CE 213A
Introduction to Environmental Science

L8: Unit 2: A. Air Pollution

Major Air pollutants & Control Techniques

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Schedule : LEC Mon Wed Fri 5:10 – 6 pm

Process of release from sources

MAJOR AIR POLLUTANTS

Combustion

Lots of oxygen:

Complete combustion

Methane + Oxygen ⟶ Carbon dioxide + Water

Some oxygen:

Incomplete combustion

Methane + Oxygen ⟶ Carbon monoxide + Water

Little oxygen:

Incomplete combustion

Methane + Oxygen ⟶ Carbon + Water

Carbon or 'soot'

Primary Air Pollutants

i. Carbon Monoxide

- Produced when organic materials are incompletely burned.
- Not a persistent pollutant.
- Binds to hemoglobin in blood and makes the hemoglobin less able to carry oxygen.
- Most dangerous in **enclosed spaces**.
- Single largest source is the **automobile.**
- **Cigarette smoking** an important source.

- Carbon Monoxide is an odourless, colourless, toxic gas.
- It reduces the amount of oxygen carried by the Red Blood Cells.
- Carbon monoxide poisoning can kill.
- Soot can clog pipes carrying waste gases.
- Faulty or blocked boilers can produce carbon monoxide.

ii. Volatile Organic Compounds

- Volatile organic compounds (VOCs) are compounds that easily become vapors or gases. They are mainly Hydrocarbons (Group of organic compounds consisting of carbon and hydrogen.)
- **Examples** of VOCs are gasoline, benzene, formaldehyde
- VOCs are released from burning fuel such as gasoline, wood, coal, or natural gas.
- They are also released from many **consumer products**:
  - Cigarettes; Solvents; Paints and thinners
  - Adhesives; Air fresheners; Building materials and furnishings
  - Copy machines and printers; Pesticides

- **VOCs combine with nitrogen oxides in the air, and form smog.**

Are VOC dangerous? Can their release be controlled?

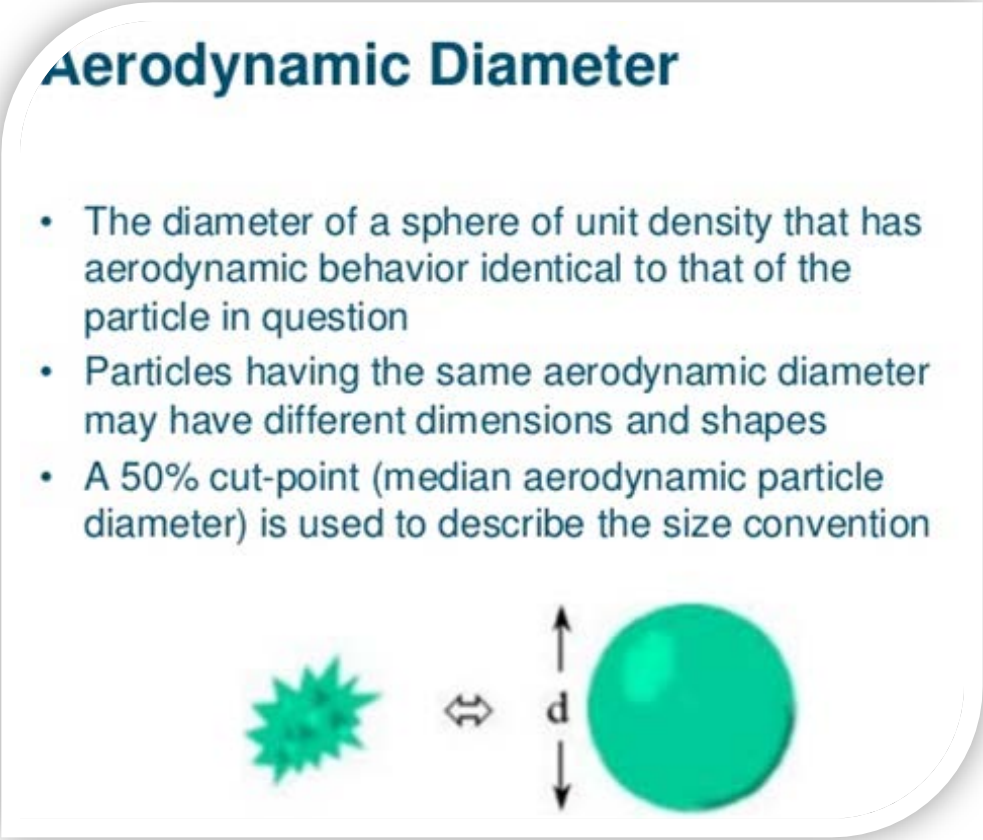
- **Volatile Organic Compounds** (**VOCs**) are extremely hazardous. **VOCs** cause eye, nose and throat irritation, frequent headaches, nausea, and can also damage the liver, kidney and central nervous system (USEPA).

- Control strategy:
  - Example of a release mechanism: Evaporated from automobile fuel or remnants of fuel incompletely burned.
  - Remedy: Catalytic converters used to burn exhaust gases more completely.

