A I R  P O L L U T I O N
Chapter 19
Central Case: Charging Toward Cleaner Air in London

- London has had bad air pollution for centuries that has killed thousands.
- Today, smog from traffic is a problem.
- The “congestion-charging” program charges drivers to drive into central London during the week.
- Congestion decreased, fewer accidents occurred and the air became cleaner.
**The Atmosphere**

- **Atmosphere** = the thin layer of gases that surrounds Earth
  - Absorbs radiation and moderates climate
  - Transports and recycles water and nutrients
  - 78% nitrogen gas, 21% oxygen gas, 1% other gases
  - Its four layers differ in temperature, density and composition
- Minute concentrations of **permanent** (remain at stable concentrations) and **variable gases** (varying concentrations)
- Human activity is changing the amounts of some gases
The atmosphere’s composition

Nitrogen (N₂) (78.08%)

Oxygen (O₂) (20.95%)

Argon (Ar): 0.93%

Other permanent gases
- Neon (Ne): 0.0018%
- Helium (He): 0.0005%
- Hydrogen (H₂): trace
- Xenon (Xe): trace

Variable gases
- Water vapor (H₂O): 0–4%
- Carbon dioxide (CO₂): 0.038%
- Methane (CH₄): 0.00017%
- Nitrous oxide (N₂O): trace
- Ozone (O₃): trace
- Chlorofluorocarbons (CFCs): trace

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The atmosphere’s four layers

- **Troposphere**: Lowermost layer, closest to the Earth's surface. It is where weather events occur.
- **Stratosphere**: Located above the troposphere, it contains the ozone layer which protects the Earth from harmful ultraviolet radiation.
- **Mesosphere**: This layer extends above the stratosphere and is where meteorites burn up as they enter the Earth's atmosphere.
- **Thermosphere**: The highest layer, it contains the ionosphere which is important for radio communication.

The graph shows the ozone concentration and temperature profiles across these layers.

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THE FIRST TWO LAYERS OF THE ATMOSPHERE

- **Troposphere** = bottommost layer
  - Air for breathing, weather
  - Temperature declines with altitude
  - **Tropopause** = limits mixing between troposphere and the layer above it

- **Stratosphere** = 11-50 km (7-31 mi) above sea level
  - Drier and less dense, with little vertical mixing
  - Colder in its lower regions
  - Contains UV radiation-blocking ozone, 17-30 km (10-19 mi) above sea level
THE TWO HIGHEST LEVELS OF THE ATMOSPHERE

- **Mesosphere** = 50-80 km (31-56 mi) above sea level
  - Extremely low air pressure
  - Temperatures decrease with altitude

- **Thermosphere** = atmosphere’s top layer
  - Extends upward to 500 m (300 mi)
ATMOSPHERIC PROPERTIES

- **Atmospheric pressure** = measures the force per unit area produced by a column of air
  - Decreases with altitude
- **Relative humidity** = the ratio of water vapor a given volume of air contains to the amount it could contain at a given temperature
- **Temperature** = varies with location and time
**Solar Energy Heats the Atmosphere**

- The spatial relationship between the Earth and sun determines the amount of solar energy striking the Earth.
  
- Energy from the sun:
  - Heats air
  - Moves air
  - Creates seasons
  - Influences weather and climate

- Solar radiation is highest near the equator.
**SOLAR ENERGY CREATES SEASONS**

- Because the Earth is tilted
  - Each hemisphere tilts toward the sun for half the year
  - Results in a change of seasons
  - Equatorial regions are unaffected by this tilt, so days average 12 hours through the year
Solar energy causes air to circulate

- Air near Earth’s surface is warmer and moister than air at 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
The atmosphere drives weather and climate

- **Weather** = specifies atmospheric conditions over short time periods and within a small geographic areas
- **Climate** = describes patterns of atmospheric conditions across large geographic regions over long periods of time
- Mark Twain said “Climate is what we expect; weather is what we get”
AIR MASSES PRODUCE WEATHER

- **Front** = the boundary between air masses that differ in temperature, moisture, and density
- **Warm Front** = the boundary where warm moist air replaces colder, drier air
- **Cold Front** = the boundary where colder, drier air displaces warmer, moister air
AIR MASSES HAVE DIFFERENT ATMOSPHERIC PRESSURES

- **High-pressure system** = air that moves away from a center of high pressure as it descends
  - Brings fair weather

- **Low-pressure system** = air moves toward the low atmospheric pressure at the center of the system and spirals upward
  - Clouds and precipitation
**THE ATMOSPHERE**

- Convective currents contribute to climatic patterns and affect moisture distribution
- **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
GLOBAL WIND PATTERNS

- The atmospheric cells interact with Earth’s rotation to produce global wind patterns
  - As Earth rotates, equatorial regions spin faster

- **Coriolis effect** = the north-south air currents of the convective cells appear to be deflected from a straight path
  - Results in curving global wind patterns
CLIMATE PATTERNS AND MOISTURE DISTRIBUTION

(a) Convection currents

(b) Global wind patterns

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**Wind Patterns**

- **Doldrums** = near the equator
  - Few winds

- **Trade winds** = between the equator and 30 degrees latitude
  - Blow from east to west

- **Westerlies** = from 30 to 60 degrees latitude
  - Originate from the west and blow east

- People used these winds to sail their ships across the ocean
AIR POLLUTION

Why do we even care about the air?
CORE CASE STUDY: WHEN IS A LICHERN LIKE A CANARY?

