Chapter
16

ENVIRONMENTAL CHEMISTRY

"The branch of chemistry which deals with the sources, chemical reaction, transportation and effect of pollutants on the environment and living organism is called environmental chemistry."

This branch of chemistry is inter-related with all other branches of science i.e. Biology, Physics, medicine, agriculture, public health and sanitary engineering etc.

DIVISION OF THE ATMOSPHERE

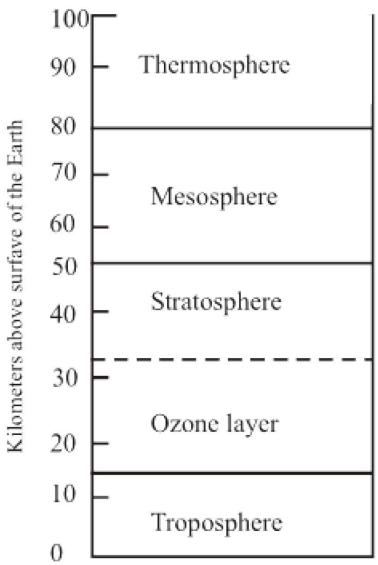
Atmosphere is divided into four layers.

(1) Troposphere:

It is the part of atmosphere in which we live. It is approximately 15 kilometer above the surface of the earth. Very small amount of ozone is present in it.

(2) Stratosphere:

This layer is from 15 km to 50 kilometer above the surface of earth. Stratosphere has a thick layer of ozone in it which absorb ultraviolet radiations of the sun. thickness of ozone layer is about 25-28 kilometers.



Division of the atmosphere and approximate location of the ozone layer

(3) Mesosphere:

This layer is 50 km to 80 km above the surface of the earth.

(4) Thermosphere:

This layer is 80 km above the surface of earth.

COMPONENTS OF THE ENVIRONMENT

The environment consists of the following components.

(1) Atmosphere (2) Hydrosphere

(3) Lithosphere (4) Biosphere

(1) Atmosphere:

The layer of gases which surrounds the earth is called atmosphere.

(i) Composition of Atmosphere:

Gas	%age	Gas	%age
N_2	78	CO_2	0.03
O_2	21	H_2, O_3, CH_4	traces
Ar	0.9	He, Ne, Kr, Xe	Traces

Traces amount of moisture or water vapours are also present in it.

(ii) Tickness:

Its thickness is about 1000 km above the surface of the earth. Half mass of gases is present only up to 5-6 km above the earth surface.

(iii) Good Protector:

The gases (especially O_3) in the atmosphere absorb ultraviolet, cosmic radiations and other radiations of the sun. The absorption of these harmful radiations protects the life on the earth.

(iv) No Life Without Gases:

The gases present in the atmosphere are essential for sustaining life on earth i.e, O_2 is required for breathing, CO_2 is required for photosphynthesis, N_2 is used by nitrogen fixing bacteria and water vapours are responsible for sustaining various forms of life on the earth. Atmosphere also maintains the heat balance of the earth.

(2) Hydrosphere:

"The hydrosphere includes all water bodies, mainly oceans covering approximately 70.8 percent of the surface of the earth." It consists of all water resources i.e., oceans, rivers, streams, lakes polar ice caps, glaciers and ground water reservoirs (water below earth surface).

(i) **Oceans** Contain **97%** of earth's water but because of high salt contents this water cannot be used for human consumption.

(ii) The polar ice caps and glaciers consist of **2%** of the earth's total water supply.

(iii) Only 1% of the total earth's water resources are available as **fresh water** i.e, Surface water; river, lake, stream and ground water. The fresh water is being used by agriculture (69%), industry (23%) and for domestic purpose (8%).

(3) Lithosphere:

"It consists of rigid rocky crust of earth and extend to the depth of 100 km." The mantle and core, are the heavy interior of the earth, making up most of the earth's mass. The 99.5% mass of the lithosphere is made of 11 elements, which are oxygen (~46.60%), Si (~ 27.72%), Al (8.13%), Fe (5.0%), Ca (3.63%), Na (2.83%), K (2.59%), Mg (2.09%) and Ti, H_2 and P (total less than 1%). The elements presents in trace amounts (0.1 to 0.02%) are C, Mn, S, Ba, Cl, Cr, F, Zr, Ni, Sr and V. these elements mostly occur in the form of minerals.

(4) Biosphere / Ecosphere:

"Biosphere is the region of earth capable of supporting life." It includes lower atmosphere, the oceans, rivers, lakes, soils and solid sediments that actively interchange materials with all types of living organisms i.e., human being, animals and plants. Ecosystem is a smaller unit of biosphere which consists of community of organisms and their interaction with environment i.e, animals, plants and microorganisms which lie in a definite zone and depend on the physical factors such as soil, water, and air.

