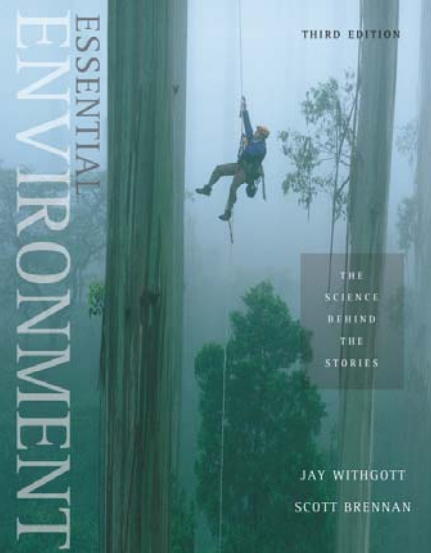


Chapter 13

Atmospheric Science and Air Pollution

PowerPoint® Slides prepared by Jay Withgott and Heidi Marcum



This lecture will help you understand:

- The Earth's atmosphere
- Outdoor pollution and solutions
- Stratospheric ozone depletion
- Acidic deposition and its consequences
- Indoor air pollution and solutions



Central Case: Charging toward cleaner air in London

- London has had bad air pollution for centuries, which has killed thousands.
 - In 1952, weather conditions trapped pollutants, killing 4,000 people; this was not the only time this happened.
 - Today, Londoners breathe cleaner air, but smog from traffic is a problem.
- The “congestion-charging” program charges drivers £8 (\$15) per day to drive into central London during the week.
 - The money pays for bus service.
 - Congestion decreased, fewer accidents occurred, and the air became cleaner.

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The atmosphere

- **Atmosphere:** the thin layer of gases that surrounds Earth
 - Provides us with oxygen
 - Absorbs solar radiation and moderates climate
 - Burns up incoming meteors
 - Transports and recycles water and nutrients
 - 78% nitrogen gas, 21% oxygen gas, 1% other gases
- Human activity is changing the amounts of some gases.
 - Carbon dioxide, methane, ozone
- The atmosphere has several layers.

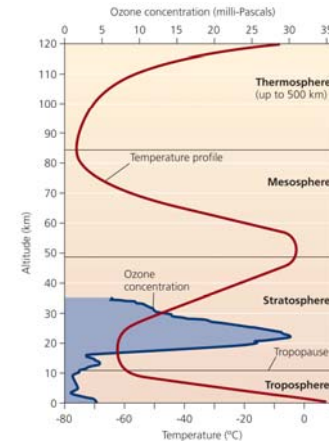
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The first two layers of the atmosphere

- **Troposphere:** bottommost layer; 11 km (7 mi) high
 - Air for breathing, weather
 - Temperature declines with altitude
- **Stratosphere:** 11-50 km (7-31 mi) above sea level
 - Drier and less dense, with little vertical mixing
 - Temperature warms with altitude
 - Contains UV radiation-blocking ozone, 17-30 km (10-19 mi) above sea level

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The atmosphere's four layers



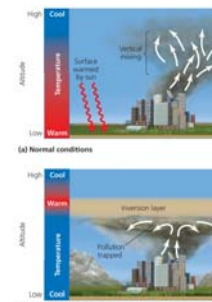
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Solar energy causes air to circulate

- Air near Earth's surface is warmer and moister than higher latitudes.
- **Convective circulation:** less dense, warmer air rises and creates vertical currents
 - Rising air expands and cools
 - Cool air descends and becomes denser, replacing warm air
 - Influences both weather and climate
- **Weather:** atmospheric conditions over short time periods and within a small geographic areas
- **Climate:** patterns of atmospheric conditions across large geographic regions over long periods of time
- "Climate is what we expect; weather is what we get." (Mark Twain)

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Thermal (temperature) inversion



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- Usually, tropospheric air temperature decreases as altitude increases.
 - Warm air rises, causing vertical mixing.
- **Thermal inversion:** a layer of cool air occurs beneath a layer of warmer air
 - **Inversion layer:** the band of air in which temperature rises with altitude
 - Denser, cooler air at the bottom of the layer resists mixing.
 - Pollutants are trapped at ground level.

