1. Details of Module and its structure

Module Detail	
Subject Name	Chemistry
Course Name	Chemistry 01 (Class XI, Semester - 2)
Module Name/Title	Environmental Chemistry: Part 2
Module Id	kech_21402
Pre-requisites	Knowledge about environmental pollution, atmospheric pollution and tropospheric pollution
Objectives	After going through this lesson, the learners will be able to: • Understand causes of ozone layer depletion and its effects • Explain causes of water and soil pollution • Know about international standards for drinking water • Suggest and implement strategies for control of environmental pollution • Appreciate the importance of green chemistry in day to day life.
keywords	Stratospheric Pollution, Ozone Hole, Water Pollution, Soil Pollution, Industrial Wastes and Green Chemistry

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1. Introduction

In the previous module you have learned that atmospheric pollution is generally studied as tropospheric and stratospheric pollution. Tropospheric pollution occurs due to the presence of undesirable solid or gaseous particles in the air. In this module you will learn about stratospheric pollution. Ozone layer is one of the important constituents of stratosphere. Some human activities are produce chemicals that are responsible for the depletion of ozone layer in the stratosphere, leading to the formation of ozone hole. You will also learn about water and soil pollution.

2. Stratospheric Pollution

2.1 Formation and Breakdown of Ozone

The upper stratosphere consists of considerable amount of ozone (O_3), which protects us from the harmful ultraviolet (UV) radiations (l255 nm) coming from the sun. These radiations cause skin cancer (melanoma) in humans. Therefore, it is important to maintain the ozone shield. Ozone in the stratosphere is a product of UV radiations acting on dioxygen (O_2) molecules. The UV radiations split apart molecular oxygen into free oxygen (O) atoms. These oxygen atoms combine with the molecular oxygen to form ozone.

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

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

Ozone is thermodynamically unstable and decomposes to molecular oxygen. Thus, a dynamic equilibrium exists between the production and decomposition of ozone molecules. In recent years, there have been reports of the depletion of this protective ozone layer because of the presence of certain chemicals in the stratosphere. The main reason of ozone layer depletion is believed to be the release of chlorofluorocarbon compounds (CFCs), also known as freons.

These compounds are nonreactive, non-flammable, non-toxic organic molecules and therefore used in refrigerators, air conditioners, in the production of plastic foam and by the electronic industry for cleaning computer parts etc. Once CFCs are released in the atmosphere, they mix with the normal atmospheric gases and eventually reach the stratosphere. In stratosphere, they get broken down by powerful UV radiations, releasing chlorine free radical.

$$CF_2Cl_2(g) \xrightarrow{UV} \dot{C}l(g) + \dot{C}F_2Cl(g) \qquad (i)$$

The chlorine radical then react with stratospheric ozone to form chlorine monoxide radicals and molecular oxygen.

$$\dot{C}l(g) + O_3(g) \rightarrow Cl\dot{O}(g) + O_2(g) \qquad (ii)$$

Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals.

$$Cl\dot{O}(g) + O(g) \rightarrow \dot{C}l(g) + O_2(g) \qquad (iii)$$

The chlorine radicals are continuously regenerated and cause the breakdown of ozone. Thus, CFCs are transporting agents for continuously generating chlorine radicals into the stratosphere and damaging the ozone layer.

2.2 The Ozone Hole

In 1980s atmospheric scientists working in Antarctica reported about depletion of ozone layer commonly known as ozone hole over the South Pole. It was found that a unique set of conditions was responsible for the ozone hole. In summer season, nitrogen dioxide and methane react with chlorine monoxide (reaction iv) and chlorine atoms (reaction v) forming chlorine sinks, preventing much ozone depletion, whereas 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 (reaction iv) gets hydrolysed to form hypochlorous acid (reaction (vi)). It also reacts with hydrogen chloride produced as per reaction (v) to give molecular chlorine.

