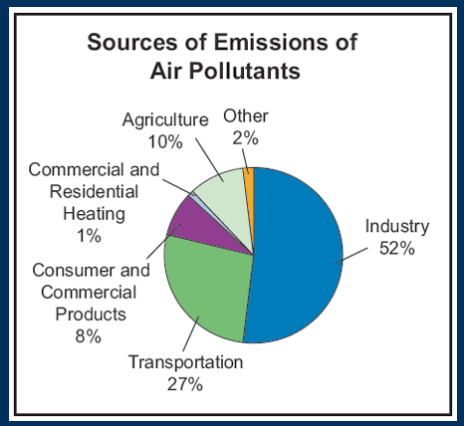
GGS 319
Part 1: Air Pollution Fundamentals

- ✓ The atmosphere and its components
- ✓ How air pollutants are categorized
- ✓ The source of air pollutants
- ✓ How pollution affects health and welfare
- ✓ Clean air acts
- ✓ Air quality management & standards

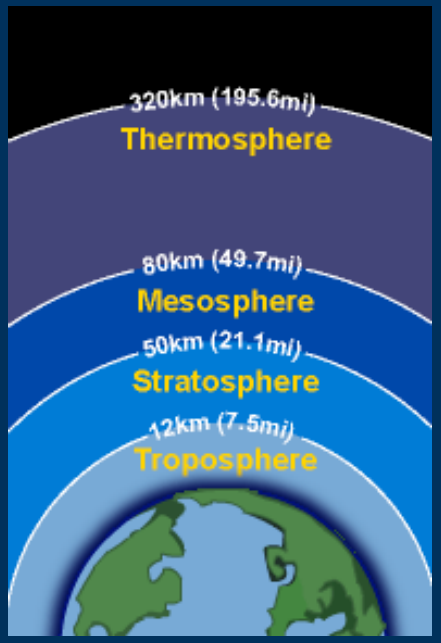


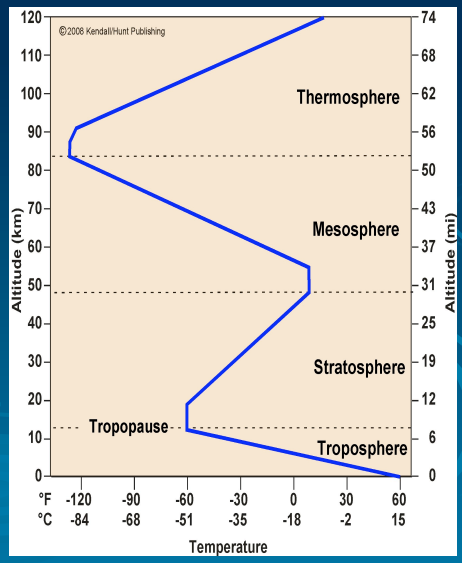




Atmosphere

- Troposphere extends 9-16 km
  - Lapse rate 6.5 ^{0}C/km
  - Well mixed
  - All weather formation
  - Pollutants and moisture confine in this layer
- Stratosphere extends to 50 km
  - Ozone formation
  - Absorption of SW radiation
  - Little mixing
  - No clouds and precipitation
  - Pollutants alter the radiation budget
- Mesosphere extends to 85 km
  - Temperature decreases
  - Coldest temperature occurrence
- Thermosphere
  - Conversion of solar energy into sensible heat





It's in the air…

D. Bodanis "It's in the air: skin, stardust, radio waves, vitamins, spider legs" Smithsonian Magazine, April, 1995.

✓ Take a deep breath. What is in one breath of air?

Atoms and Molecules:

~ 3 x 10^{22} mostly O_2 and N_2 molecules; elements forged in the interiors of stars.

- Oxygen (O_2) cycles through the biosphere (photosynthesis and respiration) roughly every 6000 years.
- Nitrogen (N_2) cycles with a 2 million year time scale.

✓ How many molecules in one breath of air was at one time breathed by Julius Caesar?

- Methane (CH_4) from cows belching…
- Argon (Ar) from extinct volcanoes
- Water vapor (H_2O) from impacting comets and meteorites over 4.5 BY and release from the deep interior of the Earth.
- Carbon Dioxide (CO_2) from respiration and fossil fuel burning.
- Hydrogen Sulfide (H_2S) from blue-green algae

✓ All of these molecules move at near the speed of sound and experience billions of collisions per second.

It's in the air…

✓ Overall, there are more than 2000 measurable trace gases in a liter of air.

