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Indira Gandhi National Open University
School of Interdisciplinary and
Trans-disciplinary Studies

MEV-001
Introduction to Environmental Health

AIR, WATER AND SOIL POLLUTION

2

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Introduction to Environmental Health

Block

2

AIR, WATER AND SOIL POLLUTION

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PROGRAMME DESIGN AND EXPERT COMMITTEE

Dr. (Ms.) Shyamala Mani
Professor, National Institute of Urban Affairs (NIUA) India Habitat Centre New Delhi

Prof. R. Baskar
Department of Environmental Science & Engineering, Guru Jambheshwar University of Science & Technology, Hisar Haryana

Prof. H.J. Shiva Prasad
Professor of Civil Engineering College of Technology, G.B. Pant University of Agriculture & Technology Pant Nagar, Uttarakhand

Dr. T.K. Joshi
Director, Occupational & Environmental Programme, Centre for Occupational & Environmental Health, Maulana Azad Medical College, New Delhi

Prof. Nilima Srivastava
School of Gender and Development Studies, Indira Gandhi National Open University, New Delhi

Prof. S.K. Yadav
School of Agriculture
Indira Gandhi National Open University, New Delhi

Dr. Rachna Agarwal
School of Vocational Education and Training, Indira Gandhi National Open University,
New Delhi

Prof. Daizy R Batish
Department of Botany, Panjab University, Chandigarh

Prof. M. Krishnan
Vice Chancellor, Madurai Kamraj University, Madurai, Tamil Nadu

Dr. Chirashree Ghosh
Department of Environmental Studies, University of Delhi,
New Delhi

Mr. Ravi Agarwal
Director, Toxic Link, Jangpura Extension, New Delhi

Prof. Jaswant Sokhi
School of Sciences, Indira Gandhi National Open University,
New Delhi

Dr. B. Rupini
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University,
New Delhi

Dr. Sushmitha Baskar
Environmental Studies
School of Interdisciplinary and Trans-disciplinary Studies
Indira Gandhi National Open University, New Delhi

Prof. Ruchika Kuba
School of Health Sciences, Indira Gandhi National Open University, New Delhi

Prof. Nandini Sinha Kapur
School of Interdisciplinary and Trans-disciplinary Studies,
Indira Gandhi National Open University, New Delhi

Dr. Shachi Shah
Environmental Studies,
School of Interdisciplinary and Trans-disciplinary Studies
Indira Gandhi National Open University, New Delhi

Dr. V. Venkat Ramanan
Environmental Studies
School of Interdisciplinary and Trans-disciplinary Studies
Indira Gandhi National Open University, New Delhi

Dr. Deeksha Dave
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies,
Indira Gandhi National Open University, New Delhi

Dr. Shubhangi Vaidya
School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University
New Delhi

Dr. Y.S.C. Khuman
School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University
New Delhi

Dr. Sadananda Sahoo
School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University
New Delhi

BLOCK PREPARATION TEAM

Unit 1 to 3
Dr. B. Rupini
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University, New Delhi

Unit 4
Dr. Sushmitha Baskar
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University, New Delhi

PROGRAMME COORDINATORS

Dr. B. Rupini
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University,
New Delhi

Dr. Sushmitha Baskar
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies,
Indira Gandhi National Open University
New Delhi

Prof. Ruchika Kuba
School of Health Sciences,
Indira Gandhi National Open University, New Delhi

COURSE COORDINATOR

Dr. B. Rupini
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University,
New Delhi

CONTENT EDITORS

Prof. Lalita S Kumar, Chemistry, School of Sciences, IGNOU, New Delhi

Prof. Ruchika Kuba School of Health Sciences, IGNOU, New Delhi

Dr. B. Rupini, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, IGNOU, New Delhi

Dr. Sushmitha Baskar, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies,IGNOU, New Delhi)

FORMAT EDITORS

Dr. B. Rupini
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies,
Indira Gandhi National Open University,
New Delhi

Dr. Sushmitha Baskar
Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University,
New Delhi

Secretarial/Technical Assistance: Ms. Sonali, SOITS, IGNOU, New Delhi; Mr. Vikram, SOITS, IGNOU, New Delhi

PRINT PRODUCTION

Mr. S. Burman
Deputy Registrar (P), IGNOU, New Delhi

Mr. Y. N. Sharma
Asst. Registrar (P), IGNOU, New Delhi

Mr. Sudhir
Section Officer (P) IGNOU, New Delhi

February, 2019

ISBN: 987-93-88498-79-1

Further information on the IGNOU courses may be obtained from the University's office at Maidan Garhi, New Delhi or the official website of IGNOU at www.ignou.ac.in

Printed and published on behalf of IGNOU, New Delhi by Registrar, MPDD, IGNOU, New Delhi.

Laser Typeset by Rajshree Computers, V-166A, Bhagwati Vihar, (Near Sec. 2, Dwarka), New Delhi

Printed at:

BLOCK 2 INTRODUCTION

Unit 1 Environmental Chemistry and Pollution provides you an overview of environmental reactions which occur in the atmosphere that causes environmental pollution. You will be surprised to know that every substance or chemical produced by human beings can pollute the environment. It described about chemical interactions between the layers of atmosphere. It makes the learner aware of about good ozone and bad ozone.

Unit 2 Air pollution dealt with some interesting factors about air pollution cause by aerosols which are carried up to the atmosphere for the earth surface. These units explained the role of chemical constituents present in the atmosphere and how the atmosphere is getting polluted by them by undergoing certain chemical process. You will be interested to know about the causes and health effects of outdoor and indoor air pollution. In the course of the unfolding of the unit, we will know various effects of the unit; we will know various effects of air pollution- industrial smog, photochemical smog, Acid precipitation and various pollutants and their health effects and effects on buildings and materials.

Unit 3 deals with the water pollution, physicochemical and biological parameters of water. This unit carries types of H_2O pollutants with specified industries such as Food processing industry, textile industry, tanning industry, paper and pulp industry, due to agro chemicals. This unit also highlighted various sewage treatment methods and emphasizes the role of the Government.

Unit 4 familiarizes us with the soil pollution components. It provided us the ultimate information about definition, causes of soil pollution, and its health effects. It also discussed the prevention measures for soil pollution.

UNIT 1 ENVIRONMENTAL CHEMISTRY AND POLLUTION

Structure

1.0 Objectives

1.1 Introduction

1.2 Environmental Pollution

- 1.2.1 Sources of Pollution
- 1.2.2 Types of Pollution

1.3 Atmospheric Effects and the Reactions in Atmosphere

- 1.3.1 Atmospheric Effects
- 1.3.2 Reactions in Atmosphere
- 1.3.3 Photochemical Reactions
- 1.3.4 Redox Reactions
- 1.3.5 Acid-Base Reactions

1.4 Greenhouse Gases and Global Warming

- 1.4.1 Global Warming Potential
- 1.4.2 Sources of Greenhouse Gases
- 1.4.3 Ozone Layer
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1.5 Let Us Sum Up

1.6 Key Words

1.7 References and Suggested Further Readings

1.8 Answers to Check Your Progresss

1.0 INTRODUCTION

The life on earth cannot exist without its environment or without collaborating with other species or ecosystems, which are the significant units of life on earth. The life cycle of living things involves assembling and de-assembling of various atoms from the environment and returning back to the environment. This cyclic process occurs in three open systems- the biosphere, the lithosphere and the hydrosphere that you have studied in Course -1. These spheres are separated from earth to outer space by a thin layer of gases known as the atmosphere. Matter is continuously interchanging within and amongst all these spheres in the environment. The industrial revolution has played a major role in the change of the atmospheric gases and the presence of particulate matterand their effects on natural environment leading to environmental pollution

In this unit, we begin with defining environmental pollution and classifying it into various types. We would discuss the importance of natural chemical processes and how anthropogenic activities disturb these processes and affect the life adversely on the earth.

1.1 OBJECTIVES

After studying this unit you should be able to:

- define and classify the types of environmental pollution and pollutants;
- describe the different atmospheric effects;
- analyse the concepts of chemical processes of the environment;
- explain various atmospheric reactions;
- define greenhouse gases and explain their effects; and
- describe the process of ozone layer depletion and its impact.

1.2 ENVIRONMENTAL POLLUTION

The term pollution is derived from the Latin word *pollutioneum* which means to defile or make dirty. There are many definitions for pollution worldwide.

According to U.S. President's Science Advisory Committee (1966):

"Environmental pollution may be defined as the unfavorable alterations of our surroundings largely as a byproduct of man's action through direct or indirect effects of change in energy pattern, radiation levels, chemical and physi-cal constitution and abundance of the organisms".

According to **National Academy of Science, USA** (1966), pollution may be de-fined as, "an undesirable change in physical, chemical and bio-logical characteristics of water, air and soil that may harmfully affect human, animal and plant life, industrial progress, living con-ditions and cultural assets."

According to **National Environmental Research Council** (1976), "Pollution is viewed as the release of substances and energy as waste prod-ucts of human activities which result in harmful changes within the natural environment".

According to **Environmental Protection Agency (EPA) -** "Pollution is the presence of substance in the environment that, because of its chemical composition or quantity, prevents the functioning of natural processes and produces undesirable environmental and health effects"

Dear learner after going through these definitions we can come to a consensus that **pollution** is a contamination of air, soil and water with undesirable amounts of material or heat which have adverse effects on natural environment as well as human health.

A **pollutant** may be defined as a physical, chemical or biological substance unintentionally released into the environment, which is directly or indirectly harmful to humans and other living organisms.

1.2.1 Sources of Pollution

Pollution can be classified broadly two types on the basis of their sources. These are given below:

Point Source Pollution (PSP): According to US. Environmental Protection Agency (EPA);it is any single identifiable source of pollution from which pollutants are emitted. Emission of contaminants in to the environment from a particular location is called PSP. For example:

- Emissions from waste water treatment plants
- Toxic effluents from industries
- Sewage effluents

Non-Point Source Pollution: It is the emission of contaminants into the environment from more than one location over a large wide spread area. There is no specific area of source; instead it comes from many unidentifiable areas. For example:

- Toxic chemicals which have not been properly disposed off
- Harmful bacteria and microorganisms from cattle wastes
- Pesticides, fungicides and nutrients from agricultural fields, residential areas.
- Oil, grease, metals and cleaning agents washed from roads, workshops
- Sediments from construction sites, forests and agricultural fields
- Leaching from garbage dumps etc.

Besides these sources of pollution another source of pollution is fugitive emissions. In this the pollutants are released into the atmosphere from leaks in equipment, pipelines, seals, valves etc., but not from the usual source.

Do You Know?

Terminology used in the pollution

Sources: The place from where the pollutants originate is called 'Source'.**Example:** Cooking and heating (combustion) are the sources of CO, NOx, and VOCs.

Sink: The place where the pollutants are transferred/moved/transported from another place or source.

Example: The major sink for atmospheric N_2O is stratosphere wherethe majority undergoes photolysis to give $N_2 + O$.

Receptor: Anything that is negatively affected by the pollutants.

Example: Human beings and plants

Transport: It is the process by whichthe pollution travels from a source to a receptor.

Example: Air and water are the transport medium.

Dispersion: Changes that occur in spreading of the pollution through the environment in the process of transport.

Example: Pollutants from various sources like vehicles, factory emissions dispersed into the atmosphere and removed from the transport medium (air) through deposition due to rain.

1.2.2 Types of Pollution

Pollution may be of the following types:

- **Air Pollution**: Due to the industrial revolution and certain anthropogenic activities the gaseous mixture and particulate matter in our atmosphere began to change and lead to air pollution. Air pollution may be defined as any substance (gases, aerosols) including radioactive radiation present in such concentrations that may have harmful effects on the living things and disturbs the natural environmental processes. The factors which determine the level of air pollution and their effects will be discussed in detail in the following units of this course.
- **Water Pollution**: Presence of undesirable substance in water bodies, which have adverse health effects is called water pollution. The diversity and breadth of impact of pollution caused by the introduction of pathogens, organic wastes, chemical pollutants, sediments and nutrients and their effects will be discussed in detail in the following units of this course.
- **Soil Pollution**: Addition of undesirable substance, which is non-biodegradable that adversely affects the soil quality and fertility, is known as soil pollution. The range of soil pollutants may vary from polluted water to solid waste to acid rain and dry deposition.The details of these types of pollution will be studied in the following units.
- **Noise Pollution**: In general noise is a sound without value. It is a shadowy human health hazard that can damage hearing and evoke other gynecological and pathological reactions besides disturbing rest, sleep and communication that in turn disrupt the balance of human or animal life.
- **Thermal Pollution**: Industries like chemical, thermal andnuclear power plants, utilize water from natural water bodies for cooling the conversion losses. The resultant waste heat energy in the form of hot water gets transferred to the natural waterways and increase its temperature by 10-15^{0}C known as thermal pollution which have deleterious effects on aquatic ecosystem.
- **RadiationPollution**: The emission of energy as electromagnetic waves, which have high energy,addition of radiation to the natural environment by using radioactive elements is known as radiation pollution. All of us are exposed to natural radiation, which comes from radioactive material in the earth like Uranium-238, inhalation of radon gas and radionucleide in food.

The details of these types of pollution will be studied in the following units. In the next section you will study about the atmospheric effects and the reactions taking place in the atmosphere but after answering the following questions.

Check Your Progress 1

Note : a) Write your answer in about 50 words.

b) Check your progress with possible answer given at the end of the unit.

1. Define pollutant and pollution.

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2. List out the types of pollution.

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1.3 ATMOSPHERIC EFFECTS AND THE REACTIONS IN ATMOSPHERE

Dear learners, to understand the pollution and its impacts you have to learn what we mean by the atmospheric effects and the factors responsible for the changes in the components of atmosphere. The study forms the basis of understanding of the concepts involved and the interactions within systems related to biosphere which directly influences the environment as well as the human health by controlling the global and regional environmental conditions. We begin with the atmospheric effects in the following subsection.

1.3.1 Atmospheric Effects

The atmosphere is considered as the smallest geological reservoir of the earth. As mentioned before natural atmosphere has three open systems viz., biosphere, lithosphere and hydrosphere. The lowest layer of atmosphere is known as troposphere, above the troposphere is the stratosphere and beyond the stratosphere are two more layers- mesosphere and thermosphere. All the layers are separated by boundaries called tropopause, stratopause, etc.The composition of the atmosphere is approximately same all over the earth because of the high level of mixing inside the atmosphere. However, some of the meteorological factors keep changing due to changing conditions.The daily alterations in temperature, air, pressure, wind, humidity and precipitation together are known as **atmospheric effects**. By having an understanding of these effects we can easily predict the human induced changes, therefore, these are very significant.

Convection:- The movement of air due to the atmospheric heating and cooling. For example,thunderstorms are the most apparent of the driving forces.

The molecules in the atmosphere absorb light energy and undergo certain reactions which do not occur at normal temperature or in the absence of light. The reactions determine the effect of chemical species responsible for air pollution. The following subsection deals with some of the important reactions that occur in atmosphere.

1.3.2 Reactions in Atmosphere

Most of the chemical reactions in atmosphere take place in the troposphere region. The chemical composition of the atmosphere is balanced due to the chemical reactions which lead to redistribution of chemical species thereby moderate the atmospheric temperatures. This is explained as follows.

The **troposphere** in atmosphere contains a mixture of important gases – O_2, N_2,CO_2,etc. along with water vapour. It is responsible for moderating and the driving energy flow to the earth, which in turn maintains the biogeochemical cycle of the gases and water vapours, etc.The troposphere is also known as “turning sphere”

because it is well mixed by convection process. The gases are generally stable but due to some changes react to form new compounds. The chemical reactions in this part of atmosphere are initiated by the solar radiations. The sun emits radiations with wide range of energies and we are concerned here with visible light that can be recognized by human eye and UV light which cannot be recognized by human eye and is of higher energy than visible light.

The earth gets heated up due to solar energy, which in turn heats up the overlying air causing the convective mixing. This is due to the hot air, which has a tendency to rise. The rising air generates high pressure up in the atmosphere, leaving low pressure area near to earth. The rising air at high pressure is cooled by radiating heat and thereby generates precipitation. Then the air flows horizontally. This pressure difference in air leads to winds.

All the gases are released into the atmosphere by some process. This could be either by natural sources or by anthropogenic sources that occur on the surface of the earth. Along with these gases some electrically charged species also exist. Most of these species found in the troposphere region have oxidising capabilities. The important species which participate in most of the atmospheric reactions are given below.

1. **Hydroxyl radical (OH.):** It is a short lived free radical and effective scavenger for trace gases in this region. Therefore, the hydroxyl radical is known as the detergent of the atmosphere. It is formed during day time by the photochemical reaction series by the photon of light.

$$O_3(g) + h_{\bar{o}} \longrightarrow O_2(g) + O(g) \quad \text{——————} \quad \text{equation} \quad \text{(i)}$$

$$O(g) + H_2O(g) \longrightarrow 2OH\,(g) \quad \text{——————} \quad \text{equation} \quad \text{(ii)}$$

Thehydroxy radical is ubiquitous hence it reacts with various compounds in the atmosphere.

For example:

The reaction between nitrogen dioxide (NO_2) and the OH radical in series of reactions that leads to the formation of nitric acid (HNO_3), one of the contributors to acid rain.

$$NO_{2\,(g)} + OH_{\,(g)} \longrightarrow HNO_{3\,(g)}$$

Kinetic measurements show that some gases (Table 1.1) have slow rates of reactions with the OH radical and have long residence time in the atmosphere. These gases accumulate in the atmosphere and escape across the hydropauseinto the stratosphere.

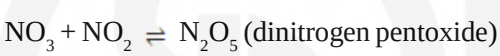
Table 1.1: Naturally occurring trace gases of the atmosphere with their residence time and concentration (from Brimble Comb1986)

Gas	Residence Time	Concentration (ppb)
Carbon dioxide (CO_2)	4 years	360000
Carbon monoxide (CO)	0.1 year	100

CH_4	3.6 years	1600
HCO_2H	10 days	1
N_2O	20-30 years	300
NO	4 days	0.1
NO_2	4 days	0.3
NH_3	2 days	1
SO_2	3-7 days	0.01-0.1
H_2S	1 day	0.05
CS_2	40 days	0.02
OCS	1 year	0.5
CH_3-S-CH_3	1 day	0.0001
CH_3Cl	30 days	0.7
CH_3I	5 days	0.002
HCl	4 days	0.01

2. **Nitrate radical (.NO_3)** - It does not sustain in sunlight hence it is a dominant oxidant during night. It is formed during night time by as low oxidation reaction of NO_2 with ozone. Nitrate free radical again reacts with NO_2 to form N_2O_5 to establish a chemical equilibrium.

$NO_2 + O_3 \longrightarrow NO_3 + O_2$



$NO_3 + NO_2 \rightleftharpoons N_2O_5$ (dinitrogen pentoxide)

3. **Peroxy radical (RO_2.)and Hydroperoxy radical(HO_2.):**

Formation of hydroperoxy radical is as per the following reaction:

$OH + CO + (O_2) \longrightarrow HO_2 + CO_2$

$OH + RH + O_2 \longrightarrow RO_2 + H_2O$

RO_2 further reacts with another molecule of RO_2 either in self-reaction or cross reaction to form HO_2 radical.

For Example:

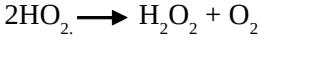
Methyl Peroxyradical

$CH_3O_2 + CH_3O_2 \longrightarrow 2CH_3O.$

$2CH_3O. + O_2 \longrightarrow HO_2. + HCHO$

4. Dismutation: Simultaneous oxidation and reduction reaction in a biological process

Hydrogen peroxide (H_2O_2): The main source of gaseous peroxide is the dismutationof the hydroperoxy radical.



$2HO_2. \longrightarrow H_2O_2 + O_2$

The source of aqueous H_2O_2 is the dissolution of gaseous H_2O_2 into atmospheric hydrometeors. The other sources are reduction of superoxide by organic compounds, hydrogen carbonate, photolysis of aqueous ozone and water vapour photonucleation.

The photonucleation involves mainly the oxidation reaction of S (IV) to S (VI) in aqueous phase. This is the important source of sulphate particles that act as cloud condensation nuclei, which play a key role in the formation of acidic aerosols and acid rain.

