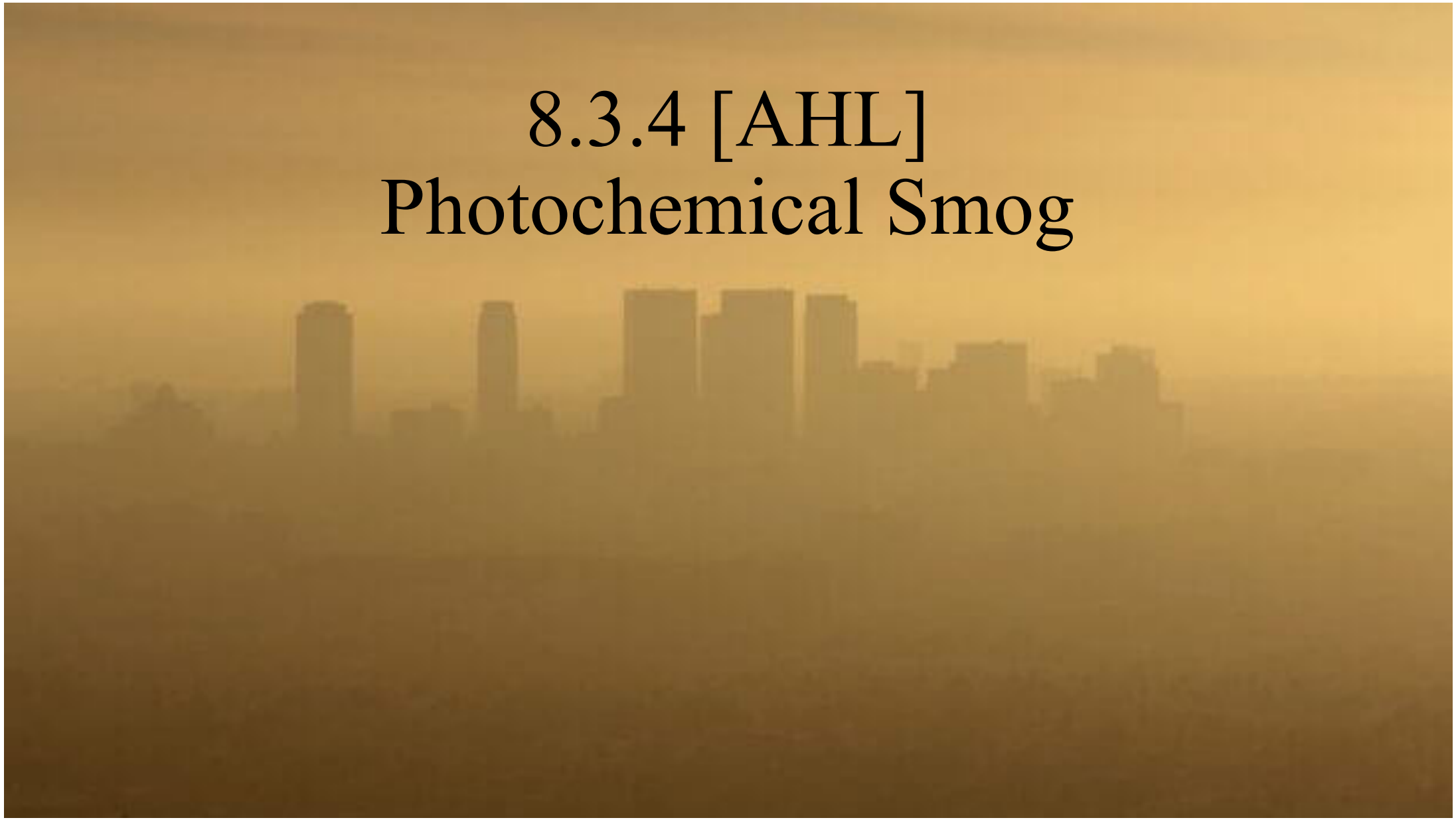
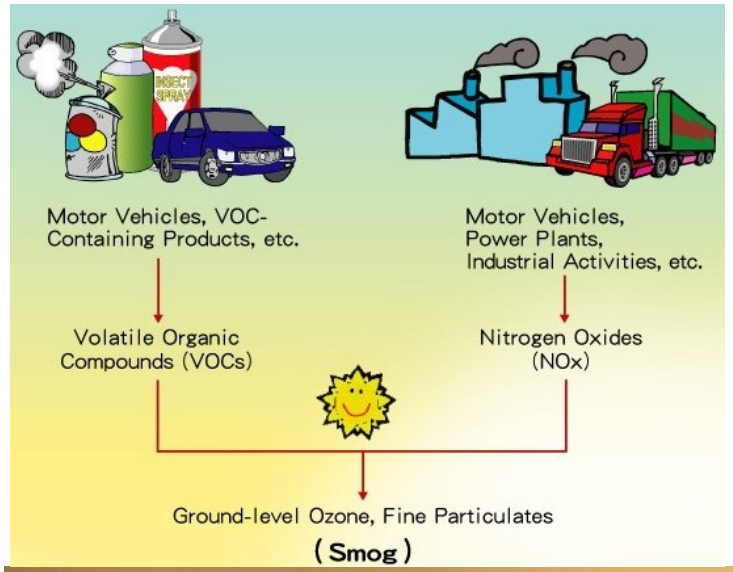


