Air Pollution
Beijing, China, 2008
Perspective

• Air pollution is not a new problem
• Pollution sources can be divided into two main classes
  ➢ Created by Humans
  ➢ Natural
• Pollution by humans has increased to an unacceptable level
• We have polluted the air, the water, the land
Drought + Forest Fire
Dust storm Kansas 1937
Sources & Types of Air Pollution

• **Air pollutants are** airborne particles and gases that occur in concentrations that endanger the health and well-being of organisms, or disrupt the orderly functioning of the environment.

• Pollution is divided into three categories:
  - **Primary** – from an easily traced point source
  - **Secondary** – formed from reaction with primary pollutant
  - **Fugitive** – unintentional leak
SOURCES OF PRIMARY POLLUTANTS

- Created by humans
  - Combustion processes
  - Chemical processes
  - Nuclear or atomic processes
  - Roasting, heating, refining processes
  - Mining, quarrying, farming

- Accentuated by humans
  - Volcanoes
  - Breaking seas
  - Pollens, terpenes
  - Fire
  - Blowing dust
  - Bacteria, viruses

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

What they are:
1. Carbon Monoxide
2. Sulphur oxides
3. Nitrogen Oxides
4. Volatile organics
5. Particulates
USA, 2007

- Carbon Monoxide: 62.7%
- Nitrogen Oxides: 13.2%
- Volatile Organics: 11.6%
- Sulfur Dioxide: 10.1%
- Particulates: 2.4%
Primary Pollutants - 2

• *Where they come from:*
  1. Transportation
  2. Stationary source fuel combustion
  3. Industrial processes
  4. Solid waste disposal
  5. Miscellaneous
<table>
<thead>
<tr>
<th>Source</th>
<th>Emissions (tons)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-road Vehicles</td>
<td>76,361,265</td>
<td>38.49%</td>
</tr>
<tr>
<td>Nonroad Equipment</td>
<td>30,702,485</td>
<td>15.48%</td>
</tr>
<tr>
<td>Fires</td>
<td>29,303,986</td>
<td>14.78%</td>
</tr>
<tr>
<td>Electricity generation</td>
<td>16,899,351</td>
<td>8.51%</td>
</tr>
<tr>
<td>Road Dust</td>
<td>11,108,355</td>
<td>5.60%</td>
</tr>
<tr>
<td>Industrial Processes</td>
<td>8,181,573</td>
<td>4.12%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6,993,504</td>
<td>3.52%</td>
</tr>
<tr>
<td>Fossil Fuel Combustion</td>
<td>6,645,307</td>
<td>3.35%</td>
</tr>
<tr>
<td>Residential Wood Combustion</td>
<td>4,673,512</td>
<td>2.36%</td>
</tr>
<tr>
<td>Solvent Use</td>
<td>4,296,662</td>
<td>2.16%</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>3,199,427</td>
<td>1.61%</td>
</tr>
<tr>
<td>Fertilizer and Livestock</td>
<td>489,118</td>
<td>0.02%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>198,414,345</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: U.S. Environmental Protection Agency
Major primary pollutants

1. Particulate matter
2. Sulfur dioxide
3. Nitrogen Oxides (NOx)
4. Volatile organic compounds (VOC)
5. Carbon Monoxide
6. Lead
PM$_{2.5}$
$<$2.5$\mu$m in diameter

PM$_{10}$
10$\mu$m in diameter

Very fine beach sand
90$\mu$m in diameter

Human hair
70$\mu$m in diameter
Sources of electrical generation, USA 2006

- Coal: 48.9%
- Natural Gas: 20.0%
- Nuclear: 19.3%
- Hydroelectric: 7.1%
- Petroleum: 1.6%
- Other: 3.1%
Secondary Pollutants

- **Photochemical** reactions - sunlight reacts with primary pollution, causing a chemical reaction.
- Occur during the day, maximizing in the summer - depends on sun angle.
- **Photochemical smog** is a noxious mixture of gases and particles - very reactive, irritating and toxic.
London 1952
Satellite measurements of SO$_2$ concentration
Ozone - Good or Bad?

• Major component of photochemical smog is ozone.
• **Ozone** causes eye and lung irritation, lowers crop yields, damages material such as rubber etc.
• Ozone in the upper atmosphere is a good thing (protects us from solar UV)
• Ozone at ground level is a bad thing
Clean Air Acts of 1970 & 1990

- Cutting emission of the most common air pollutants including carbon monoxide, particulates and lead
- Setting emission standards for motor vehicles
- Controlling the release of toxic air pollutants
- Targeting sulfur dioxide and nitrogen oxide emissions to reduce acid rain
- Keeping the air in national parks clean and clear
- Reducing pollutants that cause ozone damage
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon monoxide (CO)</strong></td>
<td></td>
</tr>
<tr>
<td>8-hour average</td>
<td>9 ppm*</td>
</tr>
<tr>
<td>1-hour average</td>
<td>35 ppm</td>
</tr>
<tr>
<td><strong>Nitrogen dioxide (NO₂)</strong></td>
<td></td>
</tr>
<tr>
<td>Annual arithmetic mean</td>
<td>0.053 ppm</td>
</tr>
<tr>
<td><strong>Ozone (O₃)</strong></td>
<td></td>
</tr>
<tr>
<td>1-hour average</td>
<td>0.12 ppm</td>
</tr>
<tr>
<td>8-hour average</td>
<td>0.08 ppm</td>
</tr>
<tr>
<td><strong>Lead (Pb)</strong></td>
<td></td>
</tr>
<tr>
<td>Quarterly average</td>
<td>1.5 µg/m³</td>
</tr>
<tr>
<td><strong>Particulate &lt; 10 micrometers (PM₁₀)</strong></td>
<td></td>
</tr>
<tr>
<td>24-hour average</td>
<td>150 µg/m³</td>
</tr>
<tr>
<td><strong>Particulate &lt; 2.5 micrometers (PM₂.₅)</strong></td>
<td></td>
</tr>
<tr>
<td>Annual arithmetic mean</td>
<td>15 µg/m³</td>
</tr>
<tr>
<td>24-hour average</td>
<td>35 µg/m³</td>
</tr>
<tr>
<td><strong>Sulfur dioxide (SO₂)</strong></td>
<td></td>
</tr>
<tr>
<td>Annual arithmetic mean</td>
<td>0.03 ppm</td>
</tr>
<tr>
<td>24-hour average</td>
<td>0.14 ppm</td>
</tr>
<tr>
<td>3-hour average</td>
<td>0.50 ppm</td>
</tr>
</tbody>
</table>

