14 ATMOSPHERE

Student Learning Outcomes [C-11-C-01 to C-11-B-14]

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 as 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)**

The atmosphere is a sphere of different gases around the earth. The components of the atmosphere may be divided into major, minor and trace components. **Major components** are nitrogen (78.00%) and oxygen (21.01%). **Minor components** are argon (0.93%), carbon dioxide (0.04%). **Trace components** are methane, hydrogen, neon, helium, krypton, and xenon.

14.1 LAYERS OF THE ATMOSPHERES

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

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 ºC to -58 ºC regularly. It is the densest layer of the atmosphere. It is the layer in which major events such as rain, lightening, and hurricanes occur.

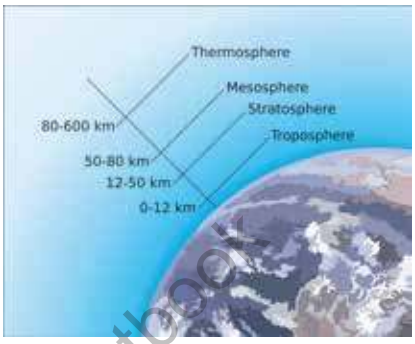

Figure 14.1 Layers of the atmosphere

ii) Stratosphere

Above the troposphere, the stratosphere lies which is at a distance of 12-50 km above the earth surface. Temperature increases from -58ºC to -2ºC. 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. It breaks down into monoatomic oxygen and diatomic oxygen.

$$O_{3\,(g)} \xrightarrow{h\upsilon} O_{2\,(g)} + O^{\bullet}_{(g)}$$

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.

$$O_{2\,(g)} + O^{\bullet}_{(g)} \longrightarrow O_{3\,(g)}$$

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

iii) Mesosphere

It extends to a height of about 50–80 km from the ground. Here, the temperature decreases with altitude from -2ºC to -93ºC. The coldest region of the atmosphere is located in this layer.

iv) Thermosphere

It extends from 80 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 ºC to 2000 ºC or higher.

14.2 AIR POLLUTANTS

Pollutants are substances (gases, liquids and solids) that are harmful to the environment. Air pollutants can be classified as primary and secondary. **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** are formed due to chemical reactions of primary pollutants.

The most important pollutants are mentioned below:

1. Oxides of Carbon (CO and CO_2)
2. Oxides of Nitrogen (NO and NO_2) collectively known as NO_x
3. Oxides of Sulphur (SO_2 and SO_3) collectively known as SO_x
4. Hydrocarbons (Methane, Ethane)
5. Low altitude Ozone (O_3)
6. Chlorofluorocarbons (CFCs)
7. Polycyclic Aromatic Hydrocarbon (PAHs)
8. Persistent Organic Pollutant (POPs)
9. Volatile Organic Compounds (VOCs)
10. Particulate Matter (PM)
11. Heavy Metals (Pb, Hg and Cd)

14.3 SOURCES OF AIR POLLUTION

There are broadly two main sources of air pollution.

14.3.1 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).

14.3.2 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.

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

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

14.4 SOURCES OF AIR POLLUTANTS

14.4.1 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) is produced mainly due to incomplete combustion of fossil fuels.

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

Did You Know?

Carbon monoxide is highly poisonous gas and causes suffocation if inhaled. It binds blood haemoglobin 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.

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

14.4.2 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 are produced as a result of the following chemical reactions:

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

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)} \text{ (Nitrogen dioxide)}$$

Natural sources of NO_2 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 NO_2 contribute to climate change and can also affect air quality.

14.4.3 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, They cause acid rain that damages ecosystem. SO_2 is the major source of acid deposition in the air.

14.4.4 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 vehicular emissions are sources of hydrocarbons. Automobiles are the major source of hydrocarbon emission. Methane is the most common hydrocarbon and air pollutant.

14.4.5 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 affect adversely.

14.4.6 Chlorofluorocarbons (CFCs)

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 ($C\ell^{\cdot}$). The chloride free radical breaks down the Ozone molecule as shown in the following reactions.