ENVIRONMENT POLLUTANTS

"Any substance in the environment which adversely affects the human health, quality of life and the natural functioning of ecosystem, is known as environment pollutant."

With continuous rapid growth in population, urbanization, industrialization and transportation, environmental pollution is spreading in almost every city of the world. The quantity of pollutants affecting the environments have increased rapidly in the last half-century and they have adversely affected human health and eco-system.

TYPES OF POLLUTION

(1) Air Pollution:

The atmosphere is polluted when harmful substances which damage the environment, human health and quality of life are mixed in it. The main sources of air pollution are:

(i) The waste products given out from chimneys of industrial units and exhaust of automobiles may contain gases such as sulphur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, ammonia, compounds of fluorine and radioactive materials. These waste products are called primary pollutants.

(ii) The primary pollutants in the atmosphere through various reactions produce secondary pollutants such as sulphuric acid, nitrogen monoxide, carbonic acid, hydrofluoric acid, peroxyacetyl-nitrate (PAN), ozone, aldehydes, ketones and peroxybenzol. All these compounds are toxic and their concentration in the atmosphere must be controlled.

Sources of Primary Pollutants:

The pollutants which are directly introduced into the environment are primary pollutants. Some sources of primary pollutants are given below:

(1) Carbon Monoxide:

It is a colourless, odourless and highly toxic gas. It is three times lighter than air. It is soluble in water. CO can be produced by following ways:

(a) Natural:

Natural sources of carbon monoxide emission are volcanic eruption, natural gas emission and oxidation of CH_4 in the atmosphere.

(b) Human Activities:

Fuel burning in various types of transportation i.e,. motor vehicles, railways and aircraft is the major source (75%) of CO in the atmosphere. Other sources of CO emission are forest fires, combustion of fossil fuel and agricultural products.

Carbon monoxide is also emitted from industries in which any type of fuel is burnt in air. These industries include iron and steel, petroleum, cement, brick kilns, etc.

Incomplete combustion and dissociation of CO_2 at high temperature also produces CO.

CO a Quiet Killer:

Carbon monoxide is highly poisonous gas and causes suffocation if inhaled. It binds blood hemoglobin more strongly than oxygen thus excluding oxygen from normal respiration. The CO poisoning can be reversed by giving high pressure oxygen. Exposure to high concentration of CO results in headache, fatigue, unconsciousness and eventually death. It is also called quiet killer.

(2) Nitrogen Oxides:

The gases, nitric oxide NO and nitrogen dioxide NO_2 are represented by NO_x.

(a) Natural Source:

Bacterial action produces NO_x mainly NO.

(b) Human Activities:

Nitrogen oxides are generally produced by combustion of coal, oil, natural gas and gasoline. Both oxides result from the oxidation of nitrogenous compounds present in

fossil fuel. The burning of fuel in the presence of air in internal combustion engine also produces NO.

$$N_2 + O_2 \longrightarrow 2NO$$

Nitrogen dioxide is produced when nitric oxide reacts with oxygen.

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

The residence time of NO and NO_2 in the atmosphere are 4 and 3 days respectively. Due to photochemical reactions, NO_x are converted to HNO_3 which is carried down in either rain fall or as dust.

(3) Sulphur Oxides:

(a) Natural Source:

On global scale most of SO_2 is produced by volcanoes (67%) and by oxidation of sulphur containing gases produced by decomposition of organic matter.

(b) Human Activities:

Air is polluted with SO_2 due to combustion of coal (containing 1-9%S), crude oil and other fossil fuel in power plants and petroleum industry, etc.

$$S + O_2 \longrightarrow SO_2$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

These gases (SO_2 and SO_3) because of their pungent odour are very irritant and suffocating. Through various reactions in the atmosphere, they form sulphate aerosols. These aerosols cause severe respiratory troubles particularly among older people. Sulphur dioxide is the major source of acid deposition in the atmosphere.

(4) Hydrocarbons:

(a) Natural Sources:

Large quantities of hydrocarbons are emitted by different trees and plants in the atmosphere. Paddy fields produce a significant amount of methane in the atmosphere. Another natural source of methane is the anaerobic decomposition of organic matter by bacteria in water sediments and in soils. Methane has a mean residence time of about 3-7 years in the atmosphere.

$$2CH_2O \xrightarrow{\text{Bacteria}} CO_2 + CH_4$$

Human Activities:

Automobiles are the major source of hydrocarbons emission. In addition to this, petroleum, coal, wood, incinerators, refuse burning and solvent evaporator also contribute towards the emission of hydrocarbons into the atmosphere.

