ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL FOR CHEMISTRY (CLASS-11)

TOPIC- ENVIRONMENTAL CHEMISTRY

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Environmental chemistry is the branch of chemistry which is concerned with the chemical phenomenon occurring in the environment.

Classification of Environment

1.**Atmosphere**

Atmosphere is Ii gaseous mixture of air that surrounds the earth. Its different layers are as

(1) **Troposphere** It is the lowest region of the atmosphere extending from earth's surface to the lower boundary of the stratosphere. It contains water vapours and is greatly affected by air pollution.

(ii) **Stratosphere** The layer of the earth's atmosphere above the troposphere and below the mesosphere, is called stratosphere. Ozone layer to; present in this region.

(iii) **Mesosphere** It is the region of the earth's atmosphere above the stratosphere and below the thermosphere. It is the coldest region (temperature – 2 to 92°C) of atmosphere.

(iv) **Thermosphere** The upper region of the atmosphere above the mesosphere is called thermosphere It is the hottest region (temperature up to 1200°C).

(v) **Exosphere** It is the uppermost region of atmosphere. It contains atomic and ionic O_2, H_2 and He.

2. **Hydrosphere**

It is the aqueous envelop of the earth e.g., oceans. lakes etc.

3. **Lithosphere**

The solid rocky portion of the earth constitute the lithosphere.

4. **Biosphere**

The biological envelop which supports the life is called biosphere. e.g., animal, human beings.

Environmental Pollution

It may be described as contamination of environment with harmful wastes mainly arising from certain human activities. These activities release materials which pollute atmosphere, water and soil.

Types of Pollutions

(i) **Natural pollution** This type of pollution is caused by the natural sources e.g., volcanic eruptions. release of methane by paddy fields and cattles, forest fires etc.
(ii) **Man-made pollution** This type of pollution is resulting from human activities like burning of the fuels, deforestation, industrial effluents, pesticides etc.

Pollutants

Any substance produced either by a natural source or by human activity which causes adverse effect on the environment is called pollutant.

Pollutants can be of the following types depending upon the following factors:

Classification on the Basis of Their Degradation

(i) **Biodegradable pollutants** Pollutants capable of being degraded by biological or microbial actions are called biodegradable pollutants, e.g., domestic sewage.
(ii) **Non-biodegradable pollutants** The substances which are normally not acted upon by microbes are called non-biodegradable pollutants. These undergo biological magnification.
They can further be of two types

(i) Wastes, e.g., glass, plastic, phenols

(ii) Poisons, e.g., radioactive substances, Hg salts, pesticides. heavy metals.

Classification on the Basis of Their Occurrence in Nature

(i) **Primary pollutants** These are present in same form in which these are added by man e.g., DDT. pesticides. fertilizers etc.
(ii) **Secondary pollutants** These occur in different forms and are formed by the reaction between the primary pollutants in the presence of sunlight e.g., HNO_3, H_2SO_4 PAN, ozone etc.

Classification on the Basis of Their Existence in Nature

(i) **Quantitative pollutants** These are naturally present in nature and also added by man. These become pollutants when their concentration reaches beyond a threshold value in the environment, e.g., CO2, nitrogen oxide etc.
(ii) **Qualitative pollutants** These arc not present in the nature but are added by nature only due to human activities. e.g., pesticides. fungicides. herbicides etc.

Tropospheric Pollution

It is caused by gaseous pollutants and particulate matter.

Gaseous air pollutants Oxides of sulphur (SO_x), oxides of nitrogen (NO_x), oxides of carbon (CO, CO_2), hydrogen sulphide (H_2S), hydrocarbons etc.
Particulate pollutants Dust, fumes. mist, smoke etc.

Air Pollution

Air pollution occurs when the concentration of a normal component of the air or a new chemical substance added or formed in air, build up to
undesirable proportions causing harm to humans, animals, vegetation and materials. The chemical substances and particles causing pollution are called air pollutants.

