

Chapter 11: Environmental Chemistry - Air

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FEDERAL BOARD
Model Textbook of
CHEMISTRY
Grade 9
Based on National Curriculum of Pakistan 2022-23

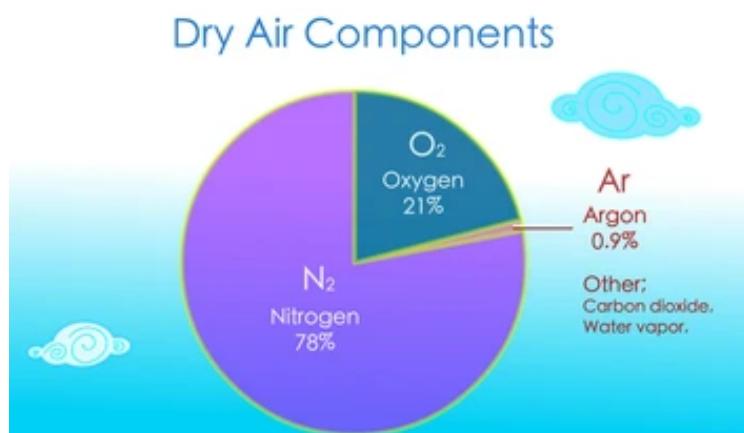
Introduction to Atmosphere

The atmosphere is the envelope of gases and water vapour surrounding the Earth. Air is a mixture of gases including nitrogen, oxygen, carbon dioxide, noble gases, and water vapor.

11.1. Composition of Atmosphere

The composition of dry air (by volume):

- 78% Nitrogen
- 21% Oxygen
- 1% Other gases (Argon, CO₂, Neon, Helium, Methane, Krypton, Hydrogen, etc.)

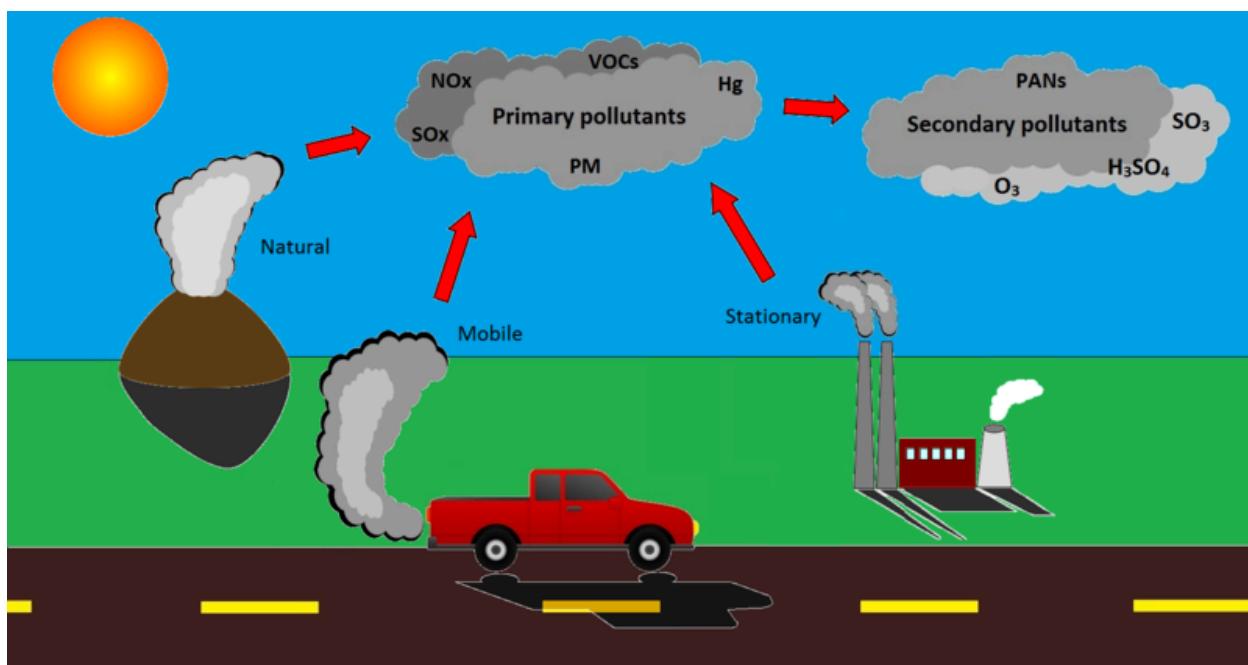


Water vapour content varies from place to place (e.g., deserts have very little, tropical rainforests up to 4%).

The envelope of gases and water vapour surrounding the planet Earth is called the atmosphere.

What are Pollutants?

Pollutants are harmful substances in air, water, or soil that negatively affect the environment, health, and quality of life.



They result from human activities such as industry, agriculture, and waste disposal.

Examples: industrial waste, pesticides, dust, smoke, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone, lead-based paints.