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Circulation systems produce climate

- Convective currents contribute to climatic patterns.
- **Hadley cells:** near the equator, surface air warms, rises, and expands
 - Releases moisture and heavy rainfall near the equator
- **Ferrel cells and polar cells:** lift air
 - Creates precipitation at 60 degrees latitude north and south
 - Causes air to descend at 30 degrees latitude and in the polar regions

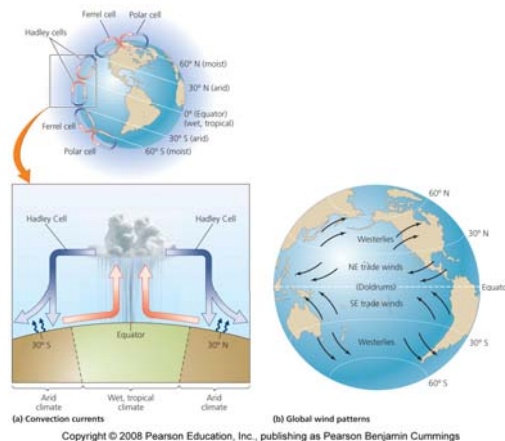
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Global wind patterns

- These three pairs of atmospheric cells account for latitudinal distribution of Earth's moisture.
 - Explains the distribution of biomes
- The convective cells also interact with Earth's rotation to produce global wind patterns.
 - As Earth rotates, equatorial regions spin faster.
 - **Coriolis effect:** the north-south air currents appear to be deflected from a straight path
 - Results in curving global wind patterns that helped ocean travel

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Climate patterns and moisture distribution



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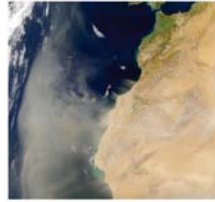
Outdoor air pollution

- **Air pollutants:** gases and particulate material added to the atmosphere
 - Can affect climate or harm people or other organisms
- **Air pollution:** the release of air pollutants
- **Outdoor (ambient) air pollution:** pollution outside
 - Has recently decreased due to government policy and improved technologies in developed countries
 - Developing countries and urban areas still have significant problems.

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Natural sources pollute: dust storms

- Winds blowing over arid terrain send huge amounts of dust aloft.
 - Unsustainable farming and grazing, erosion and desertification
- Volcanoes release large quantities of particulate matter, sulfur dioxide, and other gases.
- Fires generate soot and gases.
 - Clearing forests for agriculture



(A) Dust storm off west coast of Africa
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(B) Mount Saint Helens eruption, 1980
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Types of outdoor air pollution

- Human activity also produces air pollution.
- **Point sources:** specific spots where large quantities of pollutants are discharged (power plants and factories)
- **Non-point sources:** more diffuse, consisting of many small sources (automobiles)
- **Primary pollutants:** directly harmful and can react to form harmful substances (soot and carbon dioxide)
- **Secondary pollutants:** form when primary pollutants interact or react with constituents of the atmosphere

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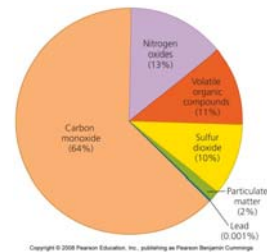
Legislation addresses pollution

- The Clean Air Act of 1970
 - Provides funds for pollution-control research
 - Sets standards for air quality, limits on emissions
 - Allows citizens to sue parties violating the standards
- Starting in 1995, businesses and utilities could buy, sell, or trade permits for pollutants.
 - Each year, the amount of allowable pollution decreases.

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The EPA sets standards

- Environmental Protection Agency (EPA) sets nationwide standards for pollutant emissions.
- States monitor air quality and develop, implement, and enforce regulations.
 - If a state's plans are not adequate, the EPA can take over enforcement.