$$Cl\dot{O}\ (g) + NO_2\ (g) \rightarrow ClONO_2(g) \quad \text{(iv)}$$
$$\dot{C}l\ (g) + CH_4\ (g) \rightarrow \dot{C}H_3(g) + HCl(g) \quad \text{(v)}$$
$$ClONO_2(g) + H_2O\ (g) \rightarrow HOCl\ (g) + HNO_3\ (g) \quad \text{(vi)}$$
$$ClONO_2(g) + HCl\ (g) \rightarrow Cl_2\ (g) + HNO_3\ (g) \quad \text{(vii)}$$

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, as given in reactions (viii) and (ix).

$$HOCl\ (g) \xrightarrow{h\nu} \dot{O}H\ (g) + \dot{C}l(g) \quad \text{(viii)}$$
$$Cl_2\ (g) \xrightarrow{h\nu} 2\dot{C}l\ (g) \quad \text{(ix)}$$

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

2.3 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, skin cancer, killing of many phytoplanktons, damage to fish productivity etc. It has also been reported that plant proteins get easily affected by UV radiations which leads to the harmful mutation of cells. It also increases 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.

3. Water Pollution

Water is essential for life. Without water there would be no life. We usually take water as granted for its purity, but we must ensure the quality of water. Pollution of water originates from human activities. Through different paths, pollution reaches surface or ground water. Easily identified source or place of pollution is called as point source. e.g., municipal and industrial discharge pipes where pollutants enter the water-source. Non point sources of pollution are those where a source of pollution cannot be easily identified, e.g., agricultural run off (from farm, animals and crop-lands), acid rain, storm-water drainage (from streets, parking lots and lawns), etc. Table 1 lists the major water pollutants and their sources.

Table 1

Pollutant	Source
Micro-organisms	Domestic sewage
Organic wastes	Domestic sewage, animal excreta and waste, decaying animals and plants, discharge from food processing factories
Plant nutrients	Chemical fertilizers
Toxic heavy metals	Industries and chemical factories
Sediments	Erosion of soil by agriculture and strip mining
Pesticides	Chemicals used for killing insects, fungi and weeds
Radioactive substances	Mining of uranium containing minerals
Heat	Water used for cooling in industries

3.1 Causes of Water Pollution

(i) Pathogens: The most serious water pollutants are the disease causing agents called pathogens. Pathogens include bacteria and other organisms that enter water from domestic sewage and animal excreta. Human excreta contain bacteria such as *Escherichia coli* and *Streptococcus faecalis* which cause gastrointestinal diseases.

(ii) Organic wastes: The other major water pollutant is organic matter such as leaves, grass, trash etc. They pollute water as a consequence of run off. Excessive phytoplankton growth within water is also a cause of water pollution. These wastes are biodegradable.

The large population of bacteria decomposes organic matter present in water. They consume oxygen dissolved in water. The amount of oxygen that water can hold in the solution is limited. In cold water, dissolved oxygen (DO) can reach a concentration up to 10 ppm (parts per million), whereas oxygen in air is about 200,000 ppm. That is why even a moderate amount of organic matter when decomposes in water can deplete the water of its dissolved oxygen. The concentration of dissolved oxygen in water is very important for aquatic life. If the concentration of dissolved oxygen of water is below 6 ppm, the growth of fish gets inhibited. Oxygen reaches water either through atmosphere or from the process of photosynthesis carried out by many aquatic green plants during day light.

However, during night, photosynthesis stops but the plants continue to respire, resulting in reduction of dissolved oxygen. The dissolved oxygen is also used by microorganisms to oxidise organic matter. If too much of organic matter is added to water, all the available oxygen is used up. This causes oxygen dependent aquatic life to die. Thus, anaerobic bacteria (which do not require oxygen) begin to break down the organic waste and produce chemicals that have a foul smell and are harmful

to human health. Aerobic (oxygen requiring) bacteria degrade these organic wastes and keep the water depleted in dissolved oxygen. Thus, 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 Biochemical Oxygen Demand (BOD). The amount of BOD in the water is a measure of the amount of organic material in the water, in terms of how much oxygen will be required to break it down biologically. Clean water would have BOD value of less than 5 ppm whereas highly polluted water could have a BOD value of 17 ppm or more.