11.2. Air Pollutants

Pollutants are things like industrial wastes, herbicides, pesticides, insecticides, particles of dust and smoke, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone and lead containing paints. These things have a negative impact on the environment. Such substances affect the environment as a result of human activity.

Anything that is in the air, water or soil which has a harmful effect on some part of the environment is called a pollutant.



11.2.1. Sulphur Oxides (SO_x)

Source: Burning of fossil fuels (power plants, vehicles, industries, generators, residential heating).

Effects:

- o Irritates respiratory system.
- o Aggravates asthma, bronchitis, emphysema, and lung diseases.
- o Causes acid rain and haze.
- o Fades colours of materials (e.g., silk clothes).

11.2.2. Nitrogen Oxides (NO_x)

Main oxides: Nitric oxide (NO) and nitrogen dioxide (NO₂).

Source: Burning fossil fuels in vehicles, power plants, industries.

Effects:

- o Highly toxic.
- o Causes acid rain, photochemical smog.
- o Leads to headaches and respiratory problems.

11.2.3. Carbon Dioxide (CO₂)

Source: Naturally present, but increased by human activities (burning fossil fuels, deforestation, industrial processes).

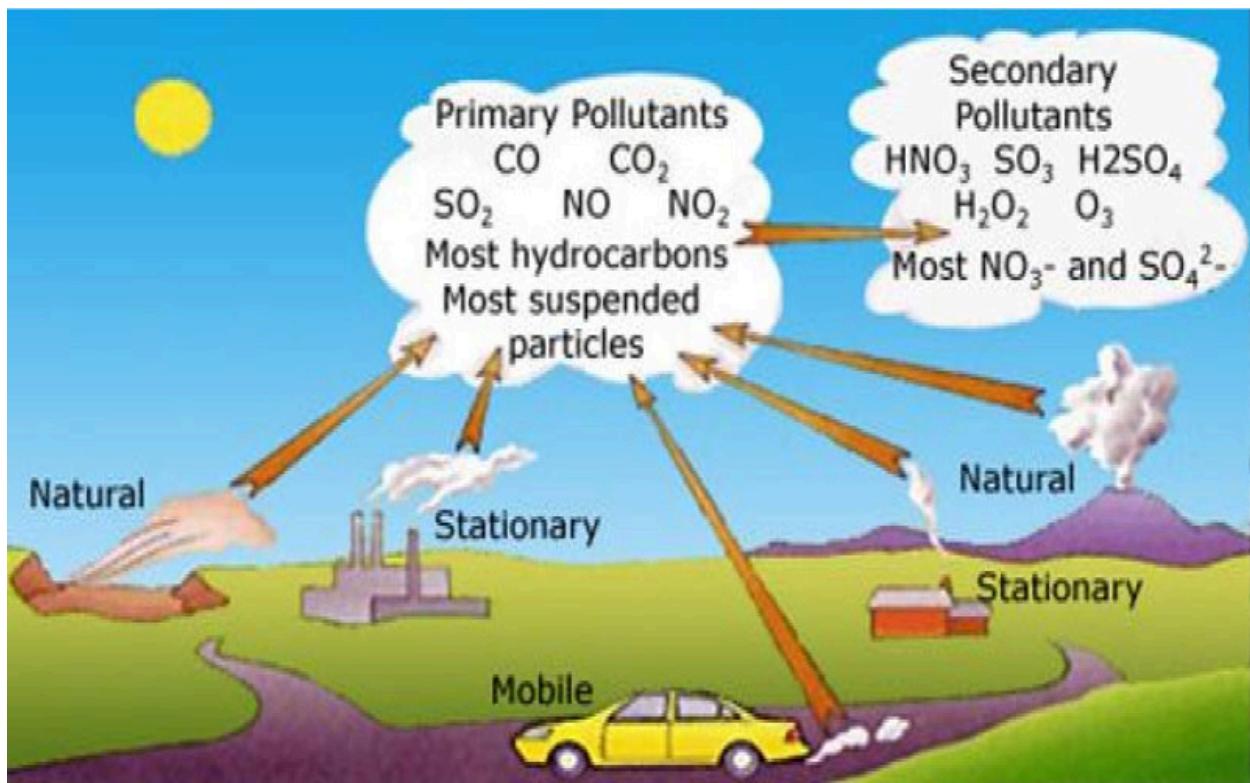
Effect: Major contributor to climate change and global warming.

11.2.4. Carbon Monoxide (CO)

Source: Incomplete combustion of fuels (vehicles, industrial processes, residential heating).

Effects:

- o Toxic, colourless, odourless gas.
- o Binds with hemoglobin to form carboxyhemoglobin, reducing oxygen transport. o Can cause unconsciousness, suffocation, and death.



Particulate Matter

Source: Incomplete combustion, soot, smoke, dust, industrial emissions.

Effects:

- o Fine particles can penetrate deep into lungs.
- o Causes respiratory problems, lung cancer, and other health issues.

