Chapter 14

ATMOSPHERE

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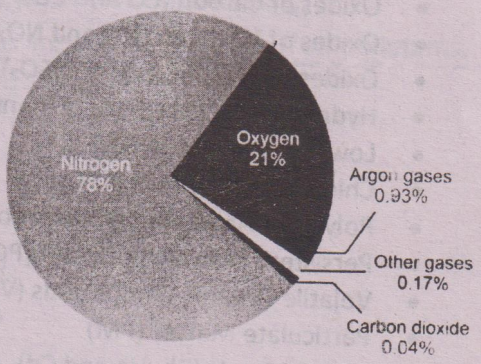
Student Learning Outcomes

After studying this chapter, students will be able to:

- Identify the properties and composition of the atmosphere. (Include the concept of 4 layers of atmosphere and their composition. **(Understanding)**
- Describe the sources and understand the effect of air pollution, (this can include both natural and human caused pollutants including Greenhouse gases (such as carbon dioxide, methane, and nitrous oxide), Chlorofluorocarbons (CFCs), and Ozone (O_3) and other ozone-depleting substances, Volatile organic compounds (VOCs), Polycyclic aromatic hydrocarbons (PAHs), Persistent organic pollutants (POPs), Heavy metals such Lead (Pb), Mercury (Hg), Cadmium (Cd). **(Understanding)**
- Describe the impact of human activities on the atmosphere including the effects of burning fossil fuels and deforestation. **(Understanding)**
- Identify the chemical reactions and processes that occur in the atmosphere (some examples include the formation of smog and acid rain). **(Understanding)**
- Identify the global scale problems of air pollution, such as global warming and the greenhouse effect. **(Understanding)**
- Describe the factors that affect air quality. **(Understanding)**
- Explain the link between air quality and human health. **(Understanding)**
- Evaluate the potential health risks associated with air pollution. **(Understanding)**
- Familiarize with use of methods and techniques to measure and monitor air quality. **(Understanding)**
- Design experiments and collect data to test hypotheses about air quality. **(Application)**
- Analyze data and interpret air quality measurements and trends. **(Understanding)**
- Explain the technologies and strategies used to reduce air pollution and improve air quality, such as emissions control and renewable energy sources. **(Understanding)**
- Identify the laws and regulations related to air quality and the measures used to control air pollution. **(Understanding)**
- Analyze the economic, social, and political issues related to air pollution and air quality management and demonstrate through answers. **(Understanding)**

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The atmosphere is a sphere of different gases around the earth. The component of the atmospheres may be divided into major, minor and trace components. Major components are nitrogen (78.00 %) and oxygen (21 %). Minor components are argon (0.93 %), carbon dioxide (0.04 %). Trace components are methane, hydrogen, neon, helium, krypton, and xenon.



LAYERS OF THE ATMOSPHERE

The atmosphere has four distinct layers which are determined by the change in temperature that is observed with increasing altitude.

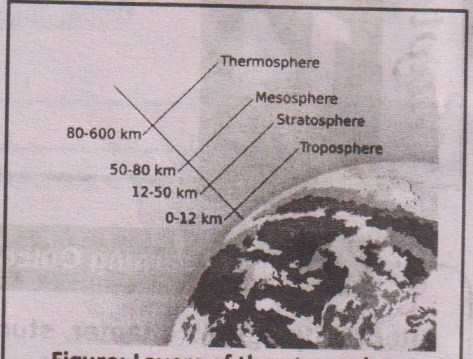


Figure: Layers of the atmosphere

i) Troposphere

It is the lowest region of the atmosphere which extends up to 12 km. It includes all the major gases present in the atmosphere i.e., nitrogen, oxygen, and carbon-dioxide, etc. In this region, temperature decreases from 17°C to –58°C regularly. It is the densest layer of the atmosphere. It is the layer in which major events such as rain, lightening, and hurricanes occur.

ii) Stratosphere

Above the troposphere, the stratosphere lies which is at a distance of 12 – 50 km above the earth surface. Temperature increases from –58°C to –2°C. Stratosphere can also be divided into three regions according to the distribution of ultraviolet radiations from the Sun. Since ozone in the upper layer absorbs high energy ultraviolet radiations from the Sun. Ozone breaks down into monoatomic oxygen and diatomic oxygen.

$$O_{3(g)} \xrightarrow{h\upsilon} O_{2(g)} + O_{(g)}$$

The middle stratosphere has less ultraviolet radiations passing through it. Here, monoatomic oxygen and diatomic oxygen recombine to form ozone which is an exothermic reaction due to which formation of ozone layer takes place.

$$O_{2(g)} + O_{(g)} \longrightarrow O_{3(g)}$$

The lower stratosphere receives very low ultraviolet radiations, thus monoatomic oxygen is not found here and ozone is not formed here.

Rack Your Mind!

1. **Which layer of the atmosphere contains the ozone layer that protects life from harmful UV rays?**
   A) Troposphere B) Mesosphere
   C) Thermosphere D) Stratosphere

Rack Your Mind!

2. **What are the four main layers of the atmosphere and their key features?**

iii) Mesosphere

It extends to a height of about 50 – 85 km from the ground. Here, the temperature decreases with altitude from –2°C to –93°C. The coldest region of the atmosphere is located in this layer.

iv) Thermosphere

It extends from 85 km to 600 km above the earth surface. This is the region where the temperature increases as the altitude increases. The increase in the temperature is caused due to the absorption of energetic ultra-violet (UV) and X-rays. Temperature in the upper thermosphere can range from 500°C to 2000°C or higher.

AIR POLLUTANTS

Pollutants are substances (gases, liquids and solids) that are harmful to the environment.

The most important pollutants are mentioned below:

- Oxides of Carbon (CO and CO_2)
- Oxides of Nitrogen (NO and NO_2) collectively known as NO_x
- Oxides of Sulphur (SO_2 and SO_3) collectively known as SO_x
- Hydrocarbons (Methane, Ethane)
- Low altitude Ozone (O_3)
- Chlorofluorocarbons (CFCs)
- Polycyclic Aromatic Hydrocarbon (PAHs)
- Persistent Organic Pollutant (POPs)
- Volatile Organic Compounds (VOCs)
- Particulate Matter (PM)
- Heavy Metals (Pb, Hg and Cd)

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Air pollutants can be classified as primary and secondary.

➢ **Primary Pollutants:**

Primary pollutants are substances **directly** produced or emitted, such as ash from a volcanic eruption or carbon monoxide gas from a motor vehicle exhaust.

➢ **Secondary Pollutants:**

Secondary pollutants are formed due to chemical reactions of primary pollutants.

Differences between Primary and Secondary Pollutants

Primary Pollutants	Secondary Pollutants
• **"The pollutants which are directly introduced into the environment from the sources are called primary pollutants."**	• **"The pollutants which are produced as a result of various reactions of primary pollutants in the environment are called secondary pollutants."**
• They are emitted in the same form as they exist in the atmosphere.	• They are formed by transformation of primary pollutants.
• They formed instantly.	• They are formed overtime through chemical or photochemical reactions.
Examples:	**Examples:**
• Sulphur dioxide, sulphur trioxide, nitrogen oxides, carbon monoxide, hydrocarbons, ammonia, compounds of fluorine and radioactive materials.	• Sulphuric acid, nitrogen monoxide, carbonic acid, hydrofluoric acid peroxyacetyl-nitrate (PAN), ozone, aldehydes, ketones and peroxybenzol.

SOURCES OF AIR POLLUTION

There are broadly two main sources of air pollution:

(i) Natural sources (ii) Human-made sources

➲ Natural Sources

- Naturally occurring particulate matter (PM) include dust from earth's surface, and biological materials in the form of pollens, spores and animal debris.
- Volcanic eruptions can introduce very large quantities of gases and particulate matter (PM) into the atmosphere.
- Thunderbolt produces significant quantities of oxides of nitrogen (NO_x).
- Other natural sources of air pollution are algae on the surface of the oceans, which gives out hydrogen sulphide (H_2S), wind erosion which introduces PM, and humid zones such as swamps, peat-bags or little deep lakes, which produce methane (CH_4).

➲ Human-Made Sources

- Such sources can be classified as either mobile (cars, trucks, air planes, marine engines) or point sources (factories, electric power plants etc.).
- The combustion of fossil fuels (coal, fuel oils, and natural gas) in vehicle engines, factories and power plants produce carbon dioxide (CO_2), carbon-monoxide (CO), and hydrocarbons (CH_4).
- The burning of wood as a domestic fuel and coal in brick kilns are also the sources of air pollutants.

☑ QUICK CHECK 14.1

a) Mention important air pollutants.