(iii) Chemical Pollutants: As we know that water is an excellent solvent, water soluble inorganic chemicals that include heavy metals such as cadmium, mercury, nickel etc constitute an important class of pollutants. All these metals are dangerous to humans because our body cannot excrete them. Over the time, it crosses the tolerance limit. These metals then can damage kidneys, central nervous system, liver etc. Acids (like sulphuric acid) from mine drainage and salts from many different sources including raw salt used to melt snow and ice in the colder climates (sodium and calcium chloride) are water soluble chemical pollutants.

The organic chemicals are another group of substances that are found in polluted water. Petroleum products pollute many sources of water e.g., major oil spills in oceans. Other organic substances with serious impacts are the pesticides that drift down from sprays or runoff from lands. Various industrial chemicals like polychlorinated biphenyls (PCBs) which are used as cleansing solvent, detergents and fertilizers add to the list of water pollutants. PCBs are suspected to be carcinogenic. Nowadays most of the detergents available are biodegradable. However, their use can create other problems. The bacteria responsible for degrading biodegradable detergent feed on it and grow rapidly. While growing, they may use up all the oxygen dissolved in water. The lack of oxygen kills all other forms of aquatic life such as fish and plants. Fertilizers contain phosphates as additives. The addition of phosphates in water enhances algae growth. Such profuse growth of algae covers the water surface and reduces the oxygen concentration in water. This leads to anaerobic conditions, commonly with accumulation of abnoxious decay and animal death. Thus, bloom-infested water inhibits the growth of other living organisms in the water body. This 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**.

3.2 International Standards for Drinking Water

The International Standards for drinking water are given below and they must be followed.

(i) Fluoride: For drinking purposes, water should be tested for fluoride ion concentration. Its deficiency in drinking water is harmful to man and causes diseases such as tooth decay etc. Soluble fluoride is often added to drinking water to bring its concentration upto 1 ppm or 1 mg dm^{-3}. The F^- ions make the enamel on teeth much harder by converting hydroxyapatite, $[3(Ca_3(PO_4)_2.Ca(OH)_2]$, the enamel on the surface of the teeth, into much harder fluorapatite, $[3(Ca_3(PO4)_2.CaF_2]$. However, F^- ion concentration above 2 ppm causes brown mottling of teeth. At the same time, excess fluoride (over 10 ppm) causes harmful effect to bones and teeth, as reported from some parts of Rajasthan.

(ii) Lead: Drinking water gets contaminated with lead when lead pipes are used for transportation of water. The prescribed upper limit concentration of lead in drinking water is about 50 ppb. Lead can damage kidney, liver, reproductive system etc.

(iii) Sulphate: Excessive sulphate (>500 ppm) in drinking water causes laxative effect, otherwise at moderate levels it is harmless.

(iv) Nitrate: The maximum limit of nitrate in drinking water is 50 ppm. Excess nitrate in drinking water can cause disease such as methemoglobinemia (‘blue baby’ syndrome).

(v) Other metals: The maximum recommended concentrations of some common metals in drinking water are given in Table 2.

Table 2

Metal	Maximum Concentration (ppm or mg dm^{-3})
Fe	0.2
Mn	0.05
Al	0.2
Cu	3.0
Zn	5.0
Cd	0.005

4. Soil Pollution

India being agriculture based economy gives high priority to agriculture, fisheries and livestock development. The surplus production is stored by governmental and non-governmental organisations (NGO) for the lean season. The food loss during the storage also needs special attention. The crops

and food items can be damaged by insects, rodents, weeds and crop diseases. To protect them we need insecticides and pesticides. However, these insecticides, pesticides and herbicides cause soil pollution. Hence, there is a need for their judicious use.

(i) Pesticides

Prior to World War II, many naturally occurring chemicals such as nicotine (by planting tobacco plants in the crop field), were used as pest controlling substance for major crops in agricultural practices. During World War II, DDT was found to be of great use in the control of malaria and other insect-borne diseases. Therefore, after the war, DDT was put to use in agriculture to control the damages caused by insects, rodents, weeds and various crop diseases. However, due to adverse effects, its use has been banned in India.