11.2.5. Methane (CH₄)

Sources:

- o Decomposition of vegetation and waste.

- o Wetlands, rice fields, landfills.
- o Digestive processes of livestock (cows, goats, sheep) through belching and flatulence.

Effect: Contributes to global warming and climate change.

11.2.6. Ground-Level Ozone (Smog)

Formation: Secondary pollutant from reactions between nitrogen oxides and volatile organic compounds (VOCs) in sunlight (photochemical reactions).

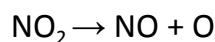
Sources: Industrial and urban areas with car and industrial emissions.

Effects:

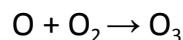
- o Irritates respiratory system.
- o Causes asthma and other respiratory issues.
- o Damages vegetation, reduces crop yield, harms forests.

Key Chemical Reactions (Photochemical Smog Formation)

1. Sunlight breaks NO₂:



2. Atomic oxygen reacts with O₂ to form ozone:



Summary Table:

Pollutant	Major Sources	Health & Environment Effects
SO _x	Fossil fuel combustion	Respiratory issues, acid rain, haze
NO _x	Vehicles, power plants, industries	Toxic, acid rain, smog, respiratory problems

CO₂	Burning fuels, deforestation	Global warming, climate change
CO	Incomplete combustion	Reduces oxygen in blood, fatal
Particulates	Smoke, dust, soot	Lung cancer, respiratory diseases
Methane (CH₄)	Livestock, waste, wetlands	Contributes to global warming
Ground-level O₃	NO _x + VOCs + sunlight	Respiratory irritation, crop damage, smog

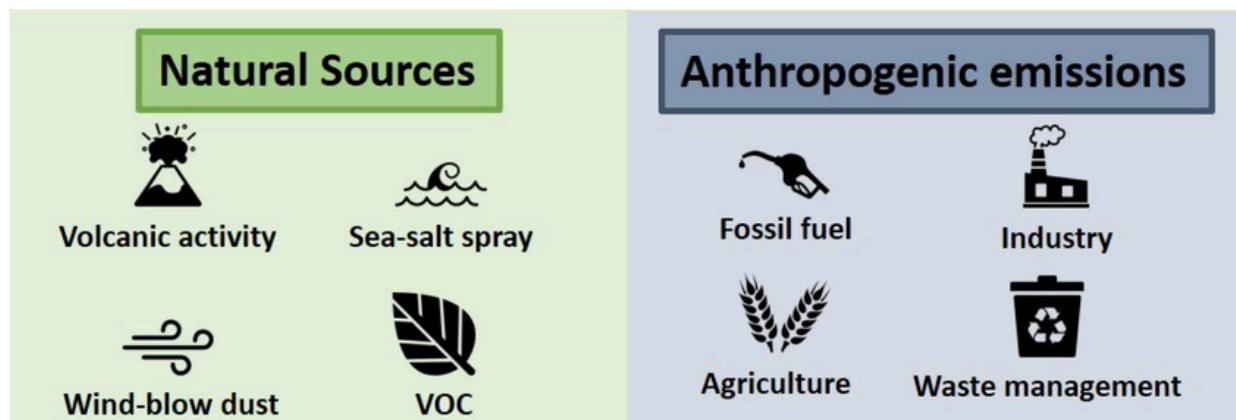
11.3. Sources of Air Pollution

Air is considered polluted when it contains harmful particles and gases.

Pollution can arise from:

11.3.1. Natural Sources

1. Forest fires – release smoke and dust particles.
2. Dust storms – release large amounts of dust into the air.
3. Volcanoes – emit ash, dust, and poisonous gases (e.g., sulfur dioxide).
4. Termites and livestock (cows, etc.) – release methane during digestion.
5. Electrical discharges (lightning) – produce nitrogen oxides in the atmosphere.



11.3.2. Human Activities

Primary source: Burning of fossil fuels (coal, petroleum, natural gas).

Major contributors:

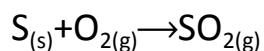
- Vehicles – nearly half of all air pollution comes from cars and motor vehicles.
- Factories and power plants – burn coal or oil, releasing poisonous gases.
- Incineration – releases CO, NO_x, SO_x.