Even the cleanest liter of air has a vast amount of **particulate matter.**

Dust: ~ 100,000 dust particles of wide range of compositions:
sea salt – many thousands per cc.
pollen, spores – tens of thousands
broken bits of insect (mostly spider) legs - thousands
smoke (soot) from around the world - thousands
meteoric dust from outer space - thousands
DNA fragments from decaying bacteria
skin flakes, soil, pet fur, dander
dust mites, millions of bacteria from your classmates.

✓ Even the cleanest "Clean Room" has > 1000 particles per liter of air.

✓ More exotic: radio waves over a vast range of wavelengths, neutrinos, microscope magnetic fields, and a wide array of atmospheric pollutants.

Take a Deep Breath. What did you breath in?

✓ **Concentration**

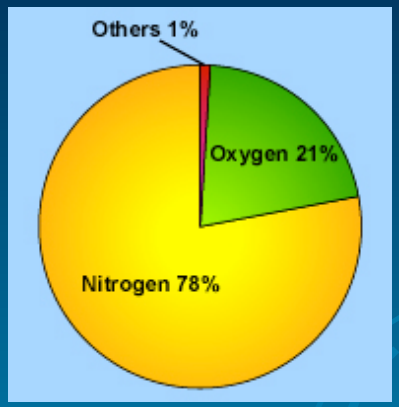
Number density:

Atoms or Molecules per cm^3

Fractional Concentration:

Molecules/Total Density

ppm = parts per million



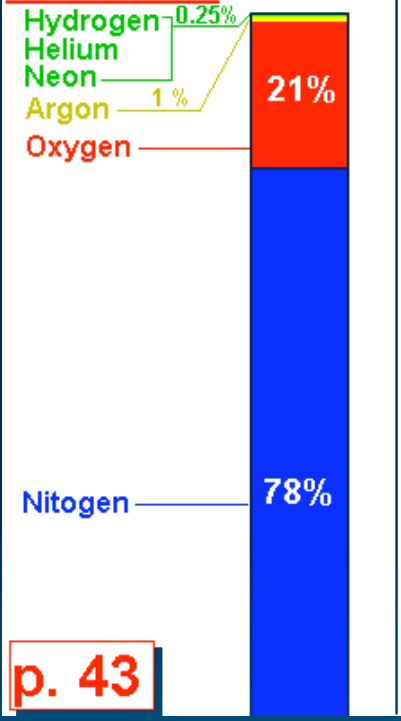
Atmospheric Composition

Constituent[a]	Molecular weight	Fractional concentration by volume
Nitrogen (N_2)	28.013	78.08%
Oxygen (O_2)	32.000	20.95%
Argon (Ar)	39.95	0.93%
Water vapor (H_2O)	18.02	0–5%
Carbon dioxide (CO_2)	44.01	380 ppm
Neon (Ne)	20.18	18 ppm
Helium (He)	4.00	5 ppm
Methane (CH_4)	16.04	1.75 ppm
Krypton (Kr)	83.80	1 ppm
Hydrogen (H_2)	2.02	0.5 ppm
Nitrous oxide (N_2O)	56.03	0.3 ppm
Ozone (O_3)	48.00	0–0.1 ppm

[a] So called *greenhouse gases* are indicated by bold-faced type. For more detailed information on minor constituents, see Table 5.1.

What Determines the Atmospheric Composition?

Constant Gases



p. 43

Variable Gases

total averages 4%

Carbon Dioxide (CO_2)
- traps thermal radiation
- consumed by plants
- accumulates with:
  1. deforestation
  2. ocean pollution
  3. fossil fuel burning

Water Vapor (H_2O)
- traps thermal radiation
- increases near liquid
- increases with heat

Ozone (O_3)
- traps thermal radiation
- most in stratosphere
- blocks UV radiation
- declines with CFC's

Particulates

suspended solids of:
- carbon (smoke, soot)
- ice (frozen water)
- silica dioxide (dust)
- salts & oxides
  - metalic (Fe, Na, K)
  - nonmetalic (S, Ca)
- organic materials (pollen, spores)

- block incoming light
- originate at surface
- condensation nuclei



Almost all atmospheric gases are produced, consumed, or affected by life.

Historical Remarks

- ✓ Air pollution is not a recent phenomenon

"As soon as I had escaped the heavy air of Rome and the stench of its smoky chimneys, which when stirred poured forth whatever pestilent vapours and soot they held enclosed, I felt a change in my disposition."

