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

• weather conditions influence the dilution and dispersal of air pollutants

• air pollution affects weather and climate

Signs of prosperity
**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

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**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.)
- Humans accentuate natural pollution

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
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
  \[ \text{CuS} + \text{O}_2 = \text{Cu} + \text{SO}_2 (\text{SO}_3) \] same for Pb, Zn and Ni (pollutant)
• B. 1900—Electricity (Powerplant) + CARS

Disaster Era—1930’s--???

• A. Meuse Valley, Belgium, 1930
• 1\textsuperscript{st} 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
- SO₂, sulfur dioxide
- H₂O
- SO₄ 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

Historical Episodes

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

Combination of unusually cold period, coal burning, and stable atmospheric conditions under a high pressure system
Historic smog death toll rises

Officials believe that as many as 12,000 people may have died in the great London smog of 1952.

Death toll

"The interesting thing is that no one realized at the time that the no of deaths were increasing," he told the BBC. "There weren't bodies lying around in the street and no one really noticed that more people were dying."

"One of the first indications was that undertakers were running out of coffins and florists were running out of flowers. The number of deaths per day during and just after that smog were three to four times the normal."
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 (PM$_{2.5}$) = combustion (fuel, wood)
   - Coarse particles (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)

Primary pollutants

3. Nitrogen Oxides (NOₓ):

- High-temperature Combustion (power plants, motor vehicles)
- Acid precipitation (HNO₃)
- Smog Formation
Primary pollutants

4. Volatile Organic Compounds (VOC):

- Hydrocarbons (carbon and hydrogen)
- Methane (CH₄)
- Incomplete combustion of gasoline
- React with NOₓ to form secondary pollutants

Primary pollutants

5. Carbon Monoxide (CO):

- Colorless, odorless, poisonous
- Incomplete burning of carbon in fuels
- Most abundant primary pollutant

[Image: Diagram showing the sources and impact of primary pollutants]
Primary pollutants

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

[Graph showing trends in emissions from 1900 to 2000, highlighting periods such as the Great Depression and WWII, Baby Boomers Drive, and Clean Air Act 1970 Est. EPA.]
Clean Air Act of 1970

- Particulates
- Sulfur dioxide
- Carbon monoxide
- Nitrogen oxides
- Ozone
- Lead (added later)

Criteria pollutants
National Ambient Air Quality Standards (Table 13-3)

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

1970  223 million tons
2001  170 million tons
24% Reduction

Keep In Mind
Population Increase
Miles driven/yr

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”
Meteorological Factors Affecting Air Pollution

**Wind:** dilution of pollutants

**Atmospheric stability**
- Surface temperature inversions
- Inversions aloft
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

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

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**Atmospheric stability**
Inversions aloft
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