8.3.4 [AHL]
Photochemical Smog

What is photochemical smog?

- A **<u>brown haze</u>** common in some cities.
  - Mainly nitrogen dioxide and ozone but
  - is a complex mixture of about 100 different primary and secondary air pollutants
- Forms when ozone, nitrogen oxides and volatile organic compounds (VOCs) from the combustion of fossil fuels react in **<u>sunlight</u>** to produce a toxic mixture of:
  - Ozone
  - nitric acid
  - aldehydes and
  - peroxyacyl nitrates (PANs).
- The biggest contribution to photochemical smog is from motor vehicle exhausts in cities.



Key components of photochemical smog

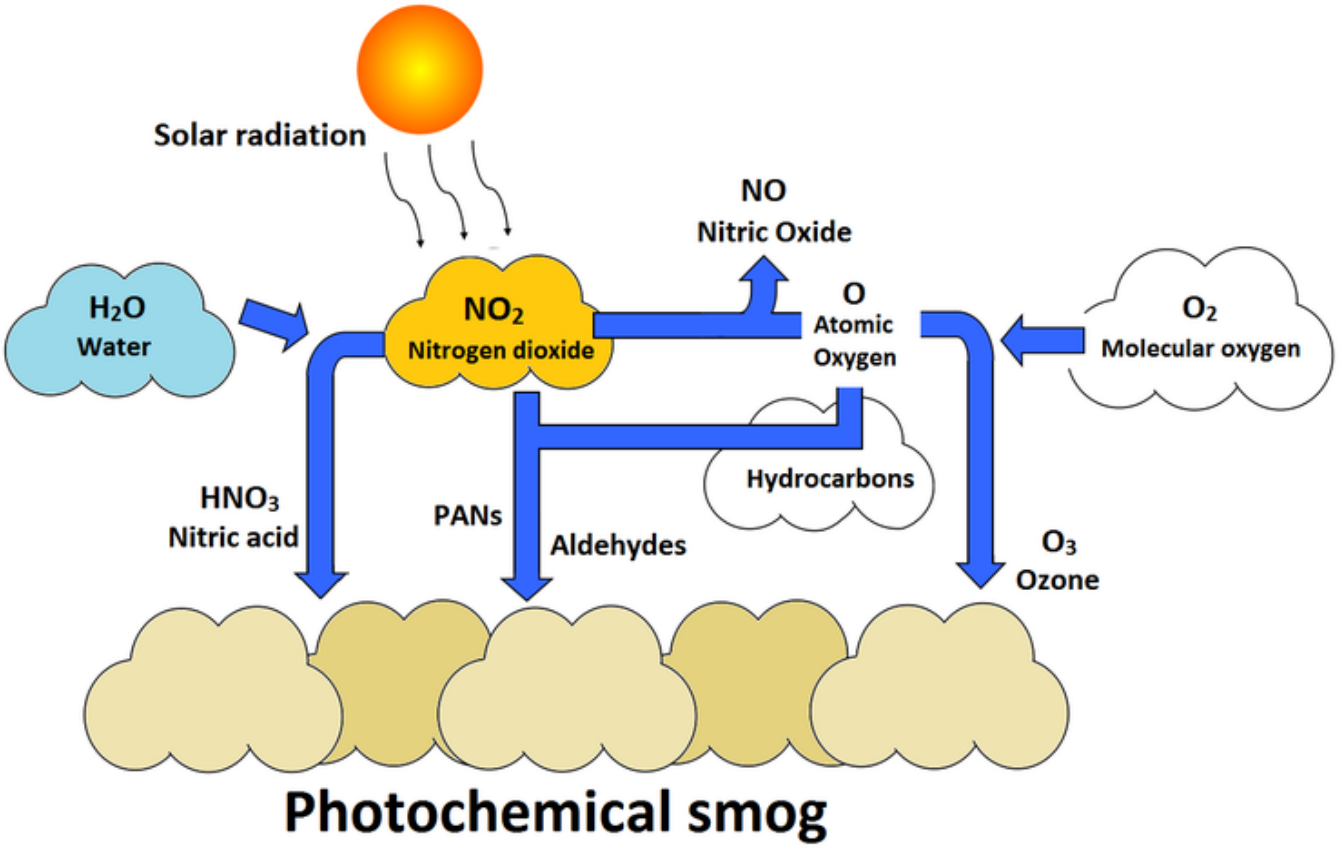
PRIMARY POLLUTANTS

- **Nitrogen oxides (NO_x)**
  (from vehicle exhaust and combustion)
- **Volatile organic compounds (VOCs)**
  (from vehicle emissions, solvents, fuel evaporation, vegetation)
- **Carbon monoxide (CO)**
  (from incomplete combustion)
- **Hydrocarbons**
  (unburned fuel vapour)

SECONDARY POLLUTANTS

- **Ozone (O_3)**
  (most abundant and harmful component)
- **Peroxyacyl nitrates (PANs)**
  (strong eye irritants and plant **toxins**)
- **Aldehydes**
  (e.g., formaldehyde, acetaldehyde)
- **Nitric acid (HNO_3)**
  (formed from NO_2 oxidation)

Formation of Photochemical Smog



Task