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

$$C\ell^{\cdot} + O_3 \longrightarrow C\ell O^{\cdot} + O_2$$

$$C\ell O^{\cdot} + O \longrightarrow C\ell^{\cdot} + O_2$$

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 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 escaping from the earth's atmosphere. The decomposition of one molecule of CFCs can destroy up to 100,000 molecules of ozone.

14.4.7 Polycyclic Aromatic Hydrocarbon (PAHs)

Polycyclic aromatic hydrocarbon (PAHs), composed of fused multiple aromatic rings are common environmental pollutants. Naphthalene, anthracene and phenanthrene are examples of PAHs. 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 phenanthrene are examples of PAHs. They have potential toxicity and carcinogenic properties.

14.4.8 Persistent Organic Pollutants (POPs)

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, 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.

Owing to their persistence, they accumulate in the environment and can have significant adverse effects on human health. Some POPs are given in Table 14.1 below:

Table 14.1 Some POPs with their uses

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

14.4.9 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.

Exposure to VOCs can cause a variety of health effects including eye, nose and throat irritation, headache, nausea after 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.

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

14.4.11 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.

14.5 IMPACT OF HUMAN ACTIVITIES ON ATMOSPHERE

Human activities have significant impact on the atmosphere, primarily through the burning of 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.)

14.5.1 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 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 and volatile organic compounds.

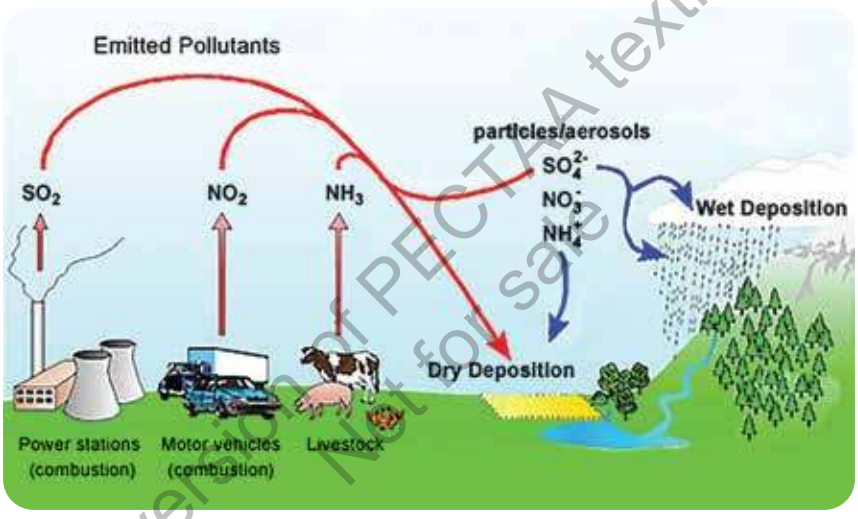

Figure 14.2 Impacts of air pollutants on the atmosphere

14.5.2 Impact of Deforestation on the Atmosphere

Deforestation is purposeful cleaning or thinning of forests by humans. Deforestation represents one of the largest issues in global climate. Forests absorb Green House Gases (GHGs) like CO_2 and clean air for us. In short, deforestation has a wide range of negative impact on the environment, including loss of biodiversity climate change, soil degradation, and water cycle disruption.

Quick Check 14.2

a) Mention man-made sources of air pollution.
b) How do polycyclic aromatic hydrocarbons (PAHs) primarily enter the atmosphere?
c) How do volatile organic compounds (VOCs) affect air quality?
d) What are major sources of heavy metals in the atmosphere?

14.6 EFFECTS OF AIR POLLUTANTS

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

14.6.1 Formation of Smog

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_x, O_3, CO and CO_2, secondary pollutants like O_3, unburned hydrocarbons, VOCs and PM of size 10-2.5 micron.

