Class XI
Chemistry
Ch14: Environmental Chemistry

TOP Concepts:

1. **Environmental pollution**: It is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings.

2. **Pollutant**: A substance, which causes pollution, is known as pollutant.

3. Pollutants can be solid, liquid or gaseous substances present in greater concentration than in natural abundance.

4. Pollutants can be natural or anthropogenic:
a. **Natural pollutants**: These are produced due to natural happenings like volcano eruptions etc.
b. **Anthropogenic pollutants**: These are produced due to human activities.

5. Pollutants can be biodegradable or non – biodegradable:
a. **Biodegradable pollutants**: These are the pollutants which rapidly break down by natural processes. Example: discarded vegetables
b. **Non – biodegradable pollutants**: These are the pollutants which are slowly degradable, and remain in the environment in an unchanged form for many decades. For example: DDT, plastic materials, heavy metals, many chemicals, nuclear wastes etc

6. Environmental pollution is of three types:
a. Atmospheric pollution
i. Tropospheric pollution
ii. Stratospheric pollution
b. Water pollution
c. Soil and land pollution

7. Atmospheric pollution occurs when the concentration of a normal component of the air or a new chemical substance added or formed in air builds up to undesirable proportions causing harm to humans, other animals, vegetation and materials.

8. **Troposphere**: The lowest region of atmosphere in which the human beings along with other organisms live is called troposphere. It extends up to the height of ~ 10 km from sea level.

9. **Stratosphere**: Above the troposphere, between 10 and 50 km above sea level lies stratosphere.

10. **Tropospheric pollution**: Is because of two types of pollutants:

a. **Gaseous air pollutants**: These are oxides of sulphur, nitrogen and carbon, hydrogen sulphide, hydrocarbons, ozone and other oxidants.
b. **Particulate pollutants**: Particulate pollutants are the minute solid particles or liquid droplets in air. These are present in vehicle emissions, smoke particles from fires, dust particles and ash from industries. Examples of particulate pollutants are dust, mist, fumes, smoke, smog etc.

11. **Oxides of sulphur as pollutant:**
Sources: Burning of fossil fuels containing sulphur
Harmful effects:

- Causes respiratory diseases e.g., asthma, bronchitis, emphysema in human beings.
- Sulphur dioxide causes irritation to the eyes, resulting in tears and redness.
- High concentration of sulphur dioxide leads to stiffness of flower buds which eventually fall off from plants.

12. **Oxides of nitrogen as pollutant:**
Sources:

- At high altitudes when lightning strikes, dinitrogen and dioxygen combine to form oxides of nitrogen.
- Burning of fossil fuel in an automobile engine, at high temperature, dinitrogen and dioxygen combine to yield significant quantities of nitric oxide (NO) and nitrogen dioxide (NO_2).

$$N_2\,(g) + O_2\,(g) \xrightarrow{1483K} 2\,NO\,(g)$$

$$2\,NO\,(g) + O_2\,(g) \rightarrow 2\,NO_2\,(g)$$

Harmful effects:

- Damage the leaves of plants and retard the rate of photosynthesis
- Nitrogen dioxide is a lung irritant that can lead to an acute respiratory disease in children
- It is toxic to living tissues also
- Nitrogen dioxide is also harmful to various textile fibres and metals

13. **Hydrocarbons as pollutant:**
Source: Incomplete combustion of fuel used in automobiles
Harmful effects:

- Hydrocarbons are carcinogenic, i.e., they cause cancer
- They harm plants by causing ageing, breakdown of tissues and shedding of leaves, flowers and twigs

14. **Oxides of carbon as pollutant:**
a. Carbon monoxide:
Source:

- Incomplete combustion of carbon of coal, firewood, petrol, etc
- By automobile exhaust

Harmful effects:

It is highly poisonous to living beings because of its ability to block the delivery of oxygen to the organs and tissues. It binds to haemoglobin to form carboxyhaemoglobin, which is about 300 times more stable than the oxygen-haemoglobin complex. In blood, when the concentration of carboxyhaemoglobin reaches about 3–4 per cent, the oxygen carrying capacity of blood is greatly reduced. This oxygen deficiency, results into headache, weak eyesight, nervousness and cardiovascular disorder.