Roman philosopher Seneca, AD 61

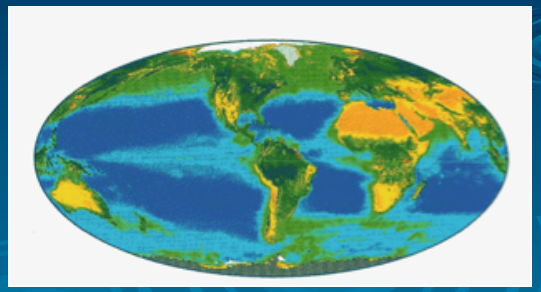
Historical Remarks

- Ambient air composition over the earth has undergone several changes throughout history
  - The primeval gaseous environment probably contained almost no free oxygen
  - Oxygen in more recent years has accumulated as a result of photosynthetic processes
  - Biological organisms, via photosynthesis, metabolize water and carbon dioxide to form carbohydrates and produce oxygen as a by-product.
  - Green trees & plants Green trees and plants are the major source of oxygen on land.
  - Phytoplankton are capable of consuming the nutrients in the euphotic zone of the ocean in a matter of days, requiring continual replenishment.

Photosynthesis: **(+sunlight)**

Water + carbon dioxide → glucose + oxygen

$6\ H_2O + 6\ CO_2 \rightarrow C_6H_{12}O_6 + O_2$



Historical Remarks

- Air pollution is not a recent phenomenon
  - Air pollution first received recognition as an urban problem in England in the 9th century when coal was discovered
  - King Edward I of England tried to clear the smoky sky over London in 1272 by banning the use of coal
  - Under Richard II (1377-1399) and later under Henry V (1413-1422), England took steps to regulate and restrict the use of coal
  - One of the earliest recorded air pollution publication is published in 1661
- Anthropogenic activities, since the 14th century when coal mostly replaced wood, have provided a clear "perturbation"
  - London wood shortages
  - Pollutants: SO2, CO, CO2, NO, soot, and PM
- The possible effect to human health was recognized in the 17th century by John Evelyn
- The petroleum products in this century (1945)

Historical Remarks

- Clean air acts have existed for at least a century
- Four classic incidents
  - **Meuse Valley, Belgium (1930) 65 deaths**
    - High concentration of SO2 in the atmosphere during a temperature inversion
  - **Donora, Pennsylvania (1948) 20 deaths**
    - High concentration of SO2 in the atmosphere during a temperature inversion and a foggy weather
  - **Poza Rica, Mexico (195) 22 deaths**
    - Accidental release of hydrogen sulfide during a temperature inversion and a foggy weather
  - **London, England (1952) 4000 deaths**
    - A 5 days temperature inversion trapped deadly acid aerosols in the atmosphere
- During 1940s, air pollution received greater attention in the US when smog was noticed in Los Angeles

The Great London Smog of 1952

- During the London incident, the fog was so thick that people could not even see their own feet
- These classic incidents served as a "wake up call" to the public and to policy-makers
- They led to the first major legislation in England, the Clean Air Act of 1956 banned emissions of black smoke