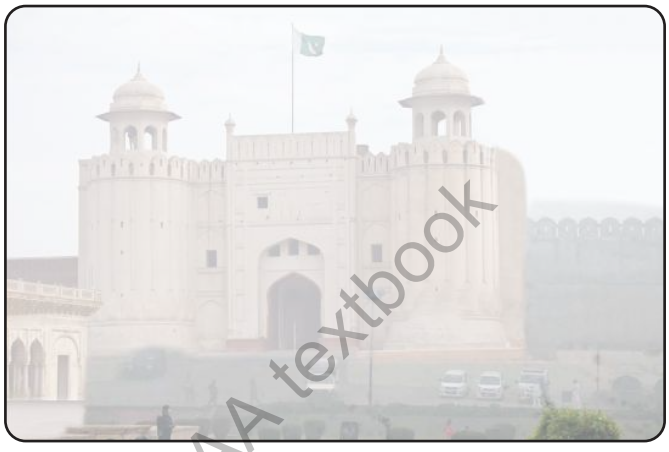

Figure 14.3 Smog in Lahore

Types of smog

i) Industrial or Classical Smog (London Smog)

ii) Photochemical smog (Los Angeles Smog)

i) Industrial or classical smog

Industrial smog also called as "**Reducing smog or Classical Smog**". It 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.

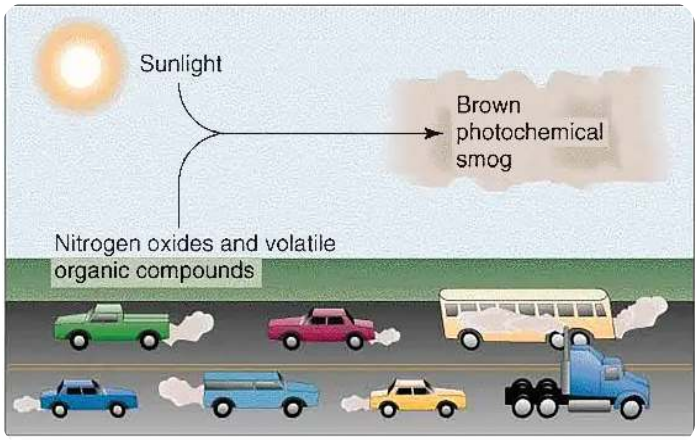

Figure 14.4 Illustration of Photochemical smog

14.6.2 Acid Rain

When rain water has pH less than 5.6, it is known as acid rain. It 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:

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

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

SO_2 from fossil fuels is oxidized to SO_3 which then reacts with water to form sulphuric acid.

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

Nitrogen oxide reacts with water to produce nitric acid and nitrous acid.

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

14.7 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**.

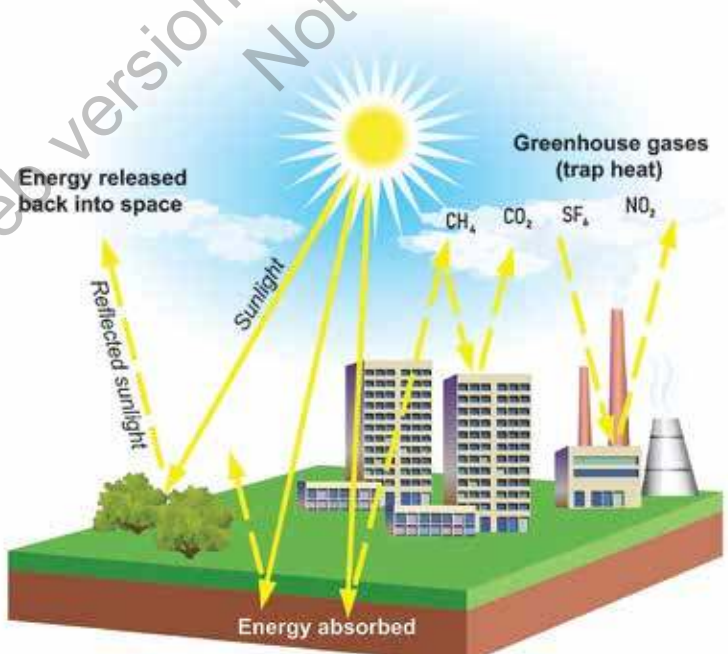

Figure 14.5 Mechanism of Global Warming

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.

The greenhouse effect is a phenomenon which is based on the gases to absorb infra-red 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.

Quick Check 14.3

a) Differentiate classical and photochemical smog.

