Chapter#16

Environmental Chemistry

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1. Define environmental chemistry.

Ans: Environmental chemistry deals with the chemicals and other pollutants in the environment. In this we study the sources, reactions, transportation of the chemicals and other toxic substances especially created by human activity in the environment and their adverse effects on human beings. This branch of chemistry is interrelated with all other branches of science, i.e. biology, physics, medicine, agriculture, public health and sanitary engineering, etc.

2. Write the names of components of environment.

Ans: Environment consists of following four components:-

i. Atmosphere
ii. Hydrosphere
iii. Lithosphere
iv. Biosphere/Ecospher
e

3. Define atmosphere. What is the composition of atmosphere?

Ans: The layer of gases surrounding the earth is called atmosphere. It consists of various gases in different proportions i.e., N_2 (78%), O_2 (21%), Ar (0.9%), CO_2 (0.03 %) and trace amounts of H_2, O_3, CH_4, CO, He, Ne, Kr and Xe. It also contains varying amounts of water vapours.

4. What is the role of atmosphere?

Ans: The gases in the atmosphere absorb most of the cosmic rays and the major portion of the harmful electromagnetic radiation coming from the sun. The absorption of these harmful radiations protects the life on the earth.
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 plant photosynthesis, 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.

5. What is hydrosphere?

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Ans: The hydrosphere includes all water bodies, mainly oceans, rivers, streams, lakes, polarice caps, glaciers and ground water reservoirs (water below earth surface).

6. What is the composition of hydrosphere?

Ans: Oceans contain 97% of earth's water but because of high salt contents this water cannotbe used for human consumption. The polar ice caps and glaciers consist of 2% of the earth's total water supply. 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 purposes (8%).

7. What is lithosphere? Give its composition.

Ans: It consists of rigid rocky crust of earth and extends 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.

8. Give composition of lithosphere.

Ans: 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, H2 and P (total less than 1 %). The elements present 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 ofminerals.

9. What is biosphere?

Ans: 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 beings, animals and plants.

10. What is ecosystem?

Ans: 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.

11. Define environmental pollutant.

Ans: Any substance in the environment which adversely affects the human health, quality of life and the natural functioning of ecosystem, is known as environmental

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pollutant.

12. What are the primary pollutants?

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

13. What are the secondary air pollutants?

Ans: The primary pollutants in the atmosphere through various reactions produce secondary pollutants such as sulphuric acid, carbonic acid, hydrofluoric acid, peroxyacetyl-nitrate (PAN), ozone, aldehydes, ketones and peroxybenzol.

14. CO is a highly poisonous gas. Justify.

Ans: Carbon monoxide is highly poisonous gas and causes suffocation if inhaled. It binds blood haemoglobin 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 (if such exposure is sustained for longer period).

15. What are the natural sources of carbon monoxide?

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

16. How is carbon monoxide released through human activities?

Ans: Fuel burning in various types of transportation i.e., motor vehicles, railways and aircraftis the major source (75%) of carbon monoxide in the atmosphere. Other sources of carbon monoxide 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, paper and pulp, etc. Incomplete combustion and dissociation of CO_2 at high temperature also produces CO.

17. What are the natural sources of nitrogen oxides?

Ans: The natural source of nitrogen oxides is the bacterial action which produces

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nitrogen oxides mainly NO.

18. How are nitrogen oxides produced through human activities?

Ans: 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 producesNO.

$$N_2 + O_2 \xrightarrow{\text{high temperature}} 2NO$$

Nitrogen dioxide is produced when nitric oxide reacts with oxygen

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

19. What are the natural sources of sulphur oxides?

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

20. How sulphur oxides are produced through human activities?

Ans: 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.

$$S + O_2 \longrightarrow SO_2$$

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

21. What are the natural sources of hydrocarbons?

Ans: 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.

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

22. How are the hydrocarbons produced through human activities?

Ans: 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.

23. What is meant by acid rain?

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Ans: The precipitation which is more acidic than natural rain is considered acid rain or acid deposition. The rain water which has pH less than 5 is considered truly acidic.

24. Write down the adverse effects of acid rain.

Ans: Acidification of the soil and rocks can leach metals like aluminium, mercury, lead and calcium and discharges them into water bodies. These heavy metals are accumulated in the fishes and are health hazards for humans and birds as they eat these fishes. The elevated concentration of aluminium is harmful for fish as it clogs the gills thus causing suffocation. Acidification of the soil can also leach nutrients thus damaging leaves and plants and growth of forest. It also damages building materials such as steel, paint, plastic, cement, masonry work and sculptural materials especially of marble and limestone.