Aqueous H_2O_2 is also involved in **Fenton** and **Photofenton** process. The Fenton reagent (Fe (II) + H_2O_2) oxidises organic and inorganic compounds present in water droplets in the atmosphere. In the photolysis process, Fe (III) complexes are converted into Fe (II) in the atmospheric hydrometeors.

Dear learners, having learnt about the species present in the atmosphere we can summarise the synergistic effect of these species in the atmosphere.

In the troposphere, there are three important end-removal processes taking place.

1. Atmospheric pollutants get converted into nonpolluting constituents like water and oxygen.
2. Gaseous pollutants are absorbed by plants, water and soil by the phenomenon of dry deposition.
3. The soluble species are eliminated by the process of precipitation.

H_2O_2 reacts with nitrous acid to form peroxynitrous acid, HOONO. It is highly unstable species and transformed into $\cdot OH$ + $\cdot NO_2$ and $\cdot NO_3$. It also increases the rate of corrosion of silver when exposed to atmosphere.

In the **stratosphere** region, the oxygen molecule (O_2) in the presence of UV radiation forms atomic oxygen. Atomic oxygen further reacts with molecule of oxygen to produce ozone (O_3). For this reason, ozone concentration is higher in the stratospheric region, which forms **ozone layer**. Stratosphere protects the earth surface from the harmful effects of the sun radiation by absorbing UV light. Chlorofluorocarbons (CFCs) are a group of volatile organic compounds (VOCs) capable of reaching stratosphere. These react with UV light to generate chlorine atoms. Chlorine molecules present in atmosphere convert ozone to oxygen molecule hence the concentration of ozone would be decreased.

The chemical reactions which take place in the atmosphere by absorbing solar radiations are:

1. Photochemical reactions
2. Redox reactions
3. Acid base reactions

These are explained in the following subsections.

1.3.3 Photochemical Reactions

Photochemical reactions are the reactions in the atmosphere that are catalysed by the electromagnetic solar radiations. These reactions are controlled by two basic principles given below.

a. Grotthus-Draper Law: It is also known as the principle of **photochemical activation**. It states that the solar radiation (light) must be absorbed by a

compound in order for a photochemical reaction to take place. For example, only the light which is absorbed by a molecule can be effective in producing photochemical changes in the molecules.

Some of the photochemical reactions are given below.

1. **Photosynthesis:** Plants use solar energy to convert carbon dioxide and water into glucose and dispose of oxygen as a by-product. Both carbohydrates and oxygen are required to sustain life on earth.

   $CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$ (g)

2. **Formation of Vitamin D:** It is a vital vitamin for bone and teeth development and kidney function. It is formed by the reaction of 7-dehydrocholesterol with sunlight.

3. **Ozone Formation:** When oxygen is exposed to sunlight it gets converted into ozone which will be discussed in Sec 1.4.

b. Stark- Einstein's Law of Photochemical Equivalence: It states that for each photon of light absorbed by a chemical system only one molecule is activated for subsequent reaction. The energy absorbed by one molecule of the reacting molecules is given by $E = h\upsilon$

Where E= Energy of each quanta

h= Plank's constant (6.6×10^{-27} erg. Sec)

υ = frequency of the radiation

Therefore, the number of molecules absorbing radiation is equal to the number of photons absorbed. This means that one molecule is activated by each quantum of radiation.

a. Primary Photochemical Reactions

In aprimary photochemical reaction molecules absorbs solar radiation, move to the excited state, and are relatively energized and reactive as well. These molecules either transfer the energy to other molecules/atoms or lose their energy by emitting light to reach the normal state.

Example: Photo dissociations

1. $NO_2 \xrightarrow{h\upsilon} NO_2.$

   $NO_2 \longrightarrow NO + O$

2. $NOCl \xrightarrow{h\upsilon} NOCl.$

   $2NOCl \longrightarrow 2NO + Cl_2$

b. Secondary Photochemical Reactions

In a secondary photochemical reaction, it is not necessary that the absorbed radiation by a molecule in the form of photon undergoes further reaction. The absorption of one photon by a molecule in the first step results in the formation of an activated molecule. This may lead to the reaction of more molecules through a chain mechanism.

Example: Formation of Free Radicals

In a chain reaction light energy stimulate a series of reactions by generating **free radicals**, which are reaction intermediates.

For example:

$$SO_2 \xrightarrow{h\upsilon} SO_2$$

$$SO_2 + O_2 \longrightarrow SO_4$$

This reaction can be terminated by reacting with other free radical or suitable species and terminates the reaction.

Example: $SO_{4.} + O_2 \longrightarrow SO_3 + O_2$

$$.CH_3 + .CH_3 \longrightarrow CH_3 - CH_3$$

The other important reaction is the formation of **photochemicalsmog**, where the photooxidation reaction between NO_2 and SO_2 leads to the formation of photochemical smog. The formation of photochemical smog is a significant phenomenon and also an important environmental issue.

Check Your Progress 2

Note : a) Write your answer in about 50 words.

b) Check your progress with possible answer given at the end of the unit.

3. What is a photochemical reaction and explain chain reaction.

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1.3.4 Redox Reactions

Redox reactions are the reactions in which oxidation and reduction reactions occur at the same time with transfer of electrons. These redox reactions in the atmosphere decide the abundance and the effects of many organic and inorganic pollutant species. Kinetics of these reactions indicates that these reactions in the atmosphere are very slow. This significant property is useful in controlling the air pollution.

The abundance of oxygen is very high in the atmosphere.Since it contains21% of oxygen,oxidation reactions in the atmosphere are thermodynamically favourable. The available oxygen in the atmosphere either reduces or oxidises the compounds containing carbon, nitrogen and sulphur.

You know that in oxidation and reduction reactions two components are always present in which one component is oxidised and the other one is reduced. When an organic compound is oxidised by a catalyst, the catalyst itself must be reduced.

Likewise, when an organic compound is reduced by a catalyst, the catalyst getsoxidised. This phenomenon can also be understood by some general statements as given in Fig.1.1.

- Increase in the number of C-O bonds or decrease in the number of C-H bonds is termed as oxidation.
- Increase in the number of C-H bonds or decrease in the number of C-O bonds is termed as reduction.

For example: Formation of CO_2 from methane

Increase in the number of C-O bond

Increase in the number of C-H bonds

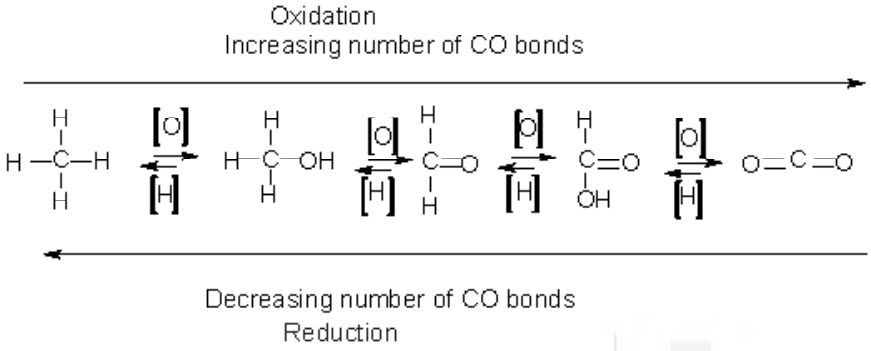

Fig. 1.1: Formation of CO_2 from methane indicating oxidation and reduction reaction

Some of the oxidation-reduction reactions are given below.

1. **Corrosion:** Rusting of Iron

   When iron is exposed to moist air, it converts iron into rust and disintegrates it slowly. Rusting is acommon term used for corrosion of iron. Rust consists of hydrated iron (III) oxides, Fe_2O_3. nH_2O, iron (III) oxide-hydroxide (FeO (OH), Fe $(OH)_3$.

2. **Acid Rain:** Nitric oxide is oxidized to nitrogendioxide then reacts with atmospheric moisture to form nitric acid,whereas sulphur dioxide is oxidised to sulphate radical,then gets converted to sulphuric acid. These compounds precipitate as snow or rain which is known as **acid rain** which we will discuss in detail in Unit-2.

   1. $4NO + 3O_2 \longrightarrow 4NO_2$

      $4NO_2 + 2H_2O \longrightarrow 4HNO_3$

   2. $SO_2 + O_2 \longrightarrow 2SO_4^{-2}$

      $2SO_4^{-2} + 2H_2O \longrightarrow 2H_2SO_4$

The products from these reactions show adverse effects on the atmosphere like the photochemical smog that will be discussed in Unit-2.

1.3.5 Acid- Base Reactions

All the species existing in the atmosphere can be classified either as acids, bases or salts. Acid-base reactions occur between acidic and basic species. In simpler terms, proton [H] donor is an acid whereas proton acceptor is a base.

Example: Inorganic Acids

HCl, H_2SO_4, HSO_4^-, H_2O, H_3O^+

Example: Inorganic Bases

H_2O, NH_3, ^-OH, $^-NH_2$

Compounds like H_2O that contain both hydrogen atoms and lone pair act as both acid and base depending on the reaction. Our atmosphere is slightly acidic in nature because of the presence of CO_2 that dissolves in atmospheric water droplets and dissociates in the following way.

$$H_2O \longrightarrow H^+ + OH^-$$

$$CO_2(g) + H2O \longrightarrow H^+ + HCO_3^-$$

$$SO_2(g) + H2O \longrightarrow H^+ + HSO_3^-$$

Strong acids like HNO_3 and H_2SO_4 are produced by the atmospheric oxidation reactions of NO, SO_2 and H_2S.

The abundance of basic species in the atmosphere is relatively small when compared to the acidic species. The most important basic species in the atmosphere is ammonia (NH_3). It enters the atmosphere from biodegradation of nitrogen containing biological matter and from bacterial reduction of nitrate ion. It neutralizes acidic species in the atmosphere like HNO_3, H_2CO_3, H_2SO_4 because it is soluble in H_2O.

Example:

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

$$NH_3 + H_2SO_4 \longrightarrow NH_4HSO_4$$

After studying the important reactions taking place in the atmosphere, in the next section we take up an important global phenomenon which is a consequence of many factors including those discussed in the above subsections. The phenomenon is called the global warming and the related factors include the greenhouse gases.

1.4 GREEN HOUSE GASES AND GLOBAL WARNING

As mentioned in the previous section, there are gases present in the atmosphere that absorb IR radiations and radiate heat because of which these are responsible for increased temperature across the globe. The gases are called the greenhouse gases due to their behaviour like that of a greenhouse. On a global scale, six main gases are referred to as greenhouse gases. These are: carbon dioxide (CO_2), methane (CH_4) nitrous oxide (N_2O), fluorinated industrial gases like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) sulphur hexafluoride (SF_6) and chlorofluorocarbons (CFC). Water vapour is also considered a greenhouse gas. The greenhouse gases are responsible for the well known **global warming**.

CO_2 average life time cannot be measured with a value since it is not destroyed over a period of time. It travels from ocean to atmosphere to land system. Since the absorption in the sink is very slow process it will remain in the atmosphere for thousands of years. Its 100 years global warming potential is one ton.

An example is given here to make you to understand the greenhouse gases and the phenomenon of global warming. The interior of a closed car heats up when the car is parked in the sun. This is due to the radiation from the sun entering through windows and getting absorbed by the inner objects of the car, then converting light energy into heat energy, which releases in the form of IR radiation. Unlike, sunlight this IR radiation is blocked inside the car and cannot leave the car. The trapped heat energy causes the rise in temperature inside the car. In the same way, gases that trap the heat in the atmosphere similar to that of glass in a greenhouse hence they are called greenhouse gases. Greenhouse gas effect increases the average temperature of the earth's climate system that is, known as **global warming**. The increase in the greenhouse gas concentration is the major cause of global warming. Let us try to understand global warming potential, a term related to global warming.

1.4.1 Global Warming Potential

All greenhouse gases (GHGs) may vary in atmospheric lifetime and heat-trapping potential.

Global Warming Potential (GWP) unit has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to carbon dioxide (CO_2) over a specified time. In general, greenhouse gas emissions are calculated in terms of how much CO_2 would be required to produce an equivalent warming effect in the given time. This is called the **carbon dioxide equivalent** (CO_2e) value and is calculated by multiplying the amount of gas by its global warming potential (GWP).

GWP value provides policy makers to compare the impacts of emissions and reductions of different greenhouse gases. For example, methane is a notable contributor of the greenhouse effect and has a GWP of 21. This means that methane has approximately 21 times more absorption capacity of heat radiation than carbon dioxide per unit of weight. Methane emissions in permafrost areas could be higher than CO_2.

DO YOU KNOW?

The Greenhouse effect was first indentified by French scientist Jean- Baptise Fourier in 1927. The Greenhouse gases are like heat blankets, insulating Earth and slowing down the process of IR energy into the space. Without this insulation average surface temperatures on earth would be about -19^{O}C instead of +14^{O}C and it would be impossible to sustain life. Therefore, our global climate depends on the concentrations of greenhouse gases in Earth.

After understanding the Greenhouse gas phenomenon we should learn about the sources and effects of greenhouse gases in the following subsection.

1.4.2 Sources of Green House Gases

The greenhouse gases are generated by different sources as detailed below for all of these.

1. **Carbon dioxide:** The increasing source of carbon dioxide in the atmosphere is by burning fossil fuels (coal, natural gas and oil) solid waste, trees and wooden products and manufacturing process of cement.

   Sink: The terrestrial sink is the absorption of CO_2 in the process of photosynthesis. The oceanic sink is by uptake of CO_2 by phytoplankton as well as dissolution acid-base reactions and reactions of carbonates. The atmospheric life-time (ALT) of CO_2 is 12.4 years and 100 years GWP is 28-36 tons.

2. **Nitrousoxide:** The main source of nitrous oxide in the atmosphere isoxidation of ammonia (NH_3) in the atmosphere and also from tropical soils. Anthropogenic sources are agricultural burning of biomass and anaerobic denitrification process.

   Sink: Most of the nitrous oxide (N_2O) participate in the photolytic process and convert it into N_2 + O. in stratosphere. The rest of the N_2O reacts with oxygen to generate nitric oxide (NO) that can participate in the ozone depletion reaction.

3. **Methane:** It is a third most important greenhouse gas and is a product of fermentation reactions catalyzed by microbes. The natural source of methane (**CH_4**) is wet lands. Bacteria emit methane in the process of decomposing organic materials in the absence of oxygen (anaerobic decay).

   Anthropogenic sources are from livestock (methane is generated in the ruminants stomach as a part of digestive process), natural gas production and transmission, rice cultivation landfills, coal mines and manure storage systems.

   Sink: The sink for methane is the atmospheric oxidation by hydroxyl radical.

> **Do You Know?**
>
> Human activities that produce CH_4 include energy production from natural gas, coal and petroleum, decomposition in landfills, raising ruminant animals and rice farming. Wetlands are the main natural source of CH_4 (marsh gas produced by the anaerobic decay of vegetation). A similar induced effect is caused by the warming planet that has recently caused permafrost melting in the Arctic with accompanying decay of vegetation that had been frozen.

CH_4 now bubbles from shallow newly-formed lakes caused by permafrost subsidence and collects under the ice when these lakes freeze over in the winter. Poking a hole in the ice and igniting the resulting rush of gas produces a striking effect, Fig. 1.2.

4. **Chlorofluorocarbons and Halocarbons:** The source of chlorofluoro-carbons and halocarbons are only anthropogenic in nature. This contains

hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, chlorofluorocarbons and nitrogen trifluoride. These gases are emitted from various industrial processes, commercial and household uses like refrigerants and fire retardants.

Sink: Removal process is very slow and they will persist from GWP-1000 yrs/10,000 years and are permanent residents.

5. **Water Vapour:** It is one of the most abundant greenhouse gas. It absorbs IR radiation and obtained through evaporation and precipitation. It undergoes rapid turnover in the lower atmosphere controlled by local temperatures. Due to the 'positive feedback' phenomenon it increases the climate sensitivity thereby increases the anthropogenic greenhouse gases.

The effects of these gases on global warming and therefore climate change depend upon the following:

1. How much is too much?It means that the adverse effects will be measured in concentrations (concentrations are measured in ppm/ppb/ppt).
2. How long is too long? Which means average times it remains in the atmosphere.
3. How strong is too strong?How strongly it absorbs energy.

1ppm- is equal to one drop of H_2O into 13 gallons of liquid.

Dear learner, we will quickly go through the consequences of global warming. Global warming results in to the following effects:

1. Rapid changes in global temperature
2. Extreme weather patterns resultin more hurricanes and drought to occur. Longer duration of heat waves and intense rain is generally experienced.
3. Ecosystem impactslikespecies habitats decrease and the chances for various ecosystems to adapt naturally would diminish.
4. Rising sea levels due to water expand when heated resulting into melting of polar caps.A large mass of human lives in the coastal line suffers.
5. Ocean acidification caused by dissolving more atmospheric CO_2 into the oceandisrupts the ability of oceanic life to make shells and skeleton of calcium carbonate.
6. Increase in pests and diseases of the agricultural crops

1.4.3 Ozone Layer

The Earth's atmosphere consists of various layers. The troposphere is the lowest layer extending to 15 kms in altitude. Next layer is stratosphere that extends upwards to an altitude of 50 kms. The terrestrial life cannot sustain in stratosphere since its density is too low but it is the house of the ozone layer, which has the ability for life to survive on earth. About 90% of ozone present in stratosphere and remaining ozone is located in troposphere. Dear learners, you have learnt in school about

ozone layer that filters the UV radiation from the sun before reaching the earth and is known as protecting layer.

The molecular oxygen (O_2) and the ozone (O_3) interconvert in stratosphere in the presence of UV radiation of the sun.

Interconversion reaction in the stratosphere can be written as follows:

1. $O_2 \xrightarrow{h\upsilon} 2O$ (i)

$O_2 + O \longrightarrow O_3$ (ii)

$O_3 \xrightarrow{h\upsilon} O_2 + O$ (iii)

The high energy solar radiation splits O_2into oxygen atoms, which combine with other molecules of O_2 to produce O_3 as in the first and second reactions. Ozone is a bluish gas with pungent odor. Ozone may be generated by many ways by the atmospheric reactions. Sometimes, ozone may be produced near high-voltage equipment by the action of electrical discharges. In the troposphere, ozone is produced by NO_2. NO_2 splits in the presence of sunlight, releases oxygen atoms and in the lower atmosphere it produces ozone. Ozone can also produced by carbon monoxide (CO)(Fig. 1.3). Oxidation of CO produces hydrogen atom that reacts with oxygen in the following way.

$CO+OH \longrightarrow CO_2+H$

$H+O_2 \longrightarrow HO_2$

The HO_2 radical undergo self-reaction to produce hydrogen peroxide.

$HO_2 + HO_2 \longrightarrow H_2O_2+O_2$

This hydrogen peroxide acts in three different ways in the atmosphere.

1. Due to its soluble nature it is removed from the atmosphere and deposited by rain water.
2. It produces hydroxy radical on photolysis.

$H_2O_2 \xrightarrow{h\upsilon} 2OH$

3. It reacts with hydroxy radical to produce HO_2 radical.

$H_2O_2 +OH \longrightarrow HO_2+H_2O$

The regenerated HO_2 reacts with atmospheric NO produce ozone in the following manner.