b. Carbon dioxide:
Source:

- Respiration
- Burning of fossil fuels for energy
- By decomposition of limestone during the manufacture of cement
- By volcanic eruptions
- Deforestation

Harmful effects:

- Causes global warming

15. **Green house effect:** About 75 % of the solar energy reaching the earth is absorbed by the earth's surface, which increases its temperature. The rest of the heat radiates back to the atmosphere. Some of the heat is trapped by gases such as carbon dioxide, methane, ozone, chlorofluorocarbon compounds (CFCs) and water vapour in the atmosphere. Thus, they add to the heating of the atmosphere. This causes global warming.
This trapping of the sun's heat near the earth's surface and keeping it warm is called natural greenhouse effect. It maintains the temperature and makes the earth perfect for life.
If the amount of carbon dioxide crosses the delicate proportion of 0.03 per cent, the natural greenhouse balance may get disturbed. This may lead to global warming.

16. **Green house:** In a greenhouse, visible light passes through the transparent glass and heats up the soil and the plants. The warm soil and plants emit infrared radiations. Since glass is opaque to infrared (heat) radiations, it partly reflects and partly absorbs these radiations. This mechanism keeps the energy of the sun trapped in the greenhouse.

17. **Global warming:** An increase in the average temperature of the earth's atmosphere (especially a sustained increase that causes climatic changes) which may be caused by additional heat being trapped by greenhouse gases.

18. **Acid rain:** Normally rain water has a pH of 5.6 due to the presence of H^+ ions formed by the reaction of rain water with carbon dioxide present in the atmosphere.

$$H_2O(l) + CO_2(g) \qquad H_2CO_3(aq)$$

$$H_2CO_3(aq) \qquad 2\,H^+ + CO_3^{2-}$$

Source: Burning of fossil fuels (which contain sulphur and nitrogenous matter) such as coal and oil in power stations and furnaces or petrol and diesel in motor engines produce sulphur dioxide and nitrogen oxides. SO_2 and NO_2 after oxidation and reaction with water are major contributors to acid rain, because polluted air usually contains particulate matter that catalyses the oxidation.

$$2SO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 2H_2SO_4(aq)$$

$$4NO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 4HNO_3(aq)$$

Harmful effects:

- Harmful for agriculture, trees and plants as it dissolves and washes away nutrients needed for their growth.
- Causes respiratory ailments in human beings and animals.
- Affects plant and animal life in aquatic ecosystem when acid rain falls and flows as ground water to reach rivers, lakes etc.
- Corrodes water pipes resulting in the leaching of heavy metals such as iron, lead and copper into the drinking water.
- Damages buildings and other structures made of stone or metal. The Taj Mahal in India has been affected by acid rain.

19. **Particulates in the atmosphere may be viable or non-viable:**

a. Viable are minute living organisms that are dispersed in the atmosphere. Example: bacteria, fungi, moulds, algae etc.
b. Non-viable particulates may be classified as:
    i. Smoke particulates: consist of solid or mixture of solid and liquid particles formed during combustion of organic matter. Example: cigarette smoke, smoke from burning of fossil fuel, garbage and dry leaves, oil smoke etc.
    ii. Dust: composed of fine solid particles (over 1μm in diameter), produced during crushing, grinding and attribution of solid materials. Sand from sand blasting, saw dust from wood works, pulverized coal, cement and fly ash from factories, dust storms etc., are some typical examples of this type of particulate emission.
    iii. Mists: Are produced by particles of spray liquids and by condensation of vapours in air. Example: sulphuric acid mist and herbicides and insecticides that miss their targets and travel through air and form mists.
    iv. Fumes: Are generally obtained by the condensation of vapours during sublimation, distillation, boiling and several other chemical reactions. Generally, organic solvents, metals and metallic oxides form fume particles.

20. **Smog:** Smoke is a mixture of smoke, dust particles and small drops of fog.