EFFECT OF POLLUTED AIR ON ENVIRONMENT

(1) Acid Rain:

"The rain having pH less than 5.6 is called acid rain."

Normal rainwater is slightly acidic due to the presence of CO_2 present in the atmosphere. Carbon dioxide gas reacts with water to form a weak acid (carbonic acid).

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

Main reason of acid rain is SO_2 and NO_2 gases. These gases reacts with water to form sulphuric acid and nitric acid.

$$SO_2 + \frac{1}{2} O_2 + H_2O \xrightarrow[\text{Metals oxide}]{\text{Hydrocarbon smoke}} H_2SO_4$$

$$NO_2 + H_2O \longrightarrow HNO_3 + NO$$

These acids get mixed with the rain and come down on the earth. Acid rian was first of all observed in Great Britain by Augus smin in mid of seventeenth century.

In some countries due to release of HCI by volcanic eruption, there is temporary acid rain.

Acid rain has following effects on environment:

(i) Acid rain corrode the steel, marble, lime stone, paint, plastic, cement, masonry work etc.

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$$

Steel

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

Marble

(ii) By acidification of soil, some nutrients of the soil leaches out and growth of the plants is affected. If a substance comes out from a solid by dissolving it in suitable solvent, it is called **leaching.**

Acidification of the soil and rocks can leach metals like alumium, mercury, lead, calcium etc, into the oceans and rivers. These heavy metals accumulate in the fish and dangerous to birds as well as human being. If concentration of aluminum on water is high it clogs the gills thus causing suffocation.

(2) Smog:

"The word smog is the combination of smoke and fog."

There are two types of smog:

(i) Reducing Smog

This smog contains high contents of SO_2, CO_2 and H_2SO_4. Usually this smog is formed due to the burning of coal which have high contents of sulphur (above 3%).

$$S + O_2 \longrightarrow SO_2$$

Some of the SO_2 changes to SO_3 by atmospheric oxygen and this SO_3 absorb in water to form H_2SO_4.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

SO_2 gas readily absorb in the respiratory system. It is a powerful irritant and is known to aggravate the symptoms in people who suffer from asthma, bronchitis, emphysema and other lung diseases.

(ii) Oxidising Smog (Photochemical Smog):

"The photochemical smog is due do high concentration of unburnt hydrocarbons, nitrogen oxide and ozone is known as photochemical smog." It is also termed as oxidising smog. Photochemical smog occurs in dry and sunny weather.

It is a yellowish grey haze which is formed in the presence of water droplets and chemical reactions of pollutants in the air. It has unpleasant odour because of its gaseous components. The main reactants of photochemical smog are **nitric oxide NO** and **unburnt hydrocarbons.** Nitric oxide is oxidized to nitrogen dioxide within minutes to hours depending upon the concentration of pollutant gas. The yellow colour in photochemical smog is due to the presence of nitrogen dioxide.

The following conditions are required for the formation of smog.

(1) There must be sufficient NO, hydrocarbons and volatile organic compounds (VOC) emitted by the vehicles.

(2) Sunlight, so that some of the chemical reactions takes place at rapid rate.

(3) The movement of air mass must be little so that reactions are not disturbed.

The overall result of photochemical smog in afternoon is the built up of oxidising agent such as H_2O_2, HNO_3, per oxy acetyl nitrate and ozone in the air.

Some initial and secondary reactions are given below which take place in the atmosphere due to pollutants.

Initiation Reaction:

$$NO_2 + \text{Sunlight} \longrightarrow NO + O$$

Secondary Reaction:

$$O + O_2 \longrightarrow O_3$$

$$O_3 + \text{Hydrocarbons} \longrightarrow \text{Aldehydes (RCHO)}$$

Tertiary Reaction:

$$O_3 + \text{Hydrocarbons} \longrightarrow \text{Aldehyde}$$

$$\text{Hydrocarbon} + O_2 + NO_2 \longrightarrow PAN\left(CH_3 - \overset{\overset{O}{\|}}{C} - O - ONO_2\right)$$

PAN is abbreviation for peroxyacetyl nitrate which is eye irritant and also toxic to plants.

(3) Ozone:

Ozone is an allotrope of O_2. It has low boiling point and present in very small amount throughout the atmosphere.

The amount of ozone in the atmosphere is expressed in **Dobson units,** (DU) the normal amount of O_3 in stratosphere is about 350 DU.