$HO_2 +NO \longrightarrow OH+NO_2$

$NO_2+ O_2 \xrightarrow{h\upsilon} NO+O_3$

The sequences of repeated chain reactions that occur in the atmosphere are as follows:

$$CO + OH \xrightarrow{O_2} CO_2 + HO_2$$

$$HO_2 + NO \longrightarrow OH + NO_2$$

$$NO_2 + O_2 \xrightarrow{h\upsilon} NO + O_3$$

The over all reaction is

$$CO + 2O_2 \longrightarrow CO_2 + O_3$$

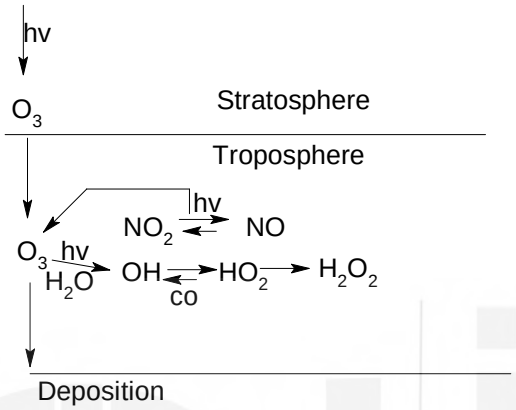

Fig. 1.3: Mechanism for O_3–HO_x–NO_x– CO chemistry

Ozone acts as a natural atmospheric filter for biologically damaging UV-B light by absorbing it in the range of 200-310 nm frequency where interconversion of ozone and molecular oxygen occurs as shown in the above reaction. The role of stratospheric ozone is by undergoing photo dissociation reaction where it intercepts the damaging UV radiations from reaching the Earth's surface. This absorption of UV radiation by stratosphere prevents 99% of UV radiation from reaching the Earth's surface. The radiation energy in this range is enough to cause skin cancer in human beings and damages our environment. For that reason stratospheric ozone is termed **ozone shield** and the '**good ozone'**. The ozone in the troposphere is highly reactive with living tissue causing adverse effects on humans, forest damage and reduced crop production and finally alters the ecological welfare. Hence the ozone in the troposphere is known as destructive ozone or '**bad ozone'**.

Let us read in the next section how the ozone layer depletion is affecting the whole ecosystem.

1.4.4 Ozone Layer Depletion

The depletion of ozone layer is not good for the living beings as has earlier been mentioned. A number of factors play role in this for example; chlorofluorocarbons play a major role in the depletion of ozone. Specific examples like $CFCl_3$ (CFC-11), CF_2Cl_2 (CFC-12) compounds are non-flammable, volatile but readily liquefiable, non-toxic and relatively inert in nature. Because of these beneficial properties they are useful in refrigerators as coolants, in foam plastic manufacturing, aerosol propellants and industrial solvents. These properties are useful for human comforts but adversely affect the stratospheric ozone. Once,

these gases release into the atmosphere, these persist for very long time because of relative inertness in the troposphere and enter into the stratosphere through atmosphere mixing. The high energy solar radiation in the stratosphere decomposes chlorofluorocarbons and is involved in reactions which curtail the concentration of ozone.

Series of chemical reactions that deplete the ozone layer in the stratosphere are cleavage of C-Cl bond that results in chlorine free radical as shown in the following steps:n the stratosphere are cleavage of C-Cl bond results in chlorine free radical

Step (i)

$$CFCl_3\,(g) \xrightarrow{h\upsilon} CF_2Cl.\,(g) + Cl.\,(g)$$

Step (ii)

The chlorine free radical reacts with ozone molecule by chain reaction mechanism producing chlorine monoxide free radical and an oxygen molecule.Chlorine monoxide free radical reacts further in the following way.

$$Cl.\,(g) + O_3\,(g) \longrightarrow ClO.\,(g) + O_2(g)$$

Step (iii) Chlorine monoxide reacts with oxygen atoms to form oxygen molecule and chlorine free radical.

$$ClO.\,(g) + O \longrightarrow Cl.+ O_2$$

The net reaction for conversion of two ozone molecules into three oxygen molecules

$$2O_3\,(g) \longrightarrow 3O_2$$

The chain reaction increases the rate at which stratospheric ozone is destroyed but it does not alter the rate of ozone formation. The reports says that, one chlorine atom will destroy as many as 1, 00,000 molecules of O_3 before it is suspended to the troposphere as HCl.

The cycle of ozone destroying reactions disturbs the abundance of ozone since ozone is depleted quickly than it is being produced.

The evidence of stratospheric ozone depletion is the formation of **Antarctic ozone hole**. According to the British atmospheric report in 1985, thinning of ozone layer in the stratosphere over the south pole in September and October.

Scientists found reasons that during summer, NO_2 and CH_4 react with chlorine monoxide to trap the chlorine forming chlorine reservoirs. During winters in the extreme cold weather a vortex of extremely cold air forms clouds containing ice crystals provides surface for various chemical reactions which produce hydrogen chloride and chlorine nitrate ($ClONO_2$). They react with each other to form chlorine molecules.

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

During spring, the chlorine molecule photodissociate into chlorine free radicals that can further involve in the ozone destruction reaction.

Do You Know?

Newer alternatives to CFCs are hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs).These compounds have similar properties as CFCs, but decomposed by OH radical before reaching the stratosphere, hence these will not participate in the radical reactions resulting in O_3destruction. Propane and butane are now used as propellants in spray cans in place of CFCs.

The 1995 Nobel Prize in chemistry was awarded to Mario Molina, Paul Crutzen and F.Sherwood Rowland for their work in elucidating the interaction of Ozone with CFCs.

Check Your Progress 3

Note : a) Write your answer in about 50 words.
b) Check your progress with possible answer given at the end of the unit.

4. Enlist the gaseous pollutants in the atmosphere?

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5. What are the anthropogenic sources of methane?

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6. Write a brief note of global warming potential.

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1.5 LET US SUM UP

This unit dealt with environmental pollution and different reactions that occur in the atmosphere, since the source of pollution is occurred by anthropogenic activities. Every substance or chemical or material produced by humans or nature can pollute the environment. Based on the chemical composition, and properties atmosphere is divided into various regions. There are different physical and chemical reactions occur in the atmosphere because of chemical interactions between its components. Tropospheric ozone, methane and nitrous oxide are considered as green house gases. These have both natural and anthropogenic sources and contribute to the global warming. The stratospheric ozone is useful for life on earth by protecting them from

UV radiation. Where as tropospheric ozone harmful to the humans and other living beings.

1.6 KEYWORDS

Acid deposition : Any form of acid precipitation and also fallout of dry acid particles.

Acid precipitation : Includes acid rain, acid fog, acid snow, and any other form of precipitation that is more acidic than normal (i.e., less than PH 5.6). Excess acidity is derived from certain air pollutants; namely, sulfur dioxide and oxides of nitrogen.

Aerosols : Microscopic liquid and solid particles originating from land and water surfaces and carried up into the atmosphere.

Anthropogenic : Referring to pollutants and other forms of impacts on natural environments that can be traced to human activities.

Base : Any compound that releases hydroxyl (OH^-) ions when dissolved in water. A solution that contains a surplus of hydroxyl ions.

Biosphere : The overall ecosystem of Earth. The sum total of all the biomes and smaller ecosystems, which ultimately are all interconnected and interdependent through global processes such as the water cycle and the atmospheric cycle.

Biotaliving : The sum total of all living organisms. The term usually is applied to the setting of natural ecosystems.

Buffer : A substance that will maintain the pH of a solution by reacting with the excess acid in the solution. Limestone is a natural buffer that helps to maintain water and soil at a near-neutral pH.

CFCs : Nuclear reaction wherein each atom that fissions (splits) causes one or more additional atoms to fission.

Chlorinated hydrocarbons: Synthetic organic molecules in which one or more hydrogen atoms have been replaced by chlorine atoms. Chlorinated hydrocarbons are hazardous compounds because they tend to be non-biodegradable and therefore to bio-accumulate and many have been shown to be carcinogenic. They are also called organochlorides.

Chlorine cycle : In the stratosphere, a cyclical chemical process in which chlorine monoxide breaks down ozone.

Chlorofluorocarbons (CFCs) : Synthetic organic molecules that contain one or more of both chlorine and fluorine atoms and that are known to cause ozone destruction.

Convection : The vertical movement of air due to atmospheric heating and cooling.

Environmental impact : Effect on the natural environment caused by human actions. Includes indirect effects, for example, through pollution, as well as direct effects such as cutting down trees.

Photosynthesis : The chemical process carried on by green plants through which light energy is used to produce glucose from carbon dioxide and water. Oxygen is released as a by-product.

Precipitation : Any form of moisture condensing in the air and depositing on the ground.

Primary pollutants : Pollutants released directly into the atmosphere mainly as a result of burning fuels and wastes, as opposed to secondary pollutants.

Troposphere : The layer of Earth's atmosphere from the surface to about 10 miles in altitude. The tropopause is the boundary between the troposphere and the stratosphere above. The troposphere is well mixed and is the site and source of our weather, as well as the primary recipient of air pollutants.

1.7 REFERENCES AND SUGGESTED FURTHER READINGS

1. Fundamentals of Environmental Chemistry by A.K.De
2. Environmental Chemistry by Stanley Manahan
3. Environmental Science textbook by Richard T. Wright

1.8 ANSWERS TO CHECK YOUR PROGRESS

1. A pollutant may be defined as a physical, chemical or biological substance unintentionally released into the environment which is directly or indirectly harmful to humans and other living organisms. Whereas pollution is the presence of substance in the environment that, because of its chemical composition or quantity, prevents the functioning of natural processes and produces undesirable environmental and health effects.
2. Air pollution, water pollution, soil pollution, Noise pollution,Thermal and Radiation pollution.
3. Reactions that occur by absorbing sunlight are known as photochemical reactions with the formation of various types of free radicals as intermediate species. A chain reaction is a sequence of reactions where a reactive product or by-product causes additional reactions to take place. In a chain reaction, positive feedback leads to a self-amplifying chain of events. Due to the abundance of oxygen molecules in the atmosphere oxidation and reduction reactions will occur. Some chemical reactions in the atmosphere

can occur as gas phase collisions between molecules, on the surfaces of solid particles (particulate matter) or in aqueous solution (in water droplets). The reactions that take place in water droplets are mainly acid-base reactions.

4. CO_2, CO, CH_4, $CFCl_3$, NOX, SOX.

5. Anthropogenic sources are from livestock (Methane is generated in the ruminants stomach as a part of digestive process) natural gas production and transmission, rice cultivation landfills, coal mines and manure storage systems.

6. The Global Warming Potential (GWP) is a measure to allow comparisons of the global warming impacts of different gases. It provides how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The higher the GWP the more that a given gas warms the earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows adding up emissions estimates of different gases and allows policymakers to compare emissions reduction opportunities across sectors and gases for making decisions.

UNIT 2 AIR POLLUTION

Structure

2.0 Introduction

2.1 Objectives

2.2 Air Pollution: Definition

2.3 Sources -of Common Air Pollutants

2.4 Types of Air Pollutants

- 2.4.1 Natural and Anthropogenic Pollutants
- 2.4.2 Primary and Secondary Air Pollutants
- 2.4.3 Indoor and Outdoor Air Pollutants
- 2.4.4 Urban and Rural Air Pollutants

2.5 Effects of Air Pollution

- 2.5.1 Industrial Smog
- 2.5.2 Photochemical Smog
- 2.5.3 Acid Precipitation

2.6 Effects of Air Pollution on Human Health

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2.8 Key Words

2.9 Let Us Sum Up

2.10 References and Suggested Further Readings

2.11 Answers to Check Your Progresss

2.0 INTRODUCTION

In the first unit of this block you have studied about the nature of atmosphere and various types of environmental reactions that occur in the atmosphere. Present day atmosphere has changed with the onset of the industrial revolution. Previously everybody heard about atmosphere consistting of various gases with major constituents like nitrogen(78.08%), oxygen(20.95%), argon(0.93%), CO_2(0.04%), water vapor(0-4%) and trace gases including ozone, helium, hydrogen, nitrogen oxides, sulfur dioxide. It is learnt that in addition to these gases, microscopic liquid and solid particles like dust, pollen grains, carbon particles, sea salt and microorganisms collectively known as aerosols are carried up to the atmosphere from land and water surfaces. In this unit you will study the role of these constituents in the atmosphere and learn about the chemical processes that explain how and why the atmosphere is getting polluted. The unit also deals with how the natural properties of air pollutants are influenced by external factors and the environmental medium where these exist. In the next section we will begin with defining air pollution.

2.1 OBJECTIVES

After studying this unit you should be able to:

- define air pollution;
- enlist the sources of common air pollutants;
- classify various types of air pollutants; and
- describe the effects of air pollution.

2.2 AIR POLLUTION: DEFINITION

By definition air pollution is the presence of contaminants or pollutants in the air like noxious gases, particles of solid and particulates of liquid matter in high concentrations that interfere with human health or welfare, or produce other harmful environmental effects (US-Environmental Protection AgencyUS-EPA). In other words, any substance in the atmosphere which can create harm to the natural environment and human beings is known as air pollutant.. The level of air pollution can be determined by three factors given below.

1. The quantity of pollutant that is present in the air
2. The area in which the pollutants are dispersed
3. The removal process of pollutants from the air

Let us first of all study the common pollutants in air and their sources.

2.3 AIR POLLUTION: DEFINITION

On the basis of adverse effects of air pollutants like impaired health, destroying the environmental resources and damaging property, as per the clean air act of 1970,the sources of air pollutants can be classified as follows:

1. **Mobile Sources**: Mobile sources of air pollution start with the exhaust from the vehicles that contains notable pollutants like lead particulates, carbon monoxide, carbon dioxide, hydrocarbons, and oxides of nitrogen, and small amounts of sulfur oxides. These pollutants generate secondary pollutants when react in the atmosphere and adversely impact on the environment like photochemical smog and acid rain.

2. **Stationary Sources:** Stationary sources are two types: point sources and rea sources

   Point sources: These include some of the most important stationary sources like furnaces and the combustion of carbonaceous fuels, boilers, ovens and dryers, process systems which produce volatile chemicals, gases, etc.

   Area sources: Solvents from solvent-based paints, leaking pipe joints, maintenance work involving the dismantling of pumps or breaking of pipeline spills, unloading /loading procedures and contaminated ground come under this type of sources.

3. **Fugitive Emissions**: Fugitive emissions are those which escape from a process rather than being discharged. They enter the atmosphere untreated

by which they show adverse effects. These emissions can be reduced by implementing standard operating procedures but natural emissions are impossible to control. For example: industrial sources, dry cleaning, agricultural practices, natural sources like volcanoes, forest fires.

The particulate matter (PM), ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb) are some of the air pollutants about which you would study in the following paragraphs. The sinks (place of absorption or dispersal) of some of these pollutants are also given here.

1. **Particulate matter:** The particulate pollutants mean very minute solid or liquid particles. They may be different in size and shape, also in physical and chemical properties. These can be either natural or man made. The major sources are stack emissions, construction work, unsealed roads etc., Since they are very small in size they provide surface for many reactions for the formation of secondary pollutants and also diffuse light by which reduce visibility. The particulate pollutants are classified as:

a. **Dust**: These are solid particles with >100¼m in diameter dispersed into the air.

b. **Fume**: These are solid particles from factories and industries usually between 0.03- 0.3 ¼m in diameter. Example: metallic oxides

c. **Mist**: These are liquid particles with 0.5-3.0 ¼m in diameter formed by condensation reactions.

For example: $SO_3 + H_2O \longrightarrow H_2SO_4$

d. **Smoke**: These are solid particles between 0.5-1.0 ¼m in diameter produced by incomplete combustion of carbon containing material.

e. **Spray**: These are liquid particles which are formed by the process of atomization.

If the size of the particulate matter is >3 μm, these are negatively charged where as particles with < 0.01 μm size are positively charged. These electrical charges will have considerable effect on the rate of coagulation and deposition. Once the particulate matter releases into the atmosphere it undergoes many physical and chemical changes like increase in size, absorb or desorb gases, change in electrical charge, colloid or cohere with other particles, change in specific gravity, converting into sulpahate and nitrate aerosols .Due to this the pH, chemical reactivity, and toxicity changes dramatically that affects the life time of these particles in the atmosphere.

For example: Polycyclic aromatic hydrocarbons (PAH). PAHs are generated by coal furnace (>1 μm), cigarette smoke (0.1 μm) and chemical reactions involving ethene and ethane > 500^0C.

2. Carbon Monoxide

Carbon monoxide is a colurless, odourless and tasteless gas found in abundance, around 530 million tonnes (about 0.00001%), with an average residence time of 36 to 100 days. The natural existence of atmospheric CO is due to volcanic eruptions, photolysis of methane and terpenes, forest fires, chlorophyll decomposition, and microbial action in oceans.

It enters the atmosphere by anthropogenic sources like transportation, disposal of solid waste, burning of agricultural waste, steel production, etc. It is also emitted directly into the atmosphere by inefficient combustion of fossil fuels.

$$2C + O_2 \longrightarrow 2CO$$

Sink: The CO in the atmosphere by anthropogenic and natural sources will be naturally removed from the air by conversion to CO_2 in a sequence of chemical reactions either by aerial oxidation or soil microorganisms.

$$2CO + O_2 \longrightarrow 2CO_2$$

3. Carbon dioxide

In the natural atmosphere carbon dioxide is generated by the combustion of organic matter, weathering or biological decomposition.

CO_2 acts as thermal absorber by which it can absorb energy from infrared (IR) radiationThe energy from the incoming IR photon causes the CO_2 molecule to vibrate and the extra energy has been removed by the emitted photon in a continuous process. This potential of CO_2 to absorb and re-emit infrared energy makes this gas an effective heat-trapping greenhouse gas. The gases like nitrogen (N_2) and oxygen (O_2) are not able to absorb infrared photons because of lack of vibration. The details of greenhouse gases and the importance of greenhouse effect have already been discussed in the previous unit. **Sink:** Because of its nature of solubility in water, the major sink for CO_2 is ocean where 50% of all anthropogenic emissions are getting absorbed. The forests also serve as a sink.

4. Sulfur Compounds

Number of sulfur compounds are released into the atmosphere from both natural and anthropogenic sources. The major sources are from volcanic eruptions and man made emissions like incomplete combustion of fossil fuels.

The common sulfur compounds exist in the atmosphere is SO_2, SO_3, H_2S and H_2SO_4. Combustion of fossil fuels and roasting of metal sulfide ores are the anthropogenic sources. Out of these sulfur trioxide (SO_3) is directly emitted in ore smelting and fossil fuel combustion and also by the oxidation of SO_2 and readily soluble in water to produce H_2SO_4 which is known as **acid rain**. The reactions of formation are as follows.

$$\mathbf{S + O_2 \longrightarrow SO_2}$$

$$\mathbf{2\,SO_2 + O_2 \longrightarrow 2SO_3}$$

$$\mathbf{SO_3 + H_2O \longrightarrow H_2SO_4}$$

It is estimated that100-130 million tonnes of SO_2 per year enter the atmosphere through anthropogenic activities and 50-70 million tonnes are released from natural sources like volcanoes, sea spray and microbial activities.

Sink:

The removal process of SO_2 from the atmosphere is by both dry and wet deposition. SO_2 dissolves in water to form a dilute solution of sulfurous acid (H_2SO_3). This sulfurous acid remains in clouds, rain droplets or at the surface.

A portion of the SO_2 is converted into H_2SO_4 by its gas-phase oxidation with subsequent aerosol formation by nucleation or condensation. Sulfuric acid reacts with ammonia (NH_3) to form ammonium hydrogen sulfate (NH_4HSO_4), ammonium sulfate [$(NH_4)_2SO_4$] or mixed salts with ammonium nitrate (NH_4NO_3) salts.

The atmospheric SO_2 is converted to sulfate aerosol in other process and is removed from the atmosphere by dry and wet deposition processes.

5. Nitrogen Compounds

The most abundant gas in the atmosphere is nitrogen with 78.09% abundance. The major gaseous forms of nitrogen in the atmosphere are molecular nitrogen (N_2), nitrous oxide (N_2O), nitrogen dioxide (NO_2), nitric oxide (NO) and ammonia (NH_3). The details of these gases and their role in pollution are explained here.

Nitrous Oxide

It is a natural constituent of the air in the atmosphere with concentration of 0.30 ppm. It acts as a strong oxidizing agent. It is also called laughing gas because of its euphoric effects. It is produced in the soil by anaerobic bacteria. It generates NO in the stratosphere by photolytic dissociation.

Nitric Oxide

Nitric oxide is generated naturally by anaerobic processes in soil and water, by combustion processes and by photochemical destruction of nitrogen compounds in the stratosphere. The major man made sources are automobile exhaust, combustion of fossil fuel-fired electric generating stations, industrial boilers, incinerators and home heaters.

Nitrogen Dioxide

Nitrogen dioxide is light yellowish orange at low concentrations and brown at high concentrations. It is produced by the direct oxidation of NO in the atmosphere as per the following reaction.