21. **Smog is of two types:**

Classical Smog	Photochemical Smog
1. It occurs in cool humid climate.	1. It occurs in warm, dry and sunny climate.
2. It is a mixture of smoke, fog & sulphur dioxide.	2. Components of photochemical smog result from the action of sunlight on unsaturated hydrocarbons & oxides of nitrogen produced by automobiles & factories.
3. It is also called reducing smog.	3. It is also called oxidizing smog.

22. **Formation of photochemical smog:**

Burning of fossil fuels

↓

Emission of a variety of pollutants (hydrocarbons and nitric oxide to troposphere

↓

At high levels, leads to

↓

Chain reaction between pollutants and sunlight:

$$2NO(g) + O_2(g) \xrightarrow{\text{sunlight}} 2\,NO_2(g)$$

$$NO_2(g) \xrightarrow{\text{sunlight}} NO(g) + O(g)$$

$$O(g) + O_2(g) \quad O_3(g)$$

$$O_3(g) + NO(g) \longrightarrow NO_2(g) + O_2(g)$$

↓

NO_2 and O_3 are strong oxidising agents and can react with the unburnt hydrocarbons in the polluted air to produce chemicals such as formaldehyde, acrolein and peroxyacetyl nitrate (PAN).

23. **Effects of photochemical smog:**

- Ozone and PAN act as powerful eye irritants.
- Ozone and nitric oxide irritate the nose and throat and their high concentration causes headache, chest pain, and dryness of the throat, cough and difficulty in breathing.

- Photochemical smog leads to cracking of rubber and extensive damage to plant life.
- It also causes corrosion of metals, stones, building materials, rubber and painted surfaces.

24. **Control of photochemical smog:**
- Use of catalytic converters in automobiles, which prevent the release of nitrogen oxide and hydrocarbons to the atmosphere.
- Certain plants e.g., Pinus, Juniparus, Quercus, Pyrus and Vitis can metabolise nitrogen oxide and therefore, their plantation could help in this matter.

25. Stratospheric pollution is basically due to ozone layer depletion.

26. **Formation of ozone in stratosphere:**

$$O_2(g) \xrightarrow{UV} O(g) + O(g)$$

$$O(g) + O_2(g) \overset{UV}{} O_3(g)$$

27. **Depletion of ozone layer:**
Release of chlorofluorocarbon compounds (CFCs), also known as freons lead to their mixing with the normal atmospheric gases and eventually reach the stratosphere.
In stratosphere,

$$CF_2Cl_2(g) \xrightarrow{UV} \dot{Cl}(g) + \dot{C}F_2Cl(g)$$

$$\dot{Cl}(g) + O_3(g) \longrightarrow \dot{Cl}O(g) + O\ (g)$$

$$\dot{Cl}O(g) + O(g) \longrightarrow \dot{Cl}(g) + O_2(g)$$

This way, the chlorine radicals are continuously regenerated and cause the breakdown of ozone layer.

28. **Ozone hole over Antarctica:**
In summer season, nitrogen dioxide and methane react with chlorine monoxide and chlorine atoms forming chlorine sinks, preventing much ozone depletion.

$$\dot{Cl}O(g) + NO_2(g) \longrightarrow ClONO\ (g)$$

$$\dot{Cl}(g) + CH_4(g) \longrightarrow \dot{C}H_3(g) + HCl\ (g)$$

In winter, special type of clouds called polar stratospheric clouds are formed over Antarctica. These polar stratospheric clouds provide surface on which chlorine nitrate formed gets hydrolysed to form hypochlorous acid.

$ClONO_2(g) + H_2O(g) \longrightarrow HOCl(g) + HNO_3(g)$

It also reacts with hydrogen chloride produced to give molecular chlorine.

$ClONO_2(g) + HCl(g) \longrightarrow Cl_2(g) + HNO_3(g)$

When sunlight returns to the Antarctica in the spring, the sun's warmth breaks up the clouds and HOCl and Cl_2 are photolysed by sunlight.