Pesticides are basically synthetic toxic chemicals with ecological repercussions. The repeated use of the same or similar pesticides give rise to pests that are resistant to that group of pesticides thus making the pesticides ineffective. Therefore, as insect resistance of DDT increased, other organic toxins such as Aldrin and Dieldrin were introduced in the market by pesticide industry. Most of the organic toxins are water insoluble and nonbiodegradable. These high persistent toxins are, therefore, transferred from lower trophic level to higher trophic level through food chain (Fig. 1). Over the time, the concentration of toxins in higher animals reach a level which
causes serious metabolic and physiological disorders.

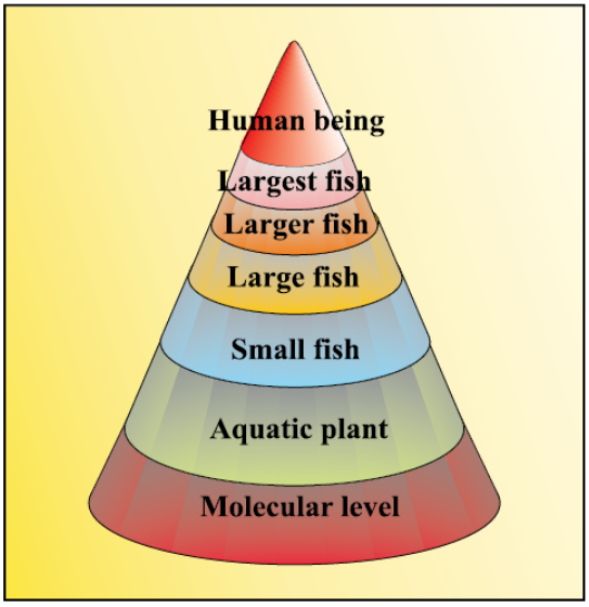


Figure 1

In response to high persistence of chlorinated organic toxins, a new series of less persistent or more bio-degradable products called organo-phosphates and carbamates have been introduced in the market. But these chemicals are severe nerve toxins and hence more harmful to humans. As a result, there are reports of some pesticides related deaths of agricultural field workers. Insects have become resistant to these insecticides also. The insecticide industry is engaged in developing new groups of insecticides. But one has to think any other solution to pest menace. These days, the pesticide industry has shifted its attention to herbicides such as sodium chlorate ($NaClO_3$), sodium arsinite (Na_3AsO_3) and many others. During the first half of the last century, the shift from mechanical to chemical weed control had provided the industry with flourishing economic market. But one must remember that these are also not environment friendly. Most herbicides are toxic to mammals but are not as persistent as organo-chlorides. These chemicals decompose in a few months. Like organo-chlorides, these too become concentrated in the food web. Some herbicides cause birth defects. Studies show that cornfields sprayed with herbicides are more prone to insect attack and plant disease than fields that are weeded manually.

Pesticides and herbicides represent only a very small portion of widespread chemical pollution. A large number of other compounds that are used regularly in chemical and industrial processes for manufacturing activities are finally released in the atmosphere in one or other form.

5. Industrial Wastes

Industrial solid wastes are also sorted out as biodegradable and non-degradable wastes. Biodegradable wastes are generated by cotton mills, food processing units, paper mills, and textile factories. Non-biodegradable wastes are generated by thermal power plants which produce fly ash; integrated iron and steel plants which produce blast furnace slag and steel melting slag. Industries manufacturing aluminium, zinc and copper produce mud and tailings.

Fertilizer industries produce gypsum. Hazardous wastes such as inflammables, composite explosives or highly reactive substances are produced by industries dealing in metals, chemicals, drugs, pharmaceuticals, dyes, pesticides, rubber goods etc. The disposal of non-degradable industrial solid wastes, if not done by a proper and suitable method, may cause serious threat to the environment. New innovations have led to different uses of waste material. Nowadays, fly ash and slag from the steel industry are utilised by the cement industry. Large quantities of toxic wastes are usually destroyed by controlled incineration, whereas small quantities are burnt along with factory garbage

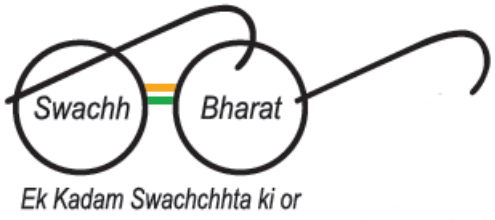
in open bins. Moreover, solid wastes if not managed effectively, affect the components of the environment.

