CHAPTER 10
AIR, NOISE, AND RADIATION
Objectives for this Chapter

A student reading this chapter will be able to:

1. List and explain the reasons why air pollution is considered a national and global threat.
2. Discuss and describe the chemical and physical components of the atmosphere, and explain the mechanisms of dispersion.
Objectives for this Chapter

A student reading this chapter will be able to:

- 3. Describe the regulatory efforts in the U.S. with emphasis on titles of the 1990 CAAA.
- 4. Discuss the issues behind stratospheric ozone depletion and global warming.
- 5. List and discuss the nature, sources, and health and welfare effects of the criteria pollutants.
Objectives for this Chapter

• A student reading this chapter will be able to:
  - 6. List, discuss, and describe the major sources of indoor air pollution, including health effects and methods of control.
AIR NOISE AND RADIATION

• Introduction

• History
  – Edward I and II of Great Britain severely punished air polluters
  – Until 1930s (Meuse Valley, Belgium.) air pollution considered a nuisance.
  – Air pollution episodes in Donora, PA, London England, Los Angeles, CA, NY City caused many deaths, raised public awareness.
Air pollution threatens global ecology
- Consensus grows that industrial emissions such as carbon dioxide and other greenhouse gases, are contributing to global warming.
- Chlorofluorocarbons may be depleting stratospheric ozone
- Acid deposition
AIR NOISE AND RADIATION

• Air pollution threatens human health
  – asthma, bronchitis, emphysema, cancer, respiratory infections, irritation, cardiovascular disease

• Air pollution threatens living plants and human-made structures
  – forest decline, corrosion of metal, soiling of buildings, degradation of paints, textiles, leather, paper, and dyes.
• Chemical Characteristics
  - Nitrogen (N2) represents a constant 78 percent of the 500 billion tons of air surrounding the planet, while oxygen (O2) remains steady at 21 percent, and argon (Ar) at 0.9 percent. (Fig. 10-1).
Fig. 10-1

Atmospheric gases with constant concentrations

- N₂: 78.1% 780,840 ppmv
- O₂: 20.95% 209,460 ppmv
- Ar: 0.0093%

Atmospheric gases with variable concentrations (ppmv)

- Water vapor: 0.1 - 30,000.00
- Carbon dioxide: 360.00
- Methane: 1.72
- Ammonia
- Carbon monoxide
- Nitrogen oxides total <0.5 ppmv
- Ozone
- Sulfur oxides

Concentration (ppmv)

18.18 5.24 1.14 0.5 0.09
Chemical Characteristics

- Human technology and explosive populations could potentially alter the atmospheric balance of gases causing changes in the earth-atmosphere system that jeopardizes our sustainability.
Physical Characteristics

• Solar Radiation
  – The life on earth requires a continuing source of energy.
  – More than 99 percent of the energy from the sun is within the spectral range of 150 to 4,000 nanometers (0.15 to 4.0 µm) (Fig. 10-2).
99% of sun’s energy flux is in the 140 to 4000 nanometer range

- 9% Ultraviolet
- 40% Violet-blue
- 40% Green
- 50% Yellow and Red
- 50% 700 - 4,000 Wavelength (nm) Infrared

- Gamma rays
- X-rays
- UV rays
- Infrared rays
- Radar
- FM
- TV
- AM
- Power waves

Wavelength (nm): 10-3, 10-1, 101, 103, 105, 107, 109, 1011, 1013, 1015
Solar Radiation

- Solar energy that is absorbed by ground surfaces is radiated back as heat in longer, lower energy, infrared wavelengths.

• Greenhouse Effect
  - If this reflected heat energy (infrared) is absorbed by infrared-absorbing gases or water vapor, it traps the warmth and reflects it back to the earth's atmosphere (Fig. 10-3).
Fig. 10-3

SUN

Stratospheric ozone layer absorbs some infrared and ultraviolet radiation.

OZONE LAYER

Absorption by atmospheric dust, carbon dioxide, and water vapor.

Energy radiated as heat back from land and water.