$HOCl(g) \xrightarrow{h\nu} \dot{O}H(g) + \dot{C}l(g)$

$Cl_2(g) \xrightarrow{h\nu} 2\dot{C}l(g)$

The chlorine radicals thus formed, initiate the chain reaction for ozone depletion.

29. **Effects of depletion of the ozone layer:**

With the depletion of ozone layer, more UV radiation filters into troposphere. UV radiations lead to:

- Ageing of skin, cataract, sunburn and skin cancer etc in human beings
- Killing of many phytoplanktons
- Damage to fish productivity
- Affect the plant proteins which lead to the harmful mutation of cells
- Increases the evaporation of surface water through the stomata of the leaves and decreases the moisture content of the soil
- Increase in UV radiations damage paints and fibres, causing them to fade faster

30. **Water pollution:**

Major water pollutants	Sources	Harmful effects
Pathogens (Micro-organisms)	Domestic sewage	Cause gastrointestinal diseases.
Organic wastes (leaves, grass, trash)	Domestic sewage, animal excreta and waste, decaying animals and plants, discharge from food processing factories	Lead to decrease in concentration of dissolved oxygen in water and lead to death of aquatic life
Plant nutrients	Chemical fertilizers	
Toxic heavy metals (cadmium, mercury, nickel)	Industries and chemical factories	Can damage kidneys, central nervous system, liver etc
Sediments	Erosion of soil by agriculture and strip mining	
Pesticides	Chemicals used for	Lead to eutrophication

(insecticides, herbicides , fungicides)	killing insects, fungi and weeds	
Radioactive substances	Mining of uranium containing minerals	
Heat	Water used for cooling in industries	

31. **Biochemical Oxygen Demand (BOD):** The amount of oxygen required by bacteria to break down the organic matter present in a certain volume of a sample of water is called BOD.

32. **Eutrophication:** The process in which nutrient enriched water bodies support a dense plant population, which kills animal life by depriving it of oxygen and results in subsequent loss of biodiversity, is known as eutrophication.

33. **Some constituents of drinking water:**

Constituent	**Maximum concentration**	**Harmful effects of higher concentration**
Fluoride	1 ppm or 1 mg dm^{-3}	Causes brown mottling of teeth
Lead	50 ppb	Can damage kidney, liver, reproductive system etc
Sulphate	500 ppm	Causes laxative effect
Nitrate	50 ppm	Causes disease such as methemoglobinemia ('blue baby' syndrome)
Metals		
Fe	0.2 ppm	
Al	0.05 ppm	
Mn	0.2 ppm	
Cu	3.0 ppm	
Zn	5.0 ppm	
Cd	0.005 ppm	

34. **Pesticides:** They are basically synthetic toxic chemicals with ecological repercussions.

35. **Herbicides:** They are used to kill weeds or undesirable vegetation. Example: sodium chlorate ($NaClO_3$), sodium arsinite (Na_3AsO_3)

36. **Strategies to control environmental pollution:**

a. Water management

- Segregate the water as biodegradable and non- biodegradable waste:
  - Biodegradable waste:
    - ✓ Generated by cotton mills, food processing units, paper mills, and textile factories.
    - ✓ Management: are deposited in landfills and are converted into compost
  - Non – biodegradable water:
    - ✓ Generated by thermal power plants which produce fly ash; integrated iron and steel plants which produce blast furnace slag and steel melting slag
    - ✓ Management:
      - Recycling
      -Toxic wastes are usually destroyed by controlled incineration

c. Green chemistry: Green chemistry is a strategy to design chemical processes and products that reduces or eliminates the use and generation of hazardous substances. The chemical reactions should be such that the reactants are fully converted into useful environmental friendly products by using an environment friendly medium so that there would be no chemical pollutants introduced in the environment.

37. **Green chemistry in daily life:**

Purpose	Earlier	Now
Dry cleaning of clothes	Tetrachloroethene ($Cl_2C=CCl_2$) which contaminates the ground water	Liquefied carbon dioxide, with a suitable detergent
Bleaching of paper	Chlorine gas	Hydrogen peroxide (H_2O_2) with suitable catalyst