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

It can also be generated by photochemical reactions of O_3, peroxy radical (RO_2), hydroxyl radical(OH)•, hydroperoxide radical (HO_2) and H_2O_2. Therefore, higher NO_2 levels occur on sunny days. Some of the important reactions are shown below.

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$RO_2 + NO \longrightarrow NO_2 + RO$$

$$HO_2 + NO \longrightarrow NO_2 + OH$$

Sink:

The significant sink for NO is its conversion by direct oxidation and photochemical processes to NO_2. A major sink for NO_2 is its conversion to nitric acid as is shown below.

$$OH\bullet + NO_2 + M \longrightarrow HNO_3 + M$$

Where M is a species which absorbs energy (generally O_2 or N_2).

$NO_2 + O_3 \longrightarrow NO_3\bullet + O_2$

$NO_2 + NO_3\bullet \longrightarrow N_2O_5$

$N_2O_5 + H_2O \longrightarrow 2HNO_3$

Nitrogen dioxide reacts with ozone to produce nitrate free radical (NO_3).The nitrate free radical further reacts with nitrogen dioxide to give dinitrogen pentaoxide (N_2O_5). This react with water swiftly to produce HNO_3. HNO_3 reacts with ammonia (NH_3) or other alkaline species to form salts like NH_4NO_3.The nitrate aerosol is removed from the atmosphere either by dry or wet deposition processes known as **acid deposition** or **acid rain** like in the sulphate aerosol.

Lead: Lead is a significant heavy metal air pollutant. The exhaust of the vehicles which use leaded petrol is the primary source of this pollutant. It is used as a fuel in the form of tetraethyl lead (Pb $(C_2H_5)_4$) to aid even combustion. The reaction is as follows:

Pb $(C_2H_5)_4$+O_2+Petrol (Halogenated organic compound $\longrightarrow$ CO_2+H_2O+$PbCl_2$+PbBrCl+$PbBr_2$

Other major sources of lead in the air are waste incinerators, processing of ore and metals, aircraft operating on leaded aviation fuel, utilities, lead-acid battery manufacturers, lead smelters, lead-based paints, ceramics, pipes, plumbing materials, solders, gasoline, batteries, ammunition and cosmetics.

Now you can assess your understanding about the sources of air pollutants by trying to answer the following questions. After this you will study the types of air pollutants in the next section.

Check Your Progress 1

1. Fill in Sources of the following air pollutants

   a. Ozone

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   b. Nitrogen Dioxide

   .....

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   c. Carbon Dioxide

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   .....

2.4 TYPES OF AIR POLLUTANTS

There are different types of air pollutants depending on how and where these are generated . These are listed below and explained in the following subsections.

Natural and Anthropogenic Pollutant

Primary and Secondary Pollutants

Outdoor and Indoor Pollutants

Stationary and Mobile Source Pollutants

2.4.1 Natural and Anthropogenic Pollutants

The pollutants which are released by the natural sources such as eruption of volcanoes, sea sprays, lightning and microbial processes are called **natural pollutants**. Where as pollutants released by human activities such as industrial and vehicular emissions are known as **anthropogenic pollutants**.

The sources for natural pollutants are listed below:

1. Biogenicsources-: soil micro organism, hydrosphere organism, vegetation and animals.
2. Geophysical sources- soil dust and sea salt
3. Geochemical sources- volcanism, burning of biomass and lightening

The anthropogenic sources are:

1. Biogenic sources- Agriculture
2. Chemical sources- chemical processes, high temperature processes and combustion
3. Physical processes -dust resuspension and volatilization

2.4.2 Primary and Secondary Air Pollutants

The pollutants which are released directly into the atmosphere from a particular source of pollution which means they are the direct products of evaporation and combustion. Example: CO, CO_2, CH_4, NO, N_2O, NH_3, H_2S, SO_2, chlorides, fluorides, bromides and participate matter/aerosols.

The carbon particulate matter is released into the atmosphere by burning of fuels and wastes. In addition to this incomplete combustion of fuel molecules releases in to the atmosphere as Volatile Organic Compounds (VOC).The nitrogen gas in the air gets oxidize during combustion at high temperatures and releases various nitrogen oxides (NO_x).The pollutants like sulfur oxides are release into the atmosphere by burning of coal. Coal contains 0.2-5.5% sulfur and heavy metal impurities like mercury.

Source: Industry or vehicles

Effects: Photochemical smog **Secondary Air Pollutants**

The primary pollutants which can under go further reactions by light energy, heat or the presence of other chemicals and get converted into undesirable toxic compounds are called **secondary pollutants**.

Example: Ozone is a secondary pollutant which is formed by the photolysis reaction of oxides of nitrogen followed by subsequent reactions with VOCs NO_2, SO_2, HNO_3 and H_2SO_4. formed from SO_2.

Effects:: Acid rain

Some pollutants may act both as primary and secondary pollutants that mean they are both emitted directly and formed from other primary pollutants also.

Some primary and secondary pollutants, their sources and the effects are listed in Table 2.1.

Table 2.1: Some Primary and secondary pollutants, their sources and effects

Primary Pollutants

Name	Symbol	Source	Effect
Suspended particulate matter	PM	Smoke, metal particles, soot from cooking and heating. Dust through wind.	Respiratory ailments, impair lung growth in infants and heart attacks
Volatile organic compounds	VOC	Incomplete combustion of fossil fuels emissions from industries, evaporation of gasoline and solvents	Carcinogenic
Carbon monoxide	CO	Incomplete combustion of fuels	It binds to hemoglobin and block the oxygen delivery tissues
Nitrogen Oxides	NOx	Burning of Nitrogen containing fuels, biomass at high temperatures, lightening and microbial process.	Causes acid rain and Lung irritation
Sulfur Oxides	SOx	Burning of Sulfur containing fuels (coal), volcanoes, sea spray and microbial process.	Causes acid rain and impairs breathing
Lead	Pb	Burning of lead containing fuels and solid waste	Causes brain damage and death
Radon	Rn	Natural breakdown of radium and Uranium containing rocks	Lung cancer
Chlorofluorocarbons causes	(CFC)	**Leakages from refrigerants and the use of aerosols.**	Causes ozone depletion and skin cancer
Secondary Pollutants			
Ozone	O_3	Photochemical reactions of VOCs & NOx	Oxidizes rubber, highly reactive in

			lungs and shows adverse effects on animals and plants
Peroxyacetylnitrates	PAN	Photochemical reactions of VOCs & NOx	Adverse effects on plants, lungs and eyes
Persistent organic pollutants	POPs	Pesticides, solvents and pharmaceuticals	Causes cardiovascular disease and cancer

2.4.3 Indoor and Outdoor Air Pollutants

Dear learner, have you ever thought that one source of pollution could be our own house which is a first indoor environment for a child? This is called indoor air pollution. Let us look into some of the factors which cause indoor air pollution that affects our health. . The causes and the health effects of indoor air pollutants are given in Table 2.2.

Table 2.2: The causes and the health effects of indoor air pollutants

S.No	Cause of indoor air pollutant	Health effect of the pollutant
1.	Inadequate ventilation in poorly ventilated dwellings pollutants will accumulate to higher concentrations than that of outside. This is known as '**Sick building syndrome'.**	Irritations of eyes, nose and throat, dry mucous membranes and skin erythema (reddening or flushing of the skin), rashes, mental fatigue, headache, sleepiness, cough, hoarseness, wheezing, nausea, dizziness, unspecific hypersensitivity reactions
2.	High temperature and humidity	Fatigue, irritability, headache and a decrease in performance and alertness
3.	Combustion of oil, gas, kerosene, coal, wood, and tobacco products.	Bronchoconstriction, lung cancer.
4.	• Building materials: Formaldehyde released from pressed wood products like hard wood, plywood, wall paneling, fibre board and urea-formaldehyde foam insulation. • Radon released from rocks and other building materials under the constructions of homes, schools and offices enters inside with dust. • Asbestos found in materials used in the automotive industry and construction of buildings, ceiling, and floor tiles.	• Irritation in eyes, nose and throat, coughing, skin rashes, headache, dizziness and vomiting. • Radon is a carcinogen. • prolonged exposure causes asbestosis, mesothelioma and lung cancer.

5.	Second hand tobacco smoke/ Environmental tobacco smoke (ETS): releases from burning end of cigarette and smoke exhaled by the smokers.	Respiratory tract infections and lung cancer
6.	Biological pollutants - Mites - Allergens – Molds developed in damp or wet areas such as cooling coils, humidifiers, condensate pans or unvented bathrooms can be moldy draperies, bedding, carpet and other areas where dust collects that may accumulate biological contaminants.	Hypersensitivity, pneumonitis, allergic rhinitis and some types of asthma
7.	Volatile organic compounds(VOCs) emitted from paints, and other solvents, wood preservatives, aerosol sprays cleansers and disinfectants, moth repellents and air fresheners, stored fuels and automotive products· dry - cleaned clothing, pesticides, building materials, furnishings, office equipment such as copiers and printers, graphics and craft materials including glues and adhesives, permanent markers and photographic solutions.	Eye, nose and throat irritation, headache, loss of coordination, nausea,· damage to liver, kidney and central nervous system cancer in animals, some are suspected to cause cancer in humans

Outdoor Air Pollutants

The causes and health effects of outdoor air pollution are given in Table 2.3.

Table 2.3: The causes and health effects of outdoor air pollution

S.No	Cause of outdoor air pollutant	Health effect
1.	Combustion of fossil fuels from domestic heating, power generation and motor vehicles releases primary particles containing sulpahate, metals and polycyclic aromatic hydrocarbons and secondary particles containing nitrogen oxides, sulphur oxides and ozone.	Respiratory morbidity (pneumonia, asthma) Increased mortality (from all causes) Decreased lung growth and function.O_3 causes lung irritation and inflammation, impaired pulmonary function, eye, nose and throat irritation
2.	Industrial processes release nitrogen oxides, CO, sulphur oxides other than dust, fly ash, smoke, fog, soot and fumes	Decrements in lung function, reduces oxygen-carrying capacity, chronic bronchitis, broncho-constriction
3.	Agricultural processes-biological agents like fungi, mycotoxins,	N-ARD, ARD, infections and cancer, Acute respiratory problems.

	glucans, actinomycetes, viruses, microbial enzymes, plant, mammalian and invertebrate proteins. Burning of agriculture waste releases greenhouse gases like N_2O and methane, SPM.	
4.	Waste incineration releases PM containing heavy metals, dioxins, furans, mercury etc.	Autism, Attention Deficit Hyperactivity Disorder (ADHD), lung cancer, dementia damages immune system
5.	Natural processes like volcanic eruptions releases CO_2, SO_2, H_2S, HF, HCl and HBr	Headache, dizziness, increased heart rate, irritation of the upper respiratory tract and , pulmonary edema and death during long exposure

Check Your Progress 2

Note : a) Write your answer in about 50 words.

b) Check your progress with possible answer given at the end of the unit.

2. What is "sick building syndrome"?

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3. What is the difference between primary and secondary air pollutants?

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4. What are the sources of VOCs?

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5. Give two sources each of the indoor and outdoor air pollutants.

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.....

2.4.4 Urban and Rural Air Pollution

Urban air pollution is mainly caused by both 'mobile' sources (vehicular) and 'stationary' sources (i.e. biomass). Other sources include exhaust fumes from vehicles, emissions from factories and power generation plants.

Three types of air pollution that affect rural areas are **solid fuels** like coal and biomass for cooking and heating, **outdoor pollution** from urban sources and **secondary pollutants** from the transport of emissions far from their primary.

Do You Know?

Lichens are natural biological indicators of air pollution because of their source of nourishment is air. Gray-green crusty lichens indicate highly polluted air, Orange crusty lichens indicate moderate air pollution and leafy lichens indicate clean air.

We will now learn about the effects of air pollution.

2.5 EFFECTS OF AIR POLLUTION

Primary and secondary pollutants are threat to human health particularly respiratory related ailments. Severe exposure to some of these pollutants will be chronic and life threatening. Some pollutants are carcinogenic too. Dear learner, we are all in one way or the other exposed to a number of particulate and gaseous pollutants with inhaled air. The adverse effects of these pollutants may vary from proximity to the source, nature of wind and weather and concentration. These effects may be additive, synergistic or antagonistic. **Additive** effects are those which occur when the exposure to various pollutants produces an effect equal to the sum of the effects of the pollutants acting alone. **Synergistic** effects are those where the sum of the effects of two or more pollutants is greater than the combined effect. **Antagonistic** effects are those where one pollutant minimizes the effect of another pollutant. These effects are more often synergistic in nature.

Smog is a kind of air pollution which reduces visibility and is composed of tropospheric ozone (O_3); primary particulate matter such as pollen and dust; and secondary particulate matter such as sulphur oxides, volatile organic compounds, nitrogen oxides (NO_x) and ammonia gas. It is of two types: Industrial smog and Photochemical smog depending on the nature of pollutants. Industrial smog generally exists in the urban areas. Smog is

Even though the colour of both appears to be brown haze but the differ in their formation and chemical composition

2.5.1 Industrial Smog

It is also called as **grey** or **black** smog and develops under cold and humid climatic conditions especially in urban areas where industrial sources like heating of reactors, roasting process in the nonferrous heavy metals etc., and power plants run on fossil fuels like coal. These industries emit approximately about 2.5 tons of sulfur per hour. This sulphur immediately reacts with water vapour and the secondary pollutant sulphurdioxide is formed. At high humidity SO_2 is rapidly oxidized to form sulphuric acid and sulphate particles. Sometimes catalytic oxidation of dust particles containing heavy metals and soot in the presence of water droplets in the atmosphere makes the droplets acidic. These create a thick blanket of haze known as **acid smog** or **industrial smog**. It is formed close to the ground. The general reactions of industrial smog are given below.

1) $C + O_2 \rightarrow CO_2$ (carbon dioxide)

2) $S + O_2 \rightarrow SO_2$ (sulfur dioxide)

3) $SO_2 + O_2 \rightarrow So_3 + O$ (sulfur trioxide)

4) $SO_3 + H_2O \rightarrow H_2SO_4$ (sulfuric acid)

5) $H_2SO_4 + NH_3 \rightarrow (NH_4)_2SO_4$ (solid ammonium sulfate)

Let us learn about another type of smog called the photochemical smog.

2.5.2 The Photochemical Smog

The photochemical smog is formed in a series of chemical reactions of secondary pollutants in the atmosphere in the presence of sunlight. Photochemical smog appears mostly in urban areas, which has exhaust from vehicles.

The photochemical smog is formed when the primary pollutants like NOx and hydrocarbons are captured in the lower atmosphere on exposure to UV radiation from the sun. The pollutants in the photochemical smog are ozone (O_3), hydrogen peroxide (H_2O_2), organic peroxides (ROOR'), organic hydroperoxides (ROOH), peroxyacyl nitrates (RCO_3NO_2) PAN . The latter are formed by the irradiation of mixtures of alkanals, ozone and nitrogen dioxide. As seen in the previous unit the concentration of O_3 in lower atmosphere is higher than formed by photolysis of NO_2 alone because chemical conversion of NO to NO_2 is not catalyzed by O_3.

The rate of formation of O_3 is influenced by the concentration of peroxy radical (RO_2.). Peroxy radicals are produced when hydroxy radicals (OH•) and HOx react with hydrocarbons. The hydroxy radicals are produced by photolysis of O_3, carbonyl compounds and nitrous acid. Thus the concentration of O_3 in polluted atmosphere is based on intensity of sunlight, nature of hydrocarbons; NO_2/NO ratios and other pollutants like alkanals and CO.

The general reactions of Photochemical Smog are given below:

1) $NO + VOC \rightarrow NO_2$ (nitrogen dioxide)

2) $NO_2 + UV \rightarrow NO + O$ (nitric oxide & molecular O)

3) $O + O_2 \rightarrow O_3$ (ozone)

4) $NO_2 + VOC \rightarrow PAN$ (peroxyacetyl nitrate)

Net result:

$NO + VOC + O_2 + UV \longrightarrow O_3 + PAN$ + other particulates

We would how learn another effect of air pollution caused by the presence of sulphur and nitrogen oxides in the atmosphere called the acid precipitation.

2.5.3 Acid Precipitation

Acid precipitation means any type of deposition like rain, fog, mist or snow which is more acidic than normal. The pH of rain water in the absence of pollution is approximately 5.6 because of solubility of CO_2 in the air to produce carbonic acid. Acid deposition is the combination of precipitation and dry acidic particle fallout with a pH less than 5.5 which occurs usually in the industrial regions.

The acid precipitation principally contains a mixture of sulfuric acid (H_2SO_4) and nitric acid (HNO_3) in a ratio of two to one. As we have read in the previous sections of this unit and also in the previous unit that burning of fuels generates sulfur and nitrogen oxides into the troposphere either by anthropogenic or natural sources. These oxides are oxidized by hydroxyl radicals to sulfuric acid and nitric acids which immediately dissolve in rain water or adsorb to particulate matter and brought down to earth as acid deposition. If the deposition is wet then we can call it as **acid rain**. Some times acidic particles brought down to earth by the phenomena of dry deposition (acid aerosols) called the **acid fog**.

Acid is any chemical that releases hydrogen ions when dissolved in water. The more acidic substance means the higher the concentration of hydrogen ions in the solution. It is expressed as pH. The pH starts from 0(highly acidic) through 7(neutral) to 14(highly basic).This scale represents the negative logarithm (power of 10)of the hydrogen ion concentration, expressed in grams per liter (g/L).

Acid materials reaching the earth by any of the above processes have significant harmful affects on flora, soil and surface waters and change the pH.

Air pollution affects the human health in various ways. Let us learn in the next subsection.

2.6 EFFECTS OF AIR POLLUTION ON HUMAN HEALTH

Ex:To say that a solution has a pH 1 means the hydrogen ion concentration in the solution is 10-1g/L(0.1g/L)

In general human beings are affected by air pollution. The first effected system of our body is the respiratory system due to the synergistic effects of ozone and NOx causing chronic respiratory and cardiovascular diseases. The air pollutants may also alter major body functions such as exchange of oxygen in the lungs and oxygen transport in the blood. Irritant pollutants may lead to irritation and long term damage to eyes, nose, throat and other wet surfaces of the body and the soluble particles get transferred to the blood. One of the most important particles in the atmosphere is H_2SO_4, which irritates the mucous membranes and leads to bronchial constrictions.

Most of the gaseous pollutants like SO_2, O_3 and NO_2 are pulmonary irritants, and cause congestion, edema and even hemorrhage. Gases like NO, H_2S and CO are asphyxiants. These gases bind the hemoglobin molecules and prevent oxygen transfer within the body. Organic gas pollutants such as acrolein (l-propenal) causes eye irritation.

Living spaces in urban areas are polluted and people suffer from chronic effects. Some of the effects are given in Table 2.4

Table 2.4 : Some pollutants and -their effects on human health

Pollutant	Effect on human health
SO_2	Bronchitis
O_3	Inflammation which leads to lung fibrosis and failure of lungs
CO	Reduces the oxygen carrying capacity of blood and contribute to the heart disease
NO_x	Impairs lung function and affect the immune system
Particulate Matter	Broad spectrum of health ailments, respiratory infections to heart disease.

Let us look into the effects specific to various pollutants.

Carbon Monoxide

Inhaling of high concentrations of carbon monoxide shows adverse effects on human beings. It binds irreversibly to hemoglobin in the blood forming carboxyhaemoglobin thereby reduce the oxygen carrying capacity of the blood. When comparing to oxygen, CO has a greater affinity (200 times greater) for haemoglobin.