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

c) Write a balanced equation, including the formation of sulfuric acid from atmospheric sulfur trioxide, SO_3.

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

14.8 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.

Air having 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.

14.8.1 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.

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.

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 14.2 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

14.9 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.

14.9.1 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.

14.10 AIR POLLUTION AND HEALTH 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's weakness.

14.10.1 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) Cardiovascular diseases

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

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.

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

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

14.11 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 and 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.

14.11.1 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 .

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.

14.12 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 matter (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 times 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.

14.13 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. Analyzing and interpreting air quality data involves measuring contents of air pollutants and identifying trends over time. 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.

14.14 STRATEGIES USED TO REDUCE AIR POLLUTION

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

i) Catalytic converter (CC)

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)

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.

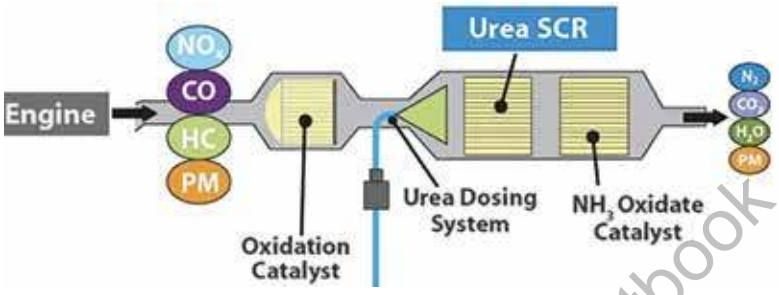

Figure 14.6 Selective Catalytic Reduction

iv) Scrubbers

Scrubbers can be used to control wide range of pollutants including PM, SO_2, HCl, NH_3 and VOCs. Scrubbers use liquids (e.g. H_2O) to remove air pollutants.

14.15 LAWS AND REGULATIONS RELATED TO ATMOSPHERE

14.15.1 Laws and Regulations

Rules and regulations to control air pollution in Pakistan are given below:

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

14.15.2 Measures to Control Air Pollutions

i. **Vehicle emission standard:** Enforcement of this standard is to reduce pollution caused by motor vehicles. The promotion of cleaner fuels such as compressed natural gas (CNG), liquid petroleum gas (LPG) and strict regulations on fuel quality is required.

ii. **Industrial emission control:** To reduce emission from industrial resources, industries should be encouraged to adopt cleaner production techniques and pollution control technologies.

iii. **Public awareness campaigns:** Educating the public about the sources and effects of air pollution is a useful strategy, such as 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 and to reduce traffic congestion.

v. **Smog control measures:** Restriction on the burning of crop residues, and should use smog control towers.

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

14.16 ECONOMIC, SOCIAL & POLITICAL ISSUES

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

14.16.1 Economic Issues

Poor air quality can reduce worker productivity due to illness. Air pollution and air quality can damage crops reducing agricultural yield and increasing food prices. Air pollution may lead to acid rain.

14.16.2 Social Issues

Vulnerable populations, such as children, the elderly, and low-income communities are chronic exposure to polluted air reduces the overall quality of life. Severe air pollution can force people to migrate leading to social displacement.

14.16.3 Political Issues

Air pollution is not confined to borders and effective management requires international corporation. Implementing air quality regulations requires strict governance. Addressing air pollution requires a multi-faceted approach, balancing socio-economic, and technological considerations.

EXERCISE

MULTIPLE CHOICE QUESTIONS

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) CO_2 and CH_4
b) SO_2 and NO_x
c) CFCs and halons
d) O_3 and 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 (NOx) 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.

SHORT ANSWER QUESTIONS

Q.2 Attempt the following short-answer questions:

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

b. How can deforestation impact air quality?

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

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.

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

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

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

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

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.

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

k. What are the specific measures to control smog?

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

m. Describe the sources of lead and mercury pollution.

DESCRIPTIVE QUESTIONS

Q.3 Discuss sources and effects of following air pollutants on environment:

i) Heavy metals ii) VOCs iii) PAHs iv) POPs

Q.4 Write short notes on the following:

i) CFCs and ozone layer depletion

ii) Greenhouse effect and global warming

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

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