Key Chemical Equations for Pollutant Formation:

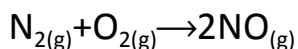
Carbon monoxide (from incomplete combustion):



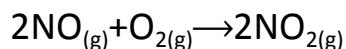
Sulphur dioxide:



Nitric oxide:



Nitrogen dioxide:



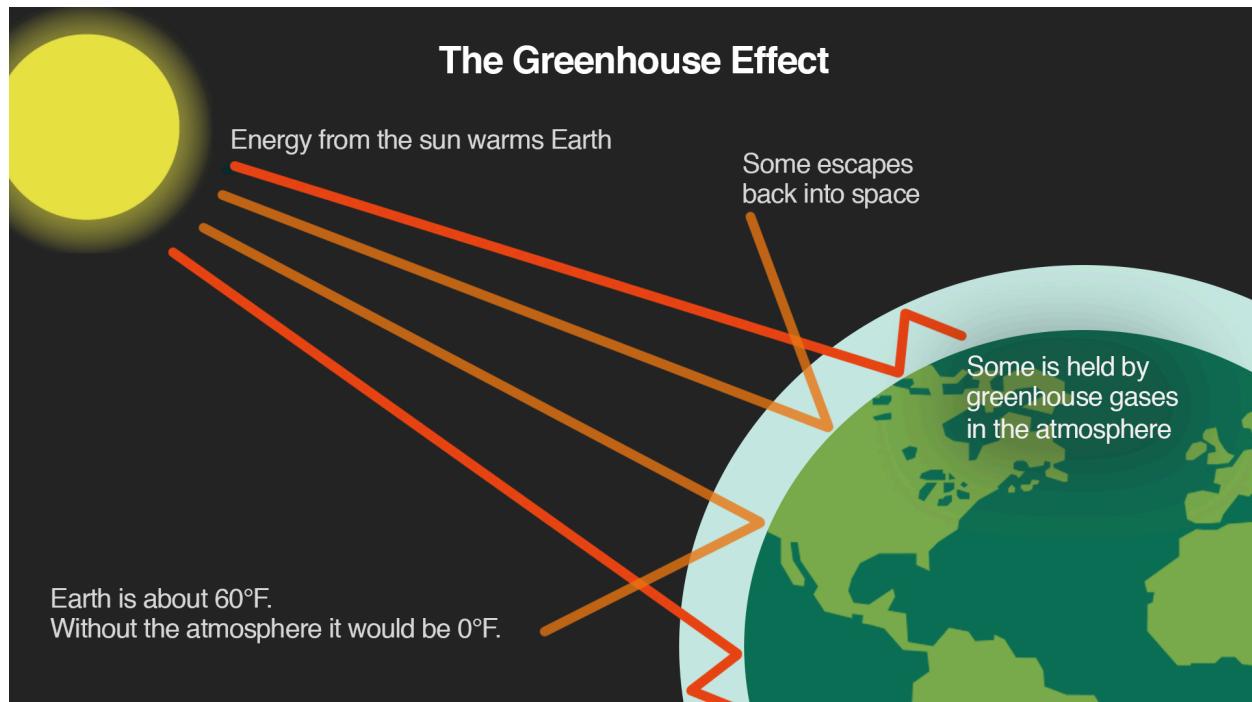
Air Pollutants – Properties, Sources, and Effects

Pollutant	Physical Properties	Sources	Harmful Effects
Carbon monoxide	Colourless, odourless, poisonous	Incomplete burning of wood/fuels, vehicle exhaust	Headache, brain damage, death

Sulphur dioxide	Colourless, unpleasant/irritating odour	Power stations, industries using fossil fuels	Breathing difficulties, bronchitis, emphysema, lung cancer, acid rain, greenhouse effect
Oxides of nitrogen	NO: colourless, odourless, soluble in water; NO ₂ : reddish-brown, pungent, soluble	Motor vehicles, power stations, industries using fossil fuels	Cough, headaches, lung diseases, acid rain, greenhouse effect (global warming)

11.4. Global Warming

- Examples: Water vapour, methane (CH₄), carbon dioxide (CO₂).
- Source of increase: Burning fossil fuels, deforestation, industrial processes.