Carbon dioxide, methane, and water vapor absorb heat being radiated from the earth and redirects some of it back to the earth.

Energy is absorbed by the ground and the water.

Absorption by clouds.

Sunlight is reflected from upper surfaces of clouds.
Vertical Temperature Differences and Atmospheric Regions

– You would normally experience a declining temperature as you gained altitude at a rate of about -6.5°C/km, or a loss of about 65°C over the zero to 10 km altitude range. This region is known as the troposphere (Fig. 10-4).
Fig. 10-4

The diagram illustrates the vertical temperature profile and altitude of different layers of the atmosphere:

- **Troposphere**: The lowest layer of the atmosphere, extending from the Earth's surface up to about 10-15 km (6-9 miles). The temperature decreases with altitude in this layer due to friction with the Earth's surface.
- **Stratosphere**: Located above the troposphere, the stratosphere extends from about 10-15 km to 50 km (6-9 miles to 31 miles). The temperature increases with altitude due to the concentration of ozone molecules, which absorb ultraviolet radiation from the sun.
- **Mesosphere**: The stratosphere is followed by the mesosphere, which extends from about 50 km to 85 km (31 miles to 52 miles). The temperature continues to decrease with altitude in this layer.
- **Stratopause**: The boundary between the stratosphere and mesosphere.
- **Ozone layer at 24-40 km**: The region within the stratosphere where the ozone concentration is highest, providing protection from harmful ultraviolet radiation.

The diagram uses a hot air balloon to illustrate the concept of flying in the stratosphere, where the temperature is relatively constant due to the high concentration of ozone.
Atmospheric Pressure and Density

- About 99 percent of the atmospheric mass is below 30 km (18 miles), 90 percent is below 12 km, and 75 percent of the atmosphere is below 10 km (Fig. 10-5).
Fig. 10-5

99% of the atmosphere is below this level

Fewer molecules appear at higher altitudes producing lower densities and lower pressure.

90% is below this level

75% of the atmosphere is below this level

More molecules appear at lower altitudes producing higher densities and higher pressure.
Atmospheric Pressure and Density

- Boiling the water atop a high mountain peak will occur at a lower temperature of perhaps 90°C, since the pressure is lower and gaseous vapors can escape more readily under lower pressure (Fig. 10-6).
Lower pressures at higher altitudes permit vapors from boiling water to escape more easily, thereby keeping the boiling temperature lower.

Higher pressures at lower altitudes restrict the escape of vapors from boiling water thereby keeping the boiling temperature at 100°C at sea level.
Atmospheric Pressure and Density

- Friction, Coriolis force, and differential warming cause air to flow into regions of low pressure or in a cyclonic or motion and then to rise. (Fig. 10-7).

- When cool air descends, it readitea outward in a motion known as anticyclonic. This motion is clockwise in the northern hemisphere (Fig. 10-7)
Warm air flows into regions of low pressure and rises. This pattern is counterclockwise in the northern hemisphere.

Cool air descends and radiates outward. This is clockwise in the northern hemisphere.
Atmospheric Inversions

- The warmer the air mass in relation to its surroundings, the more rapidly it will rise (Fig. 10-8).
  - Normal lapse rate
  - Adiabatic lapse rate
  - Environmental lapse rate
Fig. 10-8

The figure shows a graph depicting the relationship between temperature and altitude, illustrating different lapse rates. The graph is divided into two panels:

- Left panel: Shows the Adiabatic lapse rate, where air rises quickly, producing good dispersion.
- Right panel: Shows the Environmental lapse rate, where air is stable, unable to rise, producing poor dispersion.