6. Strategies to Control Environmental Pollution

After studying air, water, soil and industrial waste pollution, you must have started feeling the need of controlling environmental pollution: How can you save your immediate environment? Think of the steps/activities, which you would like to undertake for controlling air, water, soil and industrial waste pollution in your neighbourhood. Here, an idea about the strategies for the management of waste is given.

Waste Management

Solid waste is not the only waste, which you see in your household garbage box. Besides household discards, there are medical, agricultural, industrial and mining wastes. The improper disposal of wastes is one of the major causes of environmental degradation. Therefore, the management of wastes is of utmost importance. You must be aware of the '*Swachh Bharat Abhiyan*' or 'Clean India Mission' launched by the Government of India.



Two programmes are being implemented under the broad umbrella of the *Swachh Bharat Abhiyan*. These are *Swachh Bharat Mission–Urban* (SBM–U) and *Swachh Bharat Mission Gramin* (SBM–G). The SBM–U primarily aims at making Urban India free from open defecation and achieving 100% scientific management of solid waste in the country. The SBM–G targets to bring about an improvement in the general quality of life in rural areas by promoting cleanliness and hygiene, and eliminating open defecation. It is accelerating its efforts to achieve the goal of universal sanitation coverage by 2 October 2019, which is the birth aniversary of Mahatma Gandhi.

Collection and Disposal

Domestic wastes are collected in small bins, which are then transferred to community bins by private or municipal workers. From these community bins, these are collected and carried to the disposable site. At the site, garbage is sorted out and separated into biodegradable and non-biodegradable materials. Non-biodegradable materials such as plastic, glass, metal scraps etc. are sent for recycling. Biodegradable wastes are deposited in landfills and are converted into compost. The waste if not collected in garbage bins, finds its way into the sewers. Some of it is eaten by cattle. Non-biodegradable wastes like polythene bag, metal scraps, etc. choke the sewers and cause inconvenience. Polythene bags, if swallowed by animals can cost their lives also. As a normal practice, therefore, all domestic wastes should be properly collected and disposed. The poor management causes health problems leading to epidemics due to contamination of ground water. It is specially hazardous for those who are in direct contact with the waste such as rag pickers and workers involved in waste disposal, as they are the ones who handle waste materials mostly without protective device such as gloves or water proof boots and gas masks. What can you do for them?

7. Green Chemistry

It is well known fact that self-sufficiency in food has been achieved in India since late 20^{th} century by using fertilizers and pesticides and exploring improved methods of farming, good quality seeds, irrigation etc. But overexploitation of soil and excessive use of fertilizers and pesticides have resulted in the deterioration of soil, water and air. The solution of this problem does not lie in stopping the process of development that has been set in; but to discover methods, which would help in the reduction of deterioration of the environment. *Green chemistry is a way of thinking and is about utilising the existing knowledge and principles of chemistry and other sciences to reduce the adverse impact on environment. Green chemistry is a production process that would bring about minimum pollution or deterioration to the environment. The byproducts generated during a process, if not used gainfully, add to the environmental pollution. Such processes are not only environmental unfriendly but also cost-ineffective. The waste generation and its disposal both are economically unsound. Utilisation of existing knowledge base for reducing the chemical hazards along with the developmental activities is the foundation of green chemistry.* It is well known that organic solvents such as benzene, toluene, carbon tetrachloride etc., are highly toxic. One should be careful while

using them. As you know, a chemical reaction involves reactants, attacking reagents and the medium in which the reaction takes place. Extent of any reaction depends upon physical parameters like temperature, pressure and use of catalyst.