Preparation of Ozone:

In the mesoshpere, some molecules of O_2 split into oxygen atoms by short-wavelength, high energy radiations.

$$O_2 \xrightarrow[\text{Radiation}]{\text{Ultra violet}} 2O$$

Some of these highly reactive atoms disffuse down to stratosphere, where they react with oxygen to form ozone.

$$O + O_2 \longrightarrow O_3$$

Ozone layer is present 15 km above the surface of earth and its **thickness is 25 – 28 km.** Ozone is produced in most of the tropical regions by the photochemical reactions oxygen, from where it is transported to polar regions.

Ozone as Pollutant:

(1) It acts as a pollutant and causes various health problems i.e., damages eyes and aggravates asthma, decreases the elasticity of lung tissues, coughing, chest discomfort, etc.

(2) It is harmful to the plants and other materials i.e., attacks rubber, reduces durability and appearance of paint and causes fabrics, dyes to fade. The amount of ozone is less in the regions closer to the equator.

Ozone as Protector:

Ozone layer acts as filter for harmful ultraviolet radiations.

Ozone Hole or Ozone Depletion:

"The decrease in the thickness of ozone layer present in stratosphere is termed as ozone hole" or ozone depletion.

The thickness of the ozone layer has been decreasing over Antarctic during the spring time since the mid 1970C. By the mid of 1980's loss in ozone at some altitudes over Antarctica resulted in about 50% depletion of the total overhead amount. Chlorofluorocarbons are the main culprit for ozone hole.

Chlorofluorocarbons used as refrigerants in air conditioning and in aerosol sprays are inert in the troposphere but slowly diffuse into stratosphere, where they are subjected to ultraviolet radiation generating CI free radicals. Chlorofluorocarbons (CFCs) play effective role in removing O_3 in the stratosphere, due to following reactions.

$$CHCl_3 \longrightarrow CFCl_2 + Cl^{\bullet}$$

$$Cl^{\bullet} + O_3 \longrightarrow ClO^{\bullet} + O_2$$

$$ClO^{\bullet} + O \longrightarrow Cl^{\bullet} + O_2$$

A single chlorine free radical can destroy upto 100,000 ozone molecules.

Chlorofluoro-carbons have been banned in united state of America. But in may countries still it is used as refrigerant.

Ozone and Temperature:

The altitude of troposphere is from 0 – 15 km above the earth surface. The temperature in the troposphere decreases by increasing the altitude. The temperature of troposphere reaches upto $-56^{o}C$ at upper part. Near the earth temperature is greater because radiation which are reflected by the earth are absorbed in the air.

The temperature of stratosphere increase from $-56^{o}C$ to $-2^{o}C$. This increase in temperature of stratosphere is due to the presence of ozone layer. Zone layer is 25 – 28 km thick and absorb the incoming ultraviolet radiations and hence temperature increases.

WATER POLLUTION

Water is essential for the lives of living organisms. All living organisms contain water in their bodies. To sustain our lives we use many liters of water daily. Marine or aquatic life is not possible without water. Water is an essential part of our diet.

Surface water (lakes, rivers, oceans, glacier etc) and ground water are the main sources of water.

The human activities such as livestock waste, landfills, agriculture, pesticides, oil leaks and spills, disposal of industrial effluents on open land, water bodies septic tanks, detergents, mining, petroleum and natural gas production may result in the contamination of the surface and ground waters.

(1) Livestock Waste:

Mostly the livestock waste is either being dumped on the open land or is discharged into sewage, canal or rivers. This practice pollutes the surface water and ground water posing serious health problems to the population. Chemical and bacterial contents in livestock waste can contaminate surface and ground water causing such infectious diseases dysentery, typhoid and hepatitis.

(2) Oil Spillage:

Petroleum or crude oil is a complex mixture of many compounds mainly hydrocarbons. The petroleum products are used as fuel, lubricant, for manufacturing petrochemicals, plastics, electrical appliances, synthetic rubber and detergents, etc. Sea water gets polluted by accidental oil spills and leakage from cargo oil tankers in sea, tanker trucks, pipelines leakage during off shore exploration and leakage of underground storage tanks. Many petroleum products are poisonous and pose serious health problems to human, animal and aquatic life. Hydrocarbons particularly **polycyclic aromatics** are known to be **carcinogenic** even at very low concentrations. The marine organisms are severally affected by soluble aromatic fractions of **oil (C_{10} or less).** The spilled oil damages the **marine life** often causing death. The light transmission through surface of water is affected by oily layer on it, thus photosynthesis of the plants and dissolved oxygen in water is decreased.

(3) Detergent:

Detergents are largely used in industries and household as cleaning agents. The amount of disposed detergents in waste water is increasing day-by-day. This waste water when discharged in rivers or sea, greatly affects the aquatic life, further more, detergent contents of waste water mobilize the bound toxic heavy metal ions such as Pb, Cd, and Hg from sediments into water.