The graph includes temperature scales from 20°C to 22°C and altitude in meters from 0 to 100 meters, with a shaded area indicating the different lapse rates.
Atmospheric Inversions

- There are two primary types of inversions
  - Radiation inversion
    - Occur at night, and are short lived
  - Subsidence inversion (Fig. 10-9)
    - Occur mostly during fall and winter months, may persist for days.
Cool, dense air flows into the valley leaving warmer, inversion layer above that can trap pollutants in industrialized river valleys.
THE HISTORY OF AIR POLLUTION CONTROL IN THE UNITED STATES

- 1955- Congress authorized the Public Health Service in the Department of Health, Education and Welfare (DHEW)
- 1963- Clean Air Act
- 1967- Comprehensive Air quality act
- 1970- CAAA
- 1977- more amendments
- 1990 Clean Air Act Amendments
• Title I: Provisions for Attainment and Maintenance of the NAAQS
  – The 1990 CAAA attempts to strengthen the provisions protecting the public against seven of the most widespread and common pollutants designated as criteria pollutants (Table 10-1).
<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>AVERAGING TIME</th>
<th>PRIMARY STANDARD</th>
<th>MAIN SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>8 hours</td>
<td>9.0 ppm</td>
<td>Transportation</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>3 hours (6-9 am)</td>
<td>160 µg/m³</td>
<td>Transportaion, Industrial processes</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Annual average</td>
<td>0.05 ppm</td>
<td>Stationary source fossil fuel combustion, Transportation.</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>Annual average</td>
<td>0.03 ppm</td>
<td>Stationary source fossil fuel combustion.</td>
</tr>
<tr>
<td>Particulates PM\textsubscript{10}</td>
<td>Annual arithmetic mean</td>
<td>50 µg/m³</td>
<td>Multiple sources including stationary source fossil fuel combustion, industrial processes, and transportation. Fine particles are associated with photochemicals products of fossil fuel combustion</td>
</tr>
<tr>
<td>Particulates PM\textsubscript{2.5}</td>
<td>Annual arithmetic mean</td>
<td>15 µg/m³</td>
<td>Multiple sources including stationary source fossil fuel combustion, industrial processes, and transportation. Fine particles are associated with photochemicals products of fossil fuel combustion</td>
</tr>
<tr>
<td>Particulates PM\textsubscript{2.5}</td>
<td>24 hr. average</td>
<td>65 µg/m³</td>
<td>Multiple sources including stationary source fossil fuel combustion, industrial processes, and transportation. Fine particles are associated with photochemicals products of fossil fuel combustion</td>
</tr>
<tr>
<td>Ozone</td>
<td>1 hour</td>
<td>0.12 ppm</td>
<td>Secondary pollutant formed in presence of sunlight, NOx, and hydrocarbons. Fossil fuel combustion is a major contributor</td>
</tr>
<tr>
<td>Ozone</td>
<td>8 hour</td>
<td>0.08 ppm</td>
<td>Secondary pollutant formed in presence of sunlight, NOx, and hydrocarbons. Fossil fuel combustion is a major contributor</td>
</tr>
<tr>
<td>Lead</td>
<td>3 months</td>
<td>1.5 µg/m³</td>
<td>Food, dust, older houses with lead paint,</td>
</tr>
</tbody>
</table>

*July 1997 amendments to the 1990 CAAA.
The 1990 CAAA

- National Ambient Air Quality Standards (NAAQS).
- Non-attainment areas
- Air quality control regions
  - (BACT)
Title II: Provisions Relating to Mobile Sources

- Automobiles account for the greatest combined amount of criteria pollutants including carbon monoxide, hydrocarbons, and nitrogen-oxides.
Title II: Provisions Relating to Mobile Sources

- SOVs
- Recapture nozzles
- Reformulated gasoline
  - Methyl-t-butyl ether
Title III: Air Toxics

- Bhopal India, 1984
- SARA “Right to know”
- (MACT)
Title IV: Acid Deposition Control

- Acid Deposition
  - Emissions of nitrogen and sulfur oxides are partially converted in the atmosphere to nitric and sulfuric acids which return to the earth in rain, snow, fog and on dry particles.
Title IV: Acid Deposition Control

- Market-based principles
  - Emission banking
  - Trading
- An allowance is defined under 1990 CAAA as the right to emit one ton of sulfur dioxide.
Title V: Permits

- Regulated sources must obtain a permit.
  - Based on program similar to National Pollution Elimination Discharge System (NPDES)
  - State programs must be approved by the USEPA.
  - Fee is charged to cover cost of permitting.
Title VI: Stratospheric Ozone and Global Climate Protection

- Mario Molina, Sherwood Rowland and Max Planck received the Nobel Prize for chemistry in 1995 for their work in establishing that CFCs were destroying the ozone layer (Fig. 10-10).
Chlorine monoxide combines with an oxygen atom to form molecular oxygen and a free chlorine atom.

