Chapter 13
Air Pollution

Chapter Outline
• Historical Perspective
• Sources and Types of Air Pollution
  Smog
• Trends in Air Quality
• Meteorological Factors Affecting
• Acid Precipitation

Air Pollution – Meteorology
• Air Pollution Episodes or Events
  often occur when there is no major change in the output
  of contaminants

• Quantity of contaminants emitted into the atmosphere

• Atmospheric conditions promote pollution events

Air Pollution: continuing threat to our health and welfare
• Average adult male
  • 30 lbs of air/day
  • 2.6 lbs of food/day
  • 4.4 lbs of water/day

Historical Perspective
• Air is never perfectly clean
• Natural sources of pollution have always existed
  (ash, salt particles, pollen, spores, smoke from forest
  and brush fires, wind-blown dust, etc.)

• Heavilyaccentuatesaturalpollution

Historical Episodes
Before the Industrial Revolution
• Tribes were partly nomadic to get away
  from their wastes-animal, vegetable and
  human
• Fire without chimneys
• Products of incomplete combustion inside
  living quarters

Historical Episodes
Dust Bowl, Kansas 1937
**Historical Episodes**

**Before the Industrial Revolution**

- Chimney removed combustion products from inside to outside
- 61 A.D. Rome; Philosopher Seneca: “as soon as I had gotten out of the heavy air of Rome and the stink of the smoky chimneys…which poured forth…pestilential vapors and soot…I felt an alteration of my disposition

**Historical Episodes**

**The Industrial Revolution**

- 1784—Watt’s steam engine; boilers to burn fossil fuels (coal) to make steam to pump water and move machinery
- Smoke and ash from fossil fuels by powerplants, trains, ships: coal (and oil) burning = smoke, ash
- British Parliament studies 1819 1843 1848 1866 1875= lots of dirty air, nothing was done

**Smoke Abatement Era-U.S. 1880-1940’s**

- No penalties for violations in early laws
- Smoke abatement ordinances, stricter laws starting in 1940’s with penalties
- Natural gas = clean fuel
- A. Ore Smelting Era 1900-1930’s
  \[ CuS + O_2 = Cu + SO_2 \text{ (SO}_3\text{) same for Pb, Zn and Ni} \]
  \[ \text{pollutant} \]
- B. 1900—Electricity (Powerplant) + CARS

**Disaster Era—1930’s–???”

- A. Meuse Valley, Belgium, 1930
  - 1st modern air pollution disaster
  - River valley, densely populated
  - Highly industrialized
  - Winter, high barometric pressure
  - Thermal temperature inversion

**Meuse Valley, Belgium, 1930**

- 63 died (mostly elderly)
- Sore throats, shortness of breath, cough, phlegm, nausea, vomiting
- \[ SO_2 \text{ sulfur dioxide} \]
- \[ H_2O \]
- \[ SO_4 \text{ sulfuric acid mist} \]
- Cattle, birds and rats died
- Got little news coverage

**Donora, Pennsylvania—Oct. 1948**

- Monongahela River Valley
- Industrial town—steel mill, sulfuric acid plant, freight yard, etc.
- Population—14,000
- Steep hills surrounding the valley
- Oct 26—temperature inversion (warm air trapping cold air near the ground)
- Stable air, fog, lasted 4.5 days
Donora, Pennsylvania—Oct. 1948
1. 6000 people became ill
2. 20 people died
3. U.S. Public Health Service called in—first time air pollution officially recognized as potential public health problem
4. Sulfur gases + particulates, sulfuric acid mist

London
December 1952
5-day event
4000 dead
Additional events in 53 and 62

Donora, Pennsylvania—Oct. 1948

Historical Episodes

World-wide Air Pollution Episode

- November 27-December 10, 1962
- Thousands of excess deaths in many cities including NYC, London, Boston, Paris

Bhopal, India Dec. 3, 1984

- Union Carbide pesticide plant leak kills up to 2,000 with up to 350,000 injured and 100,000 with permanent disabilities
- Methyl isocyanate (MIC)—used as an intermediary in manufacture of Sevin (Carbaryl)
- CO + Cl = phosgene
- Phosgene + methylamine = MIC
- MIC—irritant to the lungs—edema, fluid (cause of death, bronchospasms, corneal opacity
- Hydrogen cyanide?
- Sabotage or industrial accident?
Similarities among Disasters

- Winter months
- Dense population
- Heavy industrialization
- Often valley
- Temperature inversion
- Stagnant air
- Accident, or mixtures from non-accidents

Sources and Types of Air Pollution

**Air pollutants:** airborne particles and gasses that occur in concentrations that endanger the health and well-being of organisms or disrupt the orderly functioning of the environment

- **Primary pollutants:** emitted directly from identifiable source
- **Secondary pollutants:** produced in the atmosphere through chemical reactions