Air Pollutants

The major air pollutants are

(i) **Carbon monoxide** (CO) It is produced by incomplete combustion of gasoline in motor vehicles, wood. coal, incineration and forest fires. It induces headache, visual difficulty, coma or death. It blocks the normal transport of oxygen from the lungs to other parts of the body, by combining with haemoglobin of the blood. (Its affinity towards haemoglobin is about 200 times more than the oxygen.)
(ii) **Sulphur dioxide** (SO_2) It is produced by petrol combustion, coal combustion, petrol refining and smelting operation.
It obstruct the movement of air in and out of lungs. It is particularly poisonous to trees causing chlorosis and dwarfing. In the
presence of air. it is oxidised to SO_3 which is also an irritant.
$2SO_2 + O_2$ (air) $\rightarrow 2SO_3$
Taj Mahal is reported to be affected by SO_2 and other pollutants released by oil refinery of Mathura.
(iii) **Oxides of nitrogen** NO_2 and NO are obtained by combustion of coal, gasoline. natural gas. petroleum refining, chemical industries and tobacco smoke. In upper atmosphere. these are emitted by high flying jets and rockets.
Breathing NO_2 causes chlorosis to plants and chronic lung conditions leading to death in human beings . These oxides destroy ozone layer.
(iv) **Smoke, dust** These are obtained in cement works, iron and steel works. gas works, power generating stations. Coal miners
suffer from black lung disease and textile workers suffer from white lung disease.
(v) **Ammonia** It is produced by fertilizer works.
(vi) **Mercaptans** These are obtained from oil refineries. coke ovens etc.
(vii) **Zn and Cd** These are obtained from zinc industries.
(viii) **Freon** (or CFC'8) Their source is refrigerator.

Smog

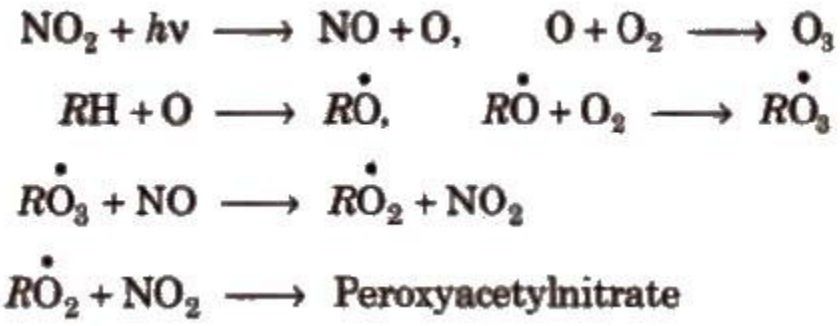
It is a mixture of smoke (composed of tiny particles of carbon, ash and oil etc from coal combustion) and fog in suspended droplet form. It is of
two types:

1. **London smog or classical smog**

It IS coal smoke plus fog The fog part is mainly SO_2 and SO_3. It has sulphuric acid aerosol. It causes bronchial irritation and acid rain. It is reducing in nature and occurs in cool humid climate.

2. **Photochemical smog or Los Angeles smog**

The oxidised hydrocarbons and ozone In a warm. dry and sunny climate cause photochemical smog. Its brown colour is due to the presence of NO_2.
The nitrogen dioxide by absorbing sunlight in blue and UV region decomposes into nitric oxide and atomic oxygen followed by a series of the other reactions producing O_3, formaldehyde, acrolein and peroxyacetyl nitrates.



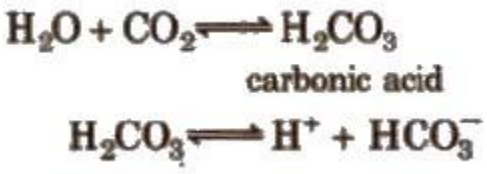
Hydrocarbons + O_2, NO_2 NO, O, O_3 Peroxides, formaldehyde, peroxyacetyl nitrate (PAN), acrolein etc.
It is oxidising in nature and causes irritation to eyes, lungs, nose, asthmatic attack and damage to plants.

Green House Effect and Global Warming
The phenomenon in which atmosphere of earth traps the heat coming from the sun and prevents it from escaping into the outer space is called green house effect. Certain gases, called green house gases [carbon dioxide, methane, ozone, chlorofluorocarbon compounds (CFCs) and water vapour] in the atmosphere absorb the heat given by earth and radiate back it to the surface of the earth. Thus, warming of the earth led to the warming of air due to green house gases. which is called global warming.

Consequences of Green House Effect (or Global Warming)
1. The green house gases are useful in keeping the earth warm with an average temperature of about 15° to 20°C.