The concentration of CO at around 10ppm has primary health effect as reduction in awareness and at around 100ppm, headaches and drowsiness are observed. Unconsciousness and death occurs at 250ppm level. The continuous exposure to low levels of CO may cause nervous disorders and finally causes heart disease. At concentrations in excess (1000ppm) death results from anoxia because of insufficient supply of O_2 to body tissues and brain. The effects of CO on human health at different concentrations are given in Table 2.5

Table 2.5 : The effects of CO on human health at different concentrations

Concentration of CO in ppm	Effect on health
10	Lowered awareness and driving performance
50 – 100	Headaches and drowsiness, changes in driving performance and increased reaction time to visual stimulation
>250	Death

Sulfur Compounds

The most important sulfur compound in the atmosphere is sulfur dioxide. The adverse effects of sulfur dioxide are often associated with particulate pollutants since both have common source of generation like combustion of fossil fuels. Hence high concentration of SO_2 is associated with high concentration of particulate matter forming sulfate aerosols. These aerosols show significant threat to human health than do sulfur dioxide emissions alone. These aerosols are retained in the lungs and cause maximum physiological damage. At elevated concentrations these result in higher mortality from bronchitis and lung cancer. Sulfur dioxide alone causes respiratory tract irritation and breathing difficulty. The effects of SO_2 to human health are given in Table 2.6. Table 2.6: Effect of SO_2 to human health at different concentrations

SO_2 (concentration in ppm)	Health effect
500	Reduction in human sensation
800	Threshold of taste
1400	Threshold of odour
4400	Bronchial constriction
20000	Immediate throat irritation
30000	Immediate eye irritation
50000	Immediate coughing

Oxides of Nitrogen

Nitric oxide is a relatively non toxic and non-irritating gas when compared with NO_2 but it is rapidly oxidized to NO_2, which is toxic in nature. Because of its less solubility in water NO_2 generally diffuses deep into the lung and causes tissue damage. At high concentrations it shows the effects like pulmonary edema. The major health problem created by nitrogen oxides is that they are the origins for the mixture of pollutants which form photochemical smog.

Hydrocarbons

All hydrocarbons are relatively nontoxic in nature at the ambient concentrations but they encounter reactions in the atmosphere with O_2, O_3, NO_x, SO_x and other components to form photochemical smog which is very harmful to human health. At high concentrations HCHO (methanal), acrolein, and peroxyacyl nitrate (PAN) cause reduction in visibility, unpleasant odours and cause skin and eye irritation. Hydrocarbons like polycyclic aromatic hydrocarbons (PAH), benzo (α) pyrene (BaP), are carcinogenic in nature.

Ozone

As per the ambient air quality standards ozone is one of the most toxic pollutant. In polluted ambient environmental conditions ozone causes significant physiological and pathological changes in both animals and human beings. The ambient air quality standard for O_3 is 0.12ppm (235mg/m^3). Some of the adverse effects of ozone on exposure are given below.

- At 0.1- 0.4ppm range of for 1-2 hours significant lung function changes in smokers, adults over 55yrs, asthmatics, or individuals with chronic obstructive lung disease are more responsive to O_3 exposures.
- Above 0.12ppm range symptoms including throat dryness, chest tightness, coughing, pain whilst deep breathing, shortness of breath, lassitude, malaise, headache, nausea and also cause decrease in athletic performance.
- O_3 exposures inhibit the immune system activity.
- At 0.08-0.10ppm concentrations for three hours causes increase in the susceptibility of mice to bacterial infectionProlonged and acute exposure causes death.

Particulate Matter

One of the major air pollutants is particulate matter. Because of its size it exhibits toxic effects like irritation. The concentration of adsorbed substances includes SO_x, polycyclic aromatic hydrocarbons (PAH), and heavy metals such as lead, cadmium, zinc and mercury. Particles less than 2.5µm are called “respirable”; they can enter pulmonary tissue and be deposited there. Particles smaller than 10µm are described as “inhalable particles” and be deposited in the respiratory system. The deposition of these particles shows adverse effects on health. It depends on their level of concentration, pH, solubility and synergistic effects with pollutants such as SO_2. The main health effects are acute bacterial and viral bronchitis, bronchial asthma and pulmonary emphysema.

At Total Suspended Particulate Level (ug/m^3) of 200 TSP, minor reversible changes are observed in the lung function of children. At 250-500 TSP acute bronchitis and at 1000 TSP results in increased mortality are observed.

Lead

Exposure to lead particulates results in lead poisoning and the most affected organs are the blood, the brain, the kidney, the nervous system and the reproductive system. Symptoms of acute lead poisoning are shock, anaemia, nervousness, and irreversible kidney and brain damage. In growing children, lead poisoning affects intelligence, length of concentration and activity. Lead poison has the ability to cross the placenta, hence in a pregnant woman results in high lead levels in the foetus that may lead to mental retardation.

Asbestos

Asbestos is the name given to a number of mineral silicates which are compressed together to form fibrous materials. It cannot be classified under distinct mineral species but applied to various fibrous materials with varied composition and physical properties for commercial purpose. The fibres in asbestos are highly toxic in nature with very long dormancy periods. Once the asbestos fiber is inhaled by an individual it has the potential to cause cancer for the rest of the individual's life.

On the basis of chemical and mineralogical studies asbestos is grouped under silicate mineral. Asbestos is a mixture of six varieties of silicate minerals having common properties of eponymous asbestiform nature. They are chrysotile, crocidolite, amosite, anthophyllite, tremolie and actinolite.

The asbestos particulates show a considerable public health problem due to their wide use in the construction and insulating material. Inhalation of the fibres causes the lung disease known as **asbestosis** which is characterized by chronic inflammation and scarring disease affecting the tissue of the lungs. Patients with asbestosis may experience acute shortness of breath and are at an increased risk for certain cancers, including lung cancer and, less commonly, mesothelioma (cancer of the lining of the body cavity).

Chromium

Chromium emissions in the air are mainly from industries like iron and chrome, and associated industries like refining, chemical and refractory processing, cement production plants, automobiles, leather tanneries, chrome based dyes and stainless steel production.

The harmful effects of chromium are related to respiratory ailments like shortness of breath, coughing, and wheezing. Chronic exposure results in septum damage, disrupted pulmonary function- pneumonia and lung cancer.

Let us now learn how the air pollution affects building and materials.

2.7 EFFECTS OF AIR POLLUTANTS ON BUILDINGS AND MATERIALS

In fact, most of the materials are affected by the direct exposure of air pollutants. Some of them are different types of stones, metals, papers and textiles which may be deteriorated by either of the processes of abrasion, chemical exposure, deposition and corrosion. The moisture, temperature and freezing and thawing are the conditions which influence the rate of deterioration.

1. **Abrasion**: Solid particles of sufficient size travelling at high speed can cause destructive abrasion.
2. **Deposition and Removal**: Solid pollutants deposited on the surface may cause discoloration and the removal of the deposit causes deterioration to the structure.

Moisture is required to cause the corrosion of iron and steel in the presence of sulfur oxides. Metal samples in dry air containing oxides of sulfur do not corrode. Deterioration by a chemical reaction will increase with temperature. Surface which is below the dew point temperature will cause surface condensation and enhanced reaction with soluble pollutant gases. If temperatures drops below the freezing point of water, freezing and defrosting cause cracks and spalling on stone, exposing new surfaces to reactive pollutants.

3. **Direct and Indirect Chemical Attack**: Some of the air pollutants like sulfur oxides, mainly sulfur trioxide (SO_3) react with marble or limestone ($CaCO_3$) irreversibly and converted to gypsum that cause deterioration. Materials made by leather absorb sulfur dioxide (SO_2) which gets converted to sulphuric acid that damage the leather goods.

4. **Corrosion:** Gases like sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are corrosive in nature and in the presence of moisture they undergo electrochemical reaction and corrode the metal objects.

We will now learn how the buildings and materials may get affected in terms of discoloration, loss of material, soiling and structural failure.

Stone: In general most of the historic monuments are constructed by different types of stones. For example: Marble, Granite and Mosaic. These get affected in the following manner in the case of marble.

Marble: Marble is a metamorphic rock of carbonate mineral. The constructions made by marble or alternate calcareous stones are vulnerable to air pollutants like total suspended particulate matter (TSPM), oxides of sulphur and nitrogen. We have already learnt about acid rain and how SO_2 gets converted into H_2SO_4.This sulphuric acid goes deep into the marble stone thereby solubilises the calcium carbonate and drags to the surface by the process of natural heating and reaction with moisture, where it is deposited as gypsum. During wet and dry environment cycles recurring deposition of gypsum and the porous crust formed has no link to the stone. It can easily detatch the stone and scale it off. The dust particles in TSPM contain soot which quickly gets deposit on porous crust which appears as a black surface.

Decolouration of Taj Mahal- a 17th Century Islamic Architecture: A Case Study

India's most famous pride and tourist attraction Taj Mahal is not an exception to be a non-living victim of the pollution. The industries like Mathura oil refinery, rubber processing, automobile located around Agra have been responsible for producing pollutants like sulphur dioxide and nitrogen oxides. These air pollutants react with water vapor present in the atmosphere forms sulphuric and nitric acid. These acids reach the ground with rain in the form of acid rain. Acid rains decolorize the white marble and also corrode the marble which is known as "**Marble cancer**".

Check Your Progress 3

5. Match the words in column A with those of column B appropriately in the following:

1.	Industrial smog	a.	Asbestos
2.	SO_2	b.	Lung fibrosis
3.	Acid rain	c.	H_2SO_4, $(NH_4)_2SO_4$
4.	Photochemical Smog	d.	Carcinogenic
5.	O_3	e.	H_2SO_4, HNO_3
6.	PAH	f.	Bronchitis
7.	Asbestos	g.	O_3

2.8 KEY WORDS

Acid Precipitation : Includes acid rain, acid fog, acid snow, and any other form of precipitation that is more acidic than normal (i.e. less than pH 5.6). Excess acidity is derived from certain air pollutants; namely, sulphur dioxide and oxides of nitrogen.

Asbestos Fibres : Crystals of asbestos, a natural mineral, that have the form of minute strands; asbestos is a serious health hazard in indoor spaces.

Greenhouse Effect : An increase in the atmospheric temperature caused by increasing amounts of carbon dioxide and certain other gases that absorb and trap heat, which normally radiates away from Earth.

Hydroxy Radical : The hydroxyl group (OH), missing the electron. The hydroxyl radical is a natural cleansing agent of the atmosphere. It is highly reactive, readily oxidizes many pollutants upon contact, and thus contributes to their removal from the air.

Nitrogen Oxides (NOx) : A group of nitrogen-oxygen compounds formed when some of the nitrogen gas in air combines with oxygen during high-temperature combustion. Nitrogen oxides are a major category of air pollutants and, along with hydrocarbons, are a primary factor in the production of ozone and other photochemical oxidants that are the most harmful components of photochemical smog. Nitrogen oxides also contribute to acid precipitation.

Photochemical Smog : The brownish haze that frequently forms on otherwise clear, sunny days over large cities with significant amounts of automobile traffic. Photochemical smog results largely from sunlight-driven chemical reactions among nitrogen oxides and hydrocarbons, both of which come primarily from auto exhausts.

Primary Pollutants : Pollutants released directly into the atmosphere mainly as a result of burning fuels and wastes, as opposed to secondary pollutants.

Secondary Air Pollutants : Air pollutants resulting from reactions of primary air pollutants resident in the atmosphere. Secondary air pollutants include ozone, other reactive organic compounds, and sulphuric and nitric acids.

2.9 LET US SUM UP

There are a number of forms of air pollutants which exists in the form of gases, fumes, clouds, smoke, mist, fog, smog, haze, dust, aerosols, etc. They are classified as natural/anthropogenic, primary/secondary, particulates/gases, ambient air/indoor air/ global, stationary/mobile etc. Air pollutant concentrations are measured in the form of their threshold values which are different for different pollutants. Above these values the pollutants shows adverse effects on human beings. The common problem is the respiratory tract infection, bronchitis and other diseases can occur due to inhalation of toxic pollutants. Pollutants such as arsenic, lead, fluoride, insecticides and pesticides affect human beings adversely. Air pollutants also deteriorate the objects made of ferrous, aluminum, copper, silver, building materials, leather, paper and textile.

2.10 REFERENCES AND SUGGESTED FURTHER READINGS

1. Fundamentals of Environmental Chemistry by A.K.De
2. Environmental Chemistry by Stanley Manahan
3. Textbook of Environmental Science by Pearson.

2.11 ANSWERS TO CHECK YOUR PROGRESS

Answers to check your progress should include the following points.

1 a. **Lead**: Exhaust of the vehicles which use leaded petrol, waste incinerators, processing of ore and metals and aircraft operating on leaded aviation fuel, utilities, lead-acid battery manufacturers, lead smelters, lead-based paint, ceramics, pipes, plumbing materials, solders, gasoline, batteries, ammunition, and cosmetics.

b. **Nitrogen dioxide**: It is produced by photochemical reactions of O_3, peroxy radical (RO_2), OH•, HO_2, and H_2O_2

c. **Carbon dioxide**: It is generated by the combustion of organic matter weathering, or biological decomposition.

2. In poorly ventilated dwellings pollutants will accumulate to higher concentrations than that of outside causes irritations of eyes, nose, and throat, dry mucous membranes and skin erythema known as 'Sick building syndrome'.

3. Primary pollutants are the pollutants which are released directly in to the atmosphere from a particular source of pollution which means they are the direct products of evaporation and combustion. Where as the primary pollutants which can under go further reactions by light energy, heat or the presence of other chemicals converted in to undesirable toxic compounds are known as secondary pollutants.

4. VOC's emitted from paints, and other solvents, wood preservatives, aerosol sprays, cleansers and disinfectants, moth repellents and air fresheners, stored fuels and automotive products, dry - cleaned clothing, pesticides,

building materials, furnishings, office equipment such as copiers and printers, graphics and craft materials including glues and adhesives, permanent markers and photographic solutions.

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   2. f,
   3. e
   4. g
   5. b
   6. d
   7. a

UNIT 3 WATER POLLUTION

Structure

3.0 Introduction

3.1 Objectives

3.2 Physico-Chemical and Biological Parameters of Water

3.3 Types of Water Pollutants

- 3.3.1 Industrial Water Pollutants
- 3.3.2 Pollutants from Food Processing Industry
- 3.3.3 Pollutants from Petrochemical Industry
- 3.3.4 Pollutants from Textile Industry
- 3.3.6 Pollutants from Tanning Industry
- 3.3.6 Pollutants from Paper and Pulp Industry
- 3.3.7 Water Pollutants due to Agrochemicals
- 3.3.8 Sewage Water Pollutants

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3.5 Role of the Government

3.6 Key Words

3.7 Let Us Sum Up

3.8 References and Suggested Further Readings

3.9 Answers to Check Your Progress

3.0 INTRODUCTION

Water pollution can be defined as the presence of any solid, liquid, gaseous material and the heat generated contaminants in such concentration that may drastically change the quality of water thereby impairing the utility of water. Water pollution problem has become more pressing nowadays because of increase in population growth and increased use of per capita material energy. This has resulted in increase in the production of by-products as effluents that reach water bodies and affect the entire biosphere. The water pollutants generated from human activities reach surface and ground water through various pathways. These pollutants are categorized as point and non-point sources. Effluents from factories, sewage systems are point sources where as agriculture run-off and atmospheric deposition are some of the examples of non-point sources. Water is an excellent solvent for many chemicals which have adverse health effects on the environment. Petroleum products, pesticide run-off and industrial chemicals pollute many water bodies even at low concentrations.

Dear learner, in this unit we would first learn about physico-chemical and biological parameters of water which is helpful in understanding the pollution levels of various water sources. The point and non-point sources of water pollutants, pollution parameters and waste water treatment methods are discussed in detail in different sections. We start with the study of physico-chemical parameters.

3.1 OBJECTIVES

After studying this unit, you should be able to:

- define various physicochemical parameters of waste water,
- define industrial effluents and describe their characteristics,
- explain the origin of pollutants in petrochemical industries,
- enlist various health effects of industrial pollutants,
- explain water pollutants due to agrochemicals
- List out the general characteristics of sewage, and
- Describe sewage treatment methods.

3.2 PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS OF WATER

Water gets contaminated by human use for different purposes that include household, industry, agriculture, etc. The contaminated water is called the waste water which is required to be estimated by known methods of analysis. Quantitative analysis of waste water is indicated by predictable parameters which delineate the nature of waste and its potential impact on the health of environment and human health. The following are the physico-chemical and biological parameters:

Total Suspended Solids 2. pH 3. Dissolved Oxygen (DO) 4 Total Dissolved Solids (TDS) 5. Oil 6. Turbidity 7. Biochemical Oxygen Demand (BOD) 8. Chemical Oxygen Demand (COD)

Let us understand these parameters in detail.

Total Suspended Solids (TSS): The particles that are larger than 2 microns and non-filterable are considered as suspended solids. These particles may be sediments, sand, silt, plankton, algae, animal decay and chemical precipitates. The heavier suspended particles settled at the bottom of the water body over a period of time are known as **sediments** or **bedload**. The remaining particles which float in water are known as **colloids**.

Effects: The SS changes the colour and reduces the light penetration there by affecting the photosynthesis process where generation of oxygen ceases.

Hypoxic inadequate supply of oxygen at the tissue level

The increase in TSS increases the water temperature and decrease in dissolved oxygen levels. The high rate of heat absorption by TSS than clear water increases the temperature of surrounding water by the process of conduction there by decrease in dissolved oxygen levels. Another effect of increase in surface water temperature is the water **stratification**. Because of this, the lower layers of water become hypoxic for survival of the organisms.

pH: pH is a chemical parameter that values between 0 to 14 on a defined scale. It provides the intensity of acidity and alkalinity of a given water sample along a

logarithmic scale. It has direct influence on the treatment procedures. It provides critical information in the treatment of waste water which removes heavy metals or organic compounds. The effluents contain heavy and toxic metals in the dissolved form. These will be removed by altering the pH by different suitable methods. High or low pH of water may kill water organisms and sterilize the water bodies, thereby inactivate the vital microorganisms in waste water treatment.

Do you Know?

The lower the number, the more acidic the water is. The higher the number, the more basic it is. A pH of 7 is considered neutral. The logarithmic scale means that each number below 7 is 10 times more acidic than the previous number when counting down. Likewise, when counting up above 7, each number is 10 times more basic than the previous number. The pH measurement can be done by using electrometric technique.

Dissolved Oxygen:

Dissolved oxygen (DO) is non-compound, free oxygen in the stream of water which is an important criterion to assess the quality of water.

The dissolved oxygen for aquatic animals varies from species to species ranges 1-6 mg/L to 4-15 mg/L. The DO is required for microbial decomposition of organic material at the bottom of the water. The DO levels decrease with increase of temperature, concentration of salts and increase in pressure.

Do You Know?

Causes of low dissolved oxygen (DO) primarily result from excessive algal growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Dying off and decomposition of submerged plants also contribute to low dissolved oxygen. The process of decomposition is called **Carbonaceous Biochemical Oxygen Demand** (CBOD). Sources of phosphorus include discharges from municipal and private wastewater treatment, cropland and urban storm water runoff, and natural decay of vegetation. Direct discharge of pollutants from point source and non-point sources into a river segment add to its CBOD loadings, creating an oxygen demand that may depress DO below acceptable concentrations.

Total Dissolved Solids (TDS): It is a measure of organic and inorganic substance in a given liquid. TDS mainly constitutes calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. The organoleptic properties (qualities like taste, colour, odour, feel, etc.) of water with respect to TDS are as follows:

<300mg/L - Excellent

300-600 mg/L –Good

600-900 mg/L –Fair

900-1200 mg/L –Poor

>1200 mg/l L -Unacceptable

TDS in water streams is generated from urban and agricultural run-off, sewage, industrial wastewater, road de-icing salts and natural sources.

Turbidity: Turbidity is the only parameter which has optical determination. It is an indicator of water quality on the basis of clarity and relatively estimated TDS in water. Turbid water looks cloudy, coloured because of suspended solids that is based on the amount of light scattered by these. In addition to the suspended solids, coloured dissolved organic matter (CDOM), fluorescent dissolved organic matter (FDOM) and dyes enhance the turbidity of water.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is the amount of dissolved oxygen required for microbial metabolism of organic compounds in water at certain temperature (~20^0C) and a period of time (~5 days). It is a chemical procedure to measure the quantity of dissolved oxygen that indicates the quality of water. It is dependant on temperature, pH, microorganisms and organic and inorganic materials.

Chemical Oxygen Demand (COD): It is the amount of oxygen required in chemical oxidation of organic matter present in water. It essentially indicates the amount of oxidizable pollutants in water body and thus helps to know the pollution levels.