Free chlorine is then available to attack more ozone molecules. This can be repeated thousands of times for each chlorine atom.

Chlorofluorocarbons (CFCs) are released from air conditioners, refrigerators, and some industrial uses. The CFCs rise to the stratosphere.

UV light breaks the chlorine free from the CFC molecule.

UV light from the sun impacts ozone to create $O_2$ and chlorine monoxide.
The World Meteorological Organization reports that the ozone hole over Antarctica peaked at 7.7 million square miles and lasting for 50 days.
Title VI: Stratospheric Ozone and Global Climate Protection

- Montreal Protocol
  - Phase out CFCs
  - Substitutes
  - As a result production is down and the accumulation rate of CFCs has decreased although the Antarctic stratospheric ozone levels are expected to decline for years (Fig. 10-11).
Fig. 10-11

Antarctic Ozone Hole
(Minimum values)

Date range included: 9 Sep. - 10 Oct.

Dobson units

Year

Health and Welfare Impacts of Ozone Depletion

• The destruction of the ozone layer could result in:
  – 1. Increases in basal and squamous cell skin cancer;
  – 2. Suppression or weakening of the human immune response system;
  – 3. Damage to the cornea and conjunctiva of the eye;
Health and Welfare Impacts of Ozone Depletion

- The destruction of the ozone layer could result in:
  - 4. Reduction in plant leaf size, total dry weight, and stunting of plant growth; and
  - 5. decreased amounts of phytoplankton and zooplankton.
Revised Ozone and Particulate Standards

- Ground-level ozone is a major component of smog that is photochemically produced as a secondary pollutant of the stratosphere from the interaction of sunlight, nitrogen oxides and hydrocarbons.
Revised Ozone and Particulate Standards

- **Ozone**
  - 1979- 0.12 ppm, one hr
  - 1997- 0.08 ppm, eight hours

- **Particulates**
  - 24 hr PM$_{2.5}$ - 65 μg/m$^3$
  - Annual PM$_{10}$ - 50 μg/m$^3$
The Issue of Global Warming

• The Hot Air Treaty, Kyoto, Japan
  – The global warming treaty completed in December 1997 (Kyoto, Japan), asked Western nations to reduce greenhouse gases to pre-1990 levels by 2010.
Global Warming: The Controversy

- Human activities may have upset the balance of atmospheric carbon dioxide through:
  - (1) the combustion of fossil fuels which releases carbon oxides;
  - (2) the burning of forests which produces CO2 and removes a vital consumer of CO2; and
  - (3) the destruction of phytoplankton by pollution of the oceans.
Global Warming: The Controversy

• An increasing blanket of carbon dioxide around the planet absorbs some of the IR energy radiating away from the earth, trapping it and causing the earth to warm in a process known as the greenhouse effect (Fig. 10-12).
Longer wavelength, lower energy, infrared is reflected back towards space.

Some of this energy is absorbed by CO$_2$, methane, and O$_3$, and reflected back to the earth much like a greenhouse contains heat when sunlight passes into it.

Higher energy, shorter wavelengths are absorbed by the ground and water.