Ans. The most important pollutants are mentioned below:

- Oxides of Carbon (CO and CO_2)
- Oxides of Nitrogen (NO and NO_2) collectively known as NO_x
- Oxides of Sulphur (SO_2 and SO_3) collectively known as SO_x
- Hydrocarbons (Methane, Ethane)

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- Low altitude Ozone (O_3)
- Chlorofluorocarbons (CFCs)
- Polycyclic Aromatic Hydrocarbon (PAHs)
- Persistent Organic Pollutant (POPs)
- Volatile Organic Compounds (VOCs)
- Particulate Matter (PM)
- Heavy Metals (Pb, Hg and Cd)

b) Give the equations for the formation and depletion of ozone in the stratosphere.

Ans. Formation of Ozone:

The middle stratosphere has less ultraviolet radiations passing through it. Here, monoatomic oxygen and diatomic oxygen recombine to form ozone which is an exothermic reaction due to which formation of ozone layer takes place.

$$O_{2(g)} + O_{(g)} \longrightarrow O_{3(g)}$$

Depletion of Ozone

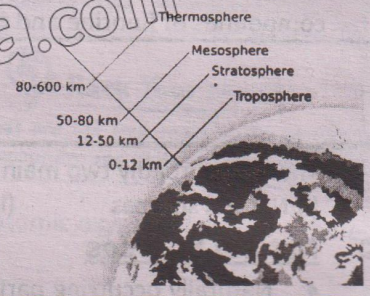
Since ozone in the upper layer absorbs high energy ultraviolet radiations from the Sun. It breaks down into monoatomic oxygen and diatomic oxygen.

$$O_{3(g)} \xrightarrow{h\upsilon} O_{2(g)} + O_{(g)}$$

c) Write down the names and approximate height of different layers of atmosphere.

Ans. The names and approximate height of different layers of atmosphere are given below;

- Troposphere – 0 to 12 km
- Stratosphere – 12 to 50 km
- Mesosphere – 50 to 80 km
- Thermosphere – 80 to 600 km



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SOURCES OF AIR POLLUTANTS

➲ Oxides of Carbon

There are two oxides of carbon i.e., carbon monoxide (CO) and carbon dioxide (CO_2).

➢ Carbon Monoxide (CO):

Carbon monoxide (CO) Carbon monoxide (CO) is produced mainly due to incomplete combustion of fossil fuels.

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$$

CO binds with haemoglobin approximately 200 to 250 times more strongly than O_2 does.

Did You Know?

Carbon monoxide is highly poisonous gas and cause suffocation if inhale. It binds blood hemoglobin more strongly than oxygen thus excluding oxygen from normal respiration. The CO poisonous can be reversed by giving high pressure oxygen.

➢ Carbon Dioxide (CO_2):

Carbon dioxide is the key greenhouse gas emitted by human activities like combustion of fossil fuels. Carbon dioxide (CO_2) is a primary greenhouse gas that traps heat in the atmosphere, leading to global warming.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

➲ Oxides of Nitrogen (NO_x)

- The gases like nitric oxide (NO) and nitrogen dioxide (NO_2) are represented by NO_x.
- These are generally produced from burning fossil fuels. NO_x is produced as a result of the following chemical reactions:

$$N_{2(g)} + O_{2(g)} \xrightarrow{\text{high temp}} 2NO_{(g)} \quad \text{(Nitric oxide)}$$

$$2NO_{(g)} + O_2 \longrightarrow 2NO_2 \quad \text{(Nitrogen-Dioxide)}$$

- Natural sources of N_2O include microbial processes in soil and oceans where bacteria break down nitrogen compounds.
- Human activities include agricultural activities (synthetic fertilizers) and industrial processes (combustion of fossil fuels). It depletes the ozone layer.
- The increased levels of N_2O contribute to climate change and can also affect air quality.

➲ Oxides of Sulphur (SO_x)

- There are **two oxides of sulphur** i.e., sulphur dioxide (SO_2) and sulphur trioxide (SO_3) which are collectively called SO_x.
- These gases are emitted primarily by burning coal and oil. When SO_x combine water vapour, it causes acid rain that damages ecosystem. SO_2 is the major source of acid deposition in the air.

➲ Hydrocarbons

- Hydrocarbons are produced naturally in various environmental processes like vegetation, wildfire, volcanoes, and seeps.
- Anthropogenic activities like incomplete burning of fossil fuels, oil spills, industrial and vehicle emission are sources of hydrocarbons.
- Automobiles are the major source of hydrocarbon emission.
- Methane is the most common hydrocarbon and air pollutant.

➲ Low-Altitude Ozone (O_3)

- Ozone is a powerful oxidizing agent. It is non-toxic in small concentrations, but above 100 parts per million (ppm), it is toxic.
- It is harmful to humans, plants and other materials i.e., rubber, fabric dyes, and durability and appearance of paints.

(Exercise L.Q.4 i)

Q.4 Write short notes on the following:
i) CFCs and ozone layer depletion

➲ Chlorofluorocarbons (CFCs) and Ozone Layer Depletion

- The decrease in the concentration of ozone in stratosphere is called depletion of ozone. This depleting of ozone has been caused by certain organic compounds called chlorofluorocarbons (CFCs).
- These compounds exist as gases or low boiling liquids at room temperature and are used as aerosols or refrigerants.
- Chlorofluorocarbons are known to diffuse into the stratosphere where they are broken down by UV radiation creating chloride free radical ($C\ell^\bullet$). The chloride free radical breaks down the Ozone molecule as shown in the following reactions.

$$CFC\ell_3 \xrightarrow{UV} CFC\ell_2 + C\ell^\bullet$$

$$C\ell^\bullet + O_3 \longrightarrow C\ell O^\bullet + O_2$$

$$C\ell^\bullet O + O_2 \longrightarrow C\ell^\bullet + O_2$$

- The formation of another chlorine free radical in the last step that can further break down another molecule of O_3. The 2nd and the 3rd steps are repeated many times.

Interesting Information!

Chlorofluorocarbons (CFCs) are used as propellants for aerosols and as coolant in refrigerators and air conditions. CFCs are 100,000 times more effective than CO_2 at preventing heat from especially from the earth's atmosphere. The decomposition of one molecule of CFCs can destroy up to 100,000 molecules of ozone.

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Q. Discuss sources and effects of following air pollutants on environment:
i) Heavy metals ii) VOCs iii) PAHs iv) POPs

➲ Polycyclic Aromatic Hydrocarbon (PAHs)

- Polycyclic aromatic hydrocarbon (PAHs), composed of fused multiple aromatic rings are common environmental pollutants. e.g., Naphthalene, anthracene and phenanthrene.
- PAHs are generated primarily during the incomplete combustion of fossil fuels (coal, oil, petrol, and wood), vehicle emissions, industrial processes and even grilled foods.
- Some PAHs in the environment originate from the natural sources such as open burning, natural loss or seepage of petroleum and coal deposits. PAHs have potential toxicity and carcinogenic properties.

➲ Persistent Organic Pollutants (POPs)

- POPs are organic compounds that are resistant to degradation through chemical, biological and photolytic processes.
- POPs are toxic and adversely affect human health and the environment, traveled by wind and water.
- Most POPs are generated in one country can affect people and wildlife far from where they are used and released.
- Because of their persistence, they accumulate in the environment and can have significant adverse effects on human health. Some POPs are given in Table below:

Table: Some POPs with their Uses

Names of POPs	Uses
Polychlorinated Biphenyls (PCBs)	Used in electrical equipment, surface coating ink, adhesives and paints
Dichlorobiphenyl tri-chloroethane (DDT)	Used as an insecticide in agriculture

➲ Volatile Organic Compounds (VOCs)

- A large group of organic compounds that easily evaporates at room temperature.
- VOCs are emitted as gases from certain solids or liquids.
- Liquid fuels are major sources of VOCs that impact outdoor air quality.
- Vehicle exhaust and burning liquid fossil fuels, wood and garbage all release VOCs into the atmosphere.

➢ Effect of VOCs:

- Exposure to VOCs can cause a variety of health effects including eye, nose and throat irritation, headache, nausea are short term exposures and damage to the liver, kidney and central nervous system are long term exposures
- They are significant air pollutants contributing to indoor and outdoor air pollution.

Examples:

- Some common VOCs are benzene, xylene, toluene, ethanol, formaldehyde, acetone etc.

➲ Particulate Matter (PM)

The term "particulate matter (PM)" refers to the wide variety of tiny substances that float in the air in the form of either solid particles or liquid droplets or both.

- Particulate matter (PM) is all the dust, smoke, and haze particles suspended in ambient air.
- Particulate matter (PM) comprises acids, organic chemicals, metals, and soil or dust particles.
- **Sources of PM** are both natural and anthropogenic.

(i) **Natural sources** include volcanoes, fires, dust storms, and aerosolized sea salt.
(ii) **Man-made sources** of particulate matter PM include combustion in mechanical and industrial processes, vehicle emissions, and tobacco smoke.