25. Define smog.

Ans: The word smog is a combination of smoke and fog.

26. What is reducing smog?

Ans: If smog contains high contents of SO_2 it is chemically reducing in nature and is known as 'reducing smog'. The main cause of reducing smog is combustion of coal.

27. What is oxidizing/photochemical smog?

Ans: Photochemical smog consists of higher concentrations of oxidants like ozone and is also termed as oxidizing smog, it is a yellowish brownish 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 overall result of photochemical smog in afternoon is the built up of oxidizing agents such as H_2O_2, HNO_3, peroxyacetyl nitrate (PAN) and ozone in the air. PAN is an eye irritant and is also toxic to plants.

28. Which conditions are required for the formation of smog?

Ans: 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 vehicular traffic.
2. Sunlight, so that some of the chemical reactions may occur at a rapid rate.

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

29. What is the role of ozone layer?

Ans: The ozone layer, 25 - 28 km high, in the stratosphere surrounds the globe and filters most of the harmful ultraviolet (UV) rays in the sunlight before they could reach on the earth.

30. What are the harmful effects of ozone as a pollutant?

Ans: Ozone is produced in most of the tropical regions by the photochemical reactions of oxygen, from where it is transported to Polar Regions. 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. It is harmful to the plants and other materials i.e., attacks rubber, reduces durability and appearance of paint and causes fabric dyes to fade.

31. What is ozone hole?

Ans: The region in which ozone depletes substantially in every year during Sep-Nov is now termed as "ozone hole".

32. What is the role of chlorofluorocarbons in destroying ozone layer?

Ans: 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 $Cl^{\cdot}$ free radicals. Chlorofluorocarbons (CFCs) play an effective role in removing O_3 in the stratosphere due to following reactions.

$$CFCl_3 \longrightarrow {}^{\cdot}CFCl_2 + Cl^{\cdot}$$
$$Cl^{\cdot} + O_3 \longrightarrow ClO^{\cdot} + O_2$$
$$ClO^{\cdot} + O \longrightarrow Cl^{\cdot} + O_2$$

A single chloride free radical can destroy up to 100,000 ozone molecules.

33. What are the harmful effects of pesticides/organic chemicals?

Ans: Some organic chemicals may have no detrimental effects at low concentrations, but many compounds can have serious and substantial heath risks, even at very low concentrations. At even higher concentrations, most of the compounds are tasteless and

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odourless. Many of the light molecular weight chlorinated hydrocarbons in drinking water arecarcinogens and they have no safe levels.

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

34. How livestock waste causes water pollution?

Ans: Mostly the livestock waste is either being dumped on the open land or is discharged into sewage, canals or rivers. This practice pollutes the surface 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 as dysentery, typhoid and hepatitis.

35. How oil spillage causes threat to aquatic life?

Ans: 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 humans, animals and aquatic life. Hydrocarbons particularly polycyclic aromatics are known to be carcinogenic even at very low concentrations. The marine organisms are severely 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 plantsand dissolved oxygen in water is decreased.

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36. What are the components of insdustrial waste effluents?

Ans: 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.

37. What are the harmful effects of industrial waste effluents?

Ans: 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. The 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 health problems like anemia, kidney diseases, nervous disorder, high blood pressure, etc.

38. How detergents pose threat to aquatic life?

Ans: The waste water containing detergents when discharged in rivers or sea, greatly affects the aquatic life. Detergent contents of waste water mobilize the bound toxic ions of heavy metals such as Pb, Cd and Hg from sediments into water.

39. Which pollutant is produced in leather tanneries?

Ans: Leather tanneries use large quantities of chromium (VI) salts for leather tanning. They are producing good variety of exportable leather, but only some units have the facility of waste water treatment by reducing Cr (VI) into trivalent state followed by alkaline precipitation of $Cr(OH)_3$.
The effluents are discharged onto 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.

40. What is dissolved oxygen (DO)?

Ans: In water the most important oxidizing agent is dissolved molecular oxygen (O_2) the concentration of which ranges from 4 - 8 ppm. The organic matter is 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.

41. What is biochemical oxygen demand (BOD)? How is it determined?

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Ans: 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 which a sealed water sample is maintained in the dark at constant temperature either at 20 °C or 25 °C.