(4) Pesticides:

Pests harm crops and transmit diseases both to human beings and animals. *"Pesticides are the substances that can directly kill an unwanted organism or otherwise control by interfering with its reproduction process."* The current ability to produce large amounts of food on relatively small area of land has been made possible around the world by the use of pesticides,. At present more than ten thousand different types of synthetic organic pesticides have been formulated. They are broadly classified into several principal types according to their general chemical nature. The most important and widely used pesticides are **insecticides** (which kill insects), **herbicides** (which kill undesired plants) and **fungicides** (which control the growth of fungus on the plant).

The use of various pesticides also helped in the eradication of diseases such as malaria, yellow fever, bubonic plague and sleeping sickness.

Wide spread use of pesticides for getting greater crop yields if not properly checked and controlled has associated risks of contaminating the soil, plants and water. The

drainage water from the agricultural land (where the pesticides are being used) mostly contains pesticides. Therefore if the use of any type of pesticide is not properly controlled it enters through various roots i.e., agricultural food products and drinking water into the food chain and thus have serious health problems to both human being and animals.

Organic chemicals in drinking water do not have any healthy effects on human or animal health.

(i) Some organic chemicals may have no detrimental effects at low concentrations. But many compounds once thought safe, especially the synthetic organic chemicals, can have serious and substantial health risks, even at very low concentration. At even **higher concentrations,** most of the compounds are tasteless and odourless.

(ii) It is now known that many of the light molecular mass chlorinated **hydrocarbons in drinking water** are **carcinogens** and they have no safe levels. They cannot be consumed through air, food, or water without the risk of adverse health effects.

(iii) When synthetic organic chemicals are **ingested through food** or drinking water, they can cause health problems. At high concentrations, they can cause nausea, dizziness tremors, and blindness. At lower concentrations, at which these compounds become tasteless and odourless, human may develop skin eruptions or central nervous system impairment. At still lower concentration when ingested over months or years, the compound can cause health problems. With human or animal carcinogens, there is often a long period of time between exposure and manifestation of the disease.

(5) Industrial Waste effluents:

The finished products in any chemical related manufacturing industries i.e., **leather, tanneries, fertilizers, oil refining, petrochemical, textiles, paper pulp and paper board, rubber products, agro-chemicals, leather goods,** etc, are always accompanied by some by-products and waste effluents. The waste products may be in the form of waste heat, smoke, solid or waste water effluents.

The industrial waste pollutants may contain organic chemicals including highly toxic synthetic organic compounds and **heavy metals** i.e., **Pb, Cd, Cr, Hg, As, Sb etc, oils, and greases, mineral acids,** etc. The toxic organic compounds and heavy metals and metalloids results in contamination of both surface and ground water used for irrigation and potable water supply. This also causes irreversible degradation of the environment causing serious health problems for public and marine life.

It must be mentioned here that heavy metals such as Pb, Cd, Cr, As, Hg, etc. are highly toxic and **do not have any safe limits;** they have accumulation effects when ingested through food or water and cause various healt problesm like anemia, kidney diseases, nervous disorder, high blood pressure etc.

(6) Leather Tanneries:

Many leather tanning units, varying from the cottage scale to big industrial units, are working in and around many big cities of Pakistan. They use big quantities of **chromium (Vl) salts** for leather tanning. They are producing good variety of exportable leather. Some units have the facility of waste water treatment by reducing Cr (V1) into trivalent state followed by alkaline precipitation of $Cr(OH)_3$. The effluents are discharged into the open land or put into the sewage system. These industries are the big source of chromium (VI) pollution in the environment. **Chromium (VI) is highly toxic** and is known to cause cancer.

QUALITY OF WATER

The quality of water is measured with the help of following factors.

(i) Dissolved oxygen (DO)

(ii) Biochemical oxygen demand (BOD)

(iii) Chemical oxygen demand (COD)

(1) Dissolved Oxygen (DO):

In water the most important oxidizing agent is dissolved molecular oxygen (O_2) which ranges from 4 – 8 ppm. The organic matters are oxidized with the help of this dissolved oxygen in water. It is a parameter to determine the quality of water. The dissolved oxygen value less than 4 ppm indicates that water is polluted.

(2) Biochemical Oxygen Demand (BOD):

It is the capacity of organic matter in natural water to consume oxygen within a period of five days. *"The value of BOD is the amount of oxygen consumed as a result of biological oxidation of dissolved organic matter in the sample."* The oxidation reaction is catalyzed by microorganisms which are already present in the natural water. It is measured experimentally by calculating the concentration of oxygen at the beginning and at the end of five days period. In this method, a sealed water is maintained in the dark at constant temperature either at 20°C or 25°C. Higher value of BOD means more polluted water.

