Chapter 15—Air Pollution and Stratospheric Ozone Depletion

Cleaning Up in Chattanooga (p. 517-8)

Module 46—Major Air Pollutants and Their Sources

After reading this module, you should be able to

• identify and describe the major air pollutants.
• describe the sources of air pollution.

Air Pollution is a global system

What does that mean?

• ___________________________ The introduction of chemicals, particulate matter, or microorganisms into the atmosphere at concentrations high enough to harm plants, animals, and materials such as buildings, or to alter ecosystems.
• The air pollution system has many ___________________ (sources of pollution) and __________________ (components that remove pollution).

Classifying Pollutants

Under the Clean Air Act, the EPA must specify allowable concentrations of certain pollutants. How do you think the pollutants are determined?

Sulfur dioxide (SO₂):

• A corrosive gas that comes primarily from combustion of fuels such as __________ and ____________.
• A ___________________________ irritant and can adversely affect plant tissue.
• Also released in large quantities during ____________________________ eruptions and in much smaller quantities, during ________________________________.

Nitrogen Oxides (NOₓ): (mainly NO and NO₂)

• Motor vehicles and stationary fossil fuel combustion are the primary __________________________ sources of nitrogen oxides.
• ___________________________ irritant, increases susceptibility to respiratory infection.
• An ____________________________ precursor, leads to formation of photochemical smog.
• Converts to ____________________________ in atmosphere, which is harmful to aquatic life and some vegetation.
• Contributes to __________________________ terrestrial and aquatic systems.
• Natural sources include forest _____________________, lightning, and microbial action in soil.

Carbon Oxides:

• Carbon monoxide (CO) is a common emission in ____________ exhaust and most other __________________ processes.
• CO can be a significant component of air pollution in ______________________ areas.
• Carbon dioxide (CO₂) released by burning __________________________ has led to its becoming a major pollutant.
• CO₂ recently exceeded a concentration of _______________ parts per million in the atmosphere and appears to be steadily increasing each year.

Remember the 3 main gases emitted during combustion of fossil fuels by “Socks, Nocks, and CO₂.”

Particulate Matter

_________________________ (PM) Solid or liquid particles suspended in air. Also known as Particulates; Particles.

Sources include

How does the size of particulate matter affect our concern about it?

Larger than 10 μm is filtered by ________________ and not a concern

Particulate matter-10 (PM₁₀)(smaller than 10 mm) can be deposited in the respiratory tract—a concern

PM₂.₅ are even greater concern

__________________________ Reduced visibility.

__________________________ A class of air pollutants formed as a result of sunlight acting on compounds such as nitrogen oxides.

__________________________ A secondary pollutant made up of three oxygen atoms bound together.

Photochemical smog Smog that is dominated by __________________. Also known as Los Angeles-type Smog; Brown smog.

Sulfurous smog Smog dominated by __________________ and sulfate compounds. Also known as London-type smog; _______________smog; _______________smog.

Lead:

• A gasoline additive, also found in ____________________________

• Impairs ____________________________

• At low concentrations, can have measurable effects on ____________________________ and ability to ____________________________

Volatile organic compound (__________) An organic compound that ____________________________ at typical atmospheric temperatures.

• Formed by ____________________________ of fuels, solvents, paints, and improper combustion of fuels such as gasoline.

• A precursor to ____________________________ formation.

Primary and Secondary Pollutants

• Primary pollutant A polluting compound that comes directly out of a smokestack, exhaust pipe, or natural emission source.

• Examples include ____________________________, and most suspended particulate matter.

• Secondary pollutant A primary pollutant that has undergone transformation in the presence of ____________________________, ____________________________, ____________________________, or other compounds.

• Examples include ____________________________
Review

Why is air pollution considered a global system?

What are the major air pollutants?

What is the difference between a primary and a secondary pollutant?

Air pollution comes from both natural and human sources

- Natural emissions of pollution include
  - (________________________ (________________________ __________________________),
  - (________________________)
  - (________________________)
  - (________________________)
  - (________________________, both living and dead (________________________
    __________))
  - Responsible for the ______________________________________________

- Anthropogenic sources include on-road ____________________________,
  __________________________, __________________________ processes,
  (incinerator).

- In the United States, emissions from human activity are __________________________,
  __________________________, and in many cases __________________________.

- Some anthropogenic sources are on-road ____________________________,
  __________________________, __________________________ processes, and
  __________________________.

- The Clean Air Act and its various amendments require that __________________________ establish standards to
  control pollutants that are harmful to “human health and welfare”.

- Through the National Ambient Air Quality Standards (NAAQS) the EPA periodically specifies
  __________________________ for each air pollutant.