Atmosphere containing greenhouse gases.
Global Warming: The Controversy

- Global warming is a concern because:
  - (1) icebergs the size of small states have broken off the Antarctic ice shelf;
  - (2) the annual average global temperature has risen by about 0.5°C (1°F) since the 19th century;
Global warming is a concern because:

- (3) global sea is rising faster (3 min/yr);
- (4) 1990, 1995, and 1997 were the warmest years in the last 600 yrs;
- (5) mountain glaciers are rapidly retreating.
Global Warming: The Controversy

• Climate is affected by:
  – 1. increases in atmospheric gases that absorb energy;
  – 2. changes in the earth's orbital geometry;
  – 3. changes in oceans temperature;
  – 4. volcanic activity; and
  – 5. variations in solar radiation.
Factors Effecting Global Climate Change

- Orbital Geometry As A Factor Effecting Climate
  - Records show that mean global temperatures fluctuated widely with transitions from warm to cold often measured in decades (Fig 10-14).
Mean Greenland temperatures over 160,000 years derived from ice core samples.

- Glaciation
- Warming
- Glaciation
- Younger Dryas Period (12,000 years ago)
- Civilization begins 10,000 years ago

Thousands of years BCE

Present

-50°F to 50°F Fahrenheit
What events caused such drastic changes?

- Milankovitch theories
  - Eccentricity
  - Obliquity
- Brodkerad and Denton
  - Ocean currents
Factors Effecting Global Climate Change

- El Nino
  - El Nino is a change or shift in ocean temperatures along with atmospheric conditions in the tropical Pacific that changes weather patterns all around the world (Fig. 10-15).
Fig. 10-15

Japan had extensive snow cover in Nagano during the Olympics.

Heavy blizzards blanketed the West coast of the U.S. all the way to New Mexico.

The northeastern U.S. experienced an unusually mild winter in 1997.

Eastern Africa suffered from heavy rains and floods.

Indonesia had severe droughts and lost over one million acres to fires.

Brazil experienced an extended drought.

Extensive flooding caused many deaths and extensive damage in Peru and Ecuador.
Factors Effecting Global Climate Change

• Volcanic Activity
  - Volcanic eruptions in the modern era may have extreme localized effects on land, and may cause short-term global changes in weather patterns as sunlight is inhibited by a layer of particles thrust into the atmosphere.
Factors Effecting Global Climate Change

- Solar Radiation
  - Sunspots show cycles of 11 and 22 years that correlate with nearly half of the global warming evidenced over the last 100 years.
The Criteria Pollutants

• Introduction
  – Nearly 46 million people live in counties that fail to meet the air quality standards for one or more of the criteria pollutants (Table 10-2).
  – A summary of criteria pollutants sources, health and welfare effects is presented in Table 10-3.
<table>
<thead>
<tr>
<th>CRITERIA POLLUTANTS</th>
<th>PERCENT CHANGE IN AMBIENT CONCENTRATIONS FROM 1970-1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>-31%</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>+8%</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>-39%</td>
</tr>
<tr>
<td>Particulates (PM$_{10}$)</td>
<td>-73%</td>
</tr>
<tr>
<td>Ozone</td>
<td>-38%</td>
</tr>
<tr>
<td>Lead</td>
<td>-98%</td>
</tr>
<tr>
<td>CRITERIA POLLUTANTS AND SOURCES</td>
<td>HEALTH EFFECTS</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>Carbon monoxide</strong>&lt;br&gt;Incomplete combustion of fossil fuels as in vehicles, kerosene heaters, boilers, and furnaces. Cigarette smoking, forest fires, and biological decomposition.</td>
<td>Interferes with oxygen transport in blood by binding with hemoglobin. Causes headaches, fatigue, cardiovascular disease, and central nervous system disorders.</td>
</tr>
<tr>
<td><strong>Nitrogen dioxide</strong>&lt;br&gt;Emitted from the combustion of fossil fuels in vehicles, industrial boilers, and electric generating utilities.</td>
<td>Causes increased risk of respiratory infections and aggravates symptoms in persons with asthma and chronic bronchitis.</td>
</tr>
<tr>
<td><strong>Sulfur dioxide</strong>&lt;br&gt;Fossil fuel combustion especially in coal-burning electric power utilities, metal smelters, oil refineries, and industrial boilers.</td>
<td>Causes irritation of the throat and lungs and aggravates symptoms in persons with asthma and chronic bronchitis.</td>
</tr>
<tr>
<td><strong>Particulates</strong>&lt;br&gt;PM_{10} and PM_{2.5}&lt;br&gt;Fossil fuel combustion emissions, industrial processes, photochemical reactions in atmosphere, mechanical abrasion.</td>
<td>Aggravates asthma, heart disease, and chronic lung disease. Alters lung's natural cleansing mechanisms. Smaller particles associated with the most severe symptoms.</td>
</tr>
<tr>
<td><strong>Ozone</strong>&lt;br&gt;A product of NOx emissions from motor vehicles, power utilities, and industries burning fossil fuels, combined with hydrocarbons and sunlight in the atmosphere.</td>
<td>Causes breathing difficulty, irritation to mucous membranes, and increases risk to respiratory infections. Acute exposures cause respiratory pain, bronchoconstriction, lung edema, and abnormal lung development.</td>
</tr>
<tr>
<td><strong>Lead</strong>&lt;br&gt;Historically emitted from vehicles burning leaded gasoline. Emissions have been reduced by 98% since 1974. Most lead exposures in US today are not airborne.</td>
<td>Damage to nervous system, blood forming tissues, kidneys. Evidence of neurobehavioral disorders including learning disabilities, and antisocial behavior.</td>
</tr>
</tbody>
</table>
The Criteria Pollutants