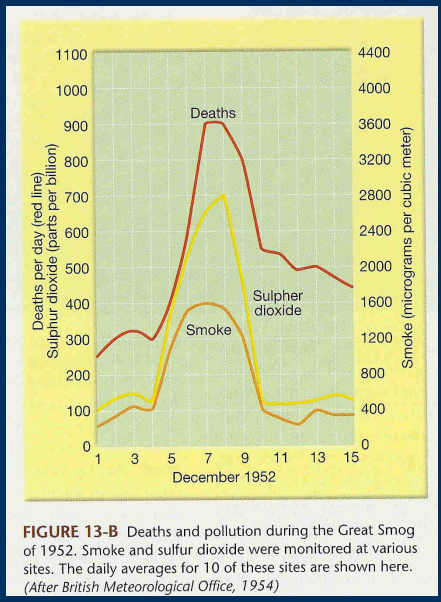
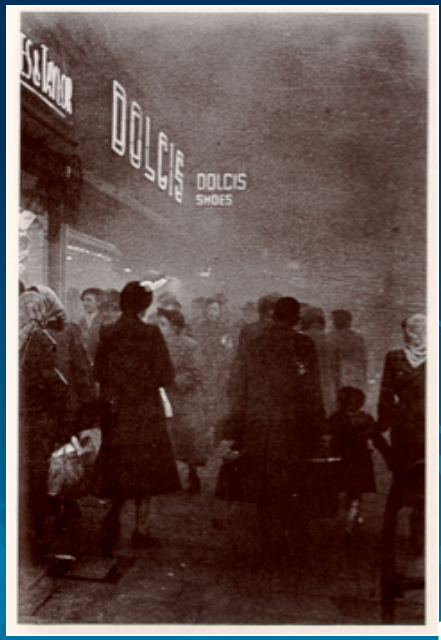
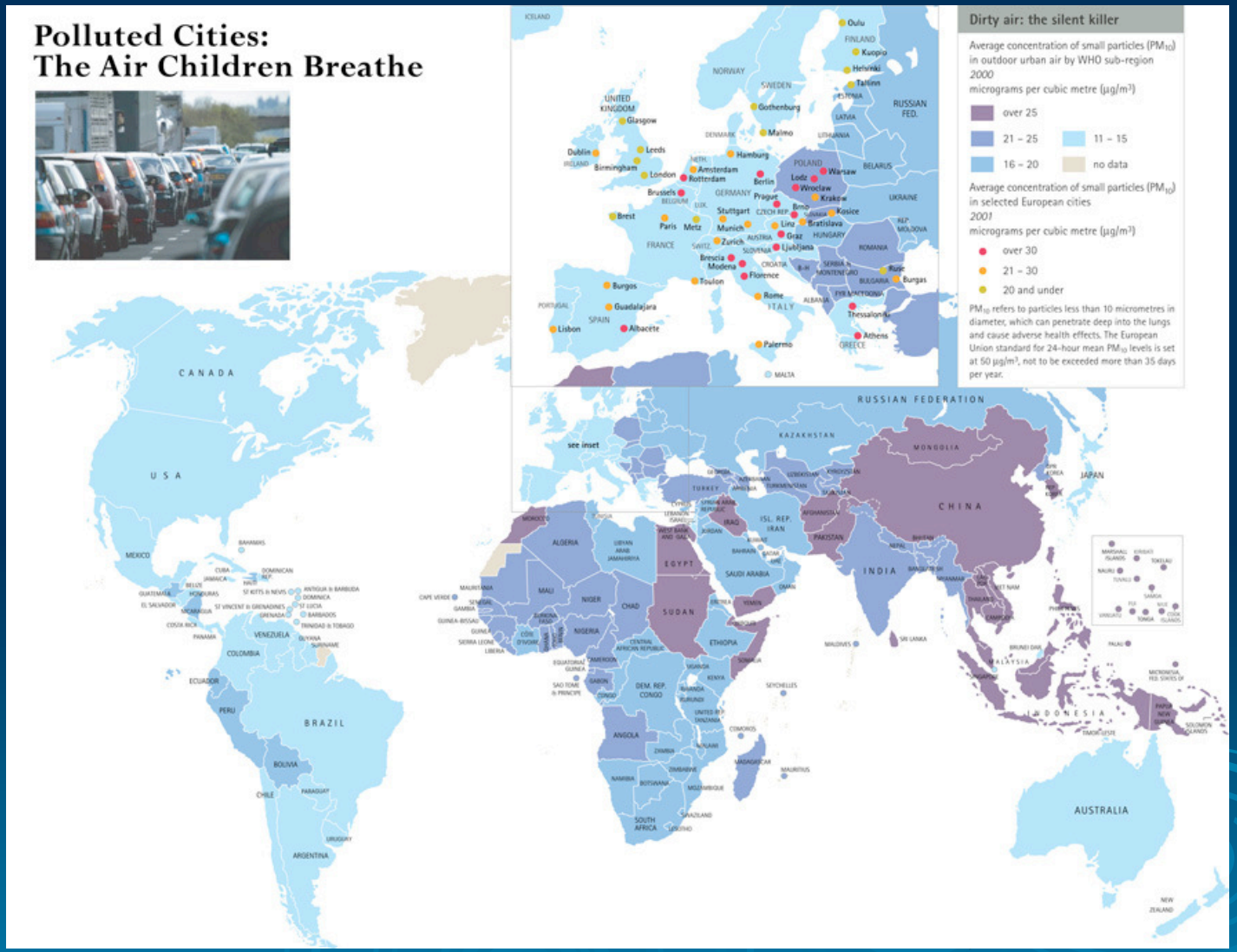


FIGURE 13-B Deaths and pollution during the Great Smog of 1952. Smoke and sulfur dioxide were monitored at various sites. The daily averages for 10 of these sites are shown here. *(After British Meteorological Office, 1954)*



