present in polluted air and produce formaldehyde, acrolein and peroxyacetylnitrate.

Photochemical smog causes severe effect on health. Ozone and peroxyacetylnitrate create acute irritation in eyes. Ozone and nitric oxide cause irritation in nose and throat. Their high concentration create the health related problems like headache, chest-pain, dryness of throat, cough and difficulty in breathing etc. Photochemical smog damages plant kingdom. The metals, stones, building materials, rubber and painted surface are also affected by erosion. For controlling formation of photochemical smog we must control the formation of NO_2, hydrocarbons, ozone and peroxyacetylnitrate. Mixing of NO_2 and hydrocorbons in atmosphere can be reduced by using catalytic converters in vehicles.

7.3.2 Stratospheric Pollution : Layer of ozone is present in upper region of stratosphere. We know it as 'Ozone Layer'. When ultraviolet radiations reach dioxygen molecule in stratosphere, two free oxygen atoms are produced. This oxygen atoms combine with dioxygen molecule and forms ozone.

$$O_{2(g)} \xrightarrow{uv} O_{(g)} + O_{(g)}$$

$$O_{(g)} + O_{2(g)} \overset{uv}{\rightleftharpoons} O_{3(g)}$$

Ozone layer protects all living beings against harmful effect of ultraviolet radiations coming from sunlight. But pollutants produced from some anthropogenic activities deplete this ozone layer. So it becomes important to discuss the reasons for depletion of ozone layer, its effects and remedies for its prevention.

● **Depletion of Ozone Layer :** In September 1980, scientists reported a large hole in ozone layer over Antarctica. 30 % loss in this ozone layer was recorded. Generally, **substances that cause depletion of ozone or make it thinner are abbreviated as ODS (Ozone Depletion Substances).** Scientists have established that one molecule of CFC is capable to destroy one lakh O_3 molecules in the stratosphere. 95 derivatives of chloro or bromo fluorocarbon are known which are familiarly known as ODS. These ODS are greatly used in refrigerator, airconditioner, watercooler and fire extinguishers. 93 countries, including India, have accepted not to use ODS by signing Montreal Protocol on 16th September, 1987. Lately many other countries have also accepted it. To create its awareness in the whole world, United Nations decided to celebrate 16th September of every year as 'Ozone Protection Day' at international level.

Reasons for Depletion of Ozone Layer :

(1) Entering in atmosphere, CFC mixed with gases of atmosphere, reaches in stratosphere. Strong ultraviolet radiations present there, break the CFC molecule and produce chlorine free radical ($\dot{Cl}_{(g)}$).

$$CF_2Cl_{2(g)} \xrightarrow{uv} \dot{Cl}_{(g)} + \dot{C}F_2Cl_{(g)}$$

This chlorine free radical reacts with ozone of stratosphere and produces chlorine monoxide free radical and oxygen molecule.

$$\dot{Cl}_{(g)} + O_{3(g)} \rightarrow \dot{ClO}_{(g)} + O_{2(g)}$$

This chlorine monoxide free radical reacts with oxygen atom and produces chlorine free radical.

$$\dot{Cl}O_{(g)} + O_{(g)} \rightarrow \dot{Cl}_{(g)} + O_{2(g)}$$

Thus, chlorine free radicals, produced continuously, deplete the ozone layer. Thus, chlorofluorocarbons are considered responsible for depletion of ozone layer.

(2) Reaction of NO_x with O_3 causes about 40 % reduction in concentration of ozone. NO_x enters into atmosphere through smoke of supersonic jet aircrafts. Amount of NO_x, resulting from atomic explosion experiments, cause reduction in concentration of ozone.

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$

$$NO_{2(g)} + O_{3(g)} \rightarrow NO_{3(g)} + O_{2(g)}$$

Effects of Depletion of Ozone Layer : Due to depletion of ozone layer, ultraviolet radiations of sunlight enter directly on the earth. These ultraviolet radiations cause skin cancer, harmful genetic changes in cell, reduction in soil moisture level and reduction in fish production.

Remedies to Protect Depletion of Ozone Layer : Depletion of ozone layer may be protected by spraying chemical compounds of alkane series in atmosphere, decreasing the production of CFC upto 50 %, forming more of polar stratospheric clouds and preventing the use of ODS.