➲ Heavy Metals (Lead, Mercury and Cadmium)

- Heavy metal like lead, mercury and cadmium can indeed be significant air pollutants.
- They are released into the atmosphere from various industrial process, transportation and other human activities.
- Metallurgy, battery waste and incineration are their major sources.

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IMPACT OF HUMAN ACTIVITIES ON THE ATMOSPHERE

Human activities have significant impact on the atmosphere, primarily through the burning fossil fuels and deforestation. These activities contribute to climate change, air pollution, poor air quality and other environmental issues.

In urban areas, most air pollution comes from human-made sources. Such sources can be classified as either mobile (cars, trucks, air planes, marine engines) or point sources (factories, electric power plants etc.)

➲ Impact of Burning Fossil Fuels on the Atmosphere

The burning of fossil fuels is the primary cause of current climate change, altering the earth ecosystem and causing human and environment health problems. The burning of fossil fuels affects the earth system in a variety of ways. Some of these ways include greenhouse gas emission, air pollution, volatile organic compounds.

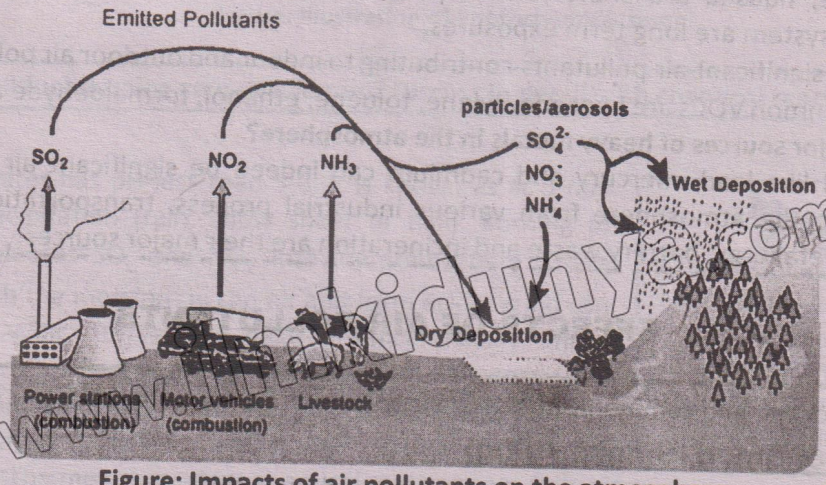


Figure: Impacts of air pollutants on the atmosphere

➲ Impact of Deforestation on the Atmosphere

Deforestation is purposeful cleaning or thinning of forests by humans.

Causes:

(i) Agricultural expansion
(ii) Logging
(iii) Urbanization (Building roads, cities and infrastructures)
(iv) Mining

Deforestation represents one of the largest issues in global climate. Forests absorb GHGs like CO_2 and clean air for us.

Negative Effects of Deforestation:

Deforestation has a wide range of negative impact on the environment, including loss of biodiversity, climate change (trees absorb CO_2, without trees more CO_2 remains in the atmosphere), soil degradation (erosion), and water cycle disruption.

☑ QUICK CHECK 14.2

a) Mention man-made sources of air pollution.

Ans. Human-made sources

Such sources can be classified as;

- Either mobile (cars, trucks, air planes, marine engines) or point sources (factories, electric power plants etc.).
- The combustion of fossil fuels (coal, fuel oils, and natural gas) in vehicle engines, factories and power plants produce carbon dioxide (CO_2) carbon-monoxide (CO), and hydrocarbons (CH_4).
- The burning of wood as a domestic fuel and coal in brick kilns are also the sources of air pollutants.

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b) How do polycyclic aromatic hydrocarbons (PAHs) primarily enter the atmosphere?

Ans.

- They are generated primarily during the incomplete combustion of fossil fuels (coal, oil, petrol, and wood), vehicle emissions, industrial processes and even grilled foods.
- Some PAHs in the environment originate from the natural sources such as open burning, natural loss or seepage of petroleum and coal deposits.
- Naphthalene, anthracene and phenanthracene are examples of PAHs.
- They have potential toxicity and carcinogenic properties.

c) How do volatile organic compounds (VOCs) affect air quality?

Ans.

- Exposure to VOCs can cause a variety of health effects including eye, nose and throat irritation, headache, nausea are short term exposures and damage to the liver, kidney and central nervous system are long term exposures.
- They are significant air pollutants contributing to indoor and outdoor air pollution.
- Some common VOCs are benzene, xylene, toluene, ethanol, formaldehyde and acetone etc,.

d) What are major sources of heavy metals in the atmosphere?

Ans. Heavy metal like lead, mercury and cadmium can indeed be significant air pollutants. They are released into the atmosphere from various industrial process, transportation and other human activities. Metallurgy, battery waste and incineration are their major sources.

EFFECTS OF AIR POLLUTANTS

The most important and commonly effects of air pollutants are formation of Smog and Acid Rain.

➲ Formation of Smog (Smoke + Fog)

Smog is a type of air pollution typically characterized by a thick haze. It primarily occurs in urban areas and is often caused by emissions from vehicle, industrial activities and other sources of pollution. It consists of fine dust or soot particles, condensed water vapor, poisonous gases like SO_2, NO_xO_3, CO, and CO_2, secondary pollutants like O_3, unburned hydrocarbons, VOCs and PM 10–2.5 micron.



Figure: Smog around Lahore Fort

➲ Types of Smog

i) Industrial or Classical Smog (London Smog)
ii) Photochemical smog (Los Angeles Smog)

i) Classical or Sulphurous Smog

Sulfurous or Industrial smog also called as "Reducing smog or Classical Smog" usually results from high quantities of sulfur oxides (SO_x) being released into the air. It is also called **London smog.**

ii) Photochemical Smog

Photochemical smog is a type in which primary air pollutants like nitrogen oxides (NO_x), VOC and unburned hydrocarbons undergo photochemical reactions in the presence of sunlight and form secondary pollutants like ozone and peroxyacetyl nitrates (PAN). This type of smog is considered more dangerous as it can cause heart palpitations, pneumonia and even lung cancer. It is also called **Los Angeles smog**.

Rack Your Mind!

3. What is smog and how is it formed?

The term 'SMOG' was coined by Dr. Des Voeux.
Smog is a type of intense air pollution. The word "smog" was coined in the early 20th century, and is a contraction of the words smoke and fog to refer to smoky fog; its opacity and odour.

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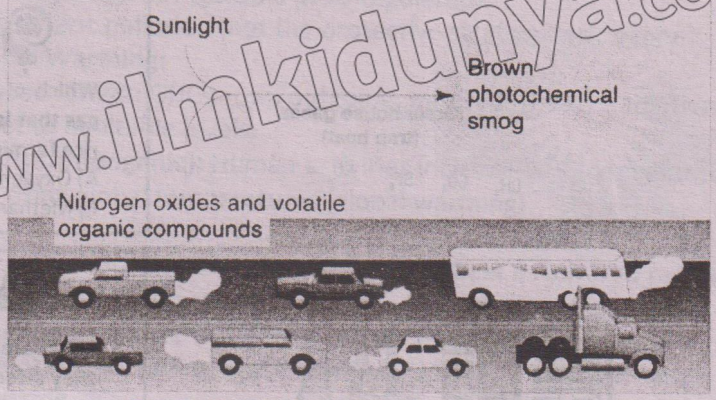


Figure: Illustration of Photochemical smog

(Exercise L.Q.5)

Q. How the fossil fuel burning causes acid rain? Discuss in detail with chemical reactions.

➲ Acid Rain

When rain water has pH less than 5-6, it is known as acid rain refers to precipitation (rain, snow sheet or hail). Burning of fossil fuels releases SO_x and NO_x into the atmosphere. These gases mix with the moisture in the air and form acids. Wind can carry these acidic droplets to huge distance. Finally, these droplets return to the ground as acid rain, acid hail, snow and even fog. Acid rain looks, feels and tastes like clean rain. Its corrosive nature causes widespread damage to the environment. The most important chemical reactions are following:

Rock Your Mind!

4. What causes acid rain?

A) Water vapor condensing into clouds

B) Sulfur dioxide and nitrogen oxides reacting with water

C) Ozone layer depletion

D) Deforestation

$$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(\ell)} \longrightarrow H_2SO_{4(aq)}$$

SO_2 from fossil fuels is oxidized to SO_3 which then reacts with water to form sulphuric acid. Nitrogen oxide reacts with water to produce nitric acid and nitrous acid.

$$NO_{(g)} + H_2O_{(\ell)} \longrightarrow HNO_{3(aq)} + HNO_{2(aq)}$$

Effect of Acid Rain on Environment

(i) Acidification of the soil and rocks can leach metals like Aluminium, mercury, lead and calcium and discharges them into water bodies. These heavy metals are accumulated in the fishes and are health hazards for humans and birds as they eat these fishes. The elevated concentration of Aluminium is harmful for fish as it clogs the gills thus causing suffocation.