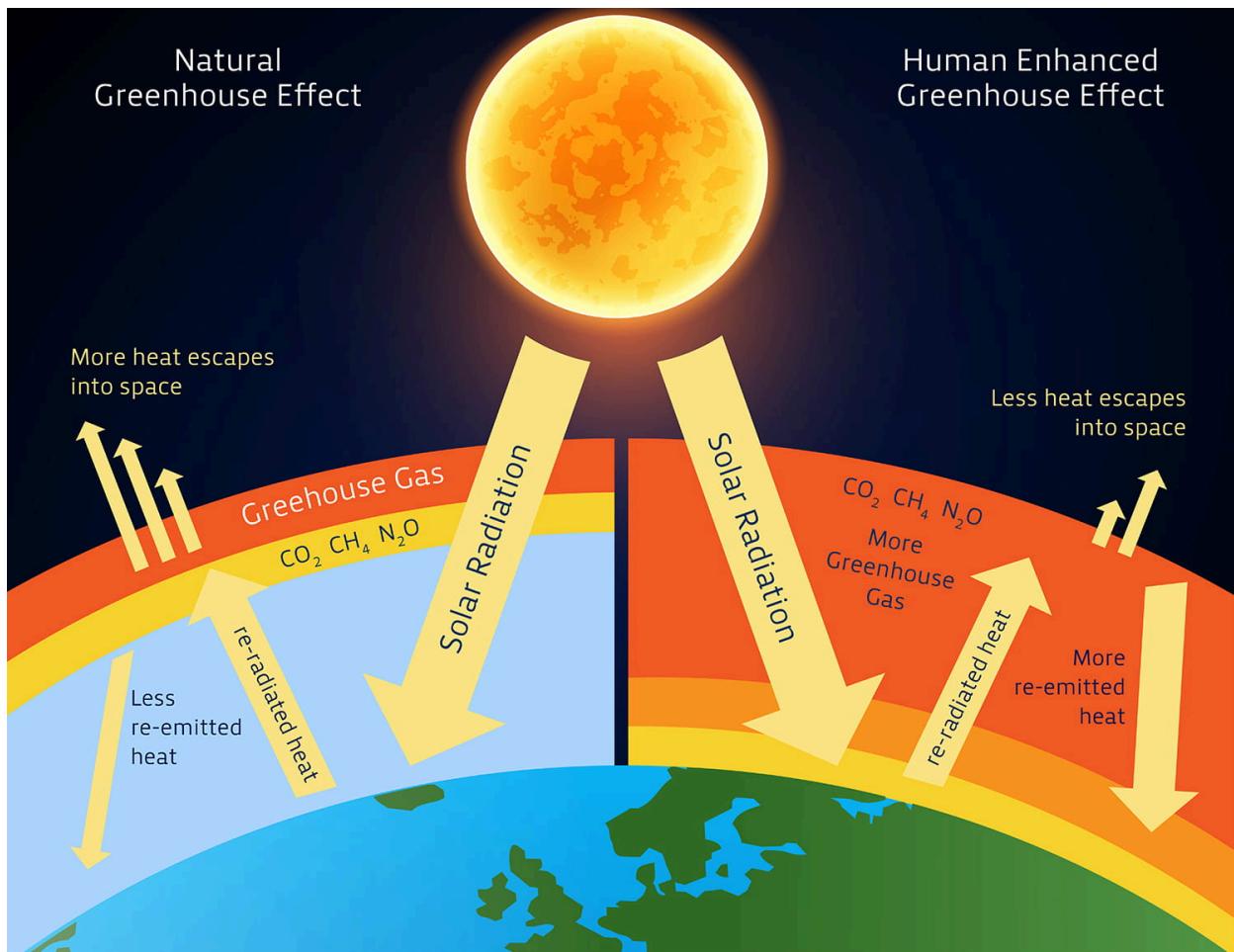
How the Greenhouse Effect Works

1. Sunlight reaches Earth → absorbed by surface (land, oceans, vegetation).
2. Earth warms up → emits energy as infrared radiation.
3. Greenhouse gases absorb this infrared radiation.
4. Gases re-radiate some energy back to Earth's surface (like a blanket).
5. Result: Trapping of heat in the lower atmosphere → warming effect.

Analogy: A greenhouse (made of glass/transparent polymer) allows sunlight in but traps heat inside, raising temperature by 10°C–15°C compared to outside.

Natural vs. Enhanced Greenhouse Effect

- Natural greenhouse effect: Essential for life; without it, Earth would be too cold.
- Enhanced greenhouse effect: Caused by human activities increasing greenhouse gas concentrations → leads to global warming.



Consequences of Global Warming

If global warming continues:

1. Increase in Earth's temperature.
2. Climate change – altered rainfall patterns:
 - o Increased flooding in some regions.
 - o Drought in others.
3. Melting of polar ice → rise in sea levels.
4. Hotter atmosphere.