7.4 Water Pollution

You might have read the slogans like - 'Water is life', 'Save Water, Water will save you' which tell us the importance of water. Such slogans indicate to save the amount of water. Not only the amount of water is important but its quality is also equally important. If the earth is divided into four parts then three parts will contain water, which indicates larger amount of water present. But not the whole amount of water is useful for us because its quality is not always good. 97 % of all available water on earth is sea water; we all know that the sea water is not usually utilized for drinking, agriculture or in other routine activities due to its salty nature. 2 % water of remaining 3 % is in the form of ice in polar regions. Thus, only 1 % water is left for utilization by human beings, which is available in the form of surface water-water in river, pond, spring and dam and the ground water-water in well. Surface and ground water become polluted due to negative effects of anthropogenic activities. Pollutants which pollute surface water, dissolved in universal solvent like water, percolate in ground and pollute ground water. These pollutants are shown in Table 7.1.

Table 7.1 Water Pollutants

No.	Pollutant	Sources
1.	Microorganisms	Domestic sewage, domestic waste water, dungheap
2.	Organic Wastes	Domestic sewage, excreta of animals, decaying of animals and plants, waste from food processing factories, detergents.
3.	Plant nutrients	Chemical fertilizers
4.	Heavy metals	Heavy metal producing chemical factories
5.	Sediments	Erosion of soil by agriculture and stripmining
6.	Pesticides	Chemicals used for killing insects, fungi and weeds
7.	Radioactive substances	Mining of uranium containing minerals
8.	Heat	Water used for cooling in industries

Pollutants listed in Table 7.1 cause mixing of soluble, insoluble, biological, physical and chemical impurities with water and pollute it. This discussion raises a question that what type of water is safe for drinking ? Types and amounts of which compounds or elements make it potable ? Attempts are being made at national and international levels to solve these questions. Institutions like **WHO (WHO : World Health Organization) at world level** and **BIS (BIS : Bureau of Indian Standards)** and **ICMR (ICMR : Indian Council of Medical Research)** at India level have prescribed standards for quality of drinking water. On the basis of this, we can decide whether the water is potable or not ? Standards prescribed by BIS, in 1991, for deciding the quality of drinking water are shown in Table 7.2 :

Table 7.2

Prescribed Standards by BIS for Quality of Drinking Water

Characteristics	Desirable limit
Physico-chemical characteristics	
pH	6.5 to 8.5
Total Dissolved Solids (TDS)	500 ppm
Total Hardness (as $CaCO_3$)	300 ppm
Nitrate	45 ppm
Chloride	250 ppm
Sulphate	200 ppm
Fluoride	1 ppm
Biological characteristics	
Escherichia Coli (E.Coli)	Not at all
Coliforms	Not to exceed 10 (In 100 ml water sample)

$1ppm = 1mgL^{-1}$

Standard analytical methods are available for estimation of physico-chemical and biological characteristics of water. We should take help of laboratory for estimation of these characteristics. Water, having higher values for physico chemical or biological characteristics than desirable limits, harms our health. So, such water cannot be considered safe for drinking.

pH : pH value of water that exceeds 8.5, reduces the effect of chlorination which is used to make the water germ free. If the water has pH values lower than 6.5 then corrosion of pipe for distribution of such water takes place. It results in mixing of harmful metals and releases Zn, Pb, Cd and Cu into drinking water.

Total Dissolved Solids (TDS) : Most of the salts are soluble in water. It includes cations like calcium, mangnesium, sodium, potassium, iron and anions like carbonate, biocarbonate, chloride, sulphate, phosphate, nitrate. Use of drinking water having total dissolved solids concentration higher than 500 ppm causes possibilities of irritation in stomach and intestine.

Total Hardness : Concentration of total hardness in water more than 300 ppm change the taste of drinking water. Regular intake of such water causes possibilities of heart disease. Such incidents are also reported.

Nitrate : Use of drinking water having the concentration of nitrate higher than 45 ppm causes possibilities of metheomoglobinemia (blue baby) diseases in children.

Chloride : Concentration of chloride in water higher than 250 ppm causes corrosion of pipes used for its distribution and results in higher amount of harmful metals in drinking water.

Sulphate : Diarrhoea and irritation is stomach are being caused by use of drinking water having concentration of sulphate more than 200 ppm.