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- The EPA and states focus on six criteria pollutants.
 - **Criteria pollutants:** pollutants judged to pose great threats to human health

Three criteria pollutants

- **Carbon monoxide (CO):** a colorless, odorless gas
 - Produced primarily by incomplete combustion of fuel
 - Binds to hemoglobin in red blood cells, preventing them from binding with oxygen
- **Sulfur dioxide (SO₂):** colorless gas with a strong odor
 - Coal emissions from electricity generation and industry
 - Can form acid precipitation
- **Nitrogen dioxide (NO₂):** foul-smelling reddish brown gas
 - **Nitrogen oxides (NO_x):** nitrogen and oxygen react at high temperatures in combustion engines
 - Vehicle engines, electrical utilities, and industrial combustion

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Criteria pollutants: tropospheric ozone

- **Tropospheric ozone (O₃):** a colorless gas with a strong odor
 - A secondary pollutant created from interactions of sunlight, heat, nitrogen oxides, and volatile carbons
 - A major component of smog
 - Poses a health risk as a result of its instability
 - Most frequently exceeds the EPA standard

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Criteria pollutants: particulate matter and lead

- **Particulate matter:** solid or liquid particles suspended in the atmosphere
 - Damages respiratory tissue when inhaled
 - Primary pollutants: dust and soot
 - Secondary pollutants: sulfates and nitrates
 - Most is wind-blown dust
- **Lead:** particulate pollutant added to gas and used in industrial metal smelting
 - Bioaccumulates and causes nervous system malfunction
 - Banned in gasoline in developed, but not in developing, countries

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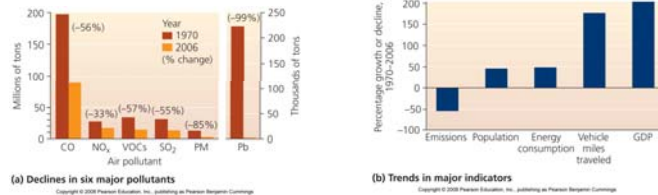
Agencies monitor pollutants

- State and local agencies also monitor, calculate, and report to the EPA the emissions of pollutants.
 - Four criteria pollutants: carbon monoxide, sulfur dioxide, particulate matter, and lead
 - All nitrogen oxides
 - Not tropospheric ozone (no emissions to monitor)
 - **Volatile organic compounds (VOCs):** carbon-containing chemicals emitted by vehicle engines and industrial processes that can react to produce ozone

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Air pollution has decreased since 1970

- Total emissions of the six monitored pollutants have declined.
 - Despite increased population, energy consumption, miles traveled, and gross domestic product

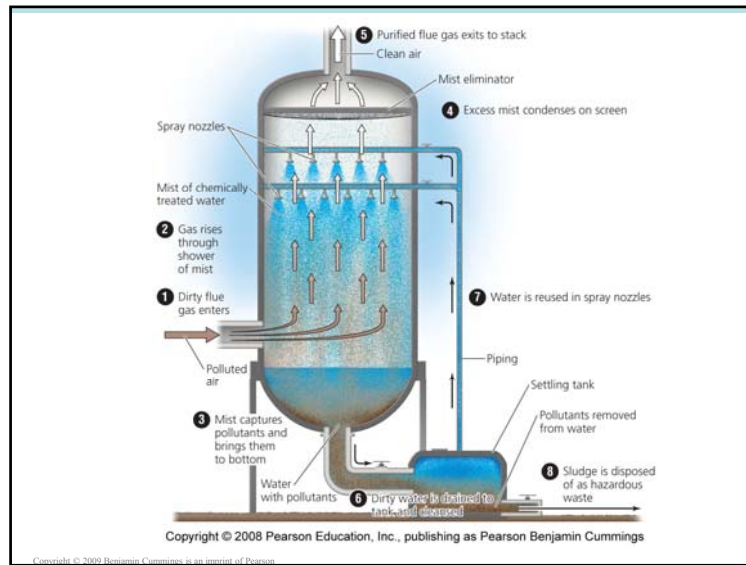


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Reasons for the decline in U.S. pollution

- Cleaner-burning vehicles and catalytic converters decrease carbon monoxide.
- Permit-trading programs and clean coal technologies reduce SO₂ emissions.
- Scrubbers:** technologies that chemically convert or physically remove pollutants before they leave the smokestacks
- Phaseout of leaded gasoline
- Improved technologies and federal policies

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Toxic substances also pollute

- Toxic air pollutants:** substances known to cause cancer, reproductive defects, or neurological, development, immune system, or respiratory problems
 - The Clean Air Act identifies 188 toxic pollutants.
 - Emissions decreased 35% between 1990 and 2002.