Check Your Progress 1

Note : a) Write your answer in about 50 words.
b) Check your progress with possible answer given at the end of the unit.

1. List out physico-chemical parameters of the waste waters.

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2. What is the importance of pH in waster waters?

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3.3 TYPES OF WATER POLLUTANTS

As mentioned earlier, water can get contaminated by various means. There are a number of sources that are responsible for adding pollutants to the running water, underground water or a natural water body. Thus the pollutants can come from Food Processing, Petrochemical, Textile, Tanning, Paper, etc. industry and also from Agrochemicals and Sewage. The pollutants from all these sources are discussed in the following subsections.

3.3.1 Industrial Water Pollutants

Industrial development leads to industrial effluents, and the untreated effluents become responsible for water, soil and air pollution. The quantitative assessment depends on

the concentration of these effluents present in the waste water. The expression of concentration of impurities is either by mgL^{-1} or ppm or percent saturation.

According to the Press Information Bureau, Government Of India (GOI), Ministry of Environment and Forest (MoEF) 2016, the Ministry of Environment, Forest and Climate Change (MoEFCC) has developed the criteria of categorization of industrial sectors based on the Pollution Index (PI) which is a function of the emissions (air pollutants), effluents (water pollutants), hazardous wastes generated and consumption of resources. For this purpose the references are taken from the the Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003, Standards so far prescribed for various pollutants under Environment (Protection) Act , 1986 and Doon Valley Notification, 1989 issued by MoEFCC. The **Pollution Index** of any industrial sector is a number from 0 to 100 and the increasing value of PI denotes the increasing degree of pollution load from the industrial sector and the following is the criteria on '**Range of Pollution Index** 'for the purpose of categorization of industrial sectors.

- Industrial Sectors having Pollution Index score of 60 and above – Red category
- Industrial Sectors having Pollution Index score of 41 to 59 – Orange category
- Industrial Sectors having Pollution Index score of 21 to 40 – Green category
- Industrial Sectors having Pollution Index score incl.&upto 20 – White category

This unit discusses about some of the industries which are under the category of Red.

3.3.2 Food processing industry

The waste from food and food processing industries are termed as by-products. These by-products have the properties of high water holding capacity, binding, gelling and thickening. Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) are the important organic parameters to determine the liquid wastes from food industry.

The by-products from some of the food processing industries which pollute the water bodies are summarized in Table 3.1.

Table 3.1: **Some food processing industries and their by-products**

Industry	**By-Products/Wastes**
Fruit and Vegetable Industry	High amount in glucose, citric and linoleic acids, tocopherols, and isorhamnetin-O-(di-deoxyhexosyl-hexoside), polysaccharides (e.g. pectin, cellulose, hemicelluloses, lignin and gums) and phenolic compounds bound with skin, i.e. dihydrochalcones, flavonols and phenolic acids

Dairy Industry	Dairy effluents, fats, oil and grease, whey by-product contains solvent proteins like ²-lactoglobulin, ±-lactalbumin, immunoglobulin, bovine serum albumin, lactoferrin, and lactoperoxidase, high content of essential amino acids, urea, uric acid, creatine, creatinine and ammonia.
Grain Processing Industry	Rice bran, oil, tocotrienols ²-glucans, the spent grain rich in cellulose and non-cellulosic polysaccharides, the hot trub and the residual yeast, the powder of macaroni boiling water, slime and waste waters
Brewery and Winery Industry	Wine prunings, grape stalks, grape pomace and grape seeds, yeast lees, tartrate, carbon dioxide and wastewater
Meat Industry	Carcasses, skins, bones, meat trimmings, blood, fatty tissues, horns, feet, hoofs or internal organs that are rich in lipids, carbohydrates and proteins
Marine Industry	É-3 PUFAs from the livers of white lean fish, waste flesh parts of fatty fish, blubber of marine animals, hydrolysates from fish guts/ cleanings, peptides, and products from crustaceans such as chitosan, chitosan oligomers and glucosamines

Check Your Progress 2

Note : a) Write your answer in about 50 words.
b) Check your progress with possible answer given at the end of the unit.

3. What are sources of waste in fruit and vegetable industry?

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4. What is the range of pollution index?

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3.3.3 Pollutants from Petrochemical Industry

Petrochemical waste from production to refining is considered to be complex to treat among the industrial wastewaters. Occasionally these are released into the atmosphere by accidental discharges due to the technical error and abnormal operations from polyethylene and ethylene oxide glycol industries. These are highly industry specific and typically generate hazardous solid waste, sludges and colloids which contain huge quantities of heavy metals, toxic organic substances like polycyclic and aromatic hydrocarbons, phenols, metal derivatives surface-active substances, sulphides, naphthylenic acids and other chemicals which contaminate the water bodies that pose adverse consequences on the ecosystem.

3.3.4 Pollutants from Textile Industry

The textile industry is one of most rapidly developing important industry on the globe. It requires large volume of water for numerous unit operations and chemicals for various processes involves wet processing sequences. The waste generated by this industry has high negative impact on the environment since this industry plays a major role in the fashion garment that varies in type of demand and coloured fabrics. The textile processing produce loads of liquid, solid and gaseous waste in each step.

The textile industry uses natural fibres like wool, hair, silk, cotton and flax and synthetic fibres like rayon and nylon. These wastes have salts, surfactants, ionic metals and their complexes, toxic chemicals, emulsifiers, dispersants and biocides that contributes to BOD,foaming and effluent aquatic toxicity. The pollutants generated in various processes of the textile industry are listed in the Table 3.2.

Table 3.2: **Nature of effluents generated in the textile industrial processes**

Process	Pollutants
Energy production	Particulate matter, NO_X, SO2
Coating, drying and curing	Volatile organic compounds
Cotton handling activities	Particulate matter
Sizing	NO_x, SO_x, CO_x
Bleaching	Chlorine and Chlorine dioxide
Dyeing	H_2S
Printing and finishing	Hydrocarbons and NH_3
Chemical storage	VOCs

3.3.5 Pollutants from Tanning Industry

Tanning Industry is considered to be one of the major sources of pollution with a potential environmental concern. The leather production process consists of the following stages and used hazardous chemicals at every stage. These are 1. Preparatory stages 2. Tanning 3. Crusting and 4. Surface Coating (Fig. 3.3).

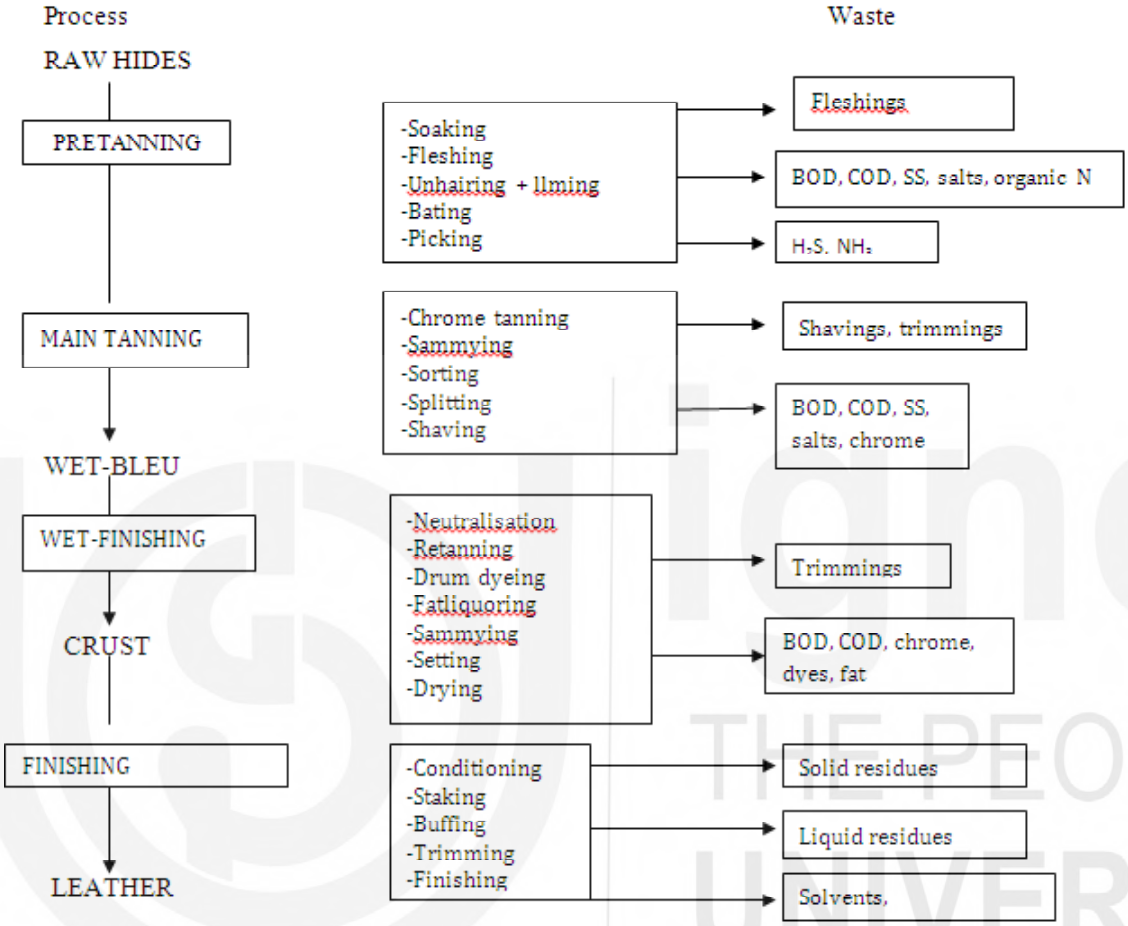

Fig. 3.3: Different stages in leather production process

Nature of Effluents: Approximately 80% of the organic pollutants, limed and non-limed waste is generated in the pretanning process. The waste water contains pollutants like salts (Cl), fats, proteins, preservatives (soaking); lime and ammonium salts, ammonia, protein (hair), and sulphides (fleshing, trimmingating); chromium(salts) and polyphenolic compounds (tanning); and dye and solvent chemicals (wet-finishing). Significant threat to environment and human health from tanneries have been observed because of chromium contamination, high chemical oxygen demand and BOD.

3.3.6 Pollutants from Paper and Pulp Industry

Paper and pulp industry is also one of the large industrial polluter to water, air and soil. The major process of a paper industry is depicted in **Fig. 3.4.**

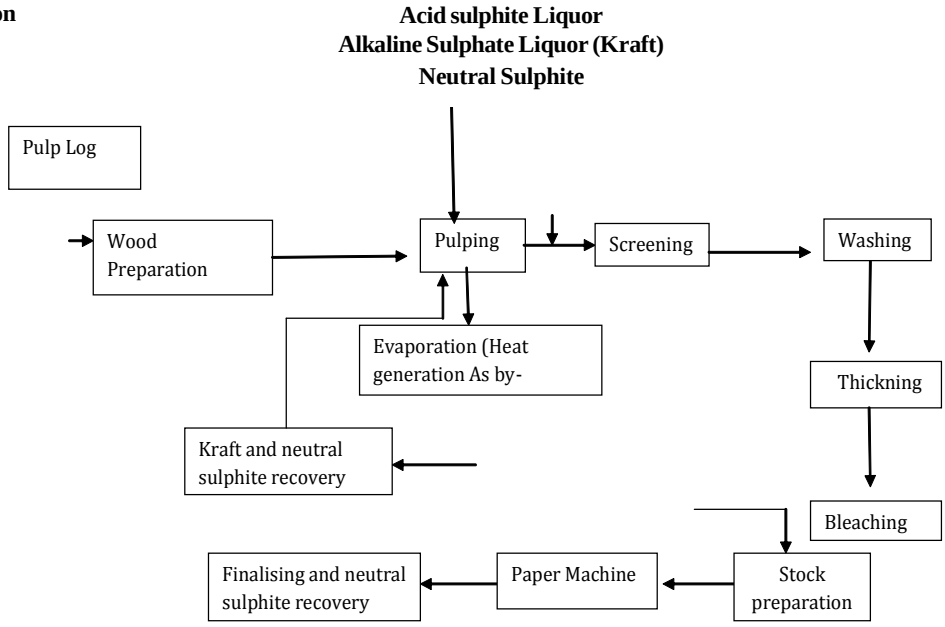

Fig. 3.4: Flow diagram of the processes in paper and pulp industry

Paper and pulp are manufactured from cellulosic fibres of wood, straw, cereal, reeds, jute, flax and esparto grass. These different raw materials used for different types of paper. For example, coarse type paper is generated from straw. Kraft, sulphite, neutral sulphite, soda, cold soda and ground wood are important pulps used to produce paper.

The major steps in the industry are raw material preparation, wood pulping, pulp bleaching and paper manufacturing. Raw material preparation includes debarking of wood, chipping of logs and screening of chips. The chemical pulping process fibres are released from the wood matrix since the lignin is eliminated by solubilizing in cooking liquor at elevated temperature.

Nature of Effluents

The major effluents from pulp and paper making are from wood preparation unit, screening and pulp cleaning unit, mechanical and chemical pulping, chemical pulping, textile fiber pulping unit, machine and bleaching waste which contains dissolved organic substances and suspended particles. They contain chlorine and chlorine based materials, sulfur, hydrogen sulfide and sulfur dioxide. The chlorinated compounds are mainly used in bleaching process of wood pulp and chemical pulp. The pollutants from bleaching process contain significant amounts of dioxins which belong to a group of POPs, with high toxic potentials. The waste waters contain various solids, nutrients; sulfur compounds and Dissolved Organic Matter (DOM). Nutrients like nitrogen and phosphorous cause eutrophication. DOM changes the ecological characteristics of water bodies that lead to the high levels of BOD which can cause the death of aquatic organisms, SO_2 released from the processing of sulphur compounds that makes the water bodies more acidic. Solid pollutants consist of clay particles, $CaCO_3$, titanium dioxide and fiber.

3.3.7 Water Pollutants due to Agrochemicals

The pesticides, biocides, manures and fertilizers are categorized under agrochemicals that are used to enhance the yield of the crop. The essential hydrological processes

that loop rainfall, runoff and leaching, and which bring about erosion and transport of chemically augmented soil particles, are important in aquatic contamination by fertilizer products. The major sources of pollutants due to pesticides are industries, agriculture, forestry and also air which becomes a means of spreading the pollutants. The dust particles in the air adsorb the pesticides from pesticides spray in agriculture, forestry and then contaminate water bodies, sediments and soil through rain water. The high quantity of the residual pesticide eventually be leached to aquifer levels and pollute the groundwater. The amount of pesticide leachability is measured in terms of the **groundwater ubiquity score** (GUS).

The GUS index can be written as

GUS = log (DT_{50}). [4–log(Ka)],Where DT_{50} and Ka are persistence and mobility respectively. The tendencies of groundwater contamination are (i) non-leacher (GUS < 1.8), (ii) transition (1.8 < GUS < 2.8) and (iii) leacher (GUS > 2.8).

Leaching of pesticides depends on the amount applied per area per year, application procedure, the solubility of the compound, how strongly it is bound by the soil and how quickly it degrades in the root zone. After a pesticide application a part of it may be lost to the atmosphere through volatilization, and a part is carried away to surface waters by runoff, or broken down by photolysis. The pesticides from the contaminated water are taken up by plants and animals and enter the food chain. Once they enter into the body they are tissue degradative, relatively stable and carcinogenic in nature. Some of them damage the liver and the nervous system. Further more, certain pesticides are found to alter the enzymatic activities of the body which leads to different types of diseases. Some of the commonly used pesticides and their health hazards are given in Table 3.3.

Table 3.3 : Most commonly used pesticides and their health hazards

Pesticide	**Diseases/Adverse effects**
Aldrin	Attacks the nervous system, convulsion, repeated dosage damages the liver, carcinogenic
Benzene hexa chloride (BHC)	Liver tumour
Captan	Abnormality in the eyes and brain, carcinogenic
Chlordane	Carcinogenic
DDT	Liver damage, carcinogenic
Dieldrin	Liver damage, carcinogenic, destroys enzymatic activities
Endosulfan	Carcinogenic
Hexa Chloro Benzene	Highly toxic, bone marrow damage, mutagenic, teratogenic, carcinogenic

Heptachlor	Liver damage, carcinogenic
Malathion	Low toxic but sometimes carcinogenic
Methoxychlor	Low toxic but sometimes carcinogenic
Mirex	Carcinogenic

Commercial fertilizers contain mainly potassium and nitrogen and phosphorous. Some of the fertilizers are identified as possible sources of water pollution. The improper dissemination causes adverse toxic effects on the environment and humans as well since these substances are toxic in nature. For example, surface water fertilization results in eutrophication, i.e., intense growth of algae which causes unmanageable changes to the biological equilibrium. These chemicals enter the water bodies by intentional or unintentional application for pest control. Globally many soils are deficient in phosphorous, which is required for plant growth. In its phosphate form, phosphorus is significant for cell's genetic material, and available as adenosine triphosphate (ATP), the energy carrier in cells. Phosphorous based fertilizer is the major contributor to run-off phosphorous pollution from the agriculture land and through manure into waterways. Excess phosphorus results into harmful algal blooms, known as **eutrophication**. The blooms consume much of the dissolved oxygen in the water, are lethal to fish and other plant life, also release toxins that are toxic to humans and animals. Toxic effects of potassium in humans are very rare since it is promptly excreted in the absence of pre-existing kidney damage. The impacts of some of the agrochemicals are listed in Table 3.3.

Table 3.4: Some agrochemicals and their impacts

Agrochemicals	**Impacts**			
	Ground water	**Surface water**	**Ecosystem**	**Humans**
Pesticides	Some pesticides may leach into groundwater and contaminate the drinking water causing human health problems.	Pesticides runoff contaminates the surface water and biota; Pesticides are also travel long distances as dust by wind and contaminate aquatic systems.	Pesticides inhibit the growth and causes reproductive failure. Consequent upon malfunctioning of ecological system in surface waters occurs by loss of top predators.	Adverse effects on human health by eating contaminated food like fruits, vegetables and fish, breathing contaminated air etc.,
Fertilizers **Nitrogen** based	Nitrogen fertilizers in any form leach in to groundwater and converted into nitrites by microorganisms that contaminate ground water.	Surface runoff carry nitrogen fertilizer to the water streams and lakes there by contaminates.	Nitrate can toxic to plants that causes stunted growth and excessive nitrate accumulates in the leaves of the crop.	Water with high quantity of nitrate and food consumed by humans and cattle gets converted into nitrites by microorganism's causes the disease

				methemogl-obinemea (blue baby syndrome) in children and by the formation nitrosamines have the same effect in cattle also.
Potassium based	Potassium is strongly held by clay particles in soil. Therefore, leaching of potassium through the soil profile and into ground water is important only on coarse-textured soils			Potassium toxicity causes chest tightness, nausea and vomiting, diarrhea, hyperkalaemia, shortness of breath and heart failure.
Phosphorous based	Leached phosphorus stored in bed sediments which is released back to the water column causing 'dead zones'. Phosphate fertilizer can also contribute heavy metal like cadmium to food chain. Cadmium is present in concentrations ranges between 5-280mgkg^{-1} in Rock phosphate.	Excess phosphorus caused harmful algal blooms known as eutrophication. The blooms consume much of the dissolved oxygen in the water, lethal to fish and other plant life, also release toxins that are toxic to humans and animals.	Excess of Phosphorous causes toxic algal blooms, loss of biodiversity and increased health risks for the plants, animals and humans that come in contact with polluted waters.	Excess of phosphate can cause health problems, such as irritation in eyes, kidney damage and osteoporosis.

Do You Know?

Methemoglobinemea is caused by high levels of methemoglobin in the blood. Methemoglobin is one of the forms of hemoglobin that contains the ferric [Fe^{3+}] ion and the affinity for oxygen of ferric iron is impaired and the binding of oxygen in the remaining heme sites that are in ferrous state within the same tetrameric hemoglobin unit will increase. Hypoxia will occur when methemoglobin concentration is elevated in red blood cells. This leads to an overall reduced ability of the red blood cell to release oxygen to tissues.