Fluoride : Fluoride is essential for strength of bones and teeth, due to which use of tooth paste containing fluoride has increased. But higher concentration of fluoride causes harmful effect on our health. If the drinking water contains fluoride in concentration higher than 1 ppm, then it causes diseases of teeth and bones in human body. If the concentration of fluoride is higher than 2 ppm, then brown mottling of teeth occurs. If concentration of fluoride exceeds 10 ppm, it causes fluorosis diseases in which teeth and bones of a person become weak.

Escherichia Coli and Coliforms Bacteria : Escherichia Coli should be absent in drinking water. Use of water for drinking, having more than 10 coliforms in 100 ml water results swelling in stomach and intestine and causes urinary tract diseases.

Purification of Drinking Water : For purificaton, the drinking water is first analysed based on which the purification method is decided. Three methods are known for purification of drinking water.

(1) Chemical Method : To make the water safe for drinking, specific chemical is being added to it to remove specific impurity of constituent. Removal of obtained precipitate results in removal of impurities e.g. to remove fluoride from water, lime and calcium chloride are added to it. It results in precipitation of sparingly soluble calcium fluoride. Removal of this by precipitation results in easy removal of fluoride from water.

(2) Physical Method : Filtration, reverse osmosis and ion exchange methods are being used for removal or reduction of soluble salts and turbidity of water. Filters of different pore size, as per requirement are used in filtration. Filters having 0.0001µ pore size are available. In reverse osmosis, when water passes through semipermeable membrane, then only water can pass through it whereas salts are being accumulated. Biological impurities can also be removed by reverse osmosis, because the pore size of semipermeable membrane is 0.0001µ which easily removes the bigger size bacteria (minimum size 0.2-0.5µ) and viruses (minimum size 0.015µ). Ion exchange methods involve use of ion exchange resins. Resin removing cation and anion are known as cation and anion exchange resins, respectively. Sequential use of cation and anion exchange resins easily remove cations like calcium, magnesium and anions like chloride, sulphate from hard water.

(3) Biological Method : We all are familiar with boiling of water to make it germ free. This method is easy, safe and reliable, due to which pediatricians recommend to use boiled drinking water for babies younger than 1 year. Except this, the water can be made germ free by chlorination (passing of chlorine gas or by use of bleaching power), by passing of ozone gas or by use of ultraviolet radiations. Water distributed by water supply unit in villages and cities is being chlorinated to make germfree. A person, if interested, can do chlorination of drinking water at residence, school or college or public institutions. For this, tablets of chlorine or bleaching powder having 33 to 35 % concentration available in market, can be used. Either one chlorine tablet should be added in about 20 litre water or 5 g bleaching powder should be added to 1000 litre water. Use of ozone gas makes the water germfree, effectively and rapidly. Passing of ultraviolet radiations from water makes it germfree. These two methods are being used intensively in industrial units for purification of drinking water. Water available in market in pouch or bottle are purified by these methods. Today general awareness of drinking water has increased with the use of water purification devices at residence, college or public places.

7.5 Soil Pollution

Soil is a thin layer of organic and inorganic materials covering the rocks of earth. The organic part of soil, which makes upper layer of soil, is formed by decomposition of animal and plant wastes. Inorganic part is formed by

constituents of rocks produced due to physical and chemical changes from thousands of years. The productive soil is needed to fulfil the requirement of food by the people. The main reasons for pollution of soil are indiscriminate uses of fertilizers and pesticides, dumping of solid waste in soil and deforestation.

Reasons for Soil Pollution :

(1) Indiscriminate use of artificial fertilizers : Soil nutrients are useful for growth and development of plants. Plant obtains carbon, hydrogen and oxygen from air or water. Whereas other essential nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulphur are being absorbed from soil. To remove the deficiency of nutrients in soil, farmers add artificial fertilizers. The contaminants present in these fertilizers, harm the soil. These cotaminants in fertilizers come from the raw materials used for their production. e.g., mixed fertilizer contains ammonium nitrate, phosphorus (as P_2O_5) and potassium (as K_2O), which contains trace of elements like As, Pb and Cd from rock phosphate used for their production. Due to non-degradability, these elements get accumulated in soil. Increased use of phosphate fertilizers results in such a higher concentration in soil that it becomes harmful to plants. The over use of artificial fertilizers like NPK in soil, results in reduced production of crops and vegetables in that soil. Moreover, it reduces the protein content of wheat, maize and grams grown in that soil.