2. There may be less rainfall in this temperature zone and more rainfall in the dried areas of the world.

3. Increase in the concentration of CO_2 in the atmosphere leads to increase in the temperature of the earth's surface. As a result evaporation of surface water will increase which further help in the rise of temperature and results in the melting of glaciers and polar ice caps and hence, level of sea water may rise.
ACid Rain
The pH of normal rain water is 5.6 due to the dissolution of CO_2 from atmosphere.



when the pH of rain water drops below 5ppm, it is called acid rain (by Robert Augus.) Oxides of N ans S are responsible for making rain
water acidic, Much of the NO_x and SO_x entering in the atmosphere are converted into HNO_3 and $H2SO_4$ respectively. The detailed photochemical reactions occurring in the atmosphere are given as

$$NO + O_3 \longrightarrow NO_2 + O_2$$
$$NO_2 + O_2 \longrightarrow NO_3 + O_2$$
$$NO_2 + NO_3 \longrightarrow N_2O_5$$
$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

HNO_3 is removed as a precipitate or as particulate nitrates after reaction with bases (like NH_3, particulate lime etc).

$$SO_2 + \frac{1}{2}O_2 + H_2O \xrightarrow[\text{Soot particles}]{(\text{Hydrocarbon, } NO_x)} H_2SO_4$$

The presence of hydrocarbons and NO_x step up the oxidation rate of the reaction. Soot particles are also known to be strongly involved in catalysing the oxidation of SO_2
Acid rain causes extensive damage to building and sculptural materials of marble, limestone, slate. mortal' etc

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

Stratospheric Pollution (Depletion of Ozone Layer)
Ozone is a light bluish gas and absorbs UV radiations of the sun which are harmful to living beings, But nowadays ozone layer is being depleted by CFCs (chlorofluorocarbons).

UV radiations cause the chlorofluorocarbons to dissociate to fOl1D highly reactive chlorine free radical which reacts with ozone to form chlorine monoxide.

$$CF_2Cl_2(g) + h\nu \longrightarrow Cl^{\bullet}(g) + {}^{\bullet}CClF_2(g)$$
(Free radicals)
$$^{\bullet}Cl(g) + O_2(g) \longrightarrow ClO^{\bullet}(g) + O_2$$
$$ClO^{\bullet}(g) + O_2 \longrightarrow Cl^{\bullet} + O_2$$

CI* (free radical) can react WIth more O_3.
Ozone hole is formed over Antarctica. and some parts of non – polar regions also.

In other parts of stratosphere NO_2, CH_4 react with CIO* and cl* respectively and act as natural sink for CIO* and CI*

$$ClO^{\bullet}(g) + NO_2(g) \longrightarrow {}^{\bullet}ClONO_2(g)$$
$$Cl^{\bullet}(g) + CH_4(g) \longrightarrow {}^{\bullet}CH_3(g) + HCl(g)$$

These reactions consume Cl* and ClO* hindrance to ozone depletion.

[In Antarctica, during winters, special types of clouds, called polar stratospheric clouds (PSCs)are formed. These clouds are of two types

Type I Clouds They contain some solidified nitric acid trihydrate ($HNO_3 * 3H_2O$) formed at about -77°C.
Type II Clouds They contain some ice formed at about – 85°C. These clouds play important role in ozone depletion by hydrolysing
chlorine nitra.

$$ClONO_2(g) + H_2O(g) \longrightarrow HOCl(g) + HNO_3(g)$$
$$ClONO_2(s) + HCl(g) \longrightarrow Cl_2(g) + HNO_3(g)$$

Hypochlorous acid and Cl_2 are formed which are reconverted into reactive chlorine atoms with the help of sunlight which causes ozone depletion.]
Polar vortex During winters, when polar stratospheric clouds are formed over Antarctica. stable wind patterns in the stratosphere encircle the continent which is called polar vortex. It is tight whirlpool of winds which is so rigid that air within it is isolated from the sun and forms the warmer air of temperate region to fill up ozone hole.
Consequences of Depletion of Ozone Layer
(a) **Loss of sight** The UV radiation damage the cornea and lens of the eyes.
(b) **Effect on immune system** The UV radiations are also likely to suppress immune system.
(c) **Skin cancer** This type of radiation is known to be cancer causing agent.
Water Pollution
The contamination of water by foreign substances which would COnstitute a health hazard and make It unfit for all purposes (domestic, industrial or agriculture etc) is known as water pollution. The polluted Water may have foul odour. bad taste, unpleasant colour etc.