Outline how photochemical smog is formed

Formation of Photochemical Smog

- Develops on **warm, sunny days** with **high traffic levels**.
  - Usually linked to fossil fuel combustion, but forest and biomass burning also contribute.
  - Large-scale forest fires in Kalimantan, Indonesia (notably in 1997 and 2019) produced smog across Southeast Asia, especially during El Niño years.
- Formation involves complex reactions generating VOCs, PANs, ozone, aldehydes, carbon monoxide, and nitrogen oxides.
- Highly reactive VOCs oxidize nitric oxide to nitrogen dioxide without degrading ozone, leading to ozone accumulation near ground level.
- Primary pollutants (NO_x and hydrocarbons) peak in morning and evening rush hours, but smog peaks in early afternoon when sunlight-driven reactions intensify.

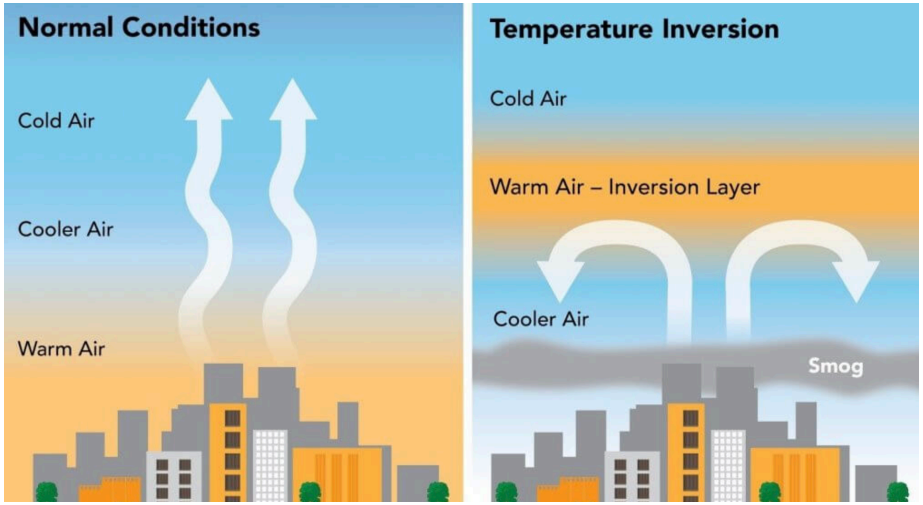
Factors of Formation of Photochemical Smog

- Topography
- Climate
- Population Density
- Fossil fuel use

Factors of Formation of Photochemical Smog

Topography

- Most severe in large, low-lying cities or valleys where hills/mountains restrict air movement.
- Thermal inversions trap pollutants by preventing warm, polluted air from rising.
- Under persistent inversion conditions, pollutant levels can become hazardous or lethal.