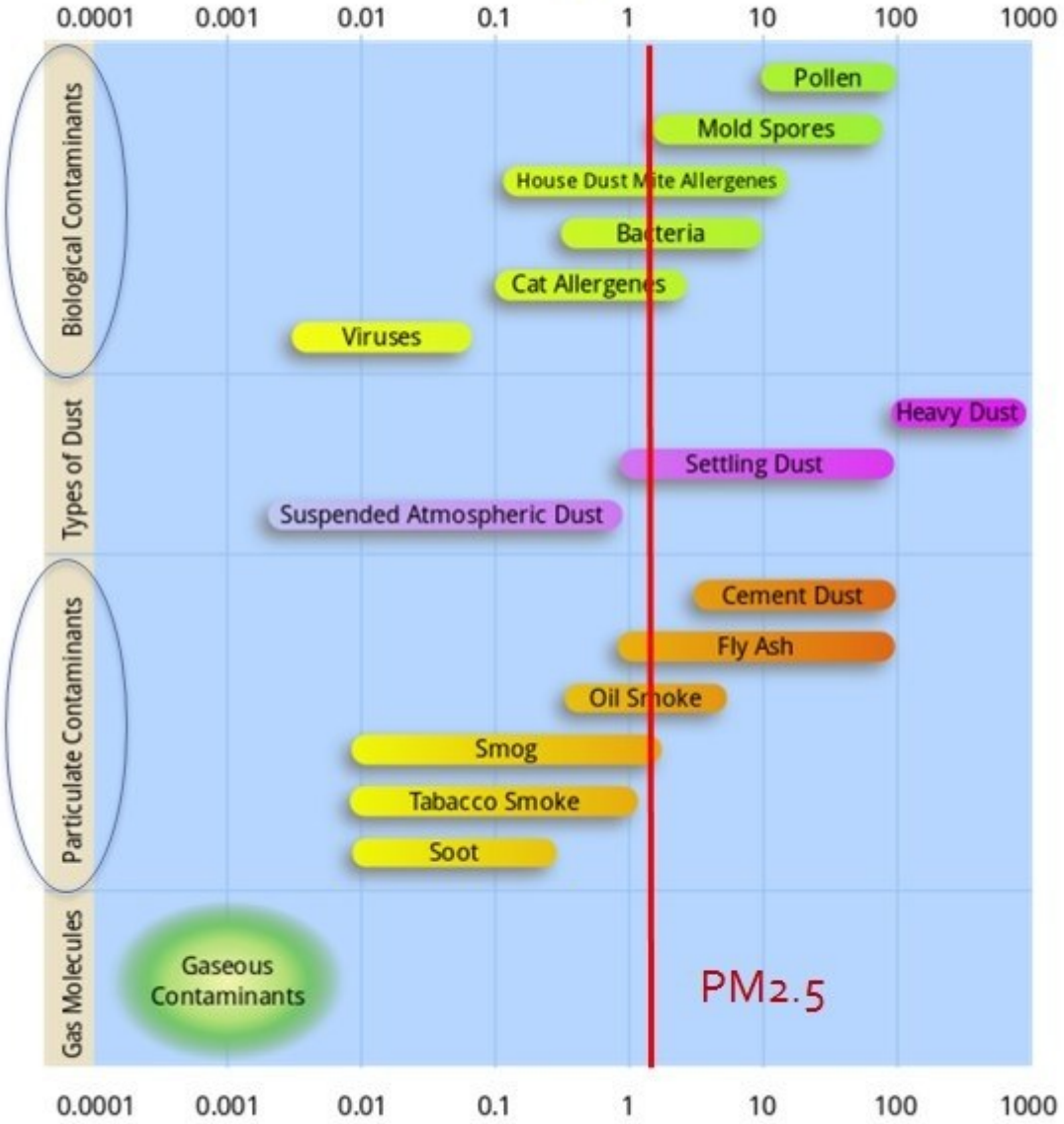
iii. Particulates

Particulate matter is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets.

Particles in air are either: **directly emitted**, for instance when fuel is burnt and when dust is carried by wind, or indirectly formed, when gaseous pollutants previously emitted to air turn into particulate matter.



What is air pollution?