Maximum prescribed concentration of some metals in drinking water is as

Metal	Maximum concentration in ppm
Fe	0.2
Al	0.2
Cu	3.0
Zn	5.0
Cd	0.005

Sources of Water Pollution
(i) **Domestic sewage** Discharge from kitchens, baths, etc.
(ii) **Industrial water** Wastes from manufacturing processes which includes acids, alkalies, pesticides, insecticides, metals. fungicides etc.

(iii) **Oil** From oil spills or washings of automobiles.
(iv) **Atomic explosion** Processing of radioactive materials.
(v) **Suspended particles (organic or inorganic)** Viruses, bacteria, algae, protozoa etc.
(vi) **Wastes from fertilizer** Industries such as phosphates, nitrates, ammonia etc.
(vii) **Clay** Ores, minerals, fine particles of soil.

Effects of Impurities in Water

(a) **Fluorides** Mottling of teeth enamel, above 1 mg/L fluoride causes fluorosis.
(b) **Sulphates** Sulphates of Na, K, Mg cause diarrhoea.
(c) **Lead** It damages kidney, liver, brain and central nervous system.
(d) **Cadmium and mercury** They causes kidney damage.
(e) **Zn** It causes dizziness and diarrhoea. .
(f) **Arsenic** It can cause cramps and paralysis.
(g) **Phosphates from fertilizers** They promote algae growth and reduce dissolved oxygen concentration of water. This process is known as **eutrophication**.

Aerobic and Anaerobic Oxidation

The oxidation of organic compounds present in sewage in the presence of good amount of dissolved or free oxygen (approx, 8.5 mlJL) by aerobic bacteria is called aerobic oxidation. When dissolved or free oxygen is below a certain value, the sewage is called **stale**.
Anaerobic bacteria bring out putrefaction by producing H_2S, NH_3, CH_4, $(NH_4)_2S$ etc. This type of oxidation is called anaerobic oxidation.
The optimum value of dissolved oxygen for good quality of water is 4·6 ppm (4-6 mg/L). The lower the concentration of dissolved oxygen, the more polluted is the water.

Biological oxygen demand (BOD) It is defined as the amount of free oxygen required for biological oxidation of the organic matter under aerobic conditions at 20°C for a period of five days. Its unit is mg/L or ppm.
An average sewage has BOD of 100 to 150 mg/L.

Chemical oxygen demand (COD) It is the measure of all types of oxidisable impurities (biologically oxidisable and biologically inert organic matter such as cellulose) present in the sewage. COD values are higher than BOD values.

Control of Water Pollution

(i) Recycling of waste water

(ii) Use of chemicals Lead poisoning can be cured by giving the patient an aqueous solution of calcium complex of EDTA. Lead ions displace calcium in the EDTA complex to form chelated lead and Ca^{2+}. The soluble lead chelate is excreted with the urine.

$$Ca - EDTA + Pb^{2+} \rightarrow Pb - EDTA + Ca^{2+}$$

(iii) Special techniques such as adsorption, ion exchangers, reverse osmosis, electrodialysis etc.

(iv) Waste water reclamation

Sewage Treatment

It involves the following steps

(i) **Preliminary process** Passing sewage through screens to remove large suspended matter and then through mesh screens to remove solids, gravels, silt etc.
(ii) **Settling process** (sedimentation) The residual water when allowed to stand in tanks, the oils and grease, float on the surface and skimmed off and solids settle down. The colloidal material is removed by adding alum, ferrous sulphate etc. Primary sludge can be separated.
(iii) **Secondary treatment or biological treatment** It is aerobic chemical oxidation or aeration which converts carbon of the organic matter to CO_2, nitrogen into NHJ and finally into nitrite and nitrates, dissolved bases form salts such as NH_4O_2, NH_4NO_3 and $Ca(NO_3)_2$ etc., and secondary sludge is obtained.
(iv) **Tertiary treatment** It is treatment of waste water with time for removal of phosphate which IS then coagulated by adding alum and ferric chloride and removed by filtration. Water is disinfected by adding chlorine.

Secondary sludge forms a good fertilizer for soil as it contains nitrogen and phosphorus compounds.