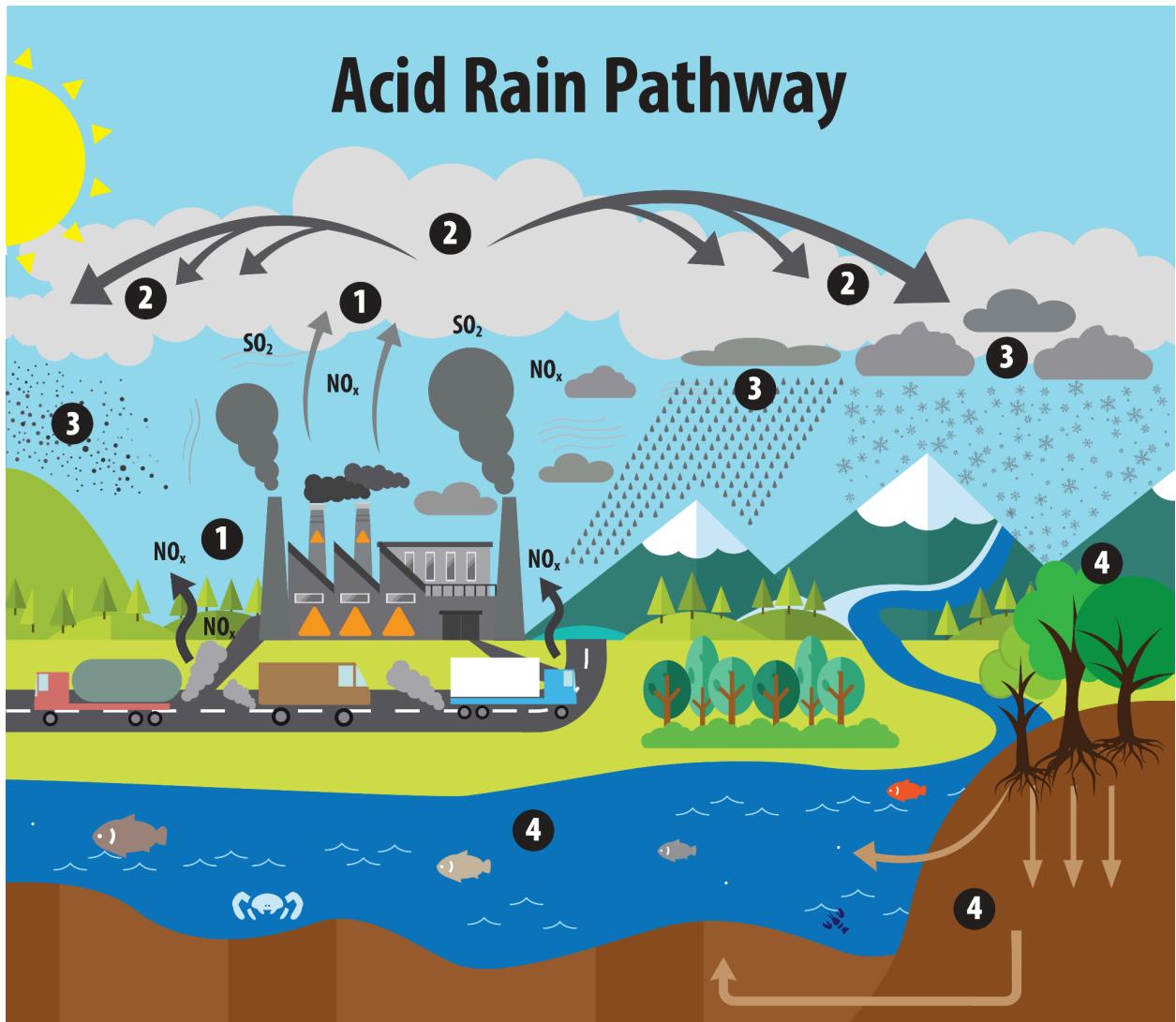
Sources & Impacts of Air Pollution & Global Warming

Topic	Key Points
Natural Sources	Volcanoes, forest fires, dust storms, livestock, lightning
Human Sources	Vehicles, industries, power plants, incineration, deforestation
Major Pollutants	CO, SO ₂ , NO _x , particulates, methane, ozone
Greenhouse Gases	CO ₂ , CH ₄ , water vapour
Greenhouse Effect	Natural process; enhanced by human activities → global warming
Global Warming Effects	Rising temps, climate change, sea-level rise, extreme weather

11.5. Acid Rain and Its Effects

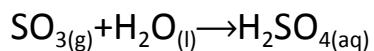
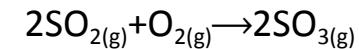
What is Acid Rain?

- Normal rainwater has a pH of 5.6 due to dissolved carbon dioxide.
- Acid rain is defined as rain with a pH less than 5.6.
- It is caused by atmospheric pollutants such as sulphur dioxide (SO₂) and nitrogen oxides (NO_x) dissolving in rainwater, forming acids.

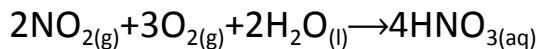


Formation of Acid Rain

1. From Sulphur Dioxide:



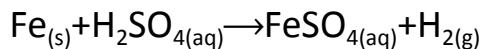
2. From Nitrogen Dioxide:



- NO_2 also catalyzes the oxidation of SO_2 to SO_3 .
- Acid rain can have a pH as low as 2.1 (more acidic than vinegar or lemon juice).

Effects of Acid Rain

1. Corrosion of Metals:



2. Damage to Stone Structures (Marble/Calcium Carbonate):



3. Environmental Damage:

- o Kills aquatic life (fish).
- o Destroys forests and vegetation.
- o Makes lakes/rivers too acidic for survival.