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Burning fossil fuels produces industrial smog

- **Smog:** unhealthy mixtures of air pollutants over urban areas
- **Industrial (gray air) smog:** formed when coal or oil is burned
 - Government regulations in developed countries reduced smog.
 - Coal-burning industrializing countries face significant health risks.



(b) Donora, Pennsylvania, at midday in the 1948 smog event
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Photochemical (brown air) smog

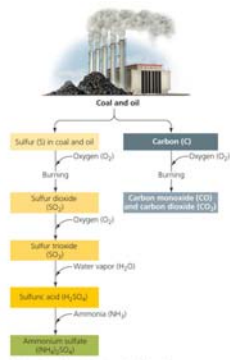
- Produced by a series of reactions
 - Light-driven reactions of primary pollutants and normal atmospheric compounds
 - Hot, sunny, windless days in urban areas
 - Morning traffic exhaust releases pollutants.
 - Irritates eyes, noses, and throats
 - Vehicle inspection programs in the U.S. have decreased smog.



(b) Photochemical smog over Mexico City
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Industrial smog

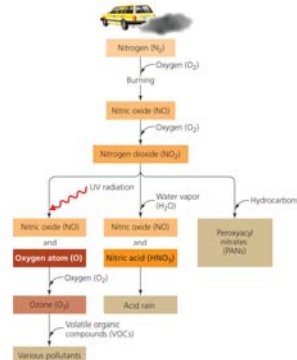


(d) Burning sulfur-rich oil or coal without adequate pollution control technologies

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Photochemical smog



(a) Formation of photochemical smog

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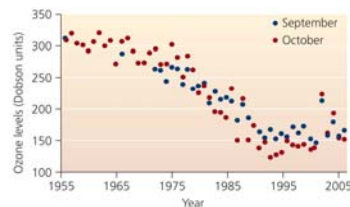
Synthetic chemicals deplete stratospheric ozone

- **Ozone layer:** ozone in the lower stratosphere
 - Blocks incoming damaging ultraviolet radiation
- **Chlorofluorocarbons (CFCs):** chemicals that attack ozone
 - Releases chlorine atoms that split ozone

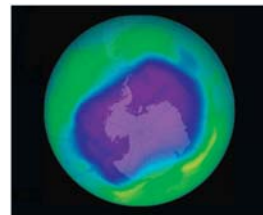
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The hole in the ozone

- **Ozone hole:** ozone levels over Antarctica had declined by 40-60%
 - Depletion also occurred in the Arctic and globally.
 - Causes skin cancer, harms crops, and decreases ocean productivity



(a) Monthly mean ozone levels at Halley, Antarctica
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(b) The "ozone hole" over Antarctica, September 24, 2006
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The Montreal Protocol addressed ozone depletion

- **Montreal Protocol:** 180 nations agreed to cut CFC production in half
 - Follow-up agreements deepened cuts, advanced timetables, and addressed other ozone-depleting chemicals.
 - Today, production and use of ozone-depleting chemicals has decreased 95%.
 - The ozone layer is beginning to recover.
- Challenges still face us.
 - CFCs will remain in the stratosphere for a long time.
- The Montreal Protocol can serve as a model for international environmental cooperation.

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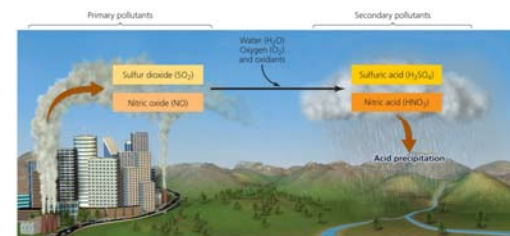
Acid deposition is another transboundary issue

- **Acidic deposition:** the deposition of acid, or acid-forming pollutants, from the atmosphere onto Earth's surface
 - **Acid rain:** precipitation of acid
 - **Atmospheric deposition:** the wet or dry deposition on land of pollutants

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Sources of acid deposition

- Originates from burning fossil fuels that release sulfur dioxide and nitrogen oxides
 - These compounds react with water to form sulfuric and nitric acids.