SMARTAIR

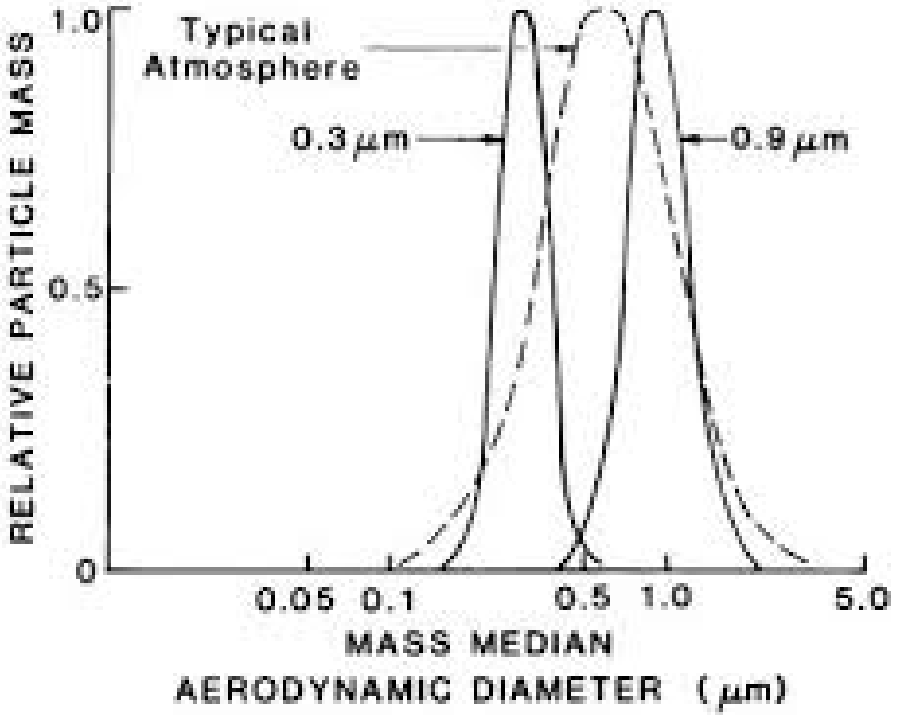
Definitions for Commonly Used Terms

The prediction of deposition : efficiency for a therapeutic aerosol based on

- Mass Median Aerodynamic Diameter (MMAD) :
  - Divides the aerosol size distribution in half diameter at which 50% of the particles of an aerosol by mass are larger and 50% are smaller than the median diameter

- Fine Particle Fraction (FPF)
  - the fraction of particles that can achieve deposition in the lower respiratory tract

Middleton's 8th edition


RELATIVE PARTICLE MASS
1.0
0.5
0
Typical
Atmosphere
0.3 μm
0.9 μm
0.05
0.1
0.5
1.0
5.0
MASS MEDIAN
AERODYNAMIC DIAMETER (μm)

iv. Sulfur Dioxide (SO_2)

- It is a Sulfur and oxygen compound produced when sulfur-containing **fossil fuels** are burned.
- Burning coal is primary **artificial** source
  - Steam Plant recently: 200 tons/day
  - After scrubbers installed (cost $250 million): 27 tons/day
- Volcanoes and hot springs are **natural** sources
  - Mt St Helens releases 50 to 250 tons/day when active
- SO_2 is also a precursor to acid rain (a secondary pollutant)

v. Nitrogen Oxides (NO, NO_2)

- Formed when combustion takes place in the air.
  - Automobile exhaust is primary source.
  - NO_x is also a precursor to acid rain and photochemical smog (both secondary pollutants) and is a greenhouse gas

Secondary Air Pollutants

- Ozone (O3)
- PANs (Peroxyacetyl nitrate)
- Aldehydes

All three formed by interaction between NO_x and VOCs.

Note: - Ozone is a pollutant in the troposphere, but beneficial in the stratosphere.

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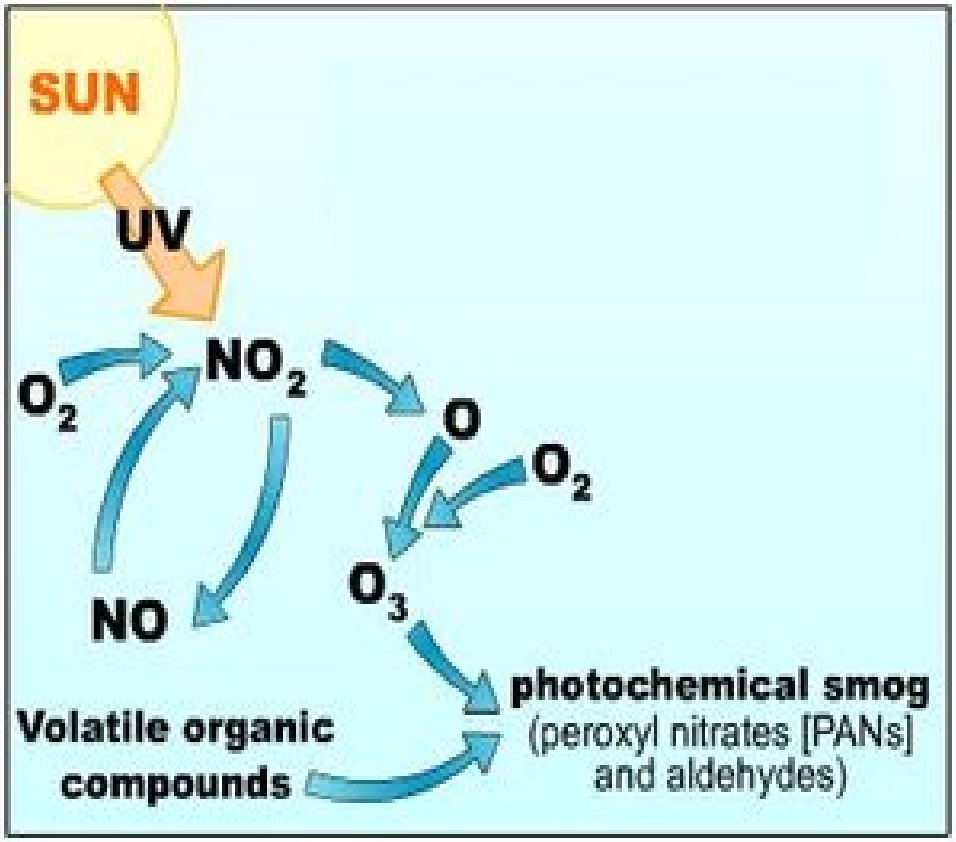
Source	Necessary conditions	Reactions take place in atmosphere	Products
Primarily automobiles	volatile organic compounds (VOC) present	$VOC + O^* \text{ or } O_3 \rightarrow$ highly reactive organic radicals $+ NO_2 \rightarrow$ Peroxyacetyl nitrates; Aldehydes	
Primarily automobiles	Nitrogen monoxide (NO) present	$NO +$ organic radicals $\rightarrow NO_2$	
From automobiles and formed from NO	Nitrogen dioxide (NO_2) present	$NO_2 \rightarrow NO + O^*$ (atomic oxygen); $O^* + O_2 \rightarrow O_3$ (ozone) $\rightarrow$ Ozone; sunlight	Ozone
Sun	Sunlight	sunlight	
Sun (summer temperatures)	Heat	Reactions take place more rapidly at higher temperatures.	