Historical Remarks

- ✓ After the petroleum products in this century (1945) outdoor air pollution



World Health Organization, Myriad Editions Ltd, 2004)

Historical Remarks

- **Perfect Combustion**

Fuel (hydrocarbons) + Air (oxygen and nitrogen) >
Carbon dioxide (CO_2) + water (H_2O) + unaffected nitrogen

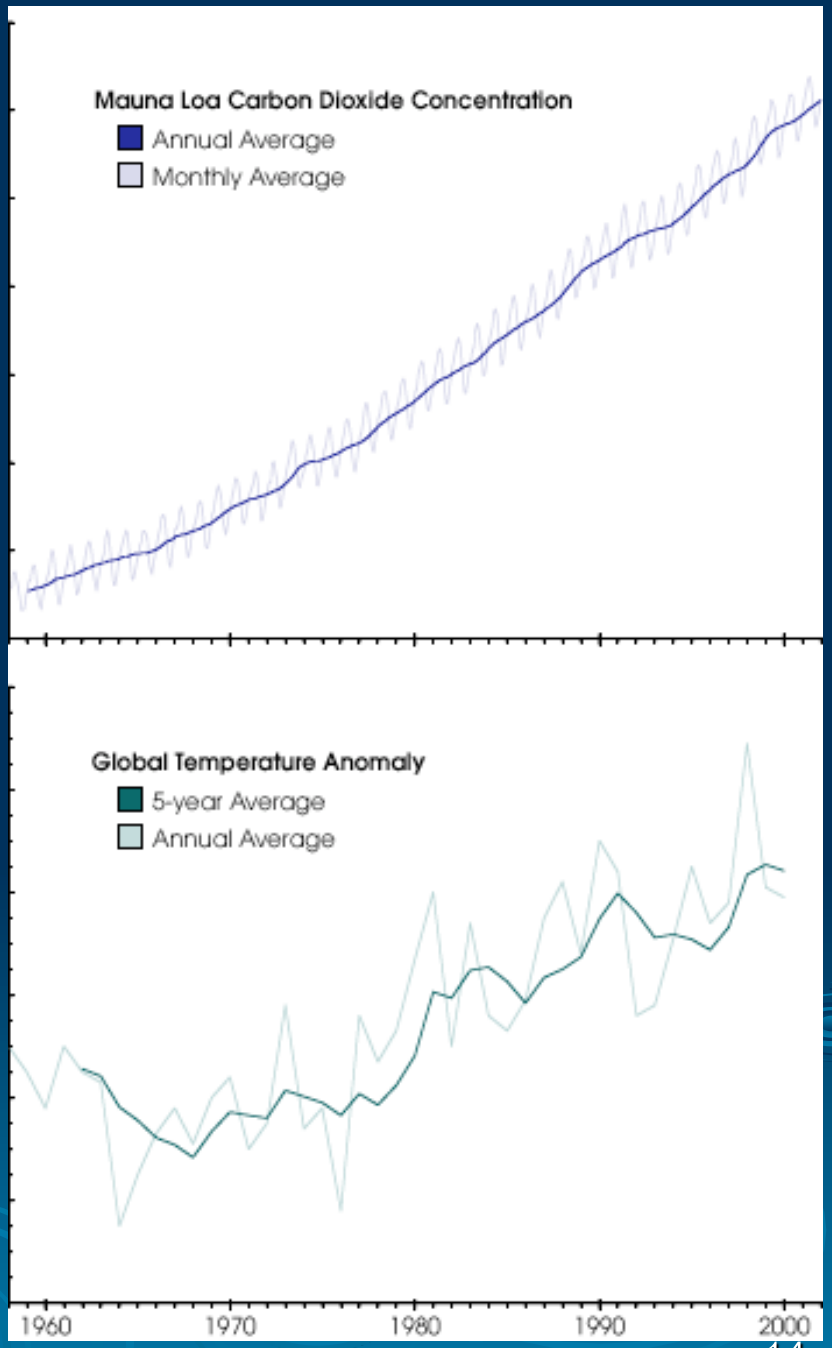
- **Typical Engine Combustion**

Fuel + Air >
Unburned Hydrocarbons + Nitrogen Oxides (NO_x) + Carbon monoxide (CO) + Carbon dioxide + water

Fossil Fuel Burning







Scope of the Problem

- Worldwide, air pollution contributes to
  - About 1,000,000 deaths/year
  - About 5,000,000 healthy life-years lost/year
- The burden is not equally distributed
  - About 65% deaths and lost life-years occur in Asia
- Need epidemiological studies in developing countries
  - The above estimates are based on the results of research conducted in developed countries that have been extrapolated to developing countries
  - However developing countries differ in
    - Nature of their air pollution
    - The conditions and magnitude of exposures to that pollution
    - The health status of the population