(3) Chemical Oxygen Demand:

"The organic content of water which consumes oxygen during chemical oxidation is evaluated oxygen demand." The oxygen demand of water can be determined directly by treating it with dechromate ions $Cr_2O_7^{-2}$ which is a powerful oxidizing agent. The organic matter in water is oxidized while the remaining dichromate is determined by volumetric titration.

Value of COD is a direct measure of chemically oxidizable matter in water. Higher values of COD will indicate more pollution.

PURIFICATION OF WATER

Surface or ground water is normally used for drinking purposes.

Ground Water:

"Water which is pumped out from ground is called ground water." This water is more clean than the surface water. This water may or may not require treatment before use.

Surface Water:

"The water obtained from rivers, lakes, glaciers and oceans is called surface water."

Surface water has various contamination in it and required some treatment before use. Water is purified by the following stages.

(1) Aeration:

The quality or raw water is improved by aeration. In this process air is passed through the water. Aeration perform the following functions.

(i) It remove the foul smell gases like, H_2S, organo sulphur compound and volatile organic compounds (VOC).

(ii) Some of the organic materials in the raw water which could be easily oxidized with air produce CO_2 in the aeration process. The remaining portions of organic material if necessary are removed by passing water over activated carbon.

(iii) Aeration process also oxidizes water soluble Fe^{2+} to Fe^{3+} which then forms insoluble $Fe(OH)_3$ and can be removed as solid.

(iv) Aeration also improves the oxygen level of raw water.

(2) Coagulation:

"The process in which colloidal particles will join together to make larger grouping, which can be seen clearly and can be separated out, is called coagulation."

The substance which is used to form grouping of colloidal particles is called **coagulant**, e.g., alum, ferric salts.

The materials which are suspended or present in the colloidal form in raw water are removed by coagulation. The coagulant such as aluminum sulphate or alum is added to the raw water, which causes the precipitation of suspended impurities. For example, alumium hydroxide is precipitated when alum is added to water in alkaline medium i.e.

$$K_2SO_4Al_2(SO_4)_3.24H_2O+3Ca(OH)_2 \longrightarrow 3CaSO_4+2Al(OH)_3+K_2SO_4+24H_2O$$

Many suspended particles get adsorbed on the surface of gelatinous aluminum hydroxide precipitate. Ferric salts are also commonly used as coagulants but they are difficult to handle because an insoluble ferric oxide is produced in the pH range from 3.0 to 13.0.

The process of coagulation can remove more than 80% of the suspended solids in the raw water.

(3) Removal of Hardness of Water:

Hard water contain Ca^{2+} and Mg^{+2} ions in it. Removal of hardness can be done by adding sodium carbonate or washing soda to the water. Calcium and magnesium ions are precipitated out as insoluble carbonates.

$$Ca^{2+}_{(aq)} + Na_2CO_{3(aq)} \longrightarrow CaCO_{3(s)} + 2Na^{+}_{(aq)}$$

$$Mg^{2+}_{(aq)} + Na_2CO_{3(aq)} \longrightarrow MgCO_{3(s)} + 2Na^{+}_{(aq)}$$

Hardness of water can also be removed by ion exchange method. Na-zeolite can remove hardness, of water, by forming Ca-zeolite or Mg-zeolite.

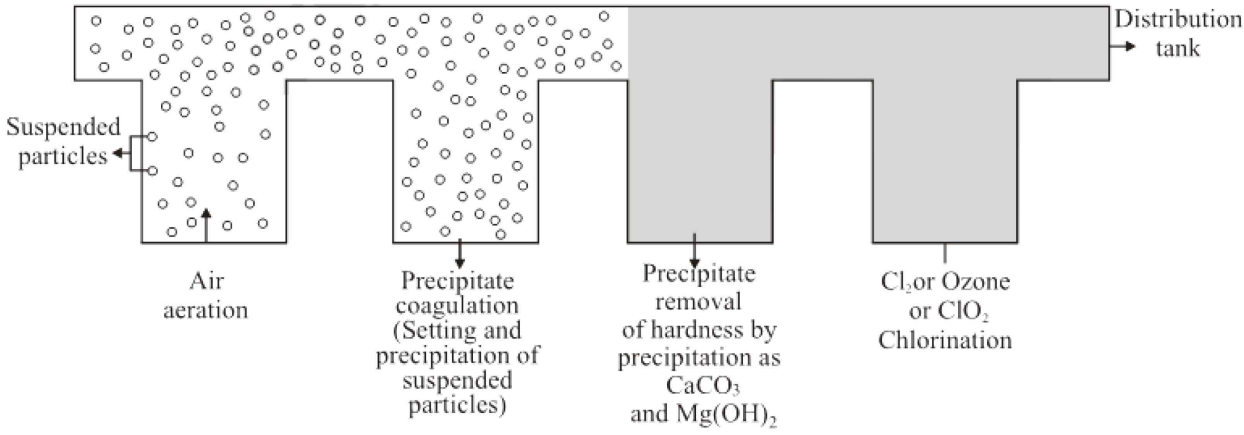
$$Na\text{—zeolite} + Ca^{2+} \longrightarrow Ca\text{—zeolite} + 2Na^{+}$$