• Particulate Matter
  – Particulate pollutants include airborne particles in liquid solid form that range in size from visible fly ash greater than 100 µm to particles 0.005 µm in size (Table 10-4).
<table>
<thead>
<tr>
<th>PARTICULATE SIZE</th>
<th>PARTICULATE SOURCES</th>
<th>CHEMISTRY</th>
</tr>
</thead>
</table>
| **Coarse Particles**  
These are coarse particles from 1 - 100 μm including the course fraction PM\textsubscript{10} (2.5 - 10 μm). | Industrial and mechanical processes such as fragmentation of matter and atomization of liquids. Agricultural and forestry activities, and dust from unpaved roadways, mold spores, and wood ash. | Silicon, aluminum, iron, potassium, and calcium are common components. The coarse particle samples tend to be alkaline. |
| **Fine Particles**  
These are fine particles less than 1 μm, but including much of the mass of the PM\textsubscript{2.5} fraction. The PM\textsubscript{2.5} fraction consists of fine particles less than 1.0 μm and some coarse particles in the 1-2.5 μm range. | Industrial and residential combustion of fossil fuels. Secondary particles produced by direct, catalytic, and photochemical oxidation of nitrogen and sulfur compounds, and volatile hydrocarbons to produce sulfates, nitrates, and oxyhydrocarbons. | Elemental and organic carbon such as from fuel combustion (soot), sulfates, nitrates, condensed organic compounds, oxyhydrocarbons, and trace metals. The fine particle samples tend to be acidic. |
Ozone And The Photochemical Oxidants

- An oxidant is a substance that readily gives up an oxygen atom, or removes hydrogen from a compound.
- Photochemical refers to the initiation of these reactions by sunlight.
Ozone And The Photochemical Oxidants

- Good O$_3$ vs. Bad O$_3$
- The bad ozone is formed on the troposphere (nose-level) by a complex series of reactions (10-16).
Fig. 10-16

1. \( \text{NO}_2 + \text{hv} \rightarrow \text{NO} + \text{O} \) (ultraviolet light (430 nm))
2. \( \text{O}_2 + \text{O} \rightarrow \text{O}_3 \)
3. \( \text{O}_3 + \text{NO} \rightarrow \text{O}_2 + \text{NO}_2 \)
4. \( \text{RO}_2 + \text{NO} \rightarrow \text{NO}_2 + \text{RO}_2 \)

Alkyl peroxy radicals formed by oxidation of hydrocarbons.

