AIR POLLUTION

Atmospheric Composition:

Dry air within several kilometers of ground level consists of 2 major components

- Nitrogen, 78.8 %
- Oxygen, 20.95 %

2 minor components

- Argon, 0.934%
- CO_2, 0.035%
- Neon, krypton, helium, xenon

Stratification of Atmosphere

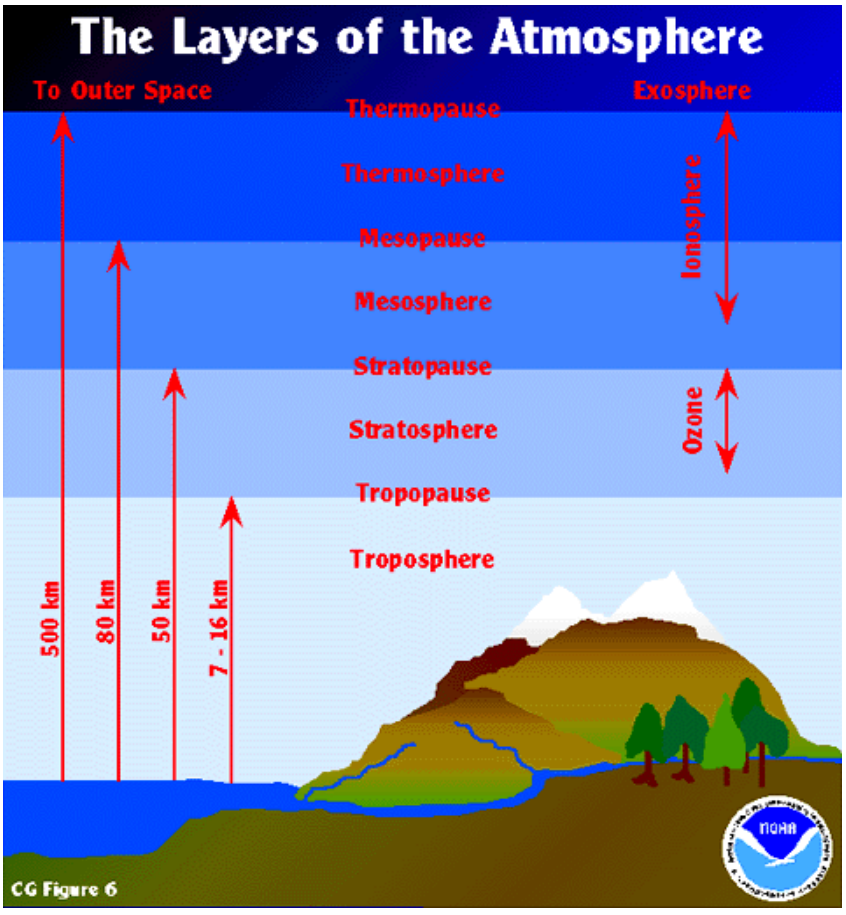
T=-1200°C

T=-92°C
P=3x10^{-4} atm

T=-2°C
P= 0.001 atm

T=56°C
P = 0.1 atm

T = 15°C,
P= 1 atm

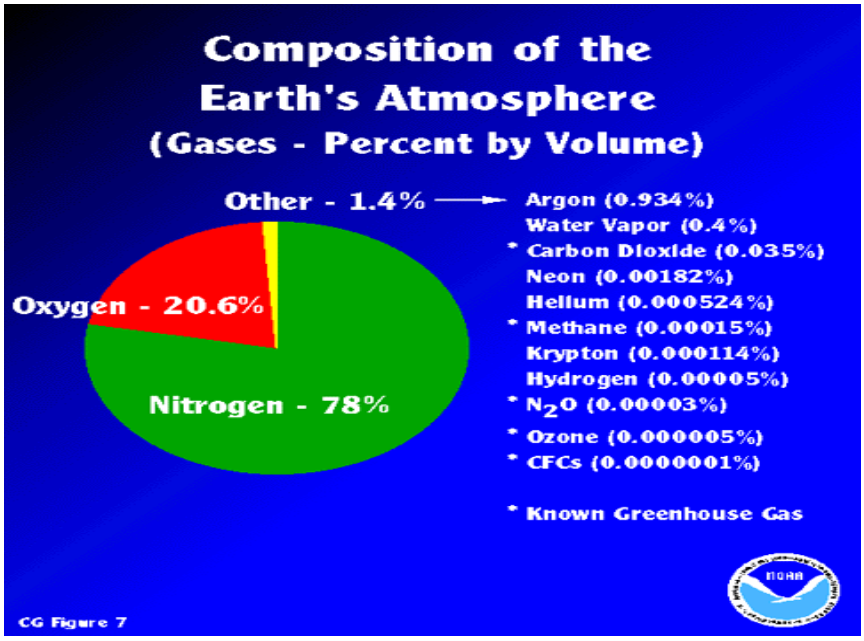


Traposphere –

- The lowest layer of the atmosphere
- Extends from sea level to an altitude of 10-16 km
- Homogenous compositions of major gases
- Homogenous composition results from constant mixing by circulating air masses.
- Water vapor content of the troposphere is extremely variable because of cloud formation, precipitation and evaporation of water from terrestrial water bodies.

Stratosphere-

- Maximum temperature : -2^{o}C
- Temperature increases with increase altitude
- This phenomenon is due to O_3, which may reach a level around 10 ppm by volume in the mid range of stratosphere.



Air pollution

- presence of chemicals in the atmosphere in quantities and duration that are harmful to human health and the environment
- Types of air pollutants:
    - **Primary pollutants** - products of natural events (like fires and volcanic eruptions) and human activities added directly to the air
    - **Secondary pollutants** - formed by interaction of primary pollutants with each other or with normal components of the air

Sources of Air Pollution

Fossil Fuel based Power Plants

- Fossil fuels provide about 90% of energy used worldwide; they are at the same time the biggest source of air pollution.
- Burning fossil fuels turns carbon to carbondioxide (a greenhouse gas) and a small amounts of carbon monoxide (a toxic gas).
- Both coal and fuel oil contain about 1-5% of sulfur.
- When burned, sulfur is oxidized to sulfurdioxide (a toxic gas) and emitted to the atmosphere.
- Combustion process, taking places at temperatures higher than 1000 ^{o}C, generated also nitrogen oxides (toxic gases).