(4) Water Disinfections of Chlorination:

Chlorine is frequently used to disinfect water. Chlorine treatment is very effective in killing the pathogens that may cause serious water-borne diseases such as typhoid and cholera which have killed many thousands of people around the world. The most commonly used disinfecting agent is hypochlorous acid HOCl. This neutral covalent compound kills microorganisms readily by passing through their cell membranes. The hypochlorous acid is unstable thus it cannot be stored, it is therefore generated by either dissolving molecular chlorine gas or sodium and calcium hypochlorite in water. Disinfections by chlorines is inexpensive.

$$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$$

Generating HOCl from sodium or calcium hypochlorites avoids the transportation and use of chlorine cylinders.



Harmful Effect of Chlorinated Water:

Chlorinated water has also some harmful effects which are discussed below.

(1) Hypochlorous acid or chlorine of water reacts with dissolved ammonia to form chloramines.

NH_2Cl, $NHCl_2$ and NCl_3 (nitrogen trichloride)

NCl_3 is a powerful eye irritant

$NH_3 + 3HOCl \longrightarrow NCl_3 + 2H_2O$

The alkaline pH can prevent the formation of chloramines.

(2) Chlorination of water containing organic materials also forms some organic compounds which are toxic. For example, if **phenol** is present in water then chlorinated phenols are formed which have offensive odour and taste and are toxic.

(3) Chloroform $CHCl_3$ is formed when hypochlorous acid reacts with organic matter (humic acid) dissolved in water. Chloroform is suspected liver carcinogen and also has negative reproduction and development effects in humans. The risk of bladder and rectal cancer increases by drinking chlorinated water.

To avoid the formation of toxic compounds with chlorine, ozone or chlorine dioxide is used for the disinfections of water.

SOLID WASTE MANAGEMENT

Solid Waste:

"Any unwanted or discarded material from residential, agricultural, commercial or industrial activities that cause environment problems is called solid waste."

For example, plastic paper, cloth, vegetables, rubber, leather, glass, metals, food waste, masonry waste, broken crockery, dead animals, rubbish, etc, are domestic and municipal wastes.

Solid Waste Management:

"The disposal of domestic, commercial, industrial, agricultural, or municipal solid waste is called solid-waste management."

METHODS OF SOLID WASTE-DISPOSAL

Following methods are usually used for the disposal of the solid waste:

(1) Dumping of waste in sea or river.

(2) Landfill

(3) Incineration

(4) Recycling

(1) Dumping of Waste in Sea and Rivers:

Water covers more than 70% of the earth and is valuable source for food and minerals. Sea and rivers have long been used for dumping waste of industrial and municipal discharges such as acids, refinery wastes, pesticides waste, construction and demolition debris, explosives, domestic refuse, garbage and radioactive waste etc. the dumping of waste materials in water has damaged the marine environment and caused health hazards in human beings.

(2) Landfill:

Landfilling is the most common and economic method for solid waste disposal.

Solid waste is mainly disposed by dumping in a landfill.

The landfill is a large hole in the ground or even a bare piece of land. When the landfill becomes full with waste, it is covered by soil or clay. The site of lands is selected on a number of factors such as topography, location of the ground, water table, nature of the solid waste, type of soil and rock and location of disposal zone in the surface water and ground water flow system.

Leachate:

"The ground water which seeps in the landfill and liquid from the waste all percholate through the refuse is called leachate."

The leachate contains many suspended particles, bacteria, heavy metals, salt of common inorganic ions such as Ca^{2+}, Mg^{2+} and volatile organic compounds such as toluene and dichloromethane. Some volatile organic acid like acetic acid and various fatty acids.

The gases which are produced in landfills from the waste are CH_4, H_2S, NH_3, and N_2.

(3) Incineration:

"The controlled combustion of organic matter is called incineration."

Incineration of Municipal Solid Waste:

Municipal solid waste is burned at temperature ranging from 900°C to 1000°C. Incineration of solid waste is done in incinerator.

In incinerator, all combustible material burns and left behind only non-combustible materials.

The ash residues of the incinerator are disposed off an the open land or landfill.