Use Figure 46.5 (p. 525) to fill in the following table:

<table>
<thead>
<tr>
<th>Major anthropogenic emissions</th>
<th>Top two sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td></td>
</tr>
<tr>
<td>Particulate matter</td>
<td></td>
</tr>
</tbody>
</table>

Use Figure 46.6 (p. 526)
For which six criteria air pollutants has the EPA set concentration limits?
Which air pollutant had the largest decrease in the US between 1990 and 2010? Why?

Which of the six criteria air pollutants did not change much between 1990 and 2010? Why?

p. 527 Review questions

What is the difference between stratospheric ozone depletion and ground-level ozone?

Module 47—Photochemical Smog and Acid Rain

After reading this module, you should be able to
• explain how photochemical smog forms and why it is still a problem in the United States.
• describe how acid deposition forms and why it has improved in the United States and become worse elsewhere.

Photochemical smog remains an environmental problem in the United States
• The formation of this photochemical smog is complex and still not well understood.
• A number of pollutants are involved and they undergo a series of complex transformations in the atmosphere.

The Chemistry of Ozone and Photochemical Smog Formation (Fig. 47.1, p. 528)
(a) In the absence of VOCs, ozone will form during the daylight hours. The reactions are

(b) After sunset, the ozone will break down. The reaction is

(c) In the presence of VOCs, ozone will form during the daylight hours. The VOCs combine with nitrogen oxides to form photochemical oxidants, which reduce the amount of ozone that will break down later and contribute to prolonged periods of photochemical smog. The reactions are

Video: Greenhouse Gases—National Geographic

Thermal Inversions
• **Thermal inversion** A situation in which a relatively ________________ layer of air at mid-altitude covers a layer of ________________, ________________ air below.
• **Inversion layer** The layer of warm air that traps ________________ in a thermal inversion.
• The warm inversion layer traps emissions that then accumulate beneath it.
• Thermal inversions that create pollution events are particularly common in some cities, where high concentration of ____________________________ and ____________________________ are easily trapped by the inversion layer.

Figure 47.2, p. 529
• (a) Under normal conditions, where temperatures ______________________ with increasing altitude, emissions ______________________ into the atmosphere.
• (b) When a mid-altitude, relatively warm inversion layer blankets a cooler layer, emissions are ______________________ and ______________________.

Video: Thermal Inversion
• Why does the inversion layer increase air pollutants at the surface?

Acid deposition has improved in the United States
• Acid deposition occurs when ______________________ and ______________________ are released into the atmosphere and combine with atmospheric oxygen and water. These form the secondary pollutants ______________________ and ______________________.
• The secondary pollutants further break down into ______________________ and ______________________, and ______________________ ions (H+) which cause the acid in acid deposition.
• Acid deposition has been ______________________ in the United States as a result of lower sulfur dioxide and nitrogen oxide emissions.

How Acid Deposition Forms and Travels
The primary pollutants sulfur dioxide and nitrogen oxides are ______________________ to acid deposition. After transformation to the secondary pollutants—____________________, acid— dissociation occurs in the presence of water. The resulting ions—hydrogen, sulfate, and nitrate—cause the adverse ecosystem effects of acid deposition.

Effects of Acid Deposition
Acid deposition has many harmful effects:
• Lowering the _______ of lake water
• Decreasing species ______________________ of aquatic organisms
• Mobilizing ______________________ that are found in soils and releasing them into surface waters
• Damaging ______________________, ______________________, and ______________________

Video: Appalachian Trail: Acid Rain: invisible Menace

How is agricultural land affected by acid rain?

How are aquatic ecosystems affected by acid rain?
How are terrestrial ecosystems affected by acid rain?

How is human construction affected by acid rain?

p. 532 Review questions

Module 48—Pollution Control Measures

After reading this module, you should be able to
• explain strategies and techniques for controlling sulfur dioxide, nitrogen oxides, and particulate matter.
• describe innovative pollution control measures.

Pollution control includes prevention, technology, and innovation

Ways to address air pollution:
• Avoid ______________________ in the first place.
• Use ______________________ fuel.
• Increase ______________________.
• Control ______________________ after combustion.
• Pollution control includes ______________________, ______________________, and ______________________

Ways of controlling emissions:
• Remove ______________________ ______________________ from coal by fluidized bed combustion.
• Install ______________________ ______________________ on cars.
• Use ______________________ filters.
• Use ______________________ precipitators.
• Install ______________________ on smokestacks.

Control of Particulate Matter

In this air pollution control device, particles are “______________________” from the exhaust stream by ______________________ droplets. A water-particle “______________________” is collected and processed for disposal.