- Power plants that work on coal and fuel oil consume immense amounts of combustible material, producing particularly large amounts of air pollutants.

Industry

Besides power plants, the major air polluters are

- chemical industry
- petroleum industry
- pulp and paper industry
- metallurgical industry and
- cement industry.

Their emissions include

- sulfur dioxide (SO_2),
- nitrogen oxides (NO_x)
- carbon monoxide (CO),
- particulate matter (PM_{10}),
- hydrogen sulfide (H_2S),
- hydrogen chloride, hydrogen fluoride, all types of volatile organic carbons, and metal particles.

Today's technology is able to remove about 90-99% of them from emissions.

Incinerators

Incineration of solid waste also generates a range of air pollutants, comprising conventional combustion gases, particulate matter (including heavy metals), polynuclear aromatic hydrocarbons (PAHs), such as dibenzodioxins (PCDDs), dibenzefurans (PCDFs) and biphenyls (PCBs), are particularly toxic and potentially mutagenic.

Motor Vehicles

Exhaust gases from motor vehicles contain carbondioxide,- carbon monoxide, nitrogen oxides, traces of hydrocarbons from unburnt fuel, particulate lead (if gasoline contains tetraethyl lead), sulfur dioxide (if diesel fuel is used) and PM_{10} (very small particles less than 10 microns across)

Indoor Pollutants

Certain substances are far more concentrated in the indoor environment than outdoors.

The foremost indoor air pollutant is radon, an odorless, colorless and tasteless radioactive gas.

In confined spaces, such as basements of houses, radon can accumulate and reach hazardous levels.

If soil contain uranium in high amounts and if the house built on such soil has poor ventilation, then radon concentrations may be exceptionally high.

Other indoor pollutants are carbon monoxide, nitrogen dioxide, particulate matter, poly nuclear aromatic hydrocarbons (PAHs) from wood stoves and fire-places, formaldehyde from plywood and wall paper, asbestos from fire insulating and noise reducing material and pesticides from household pest control activities.