Soil or Land Pollution
The addition of substances in an indefinite proportion changes the productivity of the soil. This is known as soil or land pollution.

Sources of Soil Pollution
(i) Agricultural pollutants e.g., chemicals like pesticides, fertilizers, bactericides, fumigants. insecticides, herbicides, fungicides.

(ii) Domestic refuge and industrial wastes.

(iii) Radioactive wastes from research centres, and hospitals.

(iv) Soil conditioners containing toxic metals like Hg, Pb, As. Cd etc.

(v) Farm wastes from poultries, dairies and piggery farms.

Control of Soil Pollution
(i) **Use of manures** Manures prepared from animal dung is much better than the commonly used fertilizers.
(ii) **Use of bio- fertilizers** These are the organisms which are inoculated in order to bring about nutrient enrichment of the soil. e.g., nitrogen fixing bacteria and blue-green algae.
(iii) **Proper sewerage system** A proper sewerage system must be employed and sewage recycling plants must be installed.
(iv) **Salvage and recycling** Rag pickers remove a large number of waste articles such as paper, polythene, card board. rags. empty bottles and metallic articles. These are subjected to recycling and this helps in checking soil pollution.
Radioactive Pollution
Cosmic rays that reach the parth from outer space and terrestrial radiation from radioactive elements are natural radiations. This natural or background radiation is not a health hazard due to its low concentration.

Man made sources of radiations include mining; and refining of plutonium and thorium, atomic reactors and nuclear fuel. These are produced during preparation of radio-isotopes. These are of two types: electromagnetic (radio waves UV, IR, α-rays) and particulate.

Other Sources of Radioactive Pollution

(i) **Atomic explosions** Atomic explosions produce radioactive particles which are thrown high up into the air as huge clouds.

The process releases large amount of energy as heat. Due to atomic -explosion nuclear fallout. These radioactive elements may reach the human beings through food chain.

(ii) **Radioactive wastes** Wastes from atomic power plants come in the form of spent fuels of uranium, and plutonium. People working in such power plants, nuclear reactors, fuel processors etc., are vulnerable to their exposure.

(iii) **Radio isotopes** Many radioactive isotopes like C^{14}, I^{125}, p^{32} and their compounds are used in scientific researches. The waste water of these research centres contains the radioactive elements which may reach the human beings through water and food chains.

Effects of Radiations

1. Strontium-90 accumulates in the bones to cause bone cancer and tissue degeneration in number of organs.

2. 1-131 damages WBCs, bone marrow, lymph nodes and causes skin cancer, sterility and defective eye sight.

3. These may cause ionisation of various body fluids, chromosomal aberrations and gene mutations.

4. Radioactive iodine may also cause cancer of thyroid glands.

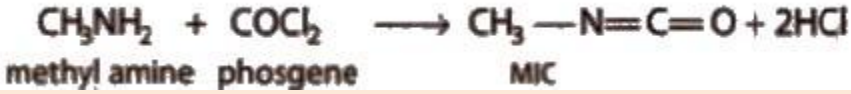
5. Cesium-137 brings about nervous, muscular and genetic change.

6. Uranium causes skin cancers and tumours in the miners.

7. Radon-222 causes leukemia, brain tumours and kidney cancers.

Bhopal Gas Tragedy

In Dec. 2, 1984 a dense cloud of methyl isocyanate gas (Mlq leaked from a storage tank of the Union Carbide ltd plant in Bhopal. It caused a great loss of life to people and animals. Methyl Isocyanate was prepared by the reaction of methyl amine with phosgene and stored in abundance



Green Chemistry-An Alternative Tool for Reducing Pollution

Green chemistry may be called chemistry involved in the design, development, and implementation of chemical products and processes to reduce or eliminate the use and generation of substances hazardous to human health and the environment.

Thus, the goal of green chemistry is ‘to promote the development of products and processes that reduce or eliminate the use or generation of toxic substances associated with the design, manufacture, and use of hazardous chemicals. Some important principles and method of green chemistry are

1. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product. .

3. Whenever possible, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Chemical products should be designed to preserve efficiency of function while reducing toxicity.

5. The use of auxiliary substance (e.g., solvents, separation agents etc.) should be avoided as far as possible.

6. Energy requirements should be recognised for their environmental and economic impacts and should be minimized.

7. Synthetic methods should be conducted at ambient temperature and pressure.

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