Pollutants in the Ambient Air

Pollutants can be grouped into two categories:

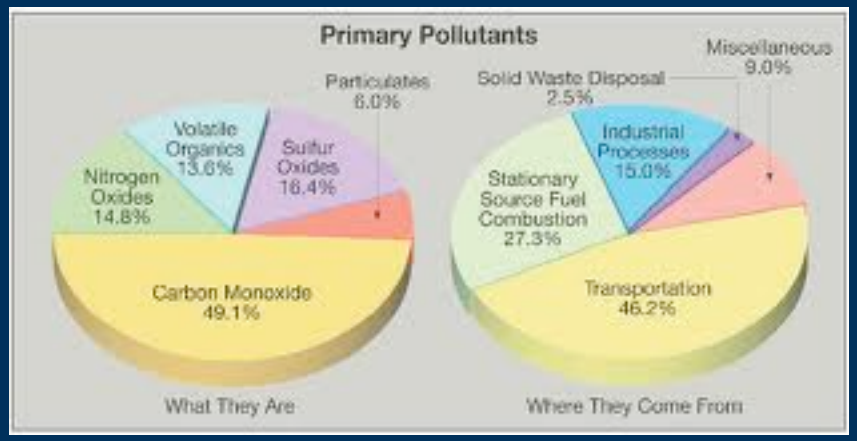
(1) Primary pollutants, which are emitted directly from identifiable sources, and retains the same chemical form (e.g., ash)
(2) Secondary pollutants, which are produced in the atmosphere when certain chemical reactions take place among primary pollutants (e.g., ozone)

EPA has further classified pollutants for regulatory purposes

(3) Hazardous air pollutants (HAPs), which are emitted directly from identifiable sources, and retains the same chemical form (e.g., ash)
(4) Criteria pollutants, which are produced in the atmosphere when certain chemical reactions take place among primary pollutants (e.g., ozone)



Primary Pollutants

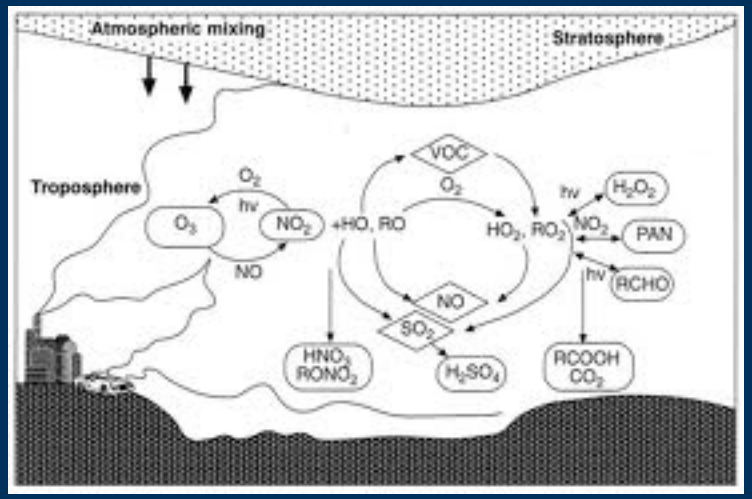


Major Air Pollutants (1)

Pollutant	Formation	Physical state	Sources
Suspended particulates	Primary & secondary	Solid, liquid	Vehicles Industrial processes Tobacco smoke
Sulphur dioxide (SO_2)	Primary	Gas	Industrial processes Vehicles
Nitrogen dioxide (NO_2)	Primary	Gas	Vehicles Gas heaters and cookers
Carbon monoxide (CO)	Primary	Gas	Vehicles Tobacco smoke

- ✓ Primary Pollutants (emitted directly from identifiable sources)
  - ✓ Particulate Matter (dust, smoke, sand, pollen, mist, fly ash)
  - ✓ Carbon monoxide (CO)
  - ✓ Sulfur dioxide (SO2)
  - ✓ Nitrogen oxides (NO2)
  - ✓ Volatile organic compounds (VOCs)