a radical is an atom, molecule, or ion that has an unpaired valence electron.

Photochemical Smog
(Brown-air smog)

- **Photochemical smog** is a condition that develops when primary pollutants (oxides of nitrogen and volatile organic compounds created from fossil fuel combustion) interact under the influence of sunlight (**photochemical reaction**) to produce a mixture of hundreds of different and hazardous chemicals known as secondary pollutants.

- During moderate to severe episodes of photochemical smog, the sky is no longer blue. Instead, **visibility is obscured by an orange-brown haze**. The air has a slightly acrid taste and smell.



FORMATION OF PHOTOCHEMICAL SMOG

Central to this system are transformation processes chemical kinetic reactions and phase changes that produce secondary pollutants whose effects are worse than the primary emissions.

In summary, tropospheric ozone is formed when a mixture of organic gases and nitrogen oxides is exposed to sunlight.

The sunlight causes NO_2 to dissociate, liberating an oxygen radical that combines with an oxygen molecule to produce ozone.

$$NO_2 + h\nu \rightarrow NO + O\bullet \qquad k_{1,max} = 0.5\ min^{-1}$$

$$O\bullet + O_2 \rightarrow O_3 \qquad k_2(298\ K) = 21.8\ ppm^{-1}\ min^{-1}$$

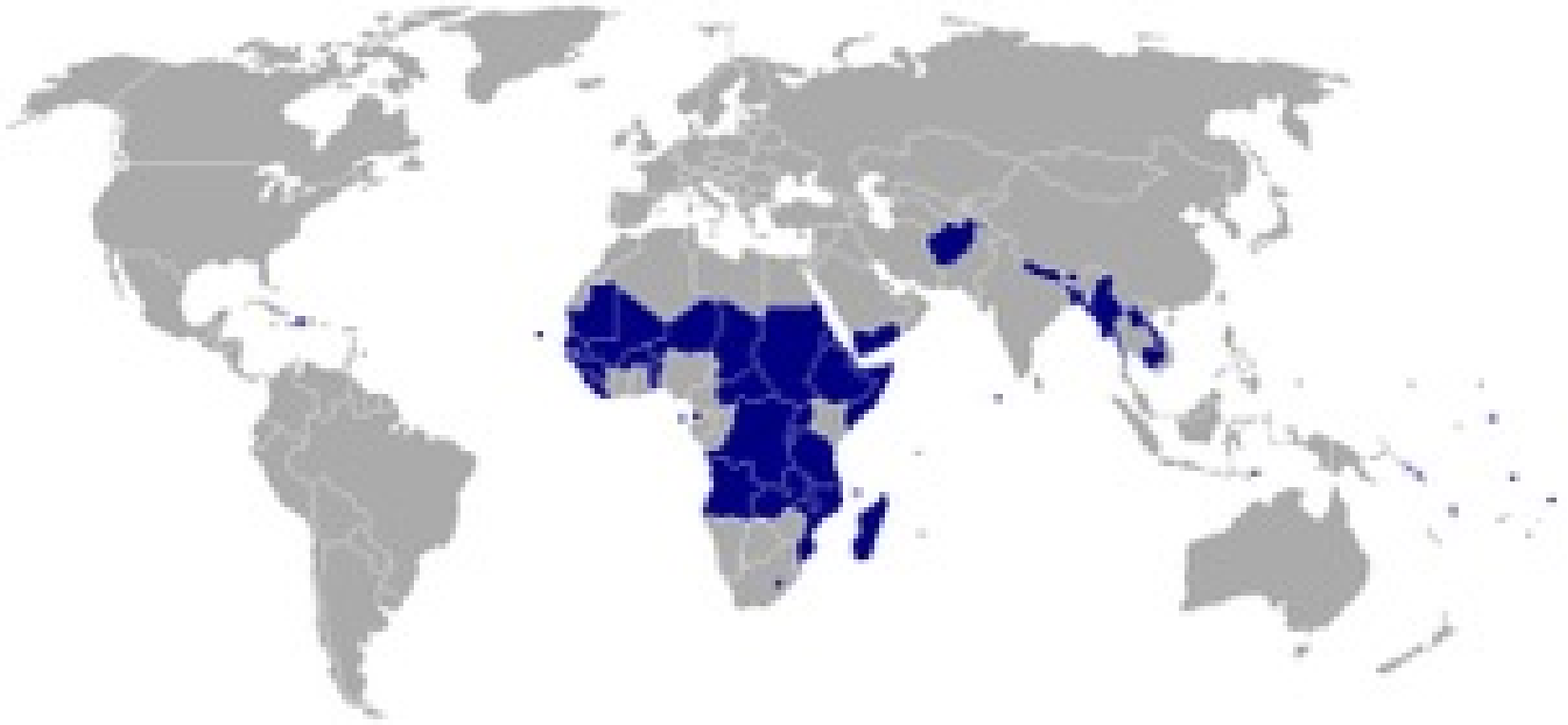
$$NO + O_3 \rightarrow NO_2 + O_2 \qquad k_3(298\ K) = 26.6\ ppm^{-1}\ min^{-1}$$