(2) Indiscriminate use of Pesticides : Insects, fungi, bacteria, viruses and other animals attack on plants for their nutrients, on which we depend for our food. For this, to protect the crop, farmers use pesticides. These pesticides are being absorbed in soil and reduce its fertility. These pesticides enter into plants from soil and respectively in human body and other living beings from plants that are harmful to their health. Pesticides include insecticides, fungicides and herbicides. Insecticide like DDT (Dichloro-diphenyltrichloroethane) is banned in India and in most of the other countries because of the evidences of its harmful effect on organs of the digestive system. Sodium chlorate and sodium arsenite used as herbicides are found toxic for mammals. Mercuric compounds used in fungicides are decomposed in soil and their products are harmful. Use of methyl mercury and its compounds caused many deaths in Iraq in 1972.

(3) Dumping of Solid Wastes in Soil : Generally, the wastes from garbage, commercial, industrial and agricultural units are in the form of solid wastes. They contain kitchen wastes, paper, cardboards, plastics, glass, old construction materials, toxic or hazardous substances in considerable amount. Among these, paper and kitchen wastes are biodegradable. Recycling of paper is possible. Although plasitc, glass and old construction materials are non-biodegradable, they can be recycled. Heavy metals, toxic and hazardous substances present in industrial effluents are non-biodegradable. When solid wastes are dumped in soil, then non biodegradable wastes remain in soil for a loger period. It disturbs the structure and fertility of soil.

(4) Deforestation : More deforestation occurs due to urbanization, industrialization and over population. To satisfy their needs human beings are destroying the forests. The soil gets exposed and it causes erosion of fertile layer of soil. Such soil cannot be utilized for agriculture.

Prevention of Soil Pollution :

(1) Use of natural fertilizers (e.g., farmyard manure, compost etc.) and biofertilizers (e.g., rhizobium, azotobacters, algae etc.) should be increased instead of chemical fertilizers to increase crop yield.

(2) Biological methods should be used instead of chemical compounds to control harmful pests. Extract of neem, Aak and Dhatura leaves can act as insecticides. Furthermore, trichoderma fungi is well known as insecticide.

(3) Conversion of wastes of paper, plastic materials and glass should be done in such a way that they can be reused. This means recycling. It can reduce the amount of solid wastes and conservation of natural sources may occur. e.g. If 1 ton wastes of paper is being reproduced, then 17 trees can be saved.

(4) Industrial effluent should be treated first by physical, chemical and biological treatments to reduce its toxicity and then it should be removed.

(5) Adoption of a policy for less cutting and more growing of trees can reduce the erosion of soil and conserve soil fertility.

7.6 Pollution from Necessary Wastes of Industries

The negative side of industrial revolution is pollution from necessary wastes of industries. Wastes produced by different industries contain different amounts of various substances. Its removal into air, water or soil ultimately proves harmful to living beings. Here, we will discuss characteristics of wastes produced by different industries.

(1) Petroleum Industry : The waste produced by such industry contains various organic and inorganic compounds, free oil, phenolic compounds, suspended solids and H_2S.

(2) Paper and Pulp Industry : The waste produced by such industry contains organic materials like dimethyl sulphide, methyl mercaptan and inorganic materials like acid, alkali and salts of heavy metals.

(3) Leather Industry : The waste produced by such industry contains alkaline substances, suspended materials, ammonium salts, sodium sulphides, salts of chromium and arsenic, sulphuric acid, detergents, enzymes and animal protein and fat.

(4) Sugar Industry : Waste water produced by such industry becomes black in colour with time due to biological activities and it smells bad due to production of H_2S gas.

(5) Electroplating and Metal Refining Industry : The waste produced by such industry contains metal ions like nickel, chromium, zinc, lead, silver, mercury etc. and toxic materials like sulphide, cyanide, hydrogen sulphide, ammonia.

(6) Detergent Industry : The waste produced by such industry contains soluble organic compounds having long chains, soluble inorganic compounds, acids and solvents.

(7) Pesticide Industry : The waste produced by such industry contains considerable amount of aromatic organic compounds and acids.

(8) Fertilizer Industry : The waste produced by such industry contains compouds of nitrogen, phosphate, fluoride and arsenic.

(9) Thermal Power Industry : The waste produced by such industry contains fly ash, inorganic compounds and heavy metals.