Secondary Pollutants

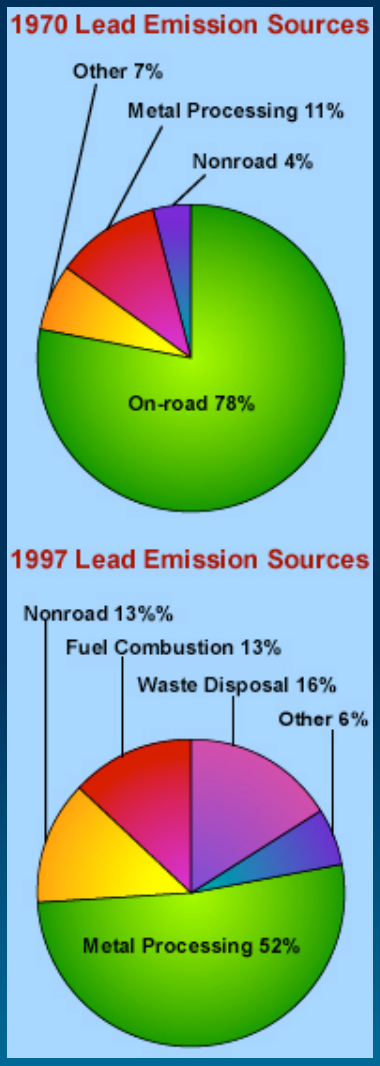


- ✓ Secondary Pollutants
  - ✓ They undergo a chemical change once they reach the atmosphere
  - ✓ For example, ozone & atmospheric sulfuric acid
  - ✓ Control of secondary pollutants are more problematic

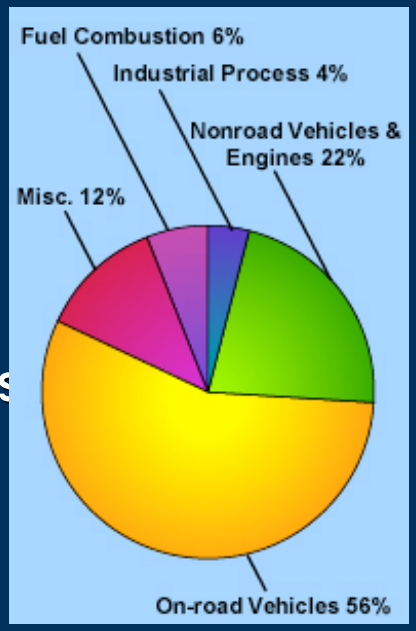
Hazardous Air Pollutants

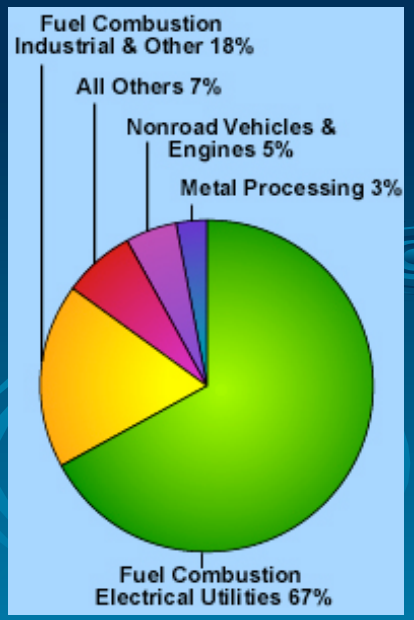
- Hazardous air pollutants are those pollutants are known or suspected to cause cancer or other serious health effects
- Fortunately, hazardous air pollutants are more localized
- They are usually found at highest levels close to their sources
  - Benzene, found in gasoline
  - Mercury, from coal combustion
  - Perchloroethylene, emitted from some dry cleaning facilities
  - Methylene chloride, used as a solvent by a number of industries

Criteria Air Pollutants



- ✓ Criteria air pollutants are those pollutants are common and found all over the US
- ✓ EPA uses these pollutants as indicators of air quality
  - ✓ Carbon Monoxide (CO)
  - ✓ Sulfur Oxides (SOx)
  - ✓ Nitrogen Oxides (NOx)
  - ✓ Ozone (O3)
  - ✓ Lead (Pb)
  - ✓ Particulate Matter