42. What is chemical oxygen demand (COD)? How is it determined?

Ans: The organic content of water which consumes oxygen during chemical oxidation is evaluated by its chemical oxygen demand. The oxygen demand of water can be determined directly by treating it with dichromate ions $Cr_2O_7^{2-}$ which is a powerful oxidizing agent. The organic matter in water is oxidized, while the remaining dichromate is determined volumetric titration. Value of COD is a direct measure of chemically oxidizable matter in water. Higher values of COD will indicate more pollution.

43. Name the stages of water purification.

Ans: Following are the stages of water purification:

a. Aeration
b. Coagulation
c. Chlorination

44. Tell about the aeration technique used in purification of water.

Ans: The quality of raw water is improved by aeration. In this process air is passed through water to remove the dissolved gases such as foul smelling H_2S, organosulphur compounds and volatile organic compounds. 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. Aeration process also oxidizes water soluble Fe^{2+} to Fe^{3+} which then forms insoluble $Fe(OH)_3$ and can be removed as solid. Aeration also improves the oxygen level of raw water.

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45. Tell about the coagulation technique used in the purification of water.

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

$$K_2SO_4.Al_2(SO_4)_3.24\ H_2O + 3Ca(OH)_2 \longrightarrow 3CaSO_4 + 2Al(OH)_3 + K_2SO_4 + 24\ H_2O$$

Many suspended particles get adsorbed on the surface of gelatinous aluminium 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. The surface or ground water may also contain calcium and magnesium salts which make the water hard. The hard water is then appropriately treated to remove Ca^{2+} and Mg^{2+}.

46. How water is disinfected by chlorine?

Ans: 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 HOCI. This neutral covalent compound kills microorganisms readily by passing through their cell membranes. The hypochlorous acid is not stable thus it cannot be stored, it is therefore generated by either dissolving molecular chlorine gas or sodium and calcium hypochlorites in water. Disinfection by chlorine is inexpensive.

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

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

47. What are the harmful effects of chlorination of water?

Ans: Harmful effects of chlorination of water are due to its reactions with dissolved ammonia and organic matters present in water. The hypochlorous acid reacts with dissolved ammonia to form chloramines NH_2Cl, $NHCl_2$ and especially nitrogen trichloride NCl_3 which is a powerful eye irritant.

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

The alkaline pH can prevent the formation of chloramines. 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. 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 disinfection of water.

48. What is a landfill?

Ans: The municipal solid waste is mainly disposed off by dumping it 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.

49. What factors are taken care of during making of a landfill?

Ans: The site of land 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.

50. What is leachate? Give its composition.

Ans: The ground water which seeps in the landfill and liquid from the waste itself all percholate through the refuse producing leachate. The leachate contains dissolved, suspended and microbial contaminants. The gases which are produced in landfills from the waste are methane, ammonia, hydrogen sulphide and nitrogen. The leachate contains volatile organic acids such as acetic acid and various fatty acids, bacteria, heavy metals and salts of common inorganic ions such as Ca^{2+}. The micropollutants present in municipal solid waste include common volatile organic compounds such as toluene and dichloromethane.

51. What is incineration?

Ans: Incineration is a waste treatment process in which solid waste is burned at high temperatures ranging from 900 to 1000 °C.

52. What do you know about incineration?

Ans: Incineration is a waste treatment process in which solid waste is burned at high temperatures ranging from 900 to 1000 °C. The burning of the solid waste in the incinerator consumes all combustible materials leaving behind the non-combustible materials and the ashresidues. The ash residues of the incinerator are disposed off on the land or landfills. The incineration may reduce the volume of the waste by two third. The

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combustible components of garbage such as paper, plastics and wood provide fuel for the fire. In incineration the heat of combustion may be used in producing steam which runs the turbines to produce electricity.

53. What is meant by recycling of waste? Give its importance.

Ans: In recycling some of the used or waste materials are not discarded after their initial use but are processed so that they can be used again. The purpose of recycling is to conserve sources such as raw material and energy. The volume of the waste is also much reduced by recycling of the materials. The most common domestic materials that are recycled are paper, plastic, glass and aluminium.

54. Name the steps involved in recycling of plastics.

Ans: The steps involved in recycling of plastics are:-

i. Reprocessing
ii. Depolymerization
iii. Transformation

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