When NO is oxidized to \( \text{NO}_2 \) by peroxy radicals (\( \text{RO}_2 \)), NO is no longer available for oxidation by \( \text{O}_3 \) and so the ozone persists in the atmosphere.
The Criteria Pollutants

• Carbon Monoxide
  – produced from the incomplete combustion of fossil fuels
  – enters the blood streams through the lungs and combines with hemoglobin of red blood cells to form carboxyhemoglobin.
  – levels of carboxyhemoglobin rise and the adverse effects associated with oxygen deficiency are observed.
The Criteria Pollutants

• Lead
  – The association of lead with behavioral problems and reduced intellectual ability caused lead to be placed on the list of criteria pollutants in 1977 when the Clean Air Act was re-authorized.
The Criteria Pollutants

• Lead
  – The phase-out of leaded gasoline has been the predominant control strategy.
  – Lead emissions from highways have decreased 99 percent since 1987
Sulfur or Oxides

- Health and Welfare Effects
  - The primary source of sulfur emissions are electric utilities.
  - Health concerns associated with SO$_2$ include respiratory illness, effects on breathing, a reduction in lung defenses, and aggravation of existing cardiovascular disease.
Sulfur or Oxides

• Acid Deposition
  – Sulfur oxides are among the main precursors to acid deposition, with nitrogen oxides being the second greatest contribution.
  – Since acidity may be found in rain, sleet, snow, fog, clouds, and adsorbed to particle, the term acid rain is being replaced by the term acid deposition.
Effects of Acid Deposition on Ecology

- Long distance transport
- Acidification of acid sensitive ecosystems (Fig. 10-17)
Fig. 10-17

Acid sensitive regions
Effects of Acid Deposition on Ecology

• Aquatic Systems
  – The spring thawing of acidic ice and snow results in shock loading.
  – The aquatic life in a body of water will experience recruitment failure when the pH falls below 5.5.
Effects on Forests and Plants:

- 1. directly damages leaves;
- 2. mobilizes toxic metals in the soil;
- 3. leaches nutrients from soil;
- 4. excess nitrates over stimulates plants.
Current Directions in $SO_x$ Control:

- (1) switching to low sulfur coal;
- (2) using scrubbers to remove $SO_2$ emissions;
- (3) washing coal removes up to 50% of the sulfur;
- (4) advanced combustion technologies.
HEALTH IMPLICATIONS OF AIR POLLUTANTS

• Fine particulates from motor vehicles and power plants are reported to kill some 64,000 Americans a year and may be a major contributor to the epidemic of childhood asthma sweeping the country (Fig. 10-18, 19).
**Fig. 10-18**

ASTHMA ATTACK
Beginning Signs
- Wheezing
- Coughing
- Difficulty in breathing

Extended Attack
- Sweating
- Pulse becomes rapid
- Skin turns blue
- Arms and legs become chilled or cold

**Bronchiole**
- Muscles contract and membranes swell around bronchioles.
- Mucous forms in airways.
- Narrowed airway makes breathing difficult.

**NORMAL AIRWAY**

**AIRWAY IN SPASM**
Fig. 10-19

Asthma Prevalence, 1982-1993

- Age (years)
  - <18
  - All ages

Percent

Source: NHLBI Data Fact Sheet, October 1995
Main Mechanisms of Air Pollutant Effects on Respiratory System

- Pollutants may produce their adverse effects by:
  - (1) inhibiting and inactivating mucociliary streaming;
  - (2) killing or neutralizing alveolar macrophages;
Pollutants may produce their adverse effects by:

- (3) constricting airways;
- (4) causing vasodilation and excess mucous secretion; or
- (5) causing changes in alveolar cell wall structure through abscesses and thickening which causes scar formation.
Indoor Air Pollution

• People spend an average of 90 percent of their time indoors while some at-risk subgroups such as the elderly, very young, and chronically ill may spend nearly all their time indoors.
Sources of Indoor Air Pollution

- Acid, coal, gas, oil
- Cleaning products
- Furnishings, carpets
- Paints (VOCs)
- Radon
- Moisture, molds, etc. (Fig. 10-20)
Fig. 10-20