(ii) Acidification of the soil can also leach nutrients thus damaging leaves and plants and growth of forest.

(iii) It also damages building materials such as steel, paint, plastic, cement, masonry work and sculptural materials especially of marble and limestone.

GREENHOUSE EFFECT AND GLOBAL WARMING

(Exercise L.Q.4 ii)

Q.4 Write short notes on the following:
ii) Greenhouse effect and global warming

Global warming refers to the long-term rise in the Earth's average surface temperature due to human activities, primarily the emission of greenhouse gases (GHGs) released by burning fossil fuels. **The progressive warming up of the earth's surface due to blanketing effect of greenhouse gases in the atmosphere is called the greenhouse effect.**

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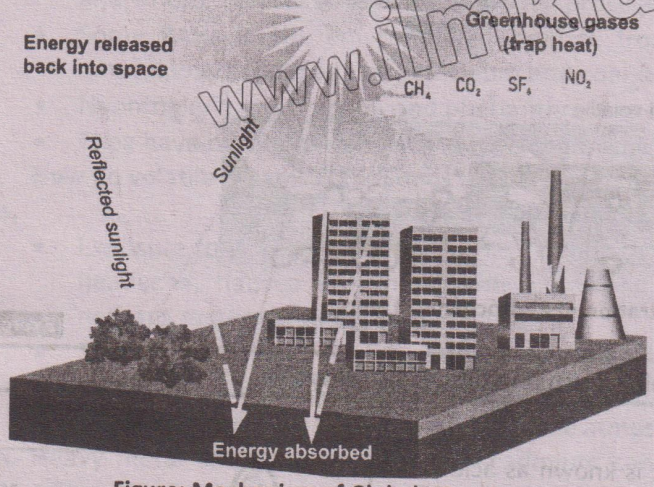


Figure: Mechanism of Global Warming

It is a global scale problem of air pollution. Carbon dioxide and water vapour in the atmosphere transmit short wavelength solar radiations but reflect back the longer wavelength heat radiation coming from warmed surface of the earth.

➢ **Greenhouse Effect:**

The greenhouse effect is a phenomenon which is based on the gases to absorb infrared radiations. In the day, heat from the sun (in the form of infrared) passes through the atmosphere heating up the earth. At night, the earth radiate heat to the outer space. Some atmospheric gases trap the heat from the sun, thus, preventing the loss of heat. Higher the concentration of carbon dioxide gas and other gases, greater will be the absorption of thermal radiations and greater will be the increase of global temperature.

Rack Your Mind!

5. Which of the following is a greenhouse gas that is also released by livestock and rice farming?
   A) Oxygen B) Nitrogen
   C) Methane D) CFC

Rack Your Mind!

6. What are greenhouse gases and how do they affect the Earth?

QUICK CHECK 14.3

a) Differentiate classical and photochemical smog.

Ans.

Feature	Classical Smog (London Smog)	Photochemical Smog (Los Angeles Smog)
Composition	Sulfur dioxide (SO_2), soot, and fog (sulfurous aerosols).	Ozone (O_3), NO_x, VOCs, PAN (Peroxyacyl nitrates).
Formation	Caused by burning **coal** (high sulfur content).	Forms due to **sunlight-driven reactions** of NO_x + VOCs.
Primary Pollutants	SO_2, particulate matter (PM), CO.	NO_x (NO, NO_2), hydrocarbons (VOCs).
Secondary Pollutants	Sulfuric acid (H_2SO_4), sulfate particles.	O_3, PAN, aldehydes.
Weather Conditions	Cold, **humid** climates (winter mornings).	Warm, **sunny** climates (summer afternoons).
Health Effects	Respiratory issues (bronchitis, asthma), reduced visibility.	Eye/nose irritation, lung damage, crop damage.
Geographical Association	Industrial cities (e.g., historic London).	Urban areas with high traffic (e.g., Los Angeles).
Key Chemical Process	Oxidation of $SO_2 \rightarrow H_2SO_4$.	NO_2 + sunlight $\rightarrow$ O_3 + other oxidants.

b) Name greenhouse gases (GHGs). How do these gases cause global warming?

Ans. Greenhouse Gases (GHGs)

(i) **Carbon Dioxide (CO_2):** Burning fossil fuels, deforestation.

(ii) **Methane (CH_4):** Agriculture (livestock), landfills, natural gas.

(iii) **Nitrous Oxide (N_2O):** Fertilizers, industrial processes.

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(iv) **Water Vapor (H_2O):** Natural evaporation, amplified by warming.
(v) **Chlorofluorocarbons (CFCs):** Refrigerants (now regulated).
(vi) **Ozone (O_3):** Tropospheric pollution (not the protective stratospheric ozone).

How GHGs Cause Global Warming:

- **Natural Greenhouse Effect:** GHGs trap outgoing infrared (heat) radiation from Earth's surface, warming the planet to habitable levels.
- **Enhanced Effect (Anthropogenic):** Human activities increase GHG concentrations, causing excessive heat retention → rising global temperatures (global warming).

In short,

(i) Sunlight reaches Earth → Surface absorbs and re-emits heat as infrared radiation.
(ii) GHGs absorb this radiation → Re-radiate heat back to Earth (like a blanket).
(iii) **Result:** Disrupted energy balance → Climate change (melting ice, extreme weather).

c) Write a balanced equation, including state symbols, showing the formation of sulfuric acid from atmospheric sulfur trioxide, SO_2.

Ans. Manufacturing of Sulphuric Acid:

$$S_{(s)} + O_{2(g)} \xrightarrow[V_2O_5]{400\text{-}500^\circ C} SO_{2(g)}$$ (Heterogeneous catalysis)

$$2SO_{2(g)} + O_{2(g)} \xrightarrow[V_2O_5]{400\text{-}500^\circ C} 2SO_{3(g)} \quad \Delta H = -269.3 \text{ kJ mol}^{-1}$$

$$H_2SO_{4(aq)} + SO_{3(g)} \longrightarrow H_2S_2O_{7(l)}$$

$$H_2S_2O_{7(l)} + H_2O_{(l)} \longrightarrow 2H_2SO_{4(aq)}$$

d) How HNO_3 is formed from NO in the atmosphere?

Ans. Nitric acid (HNO_3) forms in the atmosphere through a series of reactions involving nitrogen oxides (NOx), which include nitric oxide (NO) and nitrogen dioxide (NO_2).

Key Steps:

i. **NO Emission:** NO is emitted into the atmosphere from sources like fossil fuel combustion, industrial processes, and lighting.
ii. **NO to NO_2:** NO reacts with ozone (O_3) or oxygen (O_2) to form NO_2.
iii. **NO_2 Reaction:** NO_2 reacts with hydroxyl radicals (OH) or ozone (O_3) to form nitric acid (HNO_3).

Equation:

i. $2NO + O_2 \rightarrow 2NO_2$
ii. $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

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AIR QUALITY

(Exercise L.Q.6)

Q. What is meant by air quality AQI? Describe the factors affecting the air quality.

- Air quality is measured in terms of Air Quality Index (AQI).
- AQI is a measure of the concentrations of pollutants present in the air at a particular location.
- When the air quality is good, the air is clear and contains only small amount of solid particles and chemical pollutants.
- Poor air quality, which contain high level is often hazy and dangerous to health and the environment.
- An AQI value under 50 is considered good in quality. This means, it is safe for you to spend time outdoor without posing a risk to your health.
- An AQI over 300 is considered hazardous. Children under 18, adult over 65, people with chronic heart, and lung diseases are under high-risk.
- Outdoor workers are at higher risk because of the prolonged exposure.

➲ Factors Affecting Air Quality

Air quality is influenced by several key factors or sources.

i) Emission sources

Burning of wood and fossil fuels can increase local pollution level. Factories and power plants use fossil fuels that release dangerous pollutants in air like SO_x and NO_x. Vehicles release CO, PM and VOCs.

Rack Your Mind!

7. How does deforestation impact air quality and the atmosphere?

ii) **Meteorological conditions**

Wind, temperature, and humidity affect pollutant dispersion and concentration. A layer of warm air trapping pollutants near the ground can lead to poor air quality.

Rack Your Mind!

8. What are some methods used to improve air quality?

iv) **Natural Events**

Wild fires can release large amounts of smoke and PM into the atmosphere. Natural dust storms can significantly lower air quality.

v) **Seasonal Changes**

Temperature variations, such as heating or cooling of buildings in different seasons can increase emissions of pollutants. Seasonal pollen concentration can contribute to poor air quality.

Table: AQI and level of health concern

Air Quality Index (AQI) Values	Levels of Health Concern	Colour
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

AIR QUALITY AND HUMAN HEALTH

The link between air quality and human health is well-documented and significant. Poor air quality can have immediate and long-term health impacts.