(10) Dairy Industry : The waste produced by such industry contains suspended materials, nitrogen, phosphorus and organic compounds.

When the industrial waste is in liquid form, then to measure the amount of organic waste in it, two types of measures (methods) are used in environmental technology.

(i) Biochemical Oxygen Demand (BOD) : Generally, The organic compounds present in polluted water are also the food for bacteria. During their biochemical reactions these bacteria convert organic compounds into simple organic compounds through degradation. For it, the amount of dissolved oxygen utilized by these bacteria is called BOD. Thus, on the basis of required amount of dissolved oxygen the amount of organic materials which can be degraded by bacteria in liquid waste, can be measured. To measure BOD, the sample of liquid waste is kept at 293 K temperature for 5 days. On the basis of difference (DO_1-DO_5) between amounts of dissolved oxygen on the fifth day (DO_5) and on the first day (DO_1), the amount of dissolved oxygen used up by bacteria for degradation of organic material of waste sample can be determined. This is known as BOD for liquid waste. The unit of BOD measurement is ppm or mgL^{-1}.

(ii) Chemical Oxygen Demand (COD) : The amount of dissolved oxygen required for oxidation of all the organic materials present in liquid waste is known as COD. Thus, on the basis of required amount of dissolved oxygen, the amount of all the organic materials present in liquid waste can be determined. Thus, generally, the COD value is higher than BOD for the same liquid waste. To measure the COD, mixture the strong oxidising agents like potassium dichromate and concentrated sulphuric acid are used. This measurement requires only 2-3 hours. The unit of COD measurement is ppm or mgL^{-1}.

7.7 Remedies for Control of Environmental Pollution

Generally, we know that the main sources of environmental pollution are household wastes, like smoke from vehicles, industrial wastes and biomedical wastes. Thus, by controlling the pollution created by such sources, the control of environmental pollution becomes easy. Let us discuss the efforts to control them.

(1) Biodegradable and non-biodegradable materials of household waste should be kept separate. Municipality or Gram Panchayat should keep different containers to collect these wastes. Some developed countries follow this system. e.g. green coloured container for the collection of biodegradable materials and yellow or red coloured container for the collection of non-biodegradable materials. Compost can be prepared from biodegradable wastes whereas the non-biodegradable substances should be recycled.

(2) To control the air pollution created by exhaust smoke of vehicles, every person should check the amount of gases present in the smoke of their vehicles and regular service of the vehicles is also necessary. For this, it is essential to obtain PUC (Pollution Under Control) certificate for each vehicle.

(3) Air pollution control devices should be arranged to control the air pollutants like suspended particles, sulphur dioxide, ammonia, chlorine, hydrogen chloride, hydrogen sulphide etc. released in the air by industries. For protection against polluted air we should use gasmask.

(4) Specific treatment should be given to industrial effluent to make it non-harmful. For it, the industry should make effluent treatment plants either individually or collectively.

(5) To make germfree, biomedical wastes should be burnt or dumped in soil based on its characteristics for its removal.

Gujarat Pollution Control Board is established in Gandhinagar to control the environmental pollution in Gujarat.

7.8 Green Chemistry

Production of materials like fertilizers, pesticides, dyes, drugs, plastics and cosmetics used by human beings has become easy due to growth of chemical industries. But the effluents of these industries, which are harmful to living beings including human beings are thrown in air, water or soil. This pollutes environment. For this, presently, scientists are trying to develop methods to produce chemical compounds which are favourable to environment (eco friendly). The chemistry developed by such efforts is known as Green Chemistry. In short, green chemistry means science for environmentally favourable chemical synthesis.

In 2005, Nobel Prize for synthesis of new chemicals based on green chemistry was awarded to French scientist Professor Yves Chauvin and two other scientists of America, Robert H. Grubbs and Richard R. Schrok. Twelve principles as mentioned below are being formulated for green chemistry on the basis of works done by Paul T. Anastas for development of green chemistry. On the basis of these principles, synthesis of new chemicals are recommended in green chemistry.

Basic Principles of Green Chemistry :

During synthesis of chemical compounds,

(1) Formation of wastes or byproducts should be prevented.

(2) Reactants should be converted completely into products that means 100 % product should be obtained.

(3) Production of hazardous chemicals should be prevented.

(4) Production of safer chemicals should be aimed.

(5) Required energy for any synthesis should be minimum.

(6) Most appropriate solvent, should be selected.