POTENTIAL SOURCES OF INDOOR AIR POLLUTANTS:

1. Moisture
2. Pressed wood furniture
3. Contaminated humidifier
4. Moth repellant
5. Personal care products
6. Room air fresheners
7. Chemical cleaners and disinfectants
8. Pressed wood cabinets
9. Unvented gas stove
10. Household chemicals
11. Tobacco smoke
12. Wood stove
13. Wood paneling
14. Asbestos pipe insulation
15. Unvented dryer
16. Radon infiltration
17. Pesticides
18. Auto exhaust
19. Auto cleaners and additives
20. Paints, thinners, and stains
Sources of Indoor Air Pollution

- Ventilation is an effective way to reduce indoor concentrations of contaminants.
  - Natural Ventilation
  - Infiltration
  - Mechanical Ventilation
Signs of Indoor Air Pollution

• Physical symptoms may include:
  – (1) heating or cooling equipment that is dirty and/or moldy;
  – (2) moisture condensation on walls and windows;
  – (3) air that has a stuffy or has an unpleasant odor; and
  – (4) signs of water leakage anywhere in the building with the growth of molds.
Signs of Indoor Air Pollution

- Health indicators may include:
  - immediate or acute effects such as eye irritation, dry throat, headaches, fatigue, sinus congestion, sun irritation, shortness of breath, cough, dizziness, nausea, sneezing, and nose irritation.
Signs of Indoor Air Pollution

- When a number of occupants of a building display acute symptoms without a particular pattern and the varied symptoms cannot be associated with a particular source, the phenomenon is often referred as sick building syndrome (SBS).
Common Sources of Indoor Air Pollution

- The most common sources of indoor pollution include: environmental tobacco smoke, radon, biologicals, nitrogen dioxide, carbon monoxide, organic gases, formaldehyde, respirable particles and pesticides.
Environmental Tobacco Smoke (ETS and Other Combusted Materials)

- Smoking contributes to nearly 500,000 deaths each year in the United States.
- Main-stream smoke
- Side-stream smoke
- Environmental tobacco smoke (ETS)
Radon

- Radon is a colorless, odorless gas that occurs naturally by the decay of radium-226.
- As the uranium naturally radioactively decays it releases radon gas that further decays into short-lived, radon daughters and gamma rays (Fig. 10-21).
Fig. 10-21

3.8 days

222 Radon

$\alpha, \gamma \downarrow$

3 minutes

218 Polonium

$\alpha, \gamma \downarrow$

27 minutes

214 Lead

19.7 minutes

214 Bismuth

$\beta, \gamma \downarrow$

1.6X10^{-4} seconds

214 Polonium

$\beta, \gamma \downarrow$

19.4 Years

210 Lead
Radon

• Once lodged in human tissue, the radioactive materials increase the risk of lung cancer causing from 5,000 to 20,000 excess cancer deaths a year in the United States.
Radon Detection

- FCR 4pCi/L or above calls for action
- Alpha track detectors

• Mitigation
  - Basement ventilation
  - Sealing cracks, joints, walls, etc.
**Biological Contamination**

- Common biological contaminants include molds, mildew, viruses, bacteria, dust mites, cockroaches, pollen, animal dander, and cat saliva.

- The major threat to the biological contaminant of the home is moisture.
Biological Contamination

• Possible symptoms of illness caused by biological contaminants include running nose, colds, flu-like symptoms, headaches, unexplained fatigue, and digestive problems.
Organic Gases, Pesticides

- Paints, strippers, disinfectants, cleaners, repellants, automotive products, hobby supplies, volatile office supplies, and pesticides which are found indoors can emit potentially hazardous materials.
Formaldehyde (HCHO)

- Formaldehyde is found in pressed wood products such as cabinets and furniture made from plywood, particleboard, wall paneling, and fiberboard.
Formaldehyde (HCHO)

- Exposure to formaldehyde can produce adverse health effects including irritation to the mucous membranes, severe allergic reactions, fatigue, wheezing, and coughing.