Incinerator method has following advantages:

(i) The method reduce the volume of the solid waste and two-third volume decreases.

(ii) The combustible components of the garbage such as paper, plastic and wood provide fuel for the fire.

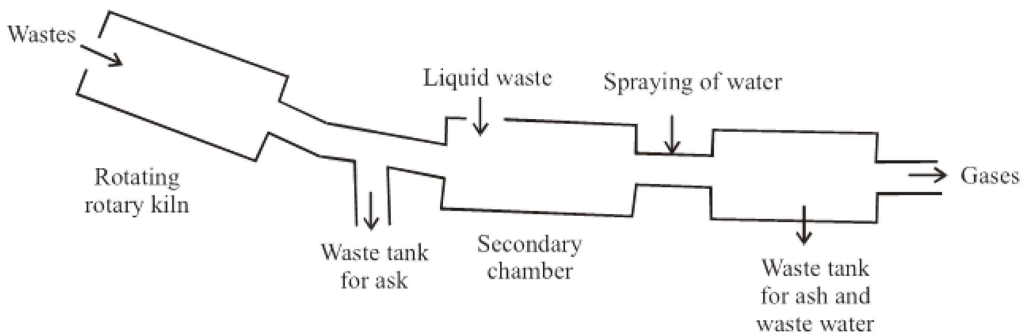
(iii) In incinerator, the heat of combustion may be used in producing steam which can run the turbine and electricity can be produced.

Treatment of Industrial Waste:

The industrial and hazardous wastes are disposed off in landfill or the waste is first incinerated and the residual ash is then disposed off in the landfill. The landfill for the hazardous waste is monitored more regularly for the leakage of the leachate and its design is almost same as that of landfill for the municipal solid waste, except it has more lining of clay and plastic so that the leachate does not contaminate soil and ground water around.

Incineration of Industrial and Hazardous Waste:

A general process of a typical type of high temperature incineration system consists of a rotary kiln which accepts all types of wastes including liquid, solid or sludge. The wastes are burned at temperature between **650° to 100°C.** Ash from the rotating chamber is collected in waste tank and the remaining gaseous materials is passed to the secondary chamber. This chamber is non-rotating and hence the temperature **range of 950° to 1300°C** is maintained. In this chamber organic molecules are completely destroyed. These gases are then cooled to 230°C by evaporating water spray. The cooled gases are then passed through scrubber system which eliminates the surviving particulate and acid forming components like CO_2. Ash residues and wastewater produced in the rotating and secondary chambers are disposed off in the landfills.



Disadvantages of the Incineration Process:

Although the volume of waste reduces to much in incineration but it has following disadvantages:

(i) It is not a clean process and by disposing solid waste by incineration, air pollution increase and some toxic ash is also formed.

(ii) Incineration of the solid waste is a significant source of dioxins which is a class of carcinogen compound.

(iii) Smoke stacks from incineration may emit oxides of nitrogen and sulphur which lead to acid rain.

(iv) Heavy metals such as lead, cadmium, mercury, etc., may also be present in the leachate of the incinerators.

(4) Recycling:

"The process in which solid wastes are not discarded but after processing it is used again, is called recycling."

In our country, glass, paper, plastic and metals such as iron, copper and alumium are recycled.

Recycling has the following advantages:

(1) The volume of the waste reduces.

(2) By recycling one conserve the sources such as raw materials and energy.

(i) Recycling of Paper:

The larger item which is recycled is newspaper and in its recycling process the release of chlorine or other bleaching acids and organic solvents, is significantly less as compared to formation of these compounds during the processing of virgin newspaper. To improve the whiteness of the recycled newspaper it is blended with the virgin newspaper or sometimes treated with peroxides and hydrosulphites. In recycling process the fiber of the **newspaper** becomes shorter so it can be recycled again and again for **five times.**

Total recycling of paper has not been possible so far. Unrecoverable paper is disposed off by incineration process.

(ii) Recycling of Plastic:

"The recycling of plastics is done by reprocessing. It is re-melted and used for the manufacturing of different products." e.g., the original use of polystyrene is for the manufacturing of foam, packaging, cutlery, furniture etc. but after its reprocessing it is used mostly for the manufacturing of toys, trays etc.

(2) De-polymerization:

"The de-polymerization is a process in which the used plastics are converted back into their original components by a chemical or thermal process so that these can be subsequently polymerized again." e.g., polyethylene tere-phthalate can be thermally de-polymerized in the presence of a catalyst and heat into its original components.

(3) Transformation:

"The transformation is a process in which used plastics are converted into low quality substances which are latter used for the production of other materials." e.g., cracking of polyethlene at high temperatures gives its monomers which are used for the manufacturing of lubricants.