In a chemical reaction, if reactants are fully converted into useful environmental friendly products by using an environment friendly medium then there would be no chemical pollutants introduced in the environment.

While designing a synthesis, care must be taken to choose starting materials that can be converted into end products with yield approximately up to 100 per cent. This can be achieved by arriving at optimum conditions of synthesis.

It may be worthwhile to carry out synthetic reactions in aqueous medium since water has high specific heat and low volatility. Water is cost effective, noninflammable and devoid of any carcinogenic effects.

Nobel Prize to Green Chemists



Yves Chauvin, Institut Français du Pétrole, Rueil-Malmaison France, **Robert H. Grubbs** California Institute of Technology (Caltech), Pasadena, CA, USA and **Richard R. Schrock** Massachusetts Institute of Technology (MIT), Cambridge, MA, USA won the 2005 Nobel Prize in chemistry for work that reduces hazardous waste in creating new chemicals. The trio won the award for their development of the metathesis method in organic synthesis –a way to rearrange groups of atoms within molecules that the Royal Swedish Academy of Sciences likened to a dance in which couples change partners. The metathesis has tremendous commercial potential in the pharmaceuticals, biotechnology and food stuffs production industries. It is also used in the development of revolutionary environmentally-friendlier polymers. This represents a great step forward for ‘green chemistry’, reducing potentially hazardous waste through smarter production. Metathesis is an example of how important application of basic science is for the benefit of man, society and the environment.

Green Chemistry in day-to-day Life

(i) Dry Cleaning of Clothes

Tetra chlroroethene ($Cl_2C=CCl_2$) was earlier used as solvent for dry cleaning. The compound contaminates the ground water and is also a suspected carcinogen. The process using this compound is now being replaced by a process, where liquefied carbondioxide, with a suitable detergent is used. Replacement of halogenated solvent by liquid CO_2 will result in less harm to ground water.

(ii) Bleaching of Clothes and Paper

Nowadays, hydrogen peroxide (H_2O_2) is used for the purpose of bleaching clothes in the process of laundary, which gives better results and makes use of lesser amount of water.

Chlorine gas was used earlier for bleaching paper. These days, hydrogen peroxide (H_2O_2) with suitable catalyst, which promotes the bleaching action of hydrogen peroxide, is used.

(iii) Synthesis of Chemicals

Ethanal (CH_3CHO) is now commercially prepared by one step oxidation of ethene in the presence of ionic catalyst in aqueous medium with a yield of 90%.

$$CH_2 = CH_2 + O_2 \xrightarrow[Pd(II)/Cu(II)(\text{in water})]{\text{Catalyst}} CH_3CHO\,(90\%)$$

(iv) 'Green Solution' to Clean Turbid Water

Powder of kernel of tamarind seeds has been found to be an effective material to make municipal and industrial waste water clean. It is non-toxic, biodegradable and cost effective material. This powder is usually discarded as agricultural waste. The present practice is to use alum to treat such water. It has been found that alum increases toxic ions in treated water and can cause diseases.

Green chemistry, in a nutshell, is a cost effective approach which involves reduction in material, energy consumption and waste generation.

8. Summary

- Some of the chemicals produced by human activities are responsible for the depletion of ozone layer in the stratosphere, leading to the formation of ozone hole.

- Through the ozone hole, more ultraviolet radiations can penetrate into the earth’s atmosphere causing mutation of genes.
- Water is the elixir of life but the same water, if polluted by pathogens, organic wastes, toxic heavy metals, pesticides etc., will turn into poison. Therefore, one should take care to follow international standards to maintain purity levels of drinking water.
- Industrial wastes and excessive use of pesticides result into pollution of land mass and water bodies.
- Judicious use of chemicals required for agricultural practices can lead to sustainable development.
- Strategies for controlling environmental pollution can be: (i) waste management i.e., reduction of the waste and proper disposal, also recycling of materials and energy, (ii) adopting methods in day-to-day life, which results in the reduction of environmental pollution.
- The second method is a new branch of chemistry, which is known as green chemistry. It utilizes the existing knowledge and practices so as to bring about reduction in the production of pollutants.