(7) Appropriate starting materials for synthesis should be selected.

(8) Use of protecting group should be avoided whenever possible.

(9) Use of catalyst should be preferred wherever possible. Presently, phase catalysts are being used.

(10) Obtained product should be biodegradable.

(11) Design of manufacturing plant should be such that the possibility of accidents during operation can be eliminated.

(12) Analytical techniques should be strengthened to control hazardous compounds.

Green Chemistry in day-to-day life :

The use of principles of green chemistry in day-to-day life is being observed.

(1) In Drycleaning of Clothes : Tetrachloroethene ($Cl_2C=CCl_2$) was used earlier as solvent for dry cleaning of clothes. It pollutes ground water and is carcinogenic. For this, today, liquefied carbon dioxide with suitable detergent is used for drycleaning instead of tetrachloroethene. Today, the use of hydrogen peroxide as bleaching agent for washing of clothes has increased which produces good results using lesser amount of water.

(2) In Bleaching of Paper : We know that paper is made up of wood. For good quality of paper it is essential to remove its lignin completely. Most of the lignin is removed during production of paper. Chlorine gas is being used for removal of remaining lignin. But chlorine gas forms dioxins by reaction with aromatic rings of lignin, which is potential carcinogenic compound. For this, as alternative of chlorine gas for bleaching of paper, hydrogen peroxide in presence of suitable catalyst is being used today which is due to the development of green chemistry.

SUMMARY

Environmental chemistry means scientific study of chemical and biochemical processes occurring in environment. Through it we can know the reasons for changes and processes occurring in environment. Solid, liquid and gaseous pollutants, polluting environment can be generally classified as rapidly degradable, slowly degradable and non-biodegradable pollutants. Pollutants which degrade rapidly are known as rapidly degradable pollutants. e.g. discarded vegetables. Pollutants which degrade slowly are known as slowly degradable pollutants. e.g. agricultural waste. Some pollutants remain for decades in their original form without degradation. They are known as non-degradable pollutants. e.g. dichlorodiphenyltrichloroethane (DDT), plastic materials, heavy metals, radioactive wastes. Troposphere and stratosphere greatly affect the biosphere of earth due to which study of pollution in these two regions is most important for study of pollution in enviornment. Gaseous pollutants - SO_x, NO_x, CO, CO_2, H_2S, O_3, hydrocarbons and particulate pollutants - dust, mist, fumes, smoke, smog etc cause pollution in troposphere. The process of warming of the earth is known as 'Green house effect' or 'Global warming' and the gases actively involved in it are called 'Green house gases'. Carbon dioxide, methane, ozone, chlorofluorocarbon (CFC), nitrous oxide and water vapour present in atmosphere act as green house gases. Heat retaining capacity of greenhouse gases are called Global Warming Potential (GWP). The GWP based sequence of green house gases is as CFC > N_2O > CH_4 > CO_2. When the pH of rain water becomes lower than 5.6 then it is called acid rain. Gaseous pollutants present in troposphere are responsible for it. The acid rain in water reservoirs like rivers, ponds adversely affect fishes, microorganisms and plants, in aquatic world. Ozone layer present in stratosphere protect the living being against harmful ultraviolet radiations from space. But ODS (Ozone Depletion Substances) used by human beings deplete ozone layer. To create awareness in the whole world about the depletion of ozone layer and the remedies to protect depletion, United Nations has decided to celebrate 16th September of every year as 'Ozone Layer Protection Day' at the international level. Today, a person hesitates to use natural water directly for drinking, because soluble, insoluble, biological, physical or chemical impurities from different sources mixing with surface water or ground water which pollute the water. Due to this, institutions like WHO (World Health Organization) at world level and BIS (Bureau of Indian Standards) and ICMR (Indian Council of Medical Research) India level have prescribed standards for quality of drinking water. Chemical, physical and biological methods are known for purification of drinking water. For soil pollution, indiscriminate use of fertilizers and pesticides, dumping of solid wastes in soil and deforestation are observed as main causes. Removal of wastes, produced from different industries in air, water or soil are ultimately harmful for living beings. To determine the amount of organic waste in liquid effluents of industries, measurements of Biochemical Oxygen Demand (BOD) and Chemical

Oxygen Demand (COD) are important. By BOD measurement, the amount of organic materials present in liquid waste, which can be degraded by bacteria can be measured. By COD measurement, the amount of all the organic materials present in liquid waste can be determined. BOD measurement requires 5 days and COD measurement requires 2-3 hours. By controlling, managing or treating the waste from households, exhausts from vehicles, industrial wastes and biomedical wastes we can control the environmental pollution. Efforts to control environmental pollution resulted in delvelopment of science for synthesis of chemicals favourable to environment, which is called green chemistry. Gujarat State Government has established the Pollution Control Board for control of environmental pollution in Gujarat.