Classification of Pollutants

Major Classes	*Subclasses*	*Typical Members of subclasses*
Particulates	Solid	Dust, smoke, fumes, fly ash
	Liquid	Mist, spray
Gases		
Organic	Hydrocarbons	Hexane, benzene, ethylene, butane
	Aldehydes and ketones	Formadehyde, acetone
	Other organics	Chlorinated hydrocarbons
Inorganic	Oxides of carbon	Carbon monoxide, carbon dioxide
	Oxides of sulfur	Sulfur dioxide, sulfur trioxide
	Oxides of nitrogen	Nitrogen dioxide, nitric oxide
	Other inorganics	Hydrogen sulfide, hydrogen fluoride, ammonia

Major Classes of Air Pollutants:

- **Carbon oxides** (CO & CO2)
  - sources = incomplete combustion of fossil fuels
    - transportation, industry, & home heating
  - CO2 is an important greenhouse gas
  - CO (carbon monoxide)
    - the most abundant pollutant know to affect human health
    - combines with hemoglobin & may create problems for infants, the elderly, & those with heart or respiratory diseases

- Colorless, tasteless and odorless, carbon monoxide gas is chemically inert under normal conditions and has an atmospheric mean life of about 2 ½ months.
- it can seriously affect human aerobic metabolism, owing its high affinity for hemoglobin, the component of the blood responsible for the transport of oxygen. Carbon monoxide reacts with the hemoglobin (Hb) of blood to give carboxyhemoglobin (COHb), thus reducing the capability of the blood to carry oxygen.
- the affinity of hemoglobin for carbon monoxide is more than 200 times as great as its affinity for oxygen, CO can seriously impair the transport of O_2, even when present at low concentrations.

Sources : Carbon monoxide sources are both natural and anthropogenic.

Argonne National Laboratory reports 3 ½ billion tones of CO are produced in nature yearly by the oxidation of methane gas from decaying vegetation.

Sources and quantities of carbon monoxide

Emissions, 10^6 tones/year

Source	**1980**
Transportation	69.1
Fuel combustion in stationary sources (power and heating)	2.1
Industrial Processes	5.8
Solid waste disposal and miscellaneous	8.4

- **Sulfur oxides** (mainly SO2, or sulfur dioxide)
    - source = combustion of coal & oil (esp. coal)
        - SO2 released in the U.S. comes from:
            - utilities 69.5%
            - industrial manufacturing processes 12.7%
            - industrial combustion 11.6%
            - transportation 3.7%
            - other sources 2.5%.
    - can react with gases in atmosphere to form sulfuric acid ('acid rain')
    - 20 million tons released in U.S. every year

The oxides of sulfur (SO_x) are probably the most widespread and the most intensely studied of all anthropogenic air pollutants. They include six different gaseous compounds:

Sulfur monoxide (SO)

Sulfur dioxide (SO_2)

Sulfur trioxide (SO_3)

Sulfur tetraoxide (SO_4)

Sulfur sesquioxide (S_2O_3)

Sulfur heptoxide (S_2O_7)

sulfur dioxide and sulfur trioxide are the two oxides of sulfur of most interest

Sulfur dioxide is a colorless, nonflammable, and nonexplosive gas.

SO_2 remains airbone an average of 2 to 4 d, during which time it may be transported as far as 1000 km. Thus the problem of SO_2 pollution can become an international one.

SO_2 can react with the water to form sulfurous acid, a weak acid which can react directly with organic dyes.

$SO_2 + H_2O \Leftrightarrow H_2SO_3$ sulfurous acid

SO_3 can react with the water to form sulfurous acid, a weak acid which can react directly with organic dyes.

$SO_3 + H_2O \Leftrightarrow H_2SO_4$ sulfuric acid

Effects of Sulfur oxides

tend to irritate mucous membranes of the respiratory tract and foster the development of chronic respiratory diseases.

In a dusty environment, SO_2, is particularly harmful because both sulfur dioxide and sulfuric acid molecules paralyze the hair like cilia which line the respiratory tract.

Without the regular sweeping action of the cilia, particulates are able to penetrate to the lungs and settle there. These particulates carry with them the concentrated amounts of SO_2, thus bringing this irritant into direct, prolonged contact with the delicate lung tissues.

Sulfuric acid aerosols will readily attack building materials, especially those containing carbonates such as marble, limestone, roofing slate

and mortar. The carbonates are replaced by sulfates which are soluble in water

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

Many of the historical monuments, public buildings, cathedrals have deteriorated from exposure to the by-products of sulfur dioxides.

Excess exposure to SO_2 accelerates corrosion rates for many metals such as iron, zinc, copper and nickel especially at relative humidities over 70%.

- **Nitrogen oxides** - NO (nitric oxide) & NO2 (nitrogen dioxide)
    - source = motor vehicles & industry (burning fossil fuels)
    - can react with other gases in atmosphere to from nitric acid (HNO3) ('acid rain')

Oxides of nitrogen (NO_x) include six known gaseous compounds: nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), nitrogen sesquioxide (N_2O_3), nitrogen tetroxide (N_2O_4) and nitrogen pentoxide (N_2O_5)

The two oxides of nitrogen of primary concern in air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2), the only two oxides of nitrogen that are emitted in significant quantities to the atmosphere.