➲ Major Air Pollutants and their Health Effects

i) **Particulate matter (PM)**

Particular matter (PM) consists of tiny particles suspended in the air, including dust, dirt, soot and smoke ranging from diameter of 2.5 micrometer to 10.0 micrometer. Inhalation of these particulate matter (PM) can cause inflammation and irritation of airways, leading to conditions such as asthma and bronchitis.

ii) **Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2)**

The short-term exposures of NO_2 and SO_2 can irritate the respiratory system, while long term exposure can increase the risk of respiratory infection, asthma and bronchitis.

AIR POLLUTION AND HALTH RISK

Air pollution poses significant health risks to humans. The potential health effects can be acute or chronic and vary depending on the type and concentration of pollutants, duration of exposure and individual weakness.

➲ Main Health Risks Associated with Air Pollutions

i) **Respiratory Diseases**

Air pollutants such as ozone, particular matters (PM) and nitrogen dioxide (NO_2) can increase asthma symptoms and trigger asthma attack.

Long term exposure may lead to chronic cough and respiratory infections like pneumonia.

ii) **Cardio-Vascular Diseases**

Exposure to particular matters and other pollutants can increase the risk of heart attack by causing inflammation, blood vessel damage, high blood pressure and finally heart stroke.

Rack Your Mind!

9. Which harmful pollutants are classified as heavy metals found in air pollution?

A) Carbon dioxide and methane

B) Lead, mercury, and cadmium

C) Nitrogen and oxygen

D) Water vapour and argon

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iii) **Cancer**
Prolonged exposure to certain air pollutants especially particulate matter (PM) and carcinogenic compounds (benzene formation) cause lung cancer.

iv) **Reproductive and Developmental Effects**
Exposure to air pollution may negatively impact reproductive health and fertility in both man and women. Premature birth and developmental problems in children may occur.

☑ QUICK CHECK 14.4

a) Explain the impact of particulate matter (PM) on the air quality.

Ans. Impact of Particulate Matter (PM) on Air Quality:

- **Health:** PM ($PM_{2.5}$, PM_{10}) causes respiratory/cardiovascular diseases.
- **Visibility:** Scatters light, reducing visibility (haze/smog).
- **Climate:** Alters radiation balance (cools or warms atmosphere).
- **Environment:** Acidifies soil/water, harms ecosystems.

b) What is AQI? How does it measure air quality?

Ans. AQI stands for Air Quality Index. AQI (Air Quality Index) is a numerical scale (0–500) that reports daily air pollution levels and associated health risks.

AQI Measures Air Quality:

Tracks Key Pollutants:

- $PM_{2.5}$, PM_{10}, O_3, CO, SO_2, NO_2.
- Converts Pollutant Concentrations into sub-indices (0–500) using standardized formulas.
- Highest Sub-Index determines the overall AQI value (e.g., if $PM_{2.5}$ is worst, it sets the AQI).

AQI Categories & Health Implications:

- 0–50 (Good): Minimal risk.
- 51–100 (Moderate): Acceptable; minor concern for sensitive groups.
- 101–150 (Unhealthy for Sensitive Groups): Children/asthmatics affected.
- 151+ (Unhealthy/Hazardous): Everyone faces health risks.

c) What are different levels of AQI? Mention the safest and the most hazardous ranges of AQI.

Ans. AQI Levels & Ranges:

1. 0–50 (Good) – Safest (minimal risk).
2. 51–100 (Moderate) – Acceptable.
3. 101–150 (Unhealthy for Sensitive Groups) – Mild risk (asthmatics, children).
4. 151–200 (Unhealthy) – Everyone affected.
5. 201–300 (Very Unhealthy) – Serious health effects.
6. 301–500 (Hazardous) – Most hazardous (emergency conditions).

In short, Safest = 0–50, Hazardous = 300+.

METHODS & TECHNIQUES TO MEASURE & MONITOR AIR QUALITY

Measuring and monitoring air quality involves a combination of methods and techniques to assess the concentration of various pollutants in the air. These pollutants can include particulates matter (PM), nitrogen dioxides (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and volatile organic compounds (VOCs). There are various methods are techniques used by environmental engineers to measure air quality accurately. The instrument used to measure air quality index (AQI) is nephelometer. This is an instrument used to monitor PM such as dust, smoke, mist and fumes. Nephelometer, also known as photometer, detects particles by measuring the total amount of light they scatter.

➲ Direct Measurement Methods

i) **Continuous Emission Monitoring System (CEMS)**
Continuous emission monitoring system (CEMS) can usually monitor gas like CO, O_3, SO_2, NO_2, VOCs and PM at industrial sites.

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ii) **Air Quality Monitoring Stations (AQMS)**
Fixed monitoring stations are equipped with various sensors and analyzers to measure pollutant level in real time located in urban areas and industrial zones.

iii) **Remote Sensing Techniques**
Satellites equipped with sensors can measure atmospheric pollutants over large areas, providing valuable data on regional and global air quality.

EXPERIMENTS AND DATA COLLECTION TO TEST HYPOTHESIS ABOUT AIR QUALITY

The design of experiments to test hypothesis about air quality involves careful planning, data collection and analysis. Following steps should be done about the air quality.

i) **Hypothesis**
As a first step, a hypothesis is developed to design an experiment. For example, the hypothesis, "The concentration of airborne particulate matters (PM 2.5) and nitrogen dioxide (NO_2) in urban areas is higher during peak traffic hours as compared to non-peak hours" can be tested by collecting air quality data at different time of the day.

ii) **Designing the experiment**
The detail of the experiment including the variables and method of data collection is planned. Busy roads sites and residential areas are selected for monitoring.

iii) **Data Collection**
The data on traffic volume during rush hours and non-rush hours is collected and finally compared. The reliable instruments and methods to collect air quality data are used.

ANALYZE DATA AND INTERPRET AIR QUALITY

The collected data is analyzed to confirm the truth or falseness of the hypothesis. The results of the analysis are interpreted and concluded.

Example Analyzing and Interpreting Air Quality Data: It involves understanding the concentration of various pollutants, identifying trends overtime and assessing the implications for public health and environmental Policy. General approach to analyze and interpret air quality measurements and trends are follows.

By carefully designing experiments, collecting and analyzing data, a hypothesis about air quality can be tested and the strategies for improving air quality can be made.

STRATEGIES USED TO REDUCE AIR POLLUTION

A variety of technologies is used to reduce air pollution and improve air quality. The following five types of technologies we can be used to control emission of air pollutants.

i) **Use of Catalytic convertor (CC) in Cars**
Oxides of nitrogen and other undesirable gases such as CO and various unburnt hydrocarbon are emitted by the vehicle engines. The most cars are equipped with catalytic convertors to convert the harmful pollutants to harmless substances. CO is oxidized to CO_2. NO_x are reduced to N_2. The unburnt hydrocarbon is converted to CO_2 and H_2O.

Ii **Diesel Particulate Filter (DPF) in Modern Diesel Engines**
Diesel particulate filter (DPF) is incorporated in modern diesel engines to reduce the emission of harmful particulate matter (PM) from the exhaust gases. The primary function of diesel particulate filter is to capture and store soot particles from the exhaust gases.

iii) **Selective Catalytic Reduction (SCR)**
SCR is used in diesel engines to remove pollutants from the emission gases. It reduces NO_x to N_2 and oxidizes CO and hydrocarbons to CO_2 and water vapour using catalysts, such as TiO_2, zeolites, etc.

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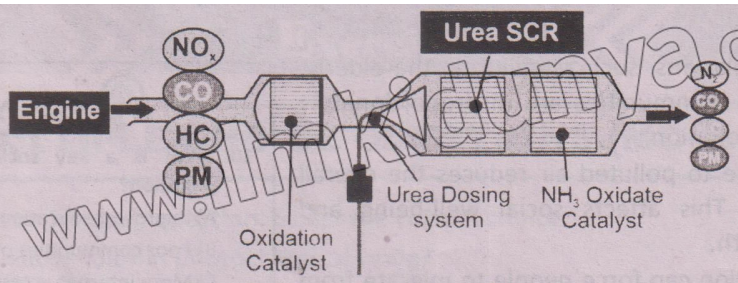


Figure: Selective Catalytic Reduction

iv) Scrubbers

Scrubbers can be used to control wide range of pollutants including particulate matters, SO_2, $HC\ell$, NH_3 and VOCs. Scrubbers use liquids (e.g., H_2O) to remove pollutants such as SO_2, PM from the industrial exhaust gases.