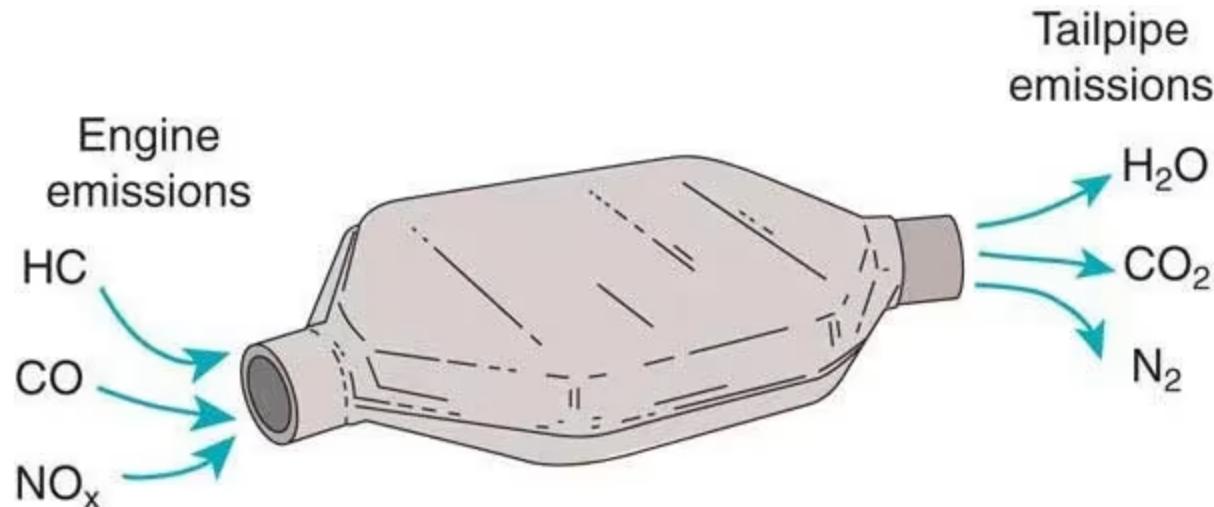
4. Long-range transport: Acid rain can fall hundreds of kilometers from its source.



11.6. Catalytic Converters

Function

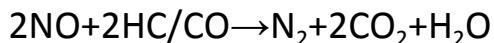
- Installed in vehicle exhaust systems.
- Use catalysts (platinum, palladium, rhodium) to convert harmful gases into less harmful substances.



Chemical Conversions

1. $\text{CO} \rightarrow \text{CO}_2$
2. $\text{NO} \rightarrow \text{N}_2 + \text{O}_2$
3. Unburned hydrocarbons $\rightarrow \text{CO}_2 + \text{H}_2\text{O}$

Example Reaction:



Importance

- Reduces emissions of CO, NO_x, and hydrocarbons.
- Recommendation: Governments (like Pakistan) should enforce installation in all vehicles.

11.7. Strategies to Reduce Environmental Problems

PROTECTING OUR PLANET STARTS WITH YOU

BIKE MORE DRIVE LESS **EDUCATE** **Volunteer!**

CONSERVE WATER **reduce REUSE recycle** **choose sustainable seafood** **PLANT A TREE**

Long-lasting light bulbs - ARE A - BRIGHT IDEA **Don't send chemicals into our waterways.** **SHOP WISELY** **Long-lasting light bulbs - ARE A - BRIGHT IDEA** **Energy efficient light bulbs reduce greenhouse gas emissions. Also flip the light switch off when you leave the room!**

Trees provide food and oxygen. They help save energy, clean the air, and help combat climate change.

When you further your own education, you can help others understand the importance and value of our natural resources.

The less water you use, the less runoff and wastewater that eventually end up in the ocean.

Buy less plastic and bring a reusable shopping bag.

Choose nontoxic chemicals in the home and office.

NOAA
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Climate Change Mitigation

1. **Transition to Renewable Energy:**
 - o Solar, wind, hydro, geothermal.
2. **Energy Efficiency:**
 - o Promote energy-efficient technologies.

3. Reduce Transport Emissions:

- o Electric vehicles, public transport, walking, cycling.

Afforestation & Reforestation

1. Planting Trees:

- o Increases CO₂ absorption via photosynthesis.
- o Reduces soil erosion, increases biodiversity.

2. Forest Regeneration:

- o Restores damaged forests, enhances carbon sequestration.

Sustainable Land Use

1. Sustainable Agriculture:

- o Organic fertilizers, reduced pesticides.
- o Lowers emissions, protects water and soil.

2. Reduce Deforestation:

- o Protects carbon sinks.

Low-Carbon Economy

1. Hydrogen Economy:

- o Hydrogen as clean fuel for transport/industry.

2. Circular Economy:

- o Minimize waste, promote recycling.

International Cooperation

1. Paris Agreement:

- o Limit global warming to below 2°C, aim for 1.5°C.

2. Policy Support:

- o Incentives for renewables, emission regulations.

11.7.2 Strategies To Solve Acid Rain

Acid Rain Mitigation

1. Emission Control:

- o Reduce SO₂ and NO_x from industries/vehicles.

2. Flue Gas Desulfurization:

- o Scrubbers in power plants remove SO₂.