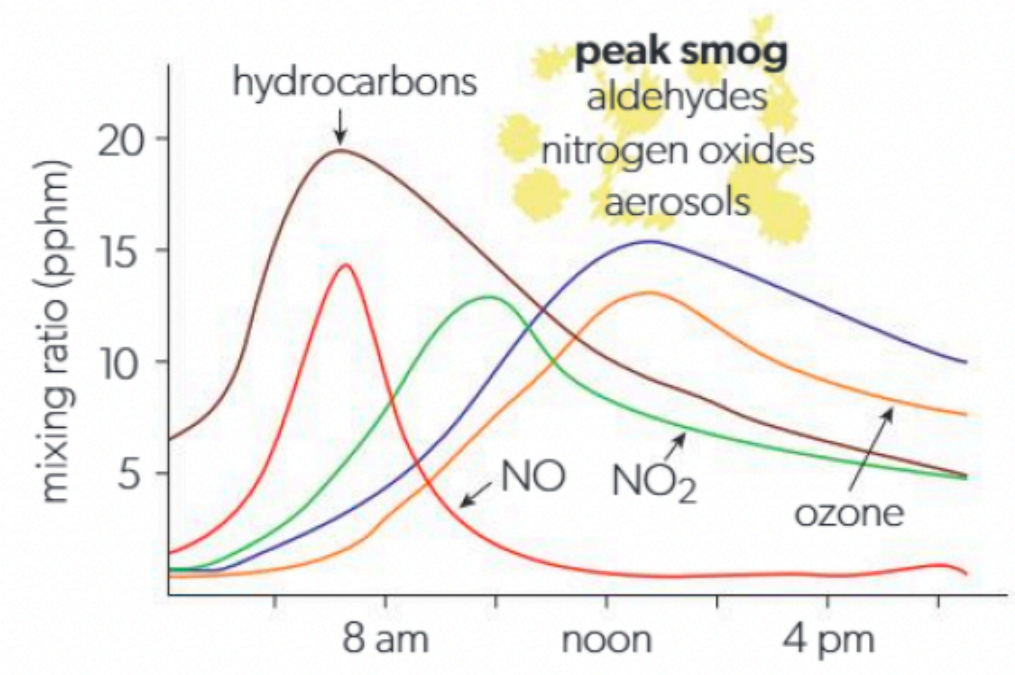


Factors of Formation of Photochemical Smog

Climate

- Most common in warm, dry climates.
- Rain removes pollutants
- Wind disperses smog.
- Smog can disperse from the city and cause environmental damage up to 150 km away.

Smog Daily Peaks



– concentration of ozone varies throughout a 24 hr period

– maximum smog production occurs soon after midday

Tropospheric Ozone

What is tropospheric ozone?

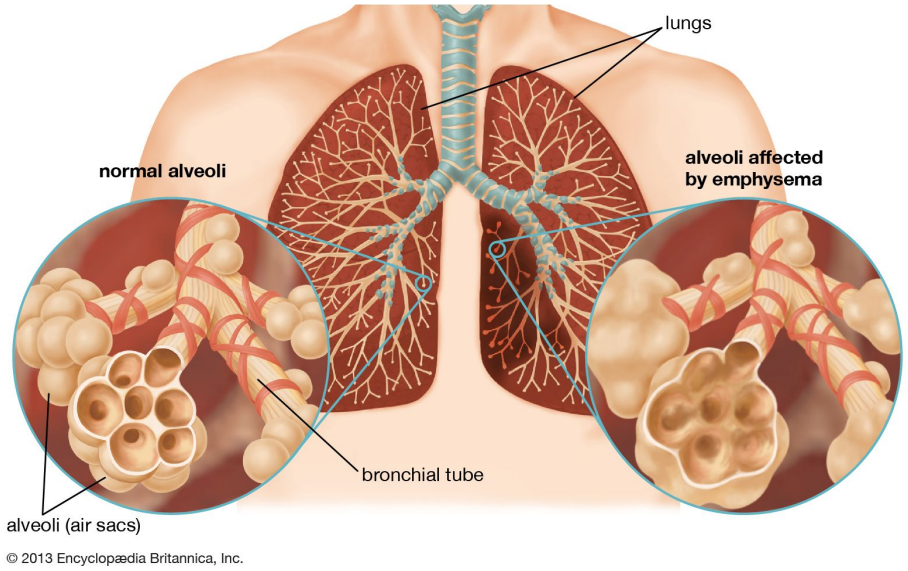
- Unlike protective stratospheric ozone, tropospheric ozone (about 10% of atmospheric ozone) is harmful.
- Concentrations above 0.7 ppm for more than 8 hours are considered unhealthy (EPA).
- Functions as a potent greenhouse gas with a global warming potential ~2,000 times that of CO_2.