Sources of Primary Pollution

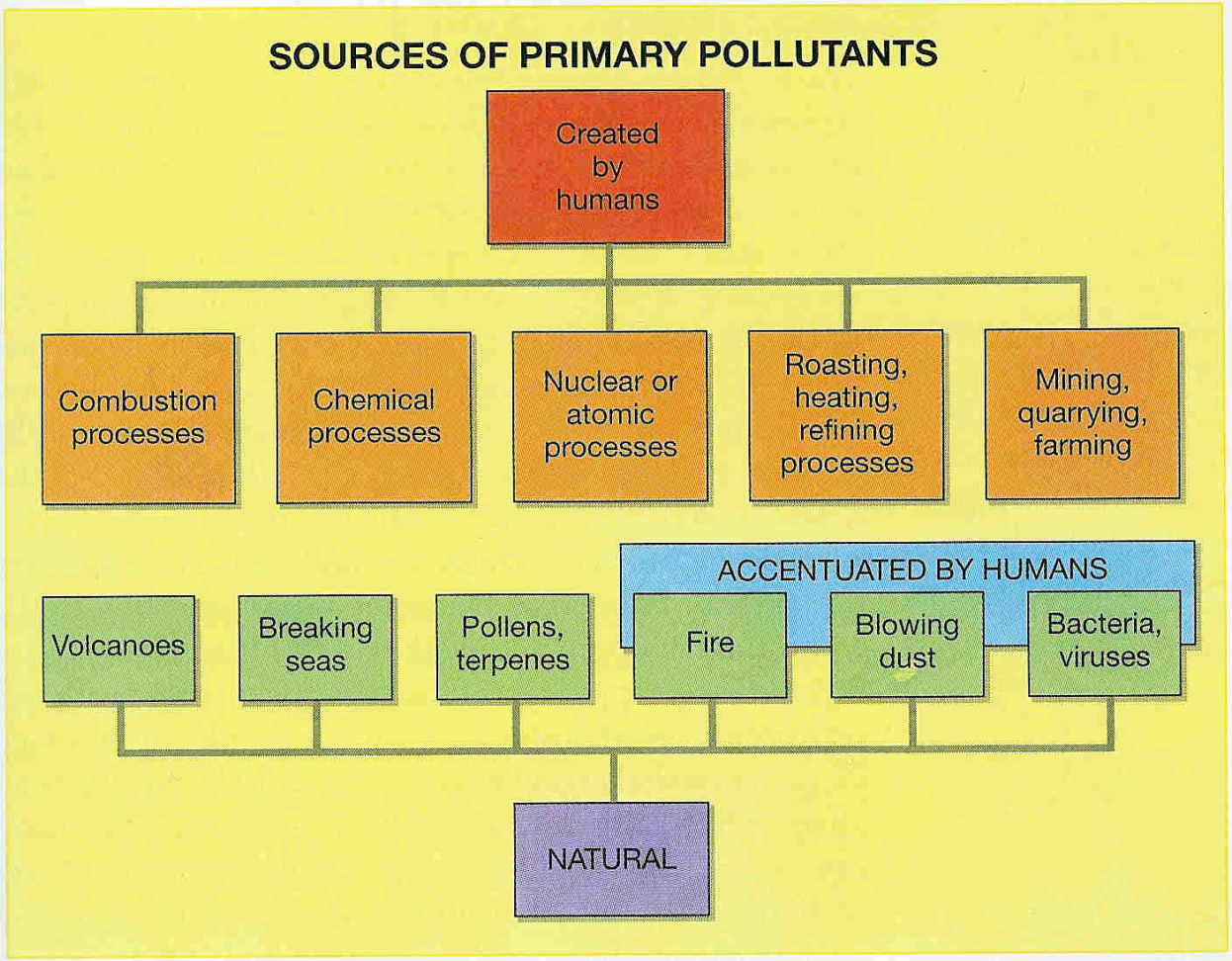


FIGURE 13-2 Sources of primary pollution. *(After Reid A. Bryson and John E. Kutzbach,* Air Pollution, *Commission on College Geography Resource Paper No. 6, Figure 2, p. 8.)*

1930's Dust Bowl

FIGURE 13-3 An example of natural air pollution that has been accentuated by human activities. This dust storm near Elkhart, Kansas, in May 1937 occurred because the soil was plowed and vulnerable to strong winds. It was because of storms like this that portions of the Great Plains were called the Dust Bowl in the 1930s. *(Photo reproduced from the collection of the Library of Congress)*



Mediterranean Dust



Fires in Greece: Summer 2007



Air-pollution source categories

Air-pollution source categories

Category	Comments
Point sources	Includes factories and electric power plants
Mobil sources	Not only includes cars and trucks but also lawn mowers, airplanes, and anything else that moves and pollutes the air
Biogenic sources	This category includes all nonanthropogenic (not human-generated) sources. Examples include trees and other vegetation, microbial activity, oil and gas seeps, etc.
Area sources	Small and individual sources such as dry cleaners and degreasing operations.