LAWS AND REGULATIONS RELATED TO ATMOSPHERE

➲ Laws and Regulations

Common rules and regulations to control air pollution in Pakistan is given below:

i) Pakistan Environmental Protection Act (PEPA 1997)
ii) Natural Environmental Quality Standard (NEQS)
iii) Punjab Environmental Protection (Amendment) Act 2012

➲ Measures to Control Air Pollutions

i. **Vehicle Emission Standard:** Enforcement of this standard is to reduce pollution from motor vehicles. The promotion of cleaner fuels such as compressed natural gas (CNG), liquid petroleum gas (LPG) and sticker regulation on fuel quality.

ii. **Industrial Emission Control:** To reduce emission from industrial resources and the encouragement of industries to adopt cleaner production techniques and pollution control technologies.

iii. **Public Awareness Campaigns:** Educating the public about the sources and effect of air pollution and ways to reduce personal contributions to air pollution also promote the use of public transport carpooling and non-motorized transport such as cycling and walking.

iv. **Urban Planning and Green Infrastructure:** Development of green belts and parks in urban / areas to improve air quality. Implementation of urban planning measures to reduce traffic congestion and promote sustainable transport options.

v. **Smog Control Measures:** Specific measures to control smog particularly during the winter months when air quality deteriorates significantly, Restrictions the burning of crop residues, which is a major contributes to smog and should use smog towers and other technologies to reduce particulates matter in the air.

vi. **Prohibition of the use of open fire:** for the disposal of domestic and industrial waste. Using open fire to bulk domestic and industrial waste can produce dust, smoke and significant amount of air pollutants.

vii. **Use of low-Sulphur Diesel:** Reduction of permissible level of sulphur in diesel.

Through these regulations and measures, Pakistan aims to improve air quality and minimize the adverse effects of air pollutions on public health and the environment.

ECONOMIC, SOCIAL & POLITICAL ISSUES

Air pollution and bad air quality is responsible for huge economic costs, social and potential issues.

➲ Economic Issues

- Poor air quality can reduce worker productivity due to illness and absenteeism.
- Air pollution and air quality can damage crops reducing agricultural yield and increasing food prices.
- Air pollution leading to acid rain can degrade buildings, bridges and other infrastructure.

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➲ Social Issues

- Vulnerable populations, such as children, the elderly, and low-income communities are disproportionately affected by air pollution.
- Chronic exposure to polluted air reduces the overall quality of life. This affects social well-being and community health.
- Severe air pollution can force people to migrate from the unhealthy polluted areas to places with better air quality, leading to social displacement and associated challenges.

Rock Your Mind!

10. What is a key social issue related to air pollution?

A) Improved education
B) Poor communities often face higher pollution
C) More internet access
D) Increased rainfall

➲ Political Issues

- Implementing effective air quality regulations can be challenging due to political and economic interests.
- Air pollution is not confined to borders and effective management requires international cooperation.
- Implementing air quality regulations requires strict governance, which might slow down industrial growth and economic development and leads to political conflicts.
- Addressing air pollution requires a multi-faceted approach, balancing socio-economic, and technological considerations.

Solution File — Rock Your Brain!

Sr. #	Option	Explanation
1.	D	The ozone layer is located in the stratosphere and absorbs most of the sun's ultraviolet radiation.
2.	S.Q	**(i) Troposphere:** Closest to Earth, weather occurs here **(ii) Stratosphere:** Contains the ozone layer **(iii) Mesosphere:** Coldest layer, where meteors burn **(iv) Thermosphere:** Hottest layer, contains auroras and satellites
3.	S.Q	Smog is a type of air pollution formed by the reaction of sunlight with pollutants like nitrogen oxides and VOCs. It causes breathing problems and eye irritation.
4.	B	These gases form sulfuric and nitric acids when they mix with water in the atmosphere, resulting in acid rain.
5.	C	Methane (CH_4) is a potent greenhouse gas emitted from natural sources and human activities like cattle digestion and wetland farming.
6.	S.Q	Greenhouse gases like CO_2, CH_4, and N_2O trap heat in the atmosphere, leading to global warming and climate change.
7.	S.Q	Deforestation reduces oxygen production, increases carbon dioxide levels, and contributes to the greenhouse effect and loss of biodiversity.
8.	S.Q	**(i)** Use of renewable energy (solar, wind) **(ii)** Emission control devices (e.g., catalytic converters) **(iii)** Air quality monitoring using sensors **(iv)** Laws and regulations like vehicle emission standards
9.	B	These heavy metals are toxic and can accumulate in the body, affecting organs and the nervous system.
10.	B	Disadvantaged groups often live in more polluted areas with fewer protections.

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Exercise

MULTIPLE CHOICE QUESTIONS (MCQs)

Q.1 Four choices are given for each question. Select the correct choice.

I. Which gas causes yellow color in photochemical smog?
a) CO b) SO_3 c) NO_2 d) SO_2

II. The depletion of Ozone in stratosphere region is mainly due to the reaction of O_3 with:
a) CO_2 b) SO_2 c) O_2 d) CFCs

III. Which particulate matter size is considered the most harmful to human health?
a) PM 10.0 b) PM 5.0 c) PM 2.5 d) PM 1.0

IV. Which of the following is a natural factor that can improve air quality?
a) Wildfire b) Urbanization c) Rainfall d) Industrial emission

V. What is a common human activity that led to increased level of carbon monoxide in the atmosphere?
a) Tree planting
b) Gasoline driven vehicles
c) Using electric appliances
d) Solar panel installation

VI. Chlorofluorocarbons (CFCs) have been primarily used in:
a) Fertilizers
b) Refrigerants and aerosol propellants
c) Pharmaceuticals
d) Pesticides

VII. What are the primary chemical processes that removes carbon dioxide from the atmosphere?
a) Combustion b) Photosynthesis c) Respiration d) Volcanic activity

VIII. An AQI value between 51 and 100 typically indicates which level of air quality?
a) Good b) Moderate c) Unhealthy d) Fatal

IX. Acid rain is primarily caused by the release of which of the following gases into the atmosphere?
a) Carbon dioxide (CO_2) and methane (CH_4)
b) Sulfur dioxide (SO_2) and nitrogen oxides (NO_x)
c) Chlorofluorocarbons (CFCs) and halons
d) Ozone (O_3) and carbon monoxide (CO)

X. In the presence of sunlight and nitrogen oxides (NO_x), VOCs can contribute to the formation of:
a) Acid rain b) Ozone depletion c) Photochemical smog d) Greenhouse gases

XI. Primary pollutants like nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight to form a key component of photochemical smog, which is a:
a) Primary pollutant.
b) Secondary pollutant.
c) Naturally occurring atmospheric gas.
d) Harmless byproduct of combustion.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanation
I.	c	NO_2	• Nitrogen dioxide (NO_2) is a brown/yellow gas that contributes to the visible color of photochemical smog.
II.	d	CFCs	• Chlorofluorocarbons (CFCs) react with ozone (O_3) in the stratosphere, breaking it down into O_2 (e.g., $Cl + O_3 \rightarrow ClO + O_2$).
III.	c	PM 2.5	• PM 2.5 (particles ≤ 2.5 μm) penetrates deep into lungs and bloodstream, causing severe health issues (e.g., asthma, heart disease).
IV.	c	Rainfall	• Rainfall scrubs pollutants (e.g., PM, SO_2) from the air, improving air quality naturally.

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V.	b	Gasoline driven vehicles	• Incomplete combustion in gasoline engines releases carbon monoxide (CO), a toxic gas.
VI.	b	Refrigerants and aerosol propellants	• CFCs were widely used in refrigerators, ACs, and spray cans before being phased out due to ozone depletion.
VII.	b	Photosynthesis	• Photosynthesis by plants/algae absorbs CO_2, converting it into oxygen and biomass.
VIII.	b	Moderate	• AQI 51–100 indicates "Moderate" air quality, acceptable but may affect sensitive groups.
IX.	b	SO_2 and NO_x	• SO_2 and NO_x react with water vapor to form sulfuric/nitric acid, causing acid rain (H_2SO_4/HNO_3).
X.	c	Photochemical smog	• VOCs + NO_x + sunlight form ozone (O_3) and PAN, key components of photochemical smog.
XI.	b	Secondary pollutant	• Ozone/PAN are secondary pollutants, formed by reactions of primary pollutants (NO_x/VOCs) in sunlight.

SHORT ANSWER QUESTIONS

Q.2 Attempt the following short-answer questions:

a. Identify and briefly explain three major natural sources of air pollutants.

Ans. The three major natural sources of air pollutants are given below;

1. **Volcanic eruptions:** Release sulfur dioxide (SO_2), ash, and gases into the atmosphere.
2. **Forest fires:** Emit carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter.
3. **Dust storms:** Spread large amounts of particulate matter (PM) into the air.

b. How can deforestation impact air quality?

Ans. Deforestation reduces the number of trees that absorb CO_2 and release oxygen, leading to increased carbon dioxide and particulate levels, thereby degrading air quality.

c. Explain the reasons for the temperature trends observed in the troposphere and the stratosphere.