Formation of Tropospheric Ozone

Formation of Tropospheric Ozone

- Emitted pollutants from fossil fuel combustion include hydrocarbons (from incomplete combustion) and nitrogen oxides.
- Nitric oxide reacts with oxygen to form nitrogen dioxide, contributing to urban haze.
- Hydrocarbons and carbon monoxide accelerate NO to NO_2 conversion.
- Sunlight photodissociates NO_2 into nitric oxide and oxygen atoms.
- Oxygen atoms react with O_2 to form ozone (O_3).
- Under clean-air conditions, ozone oxidizes nitric oxide back to NO_2, preventing major ozone buildup.

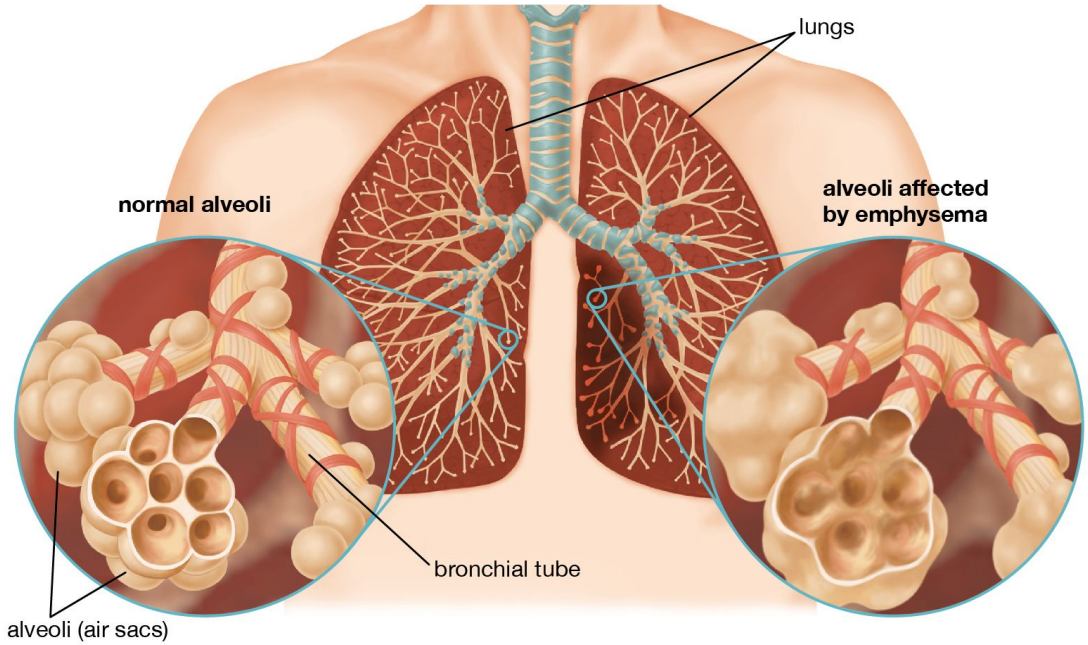
Impacts of tropospheric ozone



Impacts of tropospheric ozone

Biological impacts

- Respiratory irritation: coughing, wheezing, sore throat.
- Exacerbates asthma and pulmonary diseases; may increase risk of lung cancer.
- Reduces lung function by constricting respiratory muscles.
- Increases susceptibility to infections such as bronchitis and emphysema.
- Causes eye irritation and weakens the immune system.



Impacts of tropospheric ozone

Impacts on plants

- Inhibits plant growth by degrading chlorophyll and reducing photosynthesis.
- Damages plant cuticles and membranes; tobacco, tomato, and spinach are highly sensitive.
- Causes leaf necrosis, reducing productivity in crops and trees.

Impacts of tropospheric ozone

Impacts on materials

- Damages rubber, cellulose, paint, plastics, fabrics, and metals.
- Reduces elasticity of rubber and fabrics.
- Shortens the lifespan of car tires and other materials.
- Causes fading or bleaching of fabrics.
- Leads to increased maintenance and replacement costs.

Adaptation Stategies

Reducing impacts of tropospheric ozone

- Modify human activities that generate ozone precursors.
- Regulate emissions at their source.
- Implement environmental clean-up and restoration measures.

Reducing personal exposure

- Monitor local air quality indices.
- Stay indoors when ozone levels are high.
- Avoid strenuous outdoor activities during poor air quality periods.
- Use indoor air filtration or a respirator when necessary.
- Avoid burning wood, candles, and incense (increase particulate matter).
- Do not smoke.