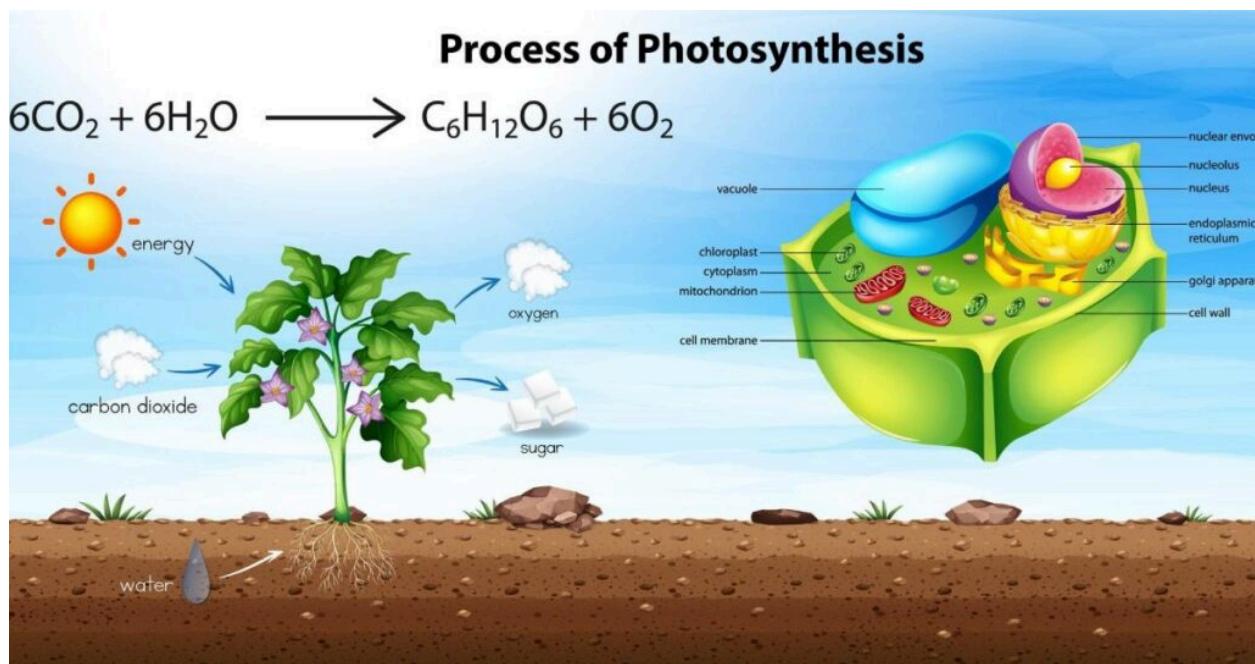
3. Low-Sulphur Fuels

- Promoting low sulphur fuels can also minimize the amount of sulphuric acid in the atmosphere causes acid rain

Catalytic Converters in Vehicles

The promotion of catalytic converters in vehicle exhaust systems can reduce emissions of platinum, harmful gases and volatile organic compounds. Converters contain catalysts such as substances palladium, and rhodium, which transform harmful gases into less harmful substances.

11.8. Photosynthesis



Equation:



- Plants convert $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{glucose} + \text{O}_2$ using solar energy.
- Role in Carbon Cycle: Removes CO_2 from atmosphere, produces oxygen and organic matter.

11.9. Personal Protective Measures Against Pollution

Masks & Respiratory Protection:

- o N95 masks: Filter particles (dust, smoke).
- o Gas masks: Activated carbon filters absorb gases/VOCs.
- o Use certified masks as per instructions.



Air Quality Indices (AQI):

- o Numerical/color-coded systems indicate pollution levels.
- o Helps in taking precautions.

Carbon Monoxide Detectors:

- o Installed in homes/offices.
- o Alerts to dangerous CO levels.
- o Enables ventilation/evacuation.

11.10 Risk Factors

Long-term Exposure to Pollutants:

NO_x, SO₂, PM, ozone → asthma, lung cancer, COPD.

Smoking:

Damages lungs, increases COPD/cancer risk.

Harmful to smokers and non-smokers (second-hand smoke).

Indoor Pollution:

Poor ventilation, mold, dust mites, pets, chemicals → allergies, asthma.

Allergens:

Pollen, mold spores, pet dander → respiratory allergies, asthma.

Climate Change:

Worsens air quality, increases wildfires, alters pollen seasons.

Aggravates respiratory symptoms.

Topic	Key Points
Acid Rain	pH < 5.6, from SO ₂ /NO _x , damages structures, ecosystems, aquatic life.
Catalytic Converters	Use Pt/Pd/Rh to convert CO→CO ₂ , NO→N ₂ , HC→CO ₂ +H ₂ O.
Climate Strategies	Renewables, afforestation, sustainable agriculture, circular economy.
Acid Rain Solutions	Emission control, scrubbers, low-sulphur fuels, catalytic converters.
Photosynthesis	Removes CO ₂ , produces O ₂ , key to carbon cycle.
Personal Protection	N95/gas masks, AQI monitoring, CO detectors.
Risk Factors	Pollution, smoking, indoor allergens, climate change → respiratory diseases.



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