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which one is not a green house gas ?

(A) H_2O (B) O_2 (C) CO_2 (D) O_3

(2) Which sequence for green house gases is truly based on GWP ?

(A) CFC > N_2O > CO_2 > CH_4 (B) CFC > CO_2 > N_2O > CH_4

(C) CFC > N_2O > CH_4 > CO_2 (D) CFC > CH_4 > N_2O > CO_2

(3) Which gas has greater contribution in global warming ?

(A) CO_2 (B) CFC (C) NO_2 (D) CH_4

(4) How many molecules of ozone gas are being depleted by one molecule of CFC ?

(A) 10^3 (B) 10^4 (C) 10^5 (D) 10^6

(5) Which method is used for purification of water ?

(A) Reverse osmosis (B) Biochemical Oxygen Demand

(C) Chemical Oxygen Demand (D) Use of ODS

(6) Which statement is true from the following ?

(A) Amount of whole organic materials present in liquid waste can be determined by measurement of BOD.

(B) Amount of microbially degradable organic materials in liquid waste can be determined by measurement of COD.

(C) COD is measured by use of mixture of potassium dichromate and concentrated sulphuric acid.

(D) Five days are required for COD measurement.

(7) Presence of higher amount of which ion than its desirable limit in drinking water may cause blue baby disease ?

(A) Fluoride (B) Nitrate (C) Chloride (D) Sulphate

(8) Which of the following substances is non-biodegradable ?

(A) Paper (B) Glass

(C) Kitchen waste (D) Rotten vegetables

(9) Generally, which industry produces fly ash as a waste ?

(A) Dairy industry (B) Detergent industry
(C) Thermal power industry (D) Fertilizer industry

(10) Which of the following statements is not proper to basic principle of green chemistry ?

(A) Synthesized product should be biodegradable.

(B) Production of waste materials or byproducts should be prevented.

(C) Energy required for synthesis should be minimum.

(D) Use of catalyst should be avoided as far as possible.

2. Answer the following questions in brief :

(1) Which compound is produced by combination of carbon monoxide with haemoglobin of blood ?

(2) When do we celebrate 'Ozone Layer Protection Day' at international level ?

(3) What should be the desirable amount of total dissolved solids in drinking water as per the BIS ?

(4) Write names of two physical methods used for purification of water.

(5) Which two chemicals are being used for dry cleaning of clothes as per the principles of green chemistry ?

(6) Write full forms : ODS, GWP, BOD, COD, WHO, BIS, ICMR, PUC

(7) Define : (1) Environmental Chemistry

(2) Analytical Chemistry

(3) Green Chemistry

(4) Acid Rain

(5) Green House Gas

3. Write answers to the following questions :

(1) What are rapidly biodegradable pollutants, slowly biodegradable pollutants and non-biodegradable pollutants ? Write one example of each.

(2) List the pollutants of troposphere.

(3) Mention names of viable and non-viable particulate pollutants.

(4) Write names of four methods used in making the water germfree.

(5) Write two differences : BOD and COD.

4. Answer the following questions in detail :

(1) Mention gaseous air pollutants. Discuss any two pollutants out of those in terms of their origin and effect.

(2) What is smog ? Explain classical and photochemical smog.

(3) Mention reasons, effects and remedies for global warming.

(4) Mention reasons for the acid rain and discuss its effect.

(5) Mention reasons, effects and remedies for depletion of ozone layer.

(6) Describe water pollutants with their sources.

(7) Mention standards prescribed by BIS for quality of drinking water.

(8) Discuss methods for purification of drinking water.

(9) Discuss main reasons for pollution of soil in detail.

(10) Describe main remedies for prevention of soil pollution.

(11) Mention characteristics of the wastes produced by petroleum and leather industries.

(12) Which remedies should be used for the control of environmental pollution.

(13) Mention the basic principles of green chemistry.

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