Industrial Smog
(Gray-air smog)

- From burning coal and oil
  - particulates, sulfur dioxide, sulfuric acid
- London was the smog capitol. In 1952, smog developed for days, no atmospheric mixing, 4,000 people died.
- Now mainly a problem in LDCs (*Least Developed Countries)* with **developing industries and no pollution control laws**.

The *least developed countries* (LDCs) are a group of *countries* that have been classified by the UN as "*least developed*" in terms of **their low gross national income (GNI), their weak human assets and their high degree of economic vulnerability**

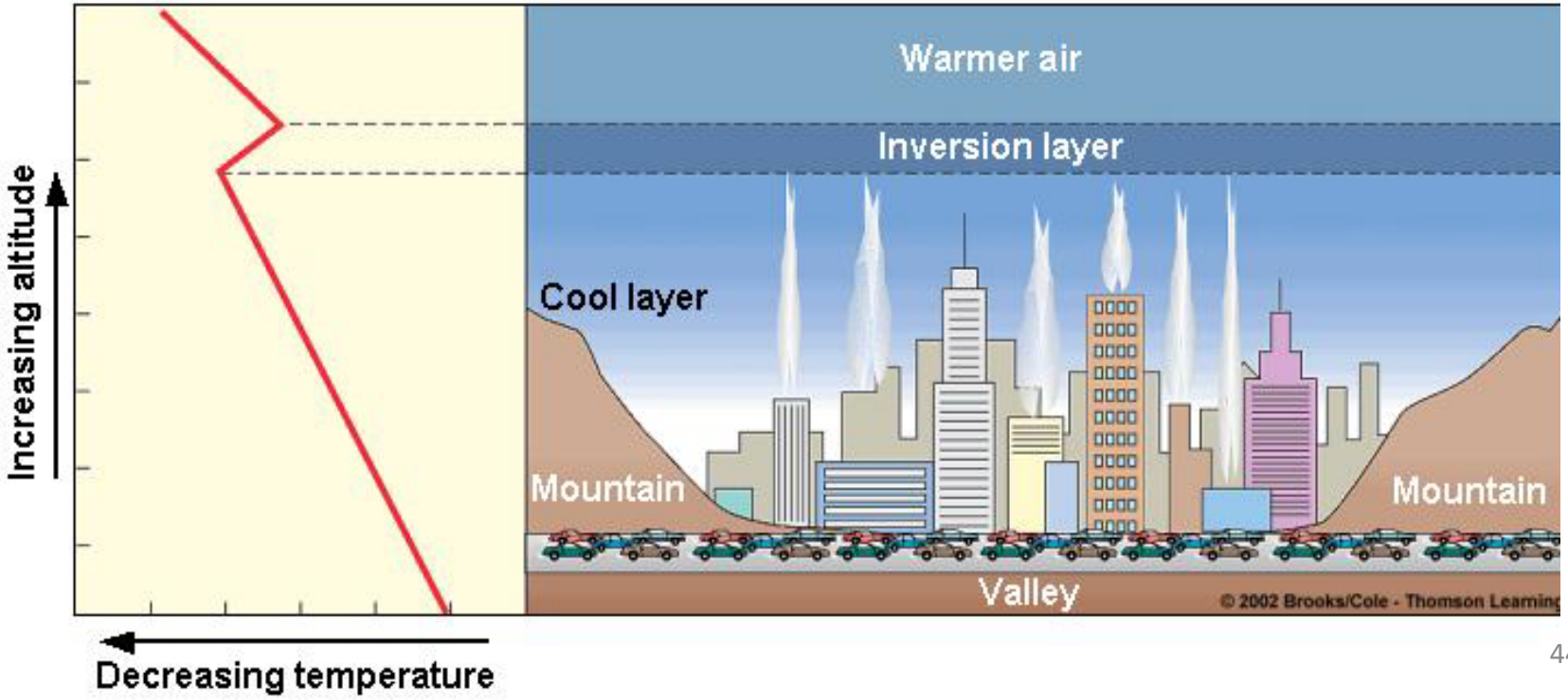
L*east developed countries* (LDCs) as of May 2016