3.3.8 Sewage Water Pollutants Sewage includes domestic wastewaters and municipal wastewater that is produced by a population. Sewage contains organic wastes as well as chemicals pollutants. It consists of grey water, black water, soaps and detergents. Sewage is drained off in large quantities into rivers and other water bodies without treating. This causes adverse effects on biodiversity and humans. The characteristics of sewage water are as follows.

i. **Temperature, Odour and Turbidity**: The information about the temperature of sewage is helpful in measuring the solubility of oxygen, which affects sedimentation and rate of biological activity. At extremely low temperature viscosity increases and affects sedimentation adversely. The odour of old sewage is offensive and unusual smell observed in the case of industrial sewage water. Fresh sewage is highly turbid and grayish in colour.

ii. **Inorganic and Organic Matter:** The nitrogen compounds in domestic sewage are proteins, amines, amino acids, and urea formed by the bacterial decomposition of organic constituents. Nitrogen content in the untreated sewage is observed to be in the range of 20 to 50 mg/L measured as Total Kjeldahl Nitrogen(TKN). Phosphorus in domestic sewage arises from food residues containing phosphorus and their disintegration products. The huge quantities of synthetic detergents add substantially to the phosphorus content.

Organic constituents in the sewage are mainly proteins, carbohydrates and fats. The microorganisms metabolize sewage organic compounds for the source of energy by catabolism. Protein contains C, N, H and O and sometimes P. The source of nitrogen in the sewage is urea that decomposes immediately to CO_2 and NH_3. Proteins also release H_2S gas in the process of reduction. Carbohydrates contain C, H, O and mainly exist in the form of sugars and starch. By the bacterial action they produce organic acids and the pH of brackish sewage water is low when compared to the fresh sewage. Fats also contain carbon, hydrogen and oxygen. They form thin film and decompose to produce filthy smell.

The parameter that characterizes all sewage organic compounds is that which can be oxidized and contains organic carbon. Oxidation of organic compounds can be measured by 1) the Biochemical Oxygen Demand (BOD) and 2) the Chemical Oxygen Demand (COD) tests. Total Organic Carbon (TOC) test is the other test to measure the concentration of the organic material.

Biochemical Oxygen Demand (BOD): The BOD of the sewage is the amount of oxygen required for the biochemical decomposition of biodegradable organic matter under aerobic conditions. The established range of BOD for raw sewage is 100 to 400 mg/L.

Chemical Oxygen Demand (COD): The COD of the sewage is the amount of oxygen required for chemical oxidation. The established range of the COD of raw sewage is 200 to 700 mg/L. In BOD test, the oxidation of organic matter takes several weeks, whereas, biochemical oxidation of organic matter takes barely two hours.

iii. **Microorganisms**: Microorganisms found in sewage emerge from two sources. 1. soil and 2. sanitary waste. One milliliter of sewage ranges between 100,000

and 1 million microorganisms. Some of them considered as good bacteria that purify sewage. In anaerobic conditions they hydrolyze protein, reduce urea and emulsify fats. They also reduce sulphate and nitrates giving rise to CH_4, CO_2 and NH_3. They add nitrites, nitrates, CO_2 and H_2O. Some forms of parasitic bacteria produce toxins that are capable to cause diseases and infection in humans and animals. Pathogens commonly found in sewage are *E. coli*, *Salmonella, Shigella, Pseudomonas aeroginosa, Streptococcus, Mycobacterium* and *Giardia Lamblia.*

3.5 SEWAGE TREATMENT METHODS

The polluted water has to be treated by using different waste water treatment technologies depending upon the type of pollutants. The type of pollutants in waste is divided into four categories.

1. Debris and grit
2. Particulate organic material
3. Colloidal and dissolved organic material
4. Dissolved inorganic matter.

In addition to these pollutants raw waste water, pesticides, heavy metals and other toxic compounds are also present. The general procedure of sewage treatment is depicted in **Fig. 3.5.**

The sewage treatment invoves the following steps:

1. **Preliminary** treatment involves screening and settling process for the removal of debris and the grit.

2. **Primary** treatment for the removal of particulate organic matter involves floating process by primary clarifiers.

3. **Secondary** treament involves **trickling-filter system** or **activated sludge system** for the removal of colloidal and dissolved organic matter. Secondary treatment is also known as **biological treatment** because it uses organisms which are natural decomposers and detritus (waste) feeders. The principle behind this is creating such environment that enables these organisms to feed on the waste containing organic matter and break it down to CO_2, mineral nutrients and water in the process of cell respiration.

4. **Biological nutrient removal (BNR)** process for the removal of dissolved inorganic material involves various processes like denitrification for nitrogen containg pollutants and chemical filtration for phosphorus containg pollutants.

The secondary-treatment systems were designed for biological digestion and the secondary activated-sludge systems have been added, which remove both nutrients and oxidize detritus by the process known as biological nutrient removal.

Nitrogen: It is converted by bacteria (ammonia and nitrate) through denitrification process into nonnutritive nitrogen gas that is released into the atmosphere.

Phosphorus: In oxygen rich environment the bacteria absorb phosphate from solution and store it in their bodies. The raw sludge is treated with these phosphate containing bacteria producing a more nutrient-rich treated-sludge product and can be removed. Phosphorous can be eliminated by precipitating as calcium phosphate with lime or treat the effluent with ferric chloride, which produces insoluble ferric phosphate, or with an organic polymer, which gives rise to a **floc**.

5. Treatment of sludge: Anaerobic digetion,composting,and pasteurization procedures are used for the treatment of sludge. These are explained below.

   Anaerobic Digestion: Anaerobic digestion is a process of enabling the bacteria to feed on the detritus in the absence of oxygen. In the absence of oxygen, organic matter is broken down by anaerobic bacteria and decomposed to biogas which is a mixture of carbon dioxide, methane, and water. Because of its methane content, biogas is flammable and can be used for fuel.

   Composting: Another process used to treat sewage sludge is composting. Raw sludge is mixed with wood chips or some other water-absorbing material to reduce the water content. It is then placed in windrows – long, narrow piles that allow air to circulate conveniently through the material and that can be turned with machinery. Bacteria and other decomposers break down the organic material to rich humus-like material that makes an excellent treatment for poor soil.

   Pasteurization: After the raw sludge is dewatered, the resulting sludge cake may be put through ovens where the sludge is pasteurized to sufficiently kill any pathogens. The product is dry, odorless and the organic pellets are used as organic fertilizer.

6. **On-site** waste water treatment systems, **reconstructing wetland** systems are the alternate treatment methods.

7. **Ground water remediation** involves drilling wells, pumping out the contaminated water, purifying and reinjecting.

   You are aware that water pollution is one of the most burning problem across the globe. The intervention of the Government is a must and it has tried to enforce a number of Acts to streamline the procedures for reducing water pollution. In the next and the last section of the unit let us study about the Acts and the regulations formulated by the Government and analyse the role of stakeholders in the whole proces.

3.6 ROLE OF THE GOVERNMENT

1. In India Water (Prevention and Control of Pollution) Act 1974 has been enacted for the Prevention and Control of Water Pollution and the maintenance or restoration of the wholesomeness of water for the establishment.

2. Central Pollution Control Board (CPCB) under the Water Act 1974 advise the Central Government on any matter concerning the prevention and control of water pollution by collecting, compiling and publishing technical and statistical data relating to water pollution and the measures devised

for its effective prevention and control and prepare manuals, codes or guides relating to treatment and disposal of sewage and trade effluents and disseminate information (MoEF).

3. CPCB in association with state pollution control boards has been monitoring the qualities of water bodies under National Water Quality Monitoring Programme (NWQMP).

4. CPCB has identified many polluted rivers and preparing action plans for prevention and treatment of pollution.

5. Steps have been taken for the initiation of installation of online effluent monitoring system, issuance of directions to the industries for implementation of zero liquid discharge etc.

3.7 LET US SUM UP

Quantitative analysis of waste waters is indicated by predictable parameters which delineate the nature of waste and its potential impact on the health of environment and human health. The physico-chemical and biological parameters are total suspended solids, pH, dissolved oxygen, oil, turbidity, biochemical oxygen demand and chemical oxygen demand. The waste water from dairy includes huge amounts of nutrients like nitrogen and phosphorus. The waste water from petrochemical industries release huge quantities of heavy metals, toxic organic substances like polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface-active substances, sulphides, naphthylenic acids and other chemicals which contaminate the water bodies that pose adverse consequences on the ecosystem. This unit also discussed different pollutants from tanning industry, paper and pulp industry. The sewage treatment plant for treating the polluted water involves different stages like, preliminary, primary, secondary, biological removal of nutrients and sludge treatment. The unit finally discusses the role of the Government to mitigate the water pollution problem in the country.

3.8 KEY WORDS

Acidity : Quantitative capacity of aqueous solutions to react with hydroxyl ions.

Chemical Oxygen Demand : Measure of oxygen consuming capacity of substances present in the waste water.

Turbidity : Condition in waste water due to the presence of suspended particles resulting in the absorption and scattering of light rays.

Eutrophication : Eutrophication, or hypertrophication, is when a water body becomes nutrient rich that influence excessive growth of plants and algae.

Herbicide : A chemical used to kill or inhibit the growth of undesired plants.

Petrochemical : A chemical made from petroleum as a base raw material –include plasic, synthetic fibre etc.

pH : Scale used to designate the acidity or alkalinity of solutions or soil, expressed as the logarithm of the concentration of hydrogen ions.(H^{+}),pH 7 is neutral; values decreasing from 7 indicate increase in acidity, values increasing from 7 increasing alkalinity.

Persistent organic pollutants (POP) : Any member of a class of organic pollutants that are resistant to biodegradation and that are often toxic; for ex: DDT, PCBs and dioxin are POPs. Such chemicals may remain present in the environment for periods of years.

Phosphate : An ion composed of a phosphorous atom with four oxygen atoms attached. Denoted PO_4^{-3}, phosphate is an important plant nutrient. In natural waters, it is frequently the limiting factor; therefore, additions of phosphate to natural water are often responsible for algal blooms.

Pathogen : An organism, usually a microbe that is capable of causing disease.

Pasteurization : The process of applying enough heat to kill pathogens to extend the shelf life of the product.

Sludge cake : Treated sewage sludge that has been dewatered to make a moist solid.

3.9 REFERENCES AND SUGGESTED FURTHER READINGS

1. Fundamentals of Environmental Chemistry by A.K.De
2. Environmental Chemistry by Stanley Manahan
3. Textbook of Environmental Science by Pearson.

3.10 ANSWERS TO CHECK YOUR PROGRESS

1. a. Total suspended solids b. Total dissolved solids c. Dissolved oxygen d. Biological oxygen demand e. Chemical oxygen demand
2. One of the most important characteristics of industrial waste is their acid or alkali content. It provides critical information in treatment of waste

waters which removes heavy metals or organic compounds. The effluents contain heavy and toxic metals in dissolved form. These will be removed by altering the pH by different suitable methods. High or low pH of water may kill water organisms and sterilize the water bodies, thereby inactivate the vital microorganisms in waste water treatment.

3. High amount in glucose, citric and linoleic acids, tocopherols, and isorhamnetin-O-(di-deoxyhexosyl-hexoside), polysaccharides (e.g. pectin, cellulose, hemicelluloses, lignin and gums) and phenolic compounds bound with skin, i.e. dihydrochalcones, flavonols, and phenolic acids.

4. The Pollution Index PI of any industrial sector is a number from 0 to 100 and the increasing value of PI denotes the increasing degree of pollution load from the industrial sector and the following is the criteria on 'Range of Pollution Index 'for the purpose of categorization of industrial sectors.

   - Industrial Sectors having Pollution Index score of 60 and above - Red category
   - Industrial Sectors having Pollution Index score of 41 to 59 – Orange category
   - Industrial Sectors having Pollution Index score of 21 to 40 – Green category
   - Industrial Sectors having Pollution Index score incl.&upto 20 - White category

5. Eutrophication, or hypertrophication, is when a water body becomes nutrient rich that influence excessive growth of plants and algae.

6. Water with high quantity of nitrate and food consumed by humans and cattle gets converted into nitrites by microorganism's causes the disease methemoglobinemea in children and by the formation nitrosamines have the same effect in cattle also.

UNIT 4 SOIL POLLUTION

Structure

4.0 Introduction

4.1 Objectives

4.2 Causes of Soil Pollution

4.3 Sources of Soil Pollution

- 4.3.1 Agricultural Sources
- 4.3.2 Industrial Sources
- 4.3.3 Urban Sources
- 4.3.4 Nuclear Waste Sources

4.4 Effects of Soil Pollution

- 4.4.1 Effects on Agriculture
- 4.4.2 Effects on Ecosystem
- 4.4.3 Effects on Humans

4.5 Prevention of Soil Pollution

4.6 Let Us Sum Up

4.7 Key Words

4.8 References and Suggested Further Readings

4.9 Answers to Check Your Progresss

4.0 INTRODUCTION

Soil is the unconsolidated outer layer of the earth's crust consisting of a mixture of minerals, organic material, living organisms, air and water that together support the growth of life. The process of soil formation is complex and involves a number of physical, chemical and biological transformations. Several factors contribute to the formation of soil. The factors include mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important determinants in the development of soils. Extremely dry or cold climates develop soils very slowly while humid and warm climates develop them more rapidly. The topmost layer of the soil richer in nutrients and supports maximum bioforms composed of minerals of varying sizes and organic matter along with pore space filled with air and water. There are different classes of soil types based on the particle size distribution patterns. The soil ecosystem includes inorganic and organic constituents, and microbial groups. The soil biota can be categorized as bacteria, algae, fungi, actinomycetes, protozoans, nematodes and microarthropods. The biota helps in decomposition of soil, organic materials and in nutrient cycling. Soil microbes are the active agents in the decomposition of plant and animal wastes and are referred to as nature's garbage disposal system. These soil microbes keep the earth free of toxins and help in biogeochemical cycling of elements i.e. C, N, and P. However, soil gets contaminated through a number ways which is referred to as soil pollution/land pollution. Soil can be contaminated with pollutants from different sources like industries and agricultural practices. Heavy metal contaminations of soil through anthropogenic activities such

as chemical and metallurgical industries have degraded the soil quality. These substances change the quality of soil and make it less fertile to support life.

4.1 OBJECTIVES

After reading this unit, you should be able to:

- define soil pollution;
- describe the sources of soil pollution and types of soil pollutants;
- explain the effects soil pollution; and
- discuss some prevention measures to reduce soil pollution.

4.2 CAUSES OF SOIL POLLUTION

Soil pollution can be defined as an undesirable change in the soil physico-chemical properties, which can result in adverse effects on human beings, plant life and animals. Soil pollution occurs when the presence of some toxic chemicals or contaminants in the soil is in reasonably higher concentrations that can pose a risk to plant life, animals and humans. Global warming, unsustainable practices, agricultural fertilizers and pesticides are responsible for converting arable land to non-arable lands finally leading to the process known as desertification. Soils are often contaminated with persistent toxic organic compounds, chemicals, salts, radioactive materials and biological disease causing agents. Pollution of the soil makes soil less suitable for crop cultivation causing severe ecological disturbances. Biological contaminants like bacteria, viruses, fungi, algae, nematodes and vectors like mosquitoes multiply in numbers in polluted soils that pose severe health threats. Some of the pollutants biomagnify in the food chain giving rise to undesirable and disastrous effects. The United Nations Food and Agricultural Organization estimate that annually 75 billion tons of soil, is lost to erosion, water-logging and salination. A healthy soil has several physical, chemical and biological properties. A healthy soil, (1) needs to incorporate adequate organic matter, (2) have a good structure, and (3) be home to a diverse mix of organisms. These properties allow the soil to carry out important functions, and this may be achieved in a natural setting by a soil reaching equilibrium with its surroundings, or in managed settings by human intervention to improve the overall soil's health. Agricultural soil health is linked to human health, as poor soils yield fewer crops with decreased nutritional value. Healthy soils also limit erosion, and help improve air and water quality (Brevik et al. 2013).

The European Commission has proposed the following definition of 'contaminated site': a site where there is a confirmed presence, caused by human activities, of hazardous substances to such a degree that they pose a significant risk to human health or the environment, taking into account land use (Commission Proposal COM (2006) 232). The major causes of soil pollution occur from industrial activities, oil spills, domestic activities, agricultural activities and acid rain. Local soil contamination occurs in places where intensive industrial activities, inadequate waste disposal, mining, military activities or accidents have introduced excessive amounts of contaminants. Soils have a limited ability to process these contaminants through filtering or transformation. Once this ability is exceeded, problems such as water pollution, plants taking up contaminants etc. become more significant (EEA, 2007).

4.3 SOURCES OF SOIL POLLUTION

Over 200 years of industrialization have caused soil contamination to be a widespread problem in the world. Decision makers, scientists, businesses and individual citizens generally accept and understand that pollution can have negative impacts on human health, but the impacts of soil pollution on our health are not so well understood. The major sources of soil pollution include: mining and quarrying, household waste, construction industry wastes, biomedical wastes, agricultural wastes etc. These wastes reach the soil and infiltrate eventually entering the ground waters, rivers, lakes, streams through rainfall, irrigation, drainage thus polluting and disturbing the natural balance of the ecosystems. Soil gets polluted in a number of ways and some important sources are discussed below.

4.3.1 Agricultural Sources

a) Pesticides

In modern agriculture the use of various agrochemicals is a common practice. A wide range of pesticides have been developed, almost more than 450 compounds. The most commonly used include herbicides, insecticides, fungicides while others include nematicides, miticides, rodenticides and molluscicides. Pesticides applied on seed or foliage act in a number of ways depending on their application and ultimately reach the soil. Accumulation of pesticide residues in the biosphere creates ecological stress causing contamination of soil, water, and food. After the Second World War, many countries suffered from food shortage and this introduced chemical fertilizers and other agricultural chemicals. Pesticides such as DDT i.e. dichlorodiphenyltrichloroethane a chemical pesticide, was introduced which is a potent nerve poison in insects. DDT was found to bioaccumulate in the food chains. Persistent pesticides may accumulate in the bodies of animals and over a period of time increase in concentration if the animal is unable to flush out the toxins leading to bioaccumulation. When an affected animal is eaten by a carnivore, the pesticide is further concentrated in the carnivore. This phenomenon of increasing in the concentration of a nondegradable substance along the food chain is called 'Biomagnification'. DDT prevents the shelling of bird eggs. The war of Vietnam in 1970's introduced another chemical, dioxin. Dioxin is a toxic chemical and was used as a defoliant by the American army. After the war, it was found that the chemical caused congenital deformities and mental aberrations to the children born to the American soldiers. Insecticides such as, lead arsenate, calcium arsenate, and Paris green are used extensively and can penetrate soil and ground water.

b) Fertilizers

Farmers started using artificial fertilizers at the end of the 19th century that enabled more land to be brought under cultivation. The production of these man-made fertilizers requires large amounts of energy and depletes the world's resources of phosphate ores. In recent decades the use of inorganic fertilizers has increased dramatically. Between 1952 and 1985, the global consumption of these fertilizers increased from 14 million tonnes to 125 million tones which is a tremendous increase. Inorganic fertilizers are used in preference to organic fertilizers as the nutrients are in a more readily available form and are released quickly after their application to the soil. The agricultural production depends on chemical fertilizer application, as most

of our high yielding varieties are fertilizer responsive. Continuous application of chemical fertilizers lead to deterioration of soil properties and cultivated soils lose their natural characteristics. Fertilizers like ammonium sulphate, ammonium chloride and urea reduce the soil pH. Many crops, for example like potato, grapes, citrus, beans are sensitive to chloride toxicity. Excessive use of inorganic nitrogen fertilizers in agricultural practices has been associated with soil acidification, partly through the process of nitrification. If the levels of NO_3^- ions in soil are in excess of plant requirements, they will behave as mobile anions, thus increasing the leaching process. The acidifying effect of nitrogen fertilizers is mobilized in the form of organo-metallic complexes. If mineral acids predominate then aluminium is mobilized in its ionic form Al^{3+}. This form of aluminium is very toxic to fish and many freshwater organisms. The excess use of nitrate containing fertilizers leads to nitrates discharged in the soil and ground waters. When human beings consume nitrate rich waters, the nitrates are converted to nitrites by the action of intestinal flora. The nitrites have an affinity to hemoglobin and combine with it to form methaemoglobin that interferes with the oxygen carrying capacity of blood. This phenomenon is called 'methaemoglobinaemia'. It is common in infants and often called the 'blue baby syndrome' as the symptoms include blue colouration of the skin, vascular and respiratory problems, headache, giddiness, and ocular tensions. Serious nitrate poisoning is reported in Rajasthan and Punjab. Integrated nutrient management helps to sustain the productivity of soils. The use of organic manures and bio fertilizers are recommended as supplements to chemical fertilizers.