Around the world people are implementing ______________________ pollution control measures

Municipalities have tried a number of strategies:
• Reduce ______________________ spilled at the pump, restrict evaporation of ______________________ fluids, and the use of ______________________ fluid.
• Reduce use of ______________________ stoves and ______________________.
• Limit ______________________ to every other day use or charge user fees for roads during heavy commute times.
Module 49—Stratospheric Ozone Depletion

**After reading this module, you should be able to**

- explain the benefits of stratospheric ozone and how it forms.
- describe the depletion of stratospheric ozone.
- explain efforts to reduce ozone depletion.

Stratospheric ozone is beneficial to life on Earth

- The stratospheric ozone layer exists roughly ______________ kilometers above Earth.
- Ozone has the ability to absorb __________________ radiation and protect life on Earth.
- The ultraviolet (UV) spectrum is made up of three increasingly energetic ranges: __________________

UV radiation of all types can damage the tissues and DNA of living things.

**UV-B**
- Increases the risk of __________________________ and __________________________
- Suppresses the __________________________ system
- Harms plant cells and reduces their ability to convert __________________________ to usable __________________________

What is the difference between stratospheric ozone and tropospheric ozone?

Formation of Stratospheric Ozone

- **UV-C radiation breaks the molecular bond holding an oxygen molecule together:**

  - A free oxygen atom (O) produced in the first reaction encounters an oxygen molecule, and they form ozone.

  - Both UV-B and UV-C radiation can break a bond in this new ozone molecule:

  - This cycle continues indefinitely, keeping the level of ozone __________________________ UNDER NORMAL CONDITIONS

Breakdown of Stratospheric Ozone

- When chlorine is present (from chlorofluorocarbons, or _______________), it can attach to an _______________ atom in an ozone molecule to form chlorine monoxide (ClO) and O₂:

  - The chlorine monoxide molecule reacts with a free oxygen atom, which pulls the oxygen from the ClO to produce free chlorine again:
• Chlorine helps the reaction occur, but is not used up. This makes it a ________________________.
• A single chlorine atom can catalyze the breakdown of as many as _____________ ozone molecules until finally one chlorine atom finds another and the process is stopped.
• In the process, the ozone molecules are no longer available to absorb incoming _____________ radiation.
• As a result, the UV-B radiation can reach Earth’s surface and cause ________________ to biological organisms.

Depletion of the Ozone Layer (page 540)
This data for one area of Switzerland shows a generally ________________ trend from 1970 to 2011.

Levels of ozone vary during seasonal changes, especially at the poles. It is believed that ice crystals promote the formation of ________________, reducing the reaction of ____________ with ozone.

Montreal Protocol on Substances that Deplete the Ozone Layer
• Signed by 24 nations in 1987; reduces CFC by 50% by 2000
  • Eventually over 180 countries committed to eliminating ________ ozone depleting compounds
  • Cl in the atmosphere is believed to be ________________ and should eventually be ________________

<table>
<thead>
<tr>
<th>Location</th>
<th>Environmental effects</th>
<th>Significant chemical involvement</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratospheric ozone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground-level ozone</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p. 541 Review Q
Module 50—Indoor Air Pollution

After reading this module you should be able to

• explain how indoor air pollution differs in developing and developed countries.
• describe the major indoor air pollutants and the risks associated with them.

Indoor air pollution is a significant hazard in developing and developed countries

• Around the world, many people burn ________________, ________________or ________________indoors for heat and cooking.
• Without proper ventilation, high levels of ________________and ________________are produced.
• Worldwide, approximately ________________deaths each year are attributable to indoor air pollution.
• Ninety percent of these deaths are in ________________countries.
• More than 50 percent are ________________.

Indoor Air Pollution in Developed Countries

A typical home in the United States may contain a variety of chemical compounds that could, under certain circumstances, be considered indoor air pollutants.

For example:

Why is indoor pollution becoming more of a concern?

• People spend more time ________________.
• Homes are better sealed for ________________efficiency
  • Reduced ________________.
• More ________________ are used in the home.

Most indoor air pollutants differ from outdoor air pollutants

Indoor air pollutants include:

• ________________ from malfunctioning heating equipment.
• ________________ A long thin fibrous silicate mineral with insulating properties, which can cause cancer when inhaled; formerly used as insulation in buildings. More of a risk for damaged tiles or when removing tiles.
• ________________ that seeps into homes through cracks in the foundation, groundwater, or rocks.
• ________________s used in furniture, paint, and building materials.

Radon

Depending on the underlying bedrock and soils, the potential for exposure to ________________exists in houses in certain parts of the United States. What is our risk?

VOCs in Home Products

Reasons for sick building syndrome:

• Inadequate or faulty ________________
• ________________ contamination from indoor sources
• ________________ contamination from outdoor sources
• ________________ contamination from outside or inside
<table>
<thead>
<tr>
<th>Type of indoor pollutant</th>
<th>Appearance</th>
<th>Source</th>
<th>Prevention or remediation</th>
<th>Human health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sick Building Syndrome