**Sources and Types of Air Pollution**

- **Primary pollutants:***
  - Point sources: factories, power plants
  - Mobil sources: transportation, lawn mowers etc.
  - Biogenic sources: all nonanthropogenic sources (trees, vegetation, gas seeps etc.)
  - Area sources: small and individual sources (dry cleaners)

**Primary pollutants**

1. Particulate matter:
   - solid particles and liquid droplets found in air
   - Fine particles ($\text{PM}_{2.5}$) = combustion (fuel, wood)
   - Coarse particles ($\text{PM}_{10}$) = aeolian (wind blown), crushing/grinding processes
   - Most obvious form of air pollution (reduce visibility, leave film on surfaces)
Primary pollutants

2. Sulfur Dioxide (SO₂):
   - Colorless, corrosive gas
   - Combustion of sulfur-containing fuels (coal, oil)
   - Acid precipitation (H₂SO₄)
   - Reduced lung function (short-term exposure)

3. Nitrogen Oxides (NOₓ):
   - High-temperature Combustion (power plants, motor vehicles)
   - Acid precipitation (HNO₃)
   - Smog Formation

4. Volatile Organic Compounds (VOC):
   - Hydrocarbons (carbon and hydrogen)
   - Methane (CH₄)
   - Incomplete combustion of gasoline
   - React with NOₓ to form secondary pollutants

5. Carbon Monoxide (CO):
   - Colorless, odorless, poisonous
   - Incomplete burning of carbon in fuels
   - Most abundant primary pollutant

6. Lead (Pb):
   - Industrial sources
   - Automotive sources (leaded gasoline)
   - Bio-accumulates in blood, bones, soft tissues
   - Damages nervous systems (children high risk)

Secondary pollutants

form as a result of reactions between primary pollutants (acid precipitation, smog)

Smog: 1905 “smoke” & “fog”

a. London, “Classical” (coal burning, high humidity: smoke and sulfur dioxide)

b. Los Angeles “Photochemical”
   
   Sunlight triggers secondary reactions
   Ozone major component of photochemical smog
densely populated cities or urban areas, such as London, New York, Los Angeles, Mexico City, Houston, Toronto, Athens, Beijing, Hong Kong.

Secondary pollutants
- Ozone-photochemical smog-formation limited to daylight hours
  - acute: reactions within hours/days
    - decreased lung function
    - chest pain
  - chronic: gradual deterioration (O) years
    - premature aging of lungs
    - reduction in agricultural crop and commercial forest yields
    - overall weakening of forest ecosystems (disease, growth, reproduction)

Trends in Air Quality
- economic activity
- population growth
- meteorological conditions
- regulatory efforts

Clean Air Act of 1970
- Particulates
- Sulfur dioxide
- Carbon monoxide
- Nitrogen oxides
- Ozone
- Lead (added later)

Example Calculation:
- CO 9 ppm 8-hr average
  35 ppm 1-hr average

Comparison of 1970 & 2001 Emissions
- 1970 223 million tons
- 2001 170 million tons
- 24% Reduction

Keep In Mind
- Population Increase
- Miles driven/yr
**Comparison of 1970 & 2001 Emissions**

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**Population exposed to air below National Ambient Air Quality Standards in 2001**

- 133 million people
  - Ozone most severe pollution problem
- Indoor Air Pollution
  - Smoke, radon gas, formaldehyde
  - 20% of US buildings are “sick”

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**Meteorological Factors Affecting Air Pollution**

- **Wind**: dilution of pollutants
- **Atmospheric stability**
  - Surface temperature inversions
  - Inversions aloft

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**Wind Speed and Dilution of Pollutants**

- Pollution Episodes more common during calm atmospheric conditions
- High wind speed = more turbulent air = rapidly mixed with non-polluted air

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**Atmospheric stability**

- Determines the extent to which vertical motions will mix the pollution with cleaner air above
- Mixing depth = vertical distance between Earth’s surface and the height to which convectional movements extend
- Thick mixing depth = cleaner air
- Stable air suppresses convectional motions

- Absolute stability: environmental lapse rate is less than the adiabatic wet rate
Atmospheric stability
- Mixing depth = greatest during summer ‘intense solar heating’
- Winter stability enhanced by temperature inversions

Los Angeles smog on 29 January 2004

Mesoscale
Country Breeze:
Urban heat island leads to warmer temps at night
Air moves from surrounding country side to city
Traps pollutants in the center of the city

Acid Precipitation (Sulfur & Nitrogen Oxides)
Extent and potency of acid precipitation
Effects of acid precipitation
Precipitation pH ranges between 5 - 6

Acidity of Precipitation
Effects of Acid Precipitation

**Human:** upper respiratory deterioration, bronchitis among children

**Environment:** pH increase in lakes, leaching of toxins from soils, fish die off, reduction in crop yields, impair forest productivity

Stacks enhance travel of pollutants.