Blue baby or methemoglobinemia

Nitrates can enter the ground water from chemical fertilizers used in agricultural areas. Excessive nitrate concentrations in drinking water pose an immediate and serious health threat to infants less than 3 months of age. The nitrate ions react with blood hemoglobin, reducing the blood's ability to carry oxygen and this produces a disease called blue baby or methemoglobinemia. In this illness the infant's blood is unable to carry enough oxygen to the body cells and tissues. An infant with moderate to serious 'blue baby syndrome' may have a brownish-blue skin tone due to the lack of oxygen. The symptoms observed include: fatigue, diarrhea, vomiting, headache, respiratory disorders and in severe cases it can cause death.

c) Excess Salts and Water

Salinization refers to the impregnation of soils by various salts most importantly, calcium sulphate (gypsum: $CaSO_4.2H_2O$) and sodium sulphate (thenardite Na_2SO_4) and in some cases various salts of magnesium sulphate (epsomite) and sodium chloride (halite). They precipitate from the ground water by percolating vertically through capillary under the influence of evapotranspiration during spells of drought, and not from the evaporation of stagnant water on impermeable soils. They dissolve again and seep downwards when rain occurs; hence an alternate vertical motion of salts occurs with time. Salinization usually occurs *per ascensum* when capillary water brings up phreatic water and when supersaturation of dissolved salts occurs through evaporation. Hence, excess irrigation which shifts the groundwater level is a significant cause of soil salinization. The irrigation water helps to produce more yield than rainfed land. Irrigation water contains dissolved salts and in the dry seasons, water

is in the form of saline solution which evaporates leaving its salts such as sodium chloride (NaCl) in the top soil. This saline soil causes stunted plant growth, lower yield and productivity. Flushing out salts reduces the salinity but makes downstream irrigation water saltier.

4.3.2 Industrial Sources

Indiscriminate dumping of untreated or inadequately treated industrial wastes is an important source of soil pollution. Fall out of gaseous and particulate air pollutants from mining and smelting operations, smoke stacks etc. are some of the major source of industrial soil pollutants. They can be wastes from textile, tannery, chemical, electroplating, glass, distilleries, paper, petroleum, cement industries, pharmaceutical etc. These wastes contain inorganic and organic materials that alter and change the natural composition of our soils. Toxic chemicals leached into the soil are potential threats to large numbers of birth defects, cancers, respiratory, nervous and kidney diseases.

Heavy metal pollution

Metalliferous wastes which include heavy metals like: mercury, lead, zinc, cadmium, copper, nickel are commonly found in soils where ore extraction and smelting processes have occurred. Further metal contamination can also occur on land/soil used for scrap metal dealing and ammunition factories. The heavy metals include all metals with atomic numbers greater than 23 (with a few exceptions). The metals are classified as "heavy metals" if in their standard state they have a specific gravity of more than 5 g/cm^3. There are sixty known heavy metals. Heavy metals get accumulated in time in soils and plants and could have a negative influence on physiological activities of plants (e.g. photosynthesis, gaseous exchange, and nutrient absorption), determining the reductions in plant growth, dry matter accumulation and yield (Devkota et al. 2000, Baker 1981). In small concentrations, the traces of the heavy metals in plants or animals are not toxic (De Vries et al. 2008). Lead, cadmium and mercury are exceptions; they are toxic even in very low concentrations (Galas-Gorchev 1991). Heavy metals are hazardous and toxic to man and other life forms. Most of them are slow poisons as they accumulate in the body and cause serious disorders. Another description often used interchangeably with heavy metals is 'trace elements'. These elements occur naturally in rocks and in variable amounts in soils, depending on their location and the rocks that have broken down to make the soil's components. The group 'heavy metals' for the purpose of discussing health risks or impacts generally includes: Arsenic (As), Lead (Pb), Cadmium (Cd), Chromium (Cr) (although only the form Cr(VI) is toxic), Copper (Cu), Mercury (Hg), Nickel (Ni), Zinc (Zn). Several of these elements are necessary for human health, and are beneficial when taken in to the body in foods or as supplements at appropriate, low levels. Conversely, cadmium, lead and mercury have no known biological function and are toxic to humans. Heavy metals are widely used in industrial processes and as biocides. These can be discharged into the environment by improper treatment, resulting in their accumulation causing public health hazards. Toxic metals can exist in soil in a number of forms including adsorbed cations, attached to clay and humus colloids and organometallic chelates. Their availability to plants depends on a number of soil metals. In soils with low cation exchange capacity (CEC), the metals are not retained effectively and will be leached from the soil. But in the case of soils with high cation exchange capacity they are fixed in the soil through adsorption. Hence the mobility and availability of heavy metals is important and is greater in acidic soils (pH<5.5) than in near neutral and alkaline soils. The heavy metals once

mobilized can enter the food chain through water supplies, aquatic organisms, arable produce and grazing animals.

Table 4.1: Some sources of heavy metals in soil

Heavy metal	Sources
Lead	Plumbing, petrol, paint, battery, refinery,
Arsenic	sm elter, plumbing pipes
Mercury	Wood preservative, pesticides,
Zinc	uranium mining, glass/copper
Cadmium	smeltersPesticides, mining, refinery,
Chromium	photography, scientific instruments
Nickel	Electroplating, textile industry
	Fertilizers, tannery, smelter, battery,
	electroplating, paint pigments
	Dyeing industry
	Electroplating industry

4.3.3 Urban Sources

Annually tonnes of untreated urban waste are produced. This cause serious health hazards to humans, pollute the soil and decreases its fertility and productivity. Plastics constitute a major portion of global domestic and industrial waste. Plastics are non-biodegradable so they remain in the environment for a number of years. Municipal wastes mainly include domestic and kitchen wastes, market wastes, hospital wastes, livestock and poultry wastes, slaughterhouse wastes etc. Wastes from the residences are usually found dumped on soil and is a serious cause of concern. These wastes include garbage, organic wastes, paper, glass, plastics, clothes, metal containers etc. These do not degrade easily and cause toxicity to the soils. Hospital wastes contain organic materials, chemicals, metal needles, plastic and glass bottles, vials, etc. Dumping of domestic and hospital wastes contaminate the environment with a variety of pathogens that can seriously affect human health. Plastics form a major part of global domestic and industrial waste. They are nonbiodegradable and remain in the soil adding to pollution. Using photodegradable plastic or biodegradable plastic are solutions to the problem. Photodegradable plastic contains an element sensitive to UV rays. Under the effect of solar rays the element is activated and breaks the polymeric chain of the photodegradable plastic. It results in small fragments that are easily digested by microbes.

4.3.4 Nuclear waste sources

Radioactive materials

They are often released into the soil from nuclear explosions, atmospheric fallout from nuclear dust, discharges from radioactive laboratories etc. Uranium, Thorium, Radium, and Cesium are commonly found in the environment that keep emitting radiations and persist for a long time. They are known to bioaccumulate in plants. Radiations can enter human beings when plants and food containing them are ingested resulting in mutations and genetic disorders.

Activity 1

- *Identify some activities in your residence/ offices that are responsible for soil pollution.*
- *Identify the soil pollution generating sources in your neighborhood.*
- *Classify them based on the sources and type*

Check Your Progress 1

Note : a) Write your answer in about 50 words.
b) Check your progress with possible answer given at the end of the unit.

1. What is soil pollution?

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2. Describe the sources of soil pollution.

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4.4 EFFECTS OF SOIL POLLUTION

Soil pollutants may be responsible for health effects costing millions of Euros, but studies to quantify them are in still in the preliminary stages. Health problems from cancers (arsenic, asbestos, dioxins), to neurological damage (lead, arsenic), kidney disease (lead, mercury, cadmium), skeletal and bone diseases (lead, fluoride, cadmium) are serious issues, that needs to be addressed. Some countries have detailed soil monitoring networks to measure soil quality, however, these may reflect national or regional priorities and standards, and so comparing results between countries is extremely difficult. Recent improvements in data collection mean that the number of reported contaminated sites could increase by as much as 50% by 2025 (EEA, 2007).

4.4.1 Effects on Agriculture

The major effects of soil pollution on agriculture are: loss of nutrients in the soil, soil erosion, less fertile land for vegetation, reduction in crop yield and reduction in nitrogen fixation. Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation. The use of pesticides decreases the general biodiversity in the soil. Pesticides can hinder nitrogen fixation in legumes. DDT was one of the first synthetic organic insecticides to be used. DDT, methyl parathion, and pentachlorophenol have been shown to interfere with legume rhizobium chemical signaling resulting in reduced nitrogen fixation and thus reduced crop yields. DDT also interferes with the production of normal eggshells in birds making them weak and thin shells. Pesticides

lead to poor root hair development, shoot yellowing and reduced plant growth. Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life. The ecological balance of any system gets affected due to the widespread contamination of the soil. Most plants are unable to adapt when the chemistry of the soil changes so radically in a short period of time. Fungi and bacteria found in the soil that bind it together begin to decline, which creates an additional problem of soil erosion. The fertility slowly diminishes, making land unsuitable for agriculture and any local vegetation to survive. The soil pollution causes large tracts of land to become hazardous to health. Unlike deserts, which are suitable for its native vegetation, such land cannot support most forms of life. The toxic chemicals present in the soil can decrease soil fertility and therefore decrease in the soil yield. The contaminated soil is then used to produce fruits and vegetables which lacks quality nutrients and may contain some poisonous substance to cause serious health problems in people consuming them.

4.4.2 Effects on Ecosystem

Soil pollution can affect the ecosystem in the following ways: ecological imbalance, permanent change in the chemical properties of soil, alteration in the metabolism of endemic microorganisms resulting in eradication of the primary food chain, adverse health effects on all organisms**.** In fact, it can sicken the livestock to a considerable extent and cause food poisoning over a long period of time. The soil pollution can even lead to widespread famines if the plants are unable to grow in it.

4.4.3 Effects on Humans

We are also affected by soil pollution as crops and plants grown on polluted soil absorb much of the toxic contaminants. Long term exposure to polluted soil can affect the genetic make-up of the body, causing congenital illnesses and chronic health problems that cannot be cured easily. These include: pollution in drinking water, contamination in vegetation due to presence of chemicals, problems of waste management, polluted environment with harmful gases to breathe in and foul smells and health issues. Exposure to pesticides by consumption of food can result in skin irritation, birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death. Soil can enter our bodies via three main routes: eating, inhalation and through the skin. (a) Ingestion: Eating soil or geophagia is common among children under the age of three. Children are particularly sensitive to contaminants and at highest risk from contaminated soils. Accidental ingestion may occur in adults (i.e. by eating fruits or vegetables with some soil contamination). When consumed, some chemicals are absorbed in the oral cavity while others are swallowed and move into the digestive system. From here, they may be absorbed into the body and transported to the liver. In the liver, some chemicals are largely returned to the digestive system via bile, but others will enter the bloodstream. Some chemicals are broken down in the liver before they reach the blood. Some chemicals are not absorbed, and remain in the gut and may cause toxicity to the gut lining. (b) Inhalation: Working with soil releases particulate matter into the air that may be inhaled by workers. These particles may enter the lungs and may be absorbed into the bloodstream. Compared to ingestion, this is a far less significant source of exposure, but may be relevant to those exposed repeatedly over a long time period. (c) Skin contact: Volatile, organic compounds are absorption through the skin. Absorption of a chemical through the skin is known as 'dermal absorption', 'cutaneous absorption' or 'transcutaneous absorption'. (d) Indirect contact: Soil contaminants may move from soils into ground or surface water, leading to contaminated drinking

water. They may also be taken up by plants which are subsequently consumed, either by humans or by agricultural livestock, causing contaminants to enter the human food chain. Some of these effects may be quite significant, as in the case of dioxins accumulating up the food chain, or large quantities of cadmium in crops grown in contaminated soils. High levels of arsenic in drinking water supplies are often another significant indirect result of soil contamination. Arsenic may also be naturally present in groundwater. A contaminant becomes toxic in the human body once the system is unable to detoxify. The body starts to be exposed to excess amounts of the chemical or the metabolite produced when the body's normal metabolic pathways are saturated. If a chemical accumulates in tissues, reaching critical toxicity long-term accumulation and toxicity occurs. Factors that are relevant in this case are the body's rate of elimination (by metabolism or excretion), and the overall 'body burden' – the quantity of chemicals stored in body tissues (Environment Agency, 2009).

Check Your Progress 2

Note : a) Write your answer in about 50 words.

b) Check your progress with possible answer given at the end of the unit.

1. Explain the various routes through which soil can enter the human body?

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2. Describe some important effects of soil pollution?

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4.5 PREVENTION OF SOIL POLLUTION

The different types of wastes namely agricultural, industrial and urbanization have decreased the soil fertility and made it highly contaminated. Some ways in which soil pollution can be controlled are discussed below:

(i) ***Proper dumping of unwanted materials*:** Excess wastes by man and animals pose a disposal problem. Open dumping is the most commonly practiced technique. Nowadays, controlled tipping is followed for solid waste disposal. The surface so obtained is used for housing or sports field.

(ii) ***Use of bio-pesticides and biofertilizers*:** Bio-pesticides should be used in place of toxic chemical pesticides. Organic fertilizers should be used in place of synthesized chemical fertilizers. To increase agricultural yield, most farmers use chemical fertilizers. The microorganisms in these fertilizers will help in increasing the fertility of the soil. Ex: Organic wastes in animal dung may be used to prepare compost manure instead of disposing them into soil. The concept of Integrated Plant Nutrient System (IPNS) can also be used.

(iii) ***Proper Hygienic Condition*:** People should be trained regarding sanitary habits. Ex: lavatories should be equipped with quick and effective disposal methods.

(iv) ***Public Awareness:*** Informal and formal public awareness programs should be imparted to educate people on health hazards by environmental education. Ex: Mass media, Educational institutions and voluntary agencies can achieve this.

(v) ***Recycling and Reuse of Wastes*:** To minimize soil pollution, the wastes such as paper, plastics, metals, glasses, organics, petroleum products and industrial effluents etc should be recycled and reused. Ex: Industrial wastes should be properly treated at source. Integrated waste treatment methods should be adopted. Therefore, people should consider shifting to reusable containers like glass, cotton bags, etc. Although paper does disintegrate faster, a lot of trees are cut for producing paper bags. Therefore, it is best to opt for cloth bags. Similarly, instead of using tissue papers in the kitchen, etc., one should use cloth napkins, handkerchief, etc. This will go a long way in reducing land-fills.

(vi) ***Ban on Toxic Chemicals*:** Ban should be imposed on chemicals and pesticides like DDT, BHC, etc which are fatal to plants and animals. Nuclear explosions and improper disposal of radioactive wastes should be banned.

(vii) ***Reduce Toxic Waste*:** Toxic waste is a significant aspect of soil pollution. Hence, industrial toxic waste should be treated to reduce its toxicity before it is disposed of. At the same time, responsible methods should be used for disposing off the waste. The best however, is to avoid the use of harmful chemicals unless they are of extreme importance.

(viii) ***Deforestation*:** To prevent soil pollution, deforestation measures have to be undertaken at rapid pace. Soil erosion is caused, when there are no trees to prevent the top layer of the soil from being transported by different agents of nature like water and air. At the same time, measures should be taken to avoid over cropping and over grazing, as it leads to flood and soil erosion and further deterioration of the soil layer.

(ix) ***Reforesting*:** Control of land loss and soil erosion can be attempted through restoring forest and grass cover to check wastelands, soil erosion and floods. Crop rotation or mixed cropping can improve the fertility of the land.

(x) ***Solid Waste Treatment*:** Industrial wastes can be treated physically, chemically and biologically until they are less hazardous. Acidic and alkaline wastes should be first neutralized; the insoluble material if biodegradable should be allowed to degrade under controlled conditions before being disposed. Further, storage of hazardous waste should be investigated such as deep well injection and more secure landfills. Composting the waste in locations situated away from residential areas is the simplest and most widely used technique of solid waste management. Environmental and aesthetic considerations must be taken into consideration before selecting the dumping sites. Incineration of other wastes is expensive and leaves a huge residue and adds to air pollution. Pyrolysis is a process of combustion in

absence of oxygen or the material burnt under controlled atmosphere of oxygen. It is an alternative to incineration. The gas and liquid thus obtained can be used as fuels. Pyrolysis of carbonaceous wastes like firewood, coconut, palm waste, corn combs, cashew shell, rice husk paddy straw and saw dust, yields charcoal along with products like tar, methyl alcohol, acetic acid, acetone and a fuel gas.

(xi) ***Soil Conservation*:** Soil conservation is the protection of soil against excessive loss of fertility by natural, chemical, or artificial means. It encompasses all management and land-use methods protecting soil against degradation, focusing on damage by erosion and chemicals. Soil conservation techniques can be achieved through crop selection and rotation, fertilizer and lime application, residue management, contouring and strip cropping, and mechanical methods (e.g., terracing).

4.6 LET US SUM UP

Dear learners, in this unit we have learnt that soil serves as a natural sink for pollutants by concentrating contaminants which end up in the soil from various sources. Modern cities have enormous impacts on soils. Here, the city's soils are covered with asphalt, cement, stone, waste piles, pollutants and the soils have lost their natural cover of vegetation. The natural exchange of gases between the soil and air is greatly reduced. Such soils lose their organic matter and are likely to be waterlogged, compacted and impervious to water flow. Pollutants decrease soil quality, disturb the soil's natural balance and may also lead to wear and erosion. Different types of soil pollution can be distinguished by their source, as well as the effects each has on the ecosystem. Anthropogenic or human activities that pollute the soil include: agricultural practices that use excessive pesticides, industrial wastes, radioactive emissions that contaminate the soil with various toxic substances etc. Soil pollution affects plants, animals and humans. Soil pollution may cause a variety of health problems in human beings, starting with headaches, nausea, fatigue, skin rash, eye irritation and potentially resulting in more serious conditions like neuromuscular blockage, kidney and liver damage and various forms of cancer. Some prevention measures for soil pollution are also discussed.

4.7 KEY WORDS

Methemoglobinemia: The nitrate ions react with blood hemoglobin, reducing the blood's ability to carry oxygen and this produces a disease called blue baby or methemoglobinemia.

Soil conservation: Soil conservation is the protection of soil against excessive loss of fertility by natural, chemical, or artificial means.

Land Farming: It is a bioremediation treatment process that is carried out in the upper soil zone.

Reforestation: It involves replanting areas of forest which have previously been damaged or destroyed, using native tree species.

Deforestation: It refers to the removal of a forest or trees where the land is thereafter converted to a non-forest use.

4.8 REFERENCES AND SUGGESTED FURTHER READINGS

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4.9 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

1. Your answer must include the following points:

   Soil pollution can be defined as an undesirable change in the soil physico-chemical properties, which can result in adverse effects on human beings, plant life and animals. Soil pollution occurs when the presence of some toxic chemicals or contaminants in the soil is in reasonably higher concentrations that can pose a risk to plant life, animals and humans.

2. Your answer must include the following points:

   Agricultural sources

   Industrial sources

   Urban sources

   Nuclear waste sources

Answers to Check Your Progress 2

1. Your answer must include the following points:

   Soil can enter our bodies via three main routes: eating, inhalation and through the skin.

Ingestion

Inhalation

Skin contact

Indirect contact

2. Your answer must include the following points:

Soil pollutants may be responsible for health effects costing millions of Euros, but studies to quantify them are in still in the preliminary stages. Health problems from cancers (arsenic, asbestos, dioxins), to neurological damage (lead, arsenic), kidney disease (lead, mercury, cadmium), skeletal and bone diseases (lead, fluoride, cadmium) are serious issues, that needs to be addressed.

Effects on Agriculture

Effects on Ecosystem

Effects on Humans

Effect on growth of plants and soil fertility