Ans. In the **troposphere**, temperature decreases with height due to less heat from Earth's surface. In this region, temperature decreases from 17°C to –58°C regularly.
In the **stratosphere**, temperature increases with height because of ozone absorption of ultraviolet (UV) radiation. Temperature increases from –58°C to –2°C.

d. Describe four significant anthropogenic (human-caused) activities that contribute to the deterioration of air quality. For each activity, name at least one major pollutant released.

Ans. Four significant anthropogenic (human-caused) activities that contribute to the deterioration of air quality are given below;

1. **Vehicle emissions:** Release nitrogen oxides (NO_x).
2. **Industrial activities:** Release sulfur dioxide (SO_2).
3. **Burning fossil fuels:** Produces carbon monoxide (CO).
4. **Agricultural practices:** Emit ammonia (NH_3) and methane (CH_4).

e. What are the environmental impacts of persistent organic pollutants (POPs)?

Ans. These are organic compounds that are resistant to degradation through chemical, biological and photolytic processes. These are toxic and adversely affect human health and the environment. POPs accumulate in the environment, harm wildlife, contaminate soil and water, and can travel long distances through air and water.

f. How does polycyclic aromatic hydrocarbon (PAHs) affect human health?

Ans. Polycyclic aromatic hydrocarbon PAHs can cause respiratory problems, skin irritation, and are known to be **carcinogenic** (cancer-causing).

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g. What is photochemical smog? Under what conditions, it forms?

Ans. Photochemical smog is a type in which primary air pollutants like nitrogen oxides (NO_x), VOC and unburned hydrocarbons undergo photochemical reactions in the presence of sunlight and form secondary pollutants like ozone and peroxyacetyl nitrates (PAN).
This type of smog is considered more dangerous as it can cause heart palpitations, pneumonia and even lung cancer.
It forms in warm, sunny, and urban areas with heavy traffic.

h. What type of data do air quality index (AQI) system provide?

Ans. The AQI provides data on the concentration of major air pollutants like $PM_{2.5}$, PM_{10}, O_3, CO, SO_2, and NO_2, and indicates how polluted the air currently is or how polluted it is forecast to become.

i. Distinguish between PM_{10} and $PM_{2.5}$, specifying the size ranges and describing why $PM_{2.5}$ is generally considered more harmful to human health.

Ans. **PM_{10}** are particles ≤ 10 micrometers; **$PM_{2.5}$** are particles ≤ 2.5 micrometers. **$PM_{2.5}$** is more harmful as it can penetrate deep into the lungs and enter the bloodstream, causing heart and lung diseases.

j. What are the main chemical processes involved in the formation of acid rain?

Ans. Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water vapor in the atmosphere to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3), which fall as acid rain.

k. What are the specific measures to control smog?

Ans. To control smog followings should be taken:
- Reducing vehicle emissions
- Using cleaner fuels
- Limiting industrial pollutants
- Planting trees
- Implementing air quality regulations.

l. How does a catalytic converter reduce harmful vehicle emissions?

Ans. Oxides of nitrogen and other undesirable gases such as CO and various unburnt hydrocarbon are emitted by the vehicle engines. The most cars are equipped with catalytic convertors to convert the harmful pollutants to harmless substances. CO is oxidized to CO_2. NO_x are reduced to N_2. The unburnt hydrocarbon is converted to CO_2 and H_2O.

m. Describe the sources of lead and mercury pollution.

Ans. **Lead pollution** comes from leaded gasoline, battery manufacturing, and paints.
Mercury pollution comes from coal burning, mining, and industrial waste.

DESCRIPTIVE QUESTIONS

Q.3 Discuss sources and effects of following air pollutants on environment:
i) Heavy metals ii) VOCs iii) PAHs iv) POPs

Ans. **See Page No. (472)**

Q.4 Write short notes on the following:
i) CFCs and ozone layer depletion ii) Greenhouse effect and global warming

Ans. **See Page No. (471, 475)**

Q.5 How the fossil fuel burning causes acid rain? Discuss in detail with chemical reactions.

Ans. **See Page No. (475)**

Q.6 What is meant by air quality AQI? Describe the factors affecting the air quality.

Ans. **See Page No. (477)**

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ADDITIONAL SLOs BASED MCQs

1. **What is a primary source of air pollution?**
   A. Natural volcanic eruptions B. Industrial emissions
   C. Forest fires D. All of the above
2. **Which gas is primarily responsible for the greenhouse effect?**
   A. Oxygen (O_2) B. Carbon dioxide (CO_2) C. Nitrogen (N_2) D. Hydrogen (H_2)
3. **Which of the following is NOT a greenhouse gas?**
   A. Methane (CH_4) B. Nitrous oxide (N_2O) C. Sulfur dioxide (SO_2) D. Water vapor (H_2O)
4. **What is the main component of smog that poses health risks to humans?**
   A. Oxygen (O_2) B. Carbon monoxide (CO) C. Sulfur dioxide (SO_2) D. Nitrogen dioxide (NO_2)
5. **Acid rain is primarily caused by the emission of:**
   A. Carbon dioxide (CO_2) B. Ammonia (NH_3) C. Sulfur dioxide (SO_2) D. Oxygen (O_2)
6. **Which of the following is a short-term effect of air pollution on human health?**
   A. Increased cancer risk B. Respiratory problems C. Long-term memory loss D. None of the above
7. **What is the main consequence of global warming?**
   A. Rising sea levels B. Decreased carbon dioxide levels
   C. Increased ozone layer thickness D. Reduced rainfall
8. **Which of these is NOT an adverse effect of air pollution on the environment?**
   A. Disruption of ecosystem B. Increased agricultural productivity
   C. Damage to buildings and monuments D. Loss of biodiversity
9. **The ozone layer depletion is primarily caused by:**
   A. Greenhouse gases B. Volcanic eruptions
   C. Chlorofluorocarbons (CFCs) D. Deforestation
10. **What can individuals do to help reduce air pollution?**
    A. Drive gasoline-powered cars B. Use single-use plastics
    C. Reduce energy consumption D. Burn waste materials openly
11. **Air is polluted by:**
    A. toxic materials B. hydrocarbons C. harmful gases D. all of above
12. **Which of following gas is not pollution?**
    A. SO_2 B. CO C. CO_2 D. NO_2
13. **Oxides of sulfur and nitrogen react with oxygen to form:**
    A. bases B. acids C. salts D. all of above
14. **Oxidizing smog consists of high concentration of:**
    A. SO_2 B. Ozone C. NO_2 D. Cl_2
15. **Ozone is destroyed by:**
    A. SO_2 B. NO_2 C. Chlorofluorocarbons D. None of above

Answer Key with Explanations

Sr. #	Ans.	Explanations
1.	D	All listed sources, including natural volcanic eruptions, industrial emissions, and forest fires, contribute significantly to air pollution.
2.	B	Carbon dioxide (CO2) is a major greenhouse gas that traps heat in the atmosphere, contributing significantly to the greenhouse effect.
3.	C	While sulfur dioxide (SO_2) is an air pollutant, it is not classified as a greenhouse gas. Greenhouse gases include methane, nitrous oxide, carbon dioxide, and water vapor.
4.	D	Nitrogen dioxide (NO_2) is a key component of smog and can cause respiratory problems and other health issues.
5.	C	Sulfur dioxide (SO_2) and nitrogen oxides (NOx) are the primary contributors to acid rain, which forms when these gases react with water vapor in the atmosphere to produce acids.

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6.	B	Short-term exposure to air pollution can cause respiratory problems such as coughing, shortness of breath, and exacerbation of asthma.
7.	A	Global warming leads to the melting of polar ice caps and glaciers, contributing to rising sea levels and potential flooding of coastal areas.
8.	B	Air pollution typically harms agriculture by damaging crops and reducing yields rather than increasing productivity.
9.	C	CFCs release chlorine atoms when they are broken down by UV radiation, which then deplete the ozone layer in the stratosphere.
10.	C	Reducing energy consumption helps decrease the demand for fossil fuels, thereby lowering the emissions of pollutants and greenhouse gases.
11.	D	Air polluted by harmful gases like CO, NO_x, SO_2, Ozone, Hydrocarbons and toxic material.
12.	C	CO_2 is not a pollutant gas as it is required for photosynthesis.
13.	B	In the atmosphere SO_2 and NO_x are transformed by reactions with oxygen and water into H_2SO_4 and HNO_3 respectively. These acids get mixed with rain. The acid deposition includes both wet (rain, snow, fog) and dry acidic deposition. $SO_2 + \frac{1}{2}O_2 + H_2O \xrightarrow{\text{Hydrocarbon, smoke, Metal oxide}} H_2SO_4$
14.	B	The photochemical smog consists of higher concentrations of oxidants like ozone and is also termed as oxidizing smog.
15.	C	Chlorofluorocarbons (CFCs) destroy ozone by releasing chlorine atoms that break down ozone molecules in the stratosphere.

ADDITIONAL SHORT ANSWER QUESTIONS

Q.1 What are the components of Environment?