*ppm, parts per million.
**mg/m³, milligrams per cubic meter of air. A milligram is one-thousandth of a gram.
***µg/m³ micrograms per cubic meter. A microgram is one-millionth of a gram.

Source: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.
Trends in national emissions

- Volatile organic compounds (VOC)
- Sulfur dioxide
- Nitrogen oxides

Emissions (millions of tons)

Year

Copyright © 2010 Pearson Prentice Hall, Inc.
Toxic Mold
Plumbing leaks and any source of moisture can cause toxic mold. Diseases associated with toxic molds are leukemia, kidney, esophagus, and liver cancer.

Dust
Dust is a harmful indoor allergen that contains particles of dust mites, chemicals, outdoor minerals, insect parts, dander, fungi, and bacteria. Inhaling dust can trigger allergies and asthma.

Viruses in the home can be caused by fungus in mattresses and pillows, parasites, indoor pests, and a variety of microorganisms that are found in homes.

Asbestos/Hazardous Materials
Asbestos and other hazardous materials like pesticides, kerosene, and other chemical based products can pollute the indoor air. Inhaling asbestos spores and chemical fumes can cause severe illness.

Carbon Dioxide
Poor ventilation creates 50% of all indoor air pollution. Stagnant air produces carbon dioxide and over exposure can be lethal.

Rats & Mice
Rats and mice can be in a home for months without being discovered. The protein in their urine dries, mingles with dust, and becomes airborne. The harmful allergen can get into the ventilation system and be circulated throughout the home. Rat and Mice allergen triggers asthma.

Lead
Many older homes contain lead paint that was painted over after a law was passed in 1978. One in twenty two American children suffer from lead poisoning.

Bacteria
A variety of serious illnesses can be caused by bacteria that is found in polluted water drains, air ducts, water supply systems, contaminated food, fungus in mattresses and pillows, and anyplace where moisture occurs.

Pollens
Plants and trees release pollen that often gets into the home through open windows and doors. Pollen causes headaches, hay fever, and triggers allergies and asthma.

Fungi
There are many different kinds of fungi in a home. Some are found in mattresses and pillows and feed on dust mite waste. Others are found beneath carpets, in garbage pails, water drains, air ducts, and in places where mildew or high humidity creates moisture. Inhaling fungus spores can trigger allergies and will cause or worsen illnesses.

Radon
Radon is an odorless gas that is found in 1 in 15 homes across the U.S. It enters a home from the ground through a crack in the foundation or floor and the deadly gas is the second leading cause of lung cancer in America. Radon causes 20,000 deaths each year.

Carbon Monoxide
Carbon monoxide is a poisonous gas that is caused by clogged fireplaces and faulty heating systems. The odorless gas causes nausea, dizziness, headaches, and over exposure can be lethal.

Dander
Cat and dog dander is a leading allergen that triggers asthma. Dander is found in carpets, beds, and every place in the home that is visited by these two popular pets.

Asian Ladybugs
Found mostly in the Northeastern states, Ladybugs hibernate inside of structures. When disturbed, ladybugs emit a yellowish secretion that triggers allergic asthma.

Dust Mites
Dust mite waste triggers asthma. Dust mites are found in 90% of all homes. 47% of all bedding in North America contains enough dust mite allergen to trigger allergies.

Cockroaches
Like mice and rats, cockroaches can also live for long periods of time in a home without being discovered. Their waste and dusty skin is a harmful allergen that also triggers asthma.
Meteorological Factors Affecting Air Quality

• The solution to pollution is dilution - disperse the contaminants
• Spread the contaminants around, keeping the levels below the toxic levels. (This cannot work forever.)

• Meteorological Factors affecting Dispersion
  1. The strength of the wind
  2. The stability of the air
Surface Temperature Inversions

• The temperature usually decreases as the altitude decreases.

• In an inversion, the air at some altitude becomes warmer than on the ground, so the surface air will not rise up through it.
Downtown Los Angeles
Downtown Denver
Acid Precipitation

The diagram illustrates the pH scale with various substances and their pH levels:

- Stomach acid: 0 (strongly acidic)
- Lemon juice: 2
- Carbonated soft drink: 3
- Tomatoes: 4
- Distilled water: 7 (neutral)
- Baking soda: 9 (weakly alkaline)
- Ammonia: 12 (strongly alkaline)
- Lye: 14 (strongly alkaline)

The scale ranges from 0 to 14, with 0 being the most acidic and 14 being the most alkaline.
Precipitation [pH 5.6 is good.]
How acid rain affects stonework.
The picture on the left was taken in 1908.
The picture on the right was taken in 1968.