LDC counties in 2016

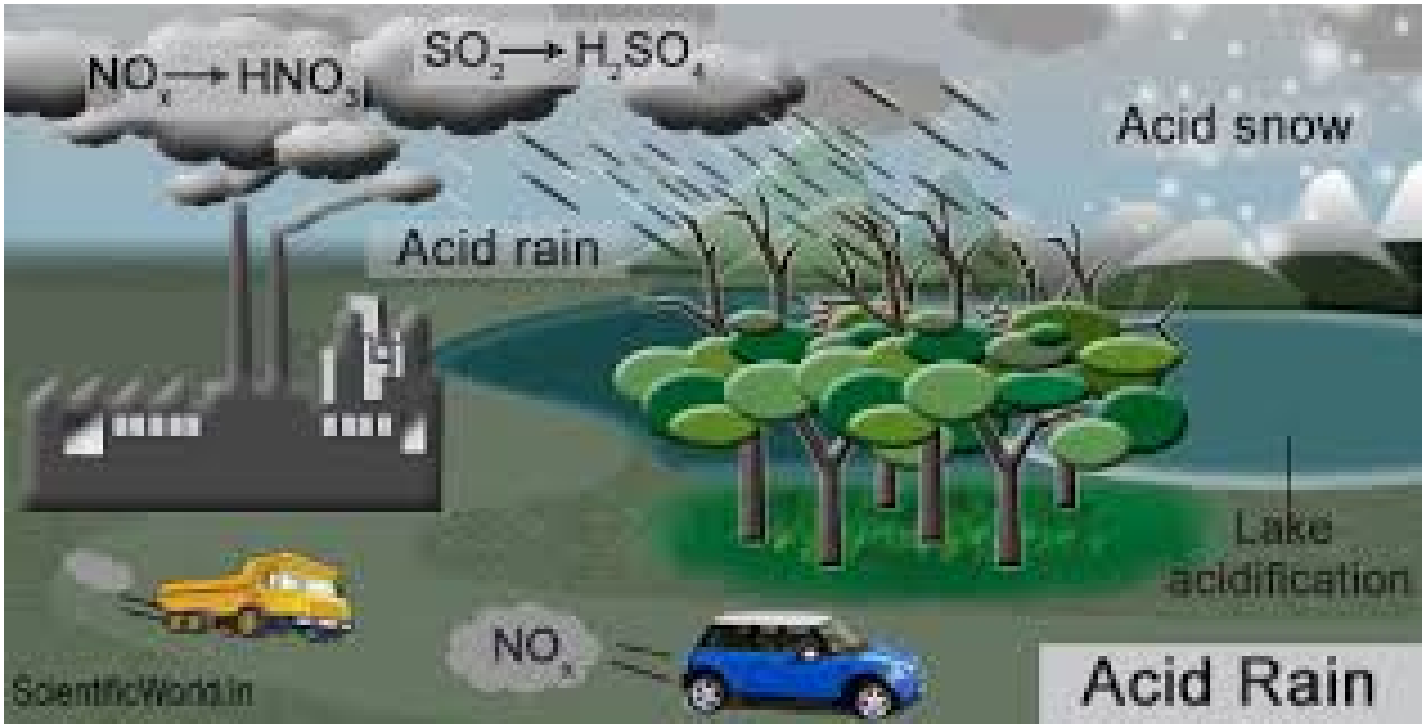
Thermal inversion

- warm air normally near surface, pollutants disperse as air rises and mixes
- when cool air trapped under warm air, confined by mountains, pollutants do not disperse, intensify with time.