Ans. Components of the Environment:

The environment consists of the following components.

- **Atmosphere:** The layer of gases which surrounds the earth.
- **Hydrosphere:** Concerned with all water bodies i.e. ocean, rivers, streams lakes, glaciers and ground water reservoirs.
- **Lithosphere:** Concerned with hard and rigid rocky earth crust.
- **Biosphere:** Area on earth which supports life i.e. air, lakes, etc.

Q.2 What is Troposphere?

Ans. Troposphere

It is the lowest region of the atmosphere which extends up to 12 km. It includes all the major gases present in the atmosphere i.e., nitrogen, oxygen, and carbon dioxide, etc. In this region, temperature decreases from 17°C to −58°C regularly. It is the densest layer of the atmosphere. It is the layer in which major events such as rain, lightening, and hurricanes occur.

Q.3 What conditions are necessary for photochemical smog?

Ans. Conditions for Smog Formation:

The following conditions are required for the formation of smog.

i. There must be sufficient NO, hydrocarbons and volatile organic compounds (VOC) emitted by the vehicles.
ii. Sunlight, so that some of the chemical reactions may occur at a rapid rate.
iii. The movement of air mass must be little so that reactions are not disturbed.
iv. Temperature greater than 18°C.

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Q.4 What are the effects of excess of CO_2 present in the atmosphere.

Ans. Effect of Excess of CO_2 Present in the Atmosphere:

If the atmosphere contains too much quantity of CO_2, the greenhouse effect is considerably increased i.e. the atmosphere; the temperature of the earth is increased too much. This too much high temperature melts all the glaciers (snow-mountains) floods the low-lying areas of the earth, changes the biological activity of oceans and the patterns of cropping etc. Thus we see that the presence of the excess of CO_2 in the atmosphere brings about climate changes.

Q.5 What is photochemical smog? Give its properties.

Ans. Smog:

"The word smog is a combination of smoke and fog".

It is formed from ground level upward to an altitude of few kilometers high.

Pollutants Causing Photochemical Smog:

- Due to having higher concentrations of oxidants like ozone, photochemical smog is also called **"oxidizing smog".**
- It is a yellowish brownish grey haze due to the presence of NO_2.
- It has unpleasant odour because of its gaseous components.

Reactants of Photochemical Smog:

- Nitric Oxide (NO) which main reactions of photochemical smog is oxidized to NO_2 within minutes to hours depending upon the concentration of pollutant gas.
- Unburnt hydrocarbons.

Q.6 What are greenhouse emissions?

Ans. Greenhouse gas emissions are gases released into the atmosphere that trap heat, contributing to global warming and climate change. The main greenhouse gases include:

- **Carbon dioxide (CO_2)** from burning fossil fuels like coal, oil, and natural gas.
- **Methane (CH_4)** from agriculture, landfills, and fossil fuel production.
- **Nitrous oxide (N_2O)** from fertilizers and industrial processes.
- **Fluorinated gases** synthetic gases used in refrigeration and manufacturing.

These gases create a "greenhouse effect" by trapping heat from the sun, leading to rising global temperatures and climate-related impacts.

Q.7 Relate greenhouse effect and global warming. Write some important points.

Ans. Here's how the greenhouse effect and global warming are related, explained point by point:

- **Greenhouse Effect is Natural:**
  It is a natural process where greenhouse gases trap some of the sun's heat in the Earth's atmosphere, keeping the planet warm enough to support life.
- **Human Activities Increase Greenhouse Gases:**
  Burning fossil fuels, deforestation, and industrial activities release excess greenhouse gases (like CO_2, CH_4, N_2O) into the atmosphere.
- **Enhanced Greenhouse Effect:**
  This build up of gases strengthens the natural greenhouse effect, trapping more heat than necessary.
- **Result: Global Warming:**
  The extra trapped heat leads to a gradual increase in Earth's average temperature—this is global warming.
- **Climate Change Link:**
  Global warming contributes to broader climate change, causing extreme weather, sea-level rise, and ecological disruptions.

In short, The greenhouse effect is the process; global warming is one of the harmful outcomes when this process is intensified by human actions.

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Q.8 Write down the impact of heavy metals like lead, Mercury and cadmium on environment and human health.

1. **Lead (Pb)**
   - **Environment:**
     - Contaminates soil and water.
     - Harms plants and animals by affecting growth and reproduction.
   - **Human Health:**
     - Damages the nervous system, especially in children.
     - Causes developmental delays, learning disabilities, and behavioral issues.
     - Long-term exposure may lead to kidney damage and high blood pressure.
2. **Mercury (Hg)**
   - **Environment:**
     - Bioaccumulates in aquatic ecosystems, especially in fish.
     - Highly toxic to wildlife, affecting reproduction and behavior.
   - **Human Health:**
     - Affects the brain and nervous system.
     - Particularly dangerous for pregnant women and young children—can cause developmental issues.
     - Inhalation or consumption (e.g., through contaminated fish) can lead to mercury poisoning.
3. **Cadmium (Cd)**
   - **Environment:**
     - Accumulates in soil and water, entering the food chain through plants.
     - Toxic to aquatic life and reduces crop productivity.
   - **Human Health:**
     - Damages kidneys and lungs.
     - Can cause bone weakness and pain.
     - Long-term exposure may lead to cancer.

Q.9 Discuss Air Quality Monitoring Stations (AQMS) as direct measurement method.

Ans. Air Quality Monitoring Stations (AQMS)-Direct Measurement Method

Air Quality Monitoring Stations (AQMS) are fixed installations used to directly measure air pollutants in the atmosphere. They play a crucial role in understanding and managing air pollution.

1. **Direct Measurement:**
   - AQMS use advanced sensors and instruments to continuously and accurately measure pollutant concentrations in real-time (e.g., PM 2.5, PM 10, CO, NO_2, SO_2, O_3).
2. **Stationary and Continuous Monitoring:**
   - These stations are usually located in urban, industrial, or sensitive ecological areas and provide 24/7 data on air quality.
3. **Data Collection and Analysis:**
   - Data from AQMS is used to generate Air Quality Index (AQI), track pollution trends, issue public health advisories, and support policymaking.
4. **High Accuracy:**
   - Compared to indirect or modeling methods, AQMS provide precise and reliable pollutant concentration levels.
5. **Regulatory Use:**
   - Governments and environmental agencies use AQMS data to enforce air quality standards and comply with environmental laws.

Advantages:

- Real-time and continuous data.
- Accurate and reliable results.
- Helps in early warning systems for pollution events.
- Supports long-term environmental planning and research.

Limitations:

- High installation and maintenance costs.
- Limited spatial coverage – fixed stations cannot cover wide areas.
- Requires skilled personnel for operation and calibration.

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SELF-ASSESSMENT Chapter # 14

Total Mark: 30

Q.1 Encircle the correct option. **(1 × 6 = 6)**

(i) A key component that distinguishes photochemical smog from industrial smog is the presence of:

A. High concentrations of sulfur dioxide.
B. A significant amount of ozone and other photochemical oxidants like PAN (peroxyacetyl nitrate).
C. Reduced visibility due to fog and smoke particles.
D. Formation primarily during the early morning hours.

(ii) Primary pollutants like nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight to form a key component of photochemical smog, which is a:

A. Primary pollutant. B. Secondary pollutant.
C. Naturally occurring atmospheric gas. D. Harmless byproduct of combustion.

(iii) Acid rain is primarily caused by the release of which of the following gases into the atmosphere?

A. Carbon dioxide (CO_2) and methane (CH_4)
B. Sulfur dioxide (SO_2) and nitrogen oxides (NO_x)
C. Chlorofluorocarbons (CFCs) and halons
D. Ozone (O_3) and carbon monoxide (CO)

(iv) An AQI value between 51 and 100 typically indicates which level of air quality?

A. Good B. Moderate C. Unhealthy D. Fatal

(v) Which gas causes yellow color in photochemical smog?

A. CO B. SO_3 C. NO_2 D. SO_2

(vi) Which particulate matter size is considered the most harmful to human health?

A. PM 10.0 B. PM 5.0 C. PM 2.5 D. PM 1.0

Q.2 Write short answers of the following questions. **(2 × 8 = 16)**

(i) Discuss the use of Catalytic convertor (CC) in Cars.
(ii) Write down the differences between Primary and Secondary Pollutants
(iii) How do volatile organic compounds (VOCs) affect air quality?
(iv) How Chlorofluorocarbons (CFCs) effect ozone?
(v) Identify and briefly explain three major natural sources of air pollutants.
(vi) How can deforestation impact air quality?
(vii) Write two measures to control air pollutions
(viii) What is AQI? How does it measure air quality?

Q.3 Extensive Questions. **(2 × 4 = 8)**

(a) Discuss the four layers of atmosphere.
(b) Write a detailed note on smog and acid rain.

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