Lecture 3: Atmospheric Chemistry and Toxicological Transformations

Air Quality and Pollution

Introduction

After studying the layers of the atmosphere, it is important to understand the chemical transformations that occur within the lower atmosphere (especially the troposphere) and how they affect air quality and human health. The following topics explain major atmospheric chemical pollutants and their biological impacts.

1. Photochemical Smog (Ground-Level Ozone)

- Ground-level ozone (O3) is a secondary pollutant formed in the troposphere.
- It is produced when nitrogen oxides (NOx) from vehicles react with sunlight.
- Main reactions:
- NO2 + hv → NO + O
- O + O2 + M → O3 + M
- Health effects: causes oxidative stress, airway inflammation, reduced lung function (FEV1), and can trigger asthma attacks.

2. Acidic Aerosols (Secondary Inorganic Particulate Matter)

- Formed from the atmospheric conversion of sulfur dioxide (SO2) and nitrogen oxides (NOx).
- Key reaction:
- SO2 + OH → HSO3 → H2SO4 (Sulfuric acid mist)
- These particles are usually part of PM2.5.
- Health effects: penetrate deep into the lungs, reach alveoli, may cause tissue scarring (fibrosis) and increase acidity of lung fluids.

3. Polycyclic Aromatic Hydrocarbons (PAHs)

- PAHs are organic compounds made of multiple fused benzene rings.
- They are released from incomplete combustion such as engines and open burning.
- Atmospheric reaction: PAHs react with NO2 under UV light to form Nitro-PAHs.
- Health effects: many PAHs are mutagenic and carcinogenic.

4. Dioxins and Furans (From Open Burning)

- Highly toxic persistent organic pollutants (POPs).
- Produced during low-temperature burning of waste containing chlorine (e.g., PVC plastics).
- Form on fly ash surfaces at temperatures between 250–400°C.
- Health effects: endocrine disruption, reproductive problems, increased susceptibility to infections.

5. Carrier Effect: Gas–Particle Partitioning

- Some gaseous toxins attach to the surface of particulate matter (PM2.5).
- This allows toxic chemicals to travel deeper into the respiratory system.
- Particles act as a 'toxic taxi' transporting harmful chemicals into the lungs.

Conclusion

Atmospheric chemical reactions transform primary pollutants into more harmful secondary pollutants. Understanding these processes helps explain how pollution forms in the lower atmosphere and why it poses serious risks to human health and the environment.