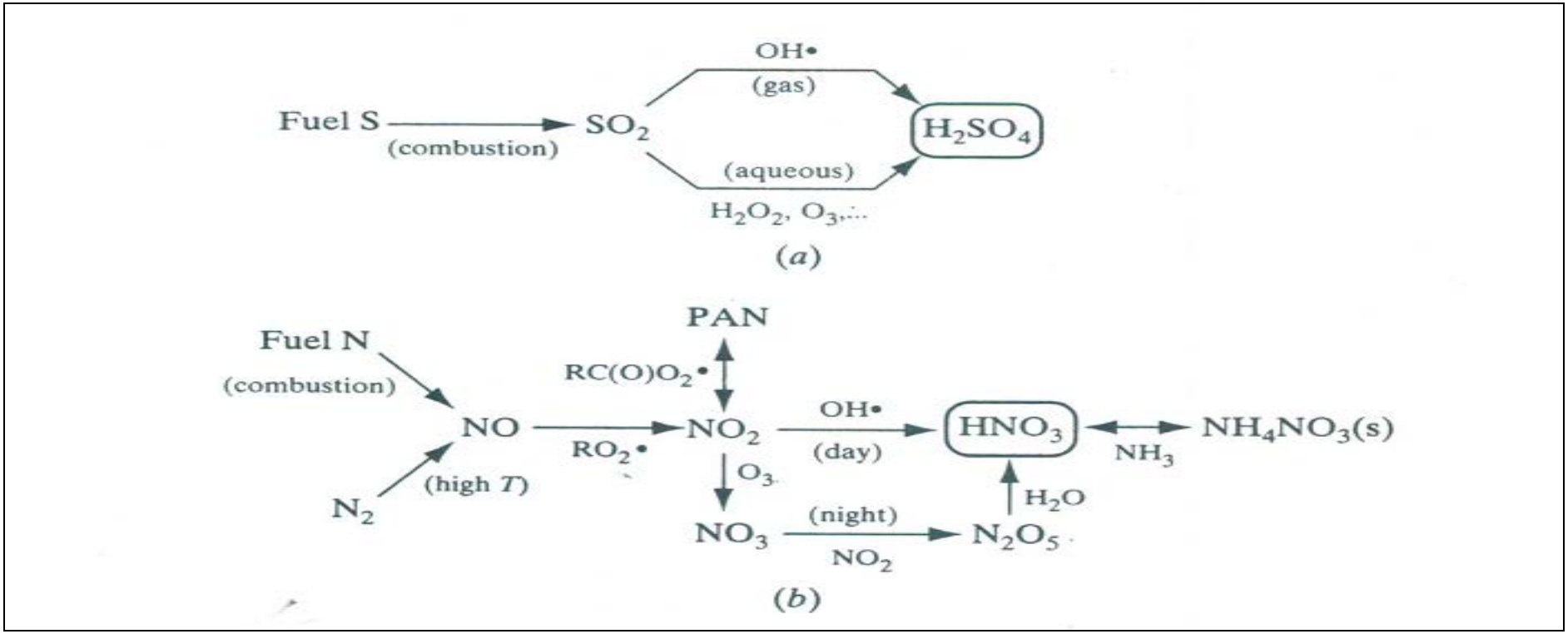


Acid Deposition OR Acid Rain

- Some compounds emitted into the atmosphere can be converted to acidic species. The deposition of excessive amounts of these species can cause economic and ecosystem damage.



Transformation dynamics that produce atmospheric acids from (*a*) sulfur oxides and (*b*) nitrogen oxides.



The arrows are labelled with the major reactant that is involved in the transformation process.

R denotes a hydrocarbon fragment such as CH_3

PANs (Peroxyacetyl nitrate), a secondary pollutant

Problems associated with Acid Rain

Acid deposition contributes to many environmental problems.

- Material damage concerns include corrosion, paint deterioration, and degradation of buildings and monuments, damage to agricultural crops, but some high-elevation forests are exhibiting damage from acidic cloud water.

- The disruption of freshwater aquatic ecosystems is also a serious concern. At issue here are both the direct effects of lower pH on aquatic life and the indirect effects of enhanced dissolution of toxic metals, such as aluminium and arsenic, from rock and soil.

Acid Deposition and Humans

- Respiratory diseases
- Toxic metal leaching
- Damage to structures, especially containing calcium carbonate
  - *Calcium carbonate* is a chemical compound with the formula CaCO3. The carbonate minerals form the rock types: limestone, chalk, *marble*, travertine, tufa, and others.
- Decreased productivity and profitability of fisheries, forests, and farms
- Decreased visibility
  - Sulfates and nitrates that form in the atmosphere from sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions contribute to **visibility** impairment, meaning we can't see as far or as clearly through the air.