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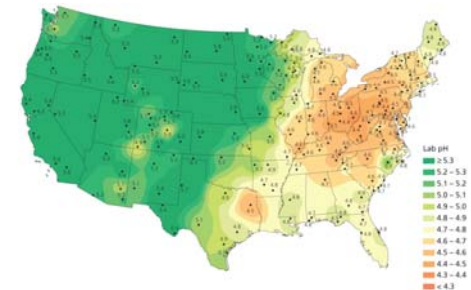
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Effects of acid deposition

- Nutrients are leached from topsoil.
- Metal ions (aluminum, zinc, etc.) are converted into soluble forms that pollute water.
- Damages agricultural crops
- Affects surface water and kills fish
- Widespread tree mortality
- Erodes stone buildings, corrodes cars, erases writing on tombstones
- New technologies such as scrubbers have helped, but deposition's effects are worse than predicted.

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pH of precipitation in the U.S.



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Many regions of acidification are downwind of major sources of pollution.

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Developing nations and air pollution

- Despite advances, developed nations need to do more to control air pollution.
- In developing nations, air pollution is getting worse.
 - Factories and power
 - Plants have little or no pollution control.
 - Wood and charcoal are used to cook and heat homes.
- China has the world's worst air pollution.
 - 80% of its cities suffer pollution above health standards.
 - 2008 Olympic athletes feared harm to their health

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Indoor air pollution

- Indoor air contains higher concentrations of pollutants than outdoor air.
 - 6,000 people die per day from indoor air pollution.
- The average U.S. citizen spends 90% of the time indoors.
 - Exposed to synthetic materials that exude volatile chemicals

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Indoor air pollution in the developing world

- Comes from burning wood, charcoal, dung, crop wastes
 - Homes have little to no ventilation.
- Fuel burning pollution causes an estimated 1.6 million deaths per year.
 - Soot and carbon monoxide



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Indoor air pollution in the developed world

- Tobacco and radon are the most dangerous indoor pollutants in the developed world.
- Secondhand smoke from cigarettes is especially dangerous.
 - Causes eye, nose, and throat irritation, asthma, cancer
 - Containing over 4,000 dangerous chemicals
 - Smoking has declined in developed nations.
- Radon causes 20,000 deaths a year in the U.S.
 - A radioactive gas resulting from natural decay of rock, soil, or water, which can seep into buildings
 - Many new homes are now radon resistant.

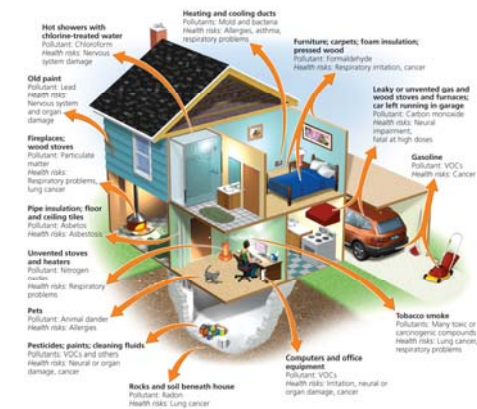
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Volatile Organic Compounds (VOCs)

- The most diverse group of indoor air pollutants
 - Released by everything from plastics and oils to perfumes and paints
 - Most VOCs are released in very small amounts.
- **Sick building syndrome:** a sickness produced by indoor pollution with an unidentifiable specific cause
 - VOCs, bacteria, fungi, mold
- Indoor air pollution can be solved by using low-toxicity building materials, monitoring air quality, keeping rooms clean, and good ventilation.

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Sources of indoor air pollution



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Conclusion

- Indoor air pollution is a potentially serious health threat.
 - We can significantly minimize risks.
- Outdoor air pollution has been addressed by government legislation and regulation in developed countries.
- Reduction in outdoor air pollution represents some of the greatest strides in environmental protection.
 - There is still room for improvement, especially in developing countries.

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