$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$ nitrous acid

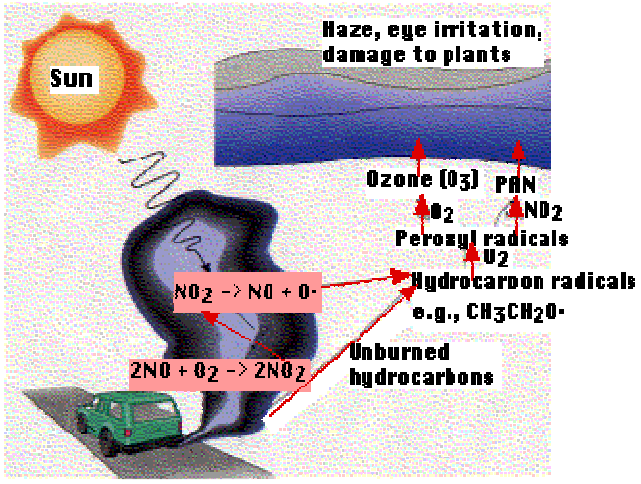
$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ nitric oxide

Secondary Pollutants of NO ➔ PHOTOSMOG

Photochemical smog

In bright sunlight

- nitrogen oxides
- hydrocarbons and
- oxygen



interact chemically to produce powerful oxidants like **ozone** (O_3) and **peroxyacetyl nitrate** (**PAN**).

These **secondary pollutants** are damaging to plant life and lead to the formation of photochemical smog. PAN is primarily responsible for the eye irritation so characteristic of this type of smog.

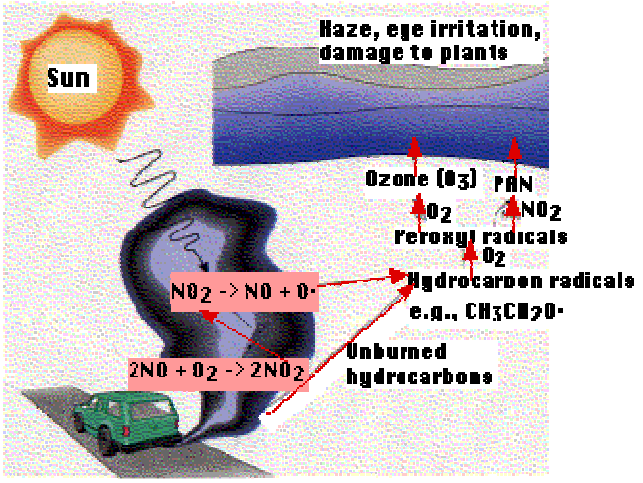
The figure outlines representative reactions leading to the formation of photochemical smog. Radicles are atoms or molecules with unpaired electrons. They are very reactive chemically.

The catalytic converter in automobile exhaust systems reduces air pollution by oxidizing hydrocarbons to CO_2 and H_2O and, to a lesser extent, converting nitrogen oxides to N_2 and O_2.

PHOTOSMOG

- was observed for the first time in Los Angeles about 50 years ago.
- present in all metropolitan areas where heavy road traffic is accompanied by clear skies and stagnant atmosphere (sunny day & no wind).
- The sequences of the steps leading to photo smog starts with the formation of nitrogen oxides produced by car engines or during any other combustion process.

$2\ NO + O_2 \rightarrow 2\ NO_2$ $\qquad$ $2NO_2 \xrightarrow{sun} NO + \underbrace{O\bullet}_{Atomic\ Oxygen}$



$$2NO_2 \xrightarrow{sun} NO + \underbrace{O\bullet}_{Atomic\ Oxygen}$$

$$O\bullet + O_2 \rightarrow O_3(Ozone) \qquad O_3 + NO \rightarrow O_2 + NO_2$$

$$Hydrocarbon + O\bullet \longrightarrow \underbrace{\bullet RO_2}_{alkylperoxy\ radicals}$$

- $\bullet RO_2 + NO \rightarrow NO_2$
- $\bullet RO_2 + O_2 + NO_2 \rightarrow Peroxyacyl\ nitrate(PAN)$

EFFECTS OF OZONE

- Although ozone in the stratosphere is essential to sustain life, its presence in the low troposphere is extremely hazardous.
- The ozone molecules oxidize matter and destroy vegetation.
- Its inhalation by humans and animals cause acute and chronic problems of the respiratory tract and lungs, which in turn