Framework for understanding air pollution problems

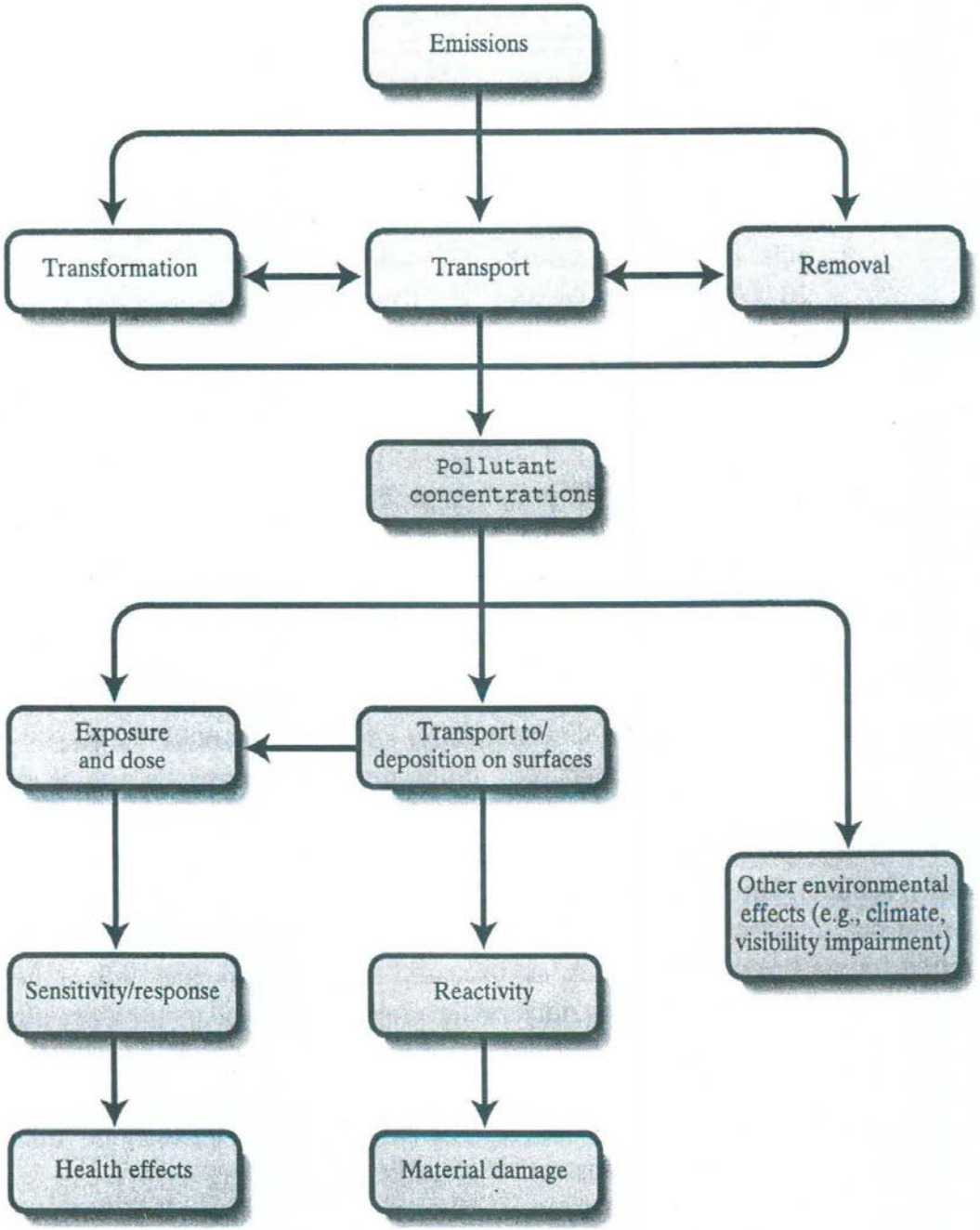


Figure 7.A.1 Framework for understanding air pollution problems.

Nazaroff, Ch. 7 'Air Pollution'

Home Assignment

- 7 Air Pollutants Commonly Found in Urban Atmosphere of India

http://www.yourarticlelibrary.com/air-pollution/7-air-pollutants-commonly-found-in-urban-atmosphere-of-india/19768/

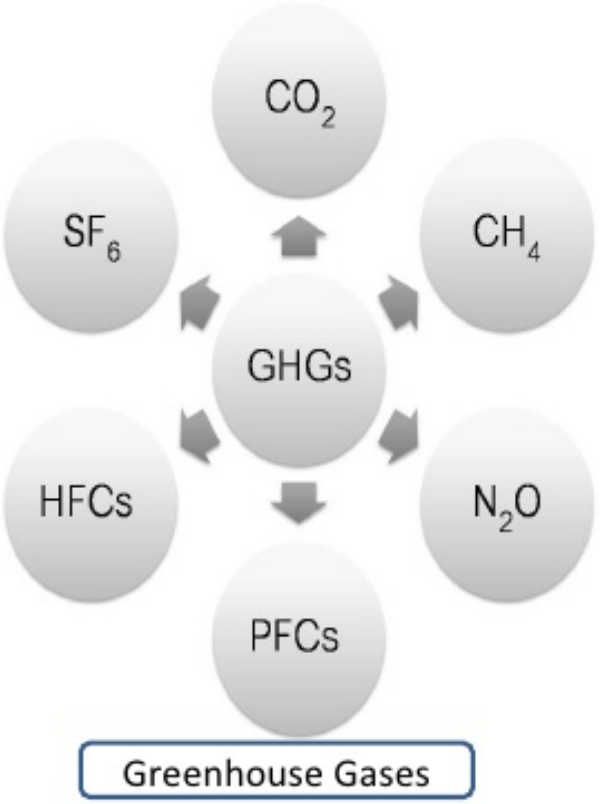
Air Quality Parameters

- *Criteria Pollutants, HAPs*

Number of Parameters used for IAQ/OAQ :

Parameters:

- Carbon Dioxide
- Carbon Monoxide
- Nitrogen Dioxide
- Sulphur Dioxide
- Total Volatile Organic Compounds
- Relative Humidity
- Hydrogen Sulphide
- Temperature
- Oxygen
- Ozone
- Ammonia
- Air Velocity
- Formaldehyde



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Hygiene. Quality. Health.

Criteria Air Pollutants

CPCB India, like USEPA, has set National Ambient Air Quality Standards for **six** principal pollutants, which are called "criteria" air pollutants.

- The **six** criteria pollutants are
- carbon monoxide (CO), nitrogen dioxide ($N0_2$), Ozone (0_3), sulfur dioxide ($S0_2$), particulate matter (PM), and lead (Pb).
  - These six pollutants are not the only ones that have adverse health effects.

Periodically, the standards are reviewed and may be revised.

Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air ($\mu g/m^3$)

Criteria Pollutant Properties

- More so than other air pollutants, they possess the following features:
  1) They are very common air pollutants, with long histories of human exposure.

  2) They each appear to have a threshold below which no adverse effects occur.

  3) Minor effects are reversible.

  4) There is a significant body of clinical and epidemiological data showing adverse human health effects at commonly encountered levels.

Hazardous Air Pollutants HAPs

- Hazardous air pollutants (HAPs) are species that are known or suspected **carcinogens**, or that have been shown to cause other serious health effects, such as **reproductive problems or birth defects**.

- HAPs include metal compounds, hydrocarbons, halogenated organics, and pesticides .

- Characterization and control of HAPs focus on major emission sources, which are usually associated **with industrial processes.**

Effects of Air Pollution on People

- Premature death
- Respiratory diseases
- Asthma
- Lung cancer
- Chronic bronchitis
- Emphysema
  - *Emphysema* is a lung condition that causes shortness of breath. In people with *emphysema*, the air sacs in the lungs (alveoli) are damaged.

UNEP 2014 Report
Air Pollution: World's Worst Environmental Health Risk
(Handout 6)