- Lichens can warn us of bad air because they absorb it as a source of nourishment.
Core Case Study: When Is a Lichen Like a Canary?

- Some lichen species are sensitive to specific air-polluting chemicals.
- After Chernobyl, more than 70,000 reindeer had to be killed because they ate highly radioactive lichens.
- Because lichens are widespread, long-lived, and anchored in place, they can help track pollution to its source.
MECHANISMS OF BREATHING

- Nose, Nasal Passages, Nasal Pharynx
- Mouth, Pharynx
- Larynx, Trachea
- Bronchi, Bronchiolus
- Air Sacs
- Alveoli
- Muscles
WHAT IS AIR?

- Nitrogen: 78%
- Oxygen: 20.9%
- Argon: 0.9%
- Carbon Dioxide: 0.03%
- Methane: 0.0002%
HAZARDOUS ATMOSPHERE

- A hazardous atmosphere is one that
  - Contains a toxic chemical above the PEL
  - Has less than 19.5% oxygen
  - Contains a combustible gas within its explosive limit
Questions

1. What is “killer” fog?
2. What is the biggest threat to our atmosphere?
3. What gases come from cars?
4. How is Ozone formed?
5. How long does it take for air to circulate around the world?
6. What is the definition of a megacity and how many are there worldwide?
7. What is the purpose of the MILAGRO project?
8. What is the boundary layer of the atmosphere?
9. How does the boundary layer move?
THE HABITABLE PLANET

“Atmosphere”

- Video on Demand - The Habitable Planet - Atmospheric Pollution
Types of outdoor air pollution

- Air pollution can come from mobile or stationary sources
- **Point Sources** = specific spots where large quantities of pollutants are discharged (power plants and factories)
- **Nonpoint 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 or components of the atmosphere (tropospheric ozone and sulfuric acid)
OUTDOOR AIR POLLUTION

- **Air pollutants** = gases and particulate material added to the atmosphere
  - Can affect climate or harm people
- **Air pollution** = the release of 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
PRIMARY AND SECONDARY

- Primary Pollutants are those that are directly emitted into the atmosphere.
  - Carbon Monoxide, Carbon Dioxide, Sulfur Dioxide, Nitrogen Monoxide and Nitrogen Dioxide, Most hydrocarbons, most suspended particles (dust)
- Secondary Pollutants are formed when primary pollutants interact with other chemicals in the atmosphere or the radiation from the sun.
  - All others including Sulfur Trioxide, Nitric Acid, PANs, Nitrate salts, Sulfate salts, Ozone (O3), Hydrogen Peroxide, etc.
THE MAJOR POLLUTANTS

- Carbon Monoxide
- Carbon Dioxide
- Nitrogen Dioxide
- Sulfur Dioxide
- Suspended Particulates
- Volatile Organic Compounds
- Ground level Ozone
MAJOR AIR POLLUTANTS

- **Carbon oxides:**
  - Carbon monoxide (CO) is a highly toxic gas that forms during the incomplete combustion of carbon-containing materials.
  - 93% of carbon dioxide (CO$_2$) in the troposphere occurs as a result of the carbon cycle.
  - 7% of CO$_2$ in the troposphere occurs as a result of human activities (mostly burning fossil fuels).
    - It is not regulated as a pollutant under the U.S. Clean Air Act.
**MAJOR AIR POLLUTANTS**

- **Nitrogen oxides** and **nitric acid**:
  - Nitrogen oxide (NO) forms when nitrogen and oxygen gas in air react at the high-combustion temperatures in automobile engines and coal-burning plants. NO can also form from lightening and certain soil bacteria.
  - NO reacts with air to form NO\(_2\).
  - NO\(_2\) reacts with water vapor in the air to form nitric acid (HNO\(_3\)) and nitrate salts (NO\(_3^-\)) which are components of acid deposition.
Major Air Pollutants

- **Sulfur dioxide (SO$_2$) and sulfuric acid:**
  - About one-third of SO$_2$ in the troposphere occurs naturally through the sulfur cycle.
  - Two-thirds come from human sources, mostly combustion (S + O$_2$ $\rightarrow$ SO$_2$) of sulfur-containing coal and from oil refining and smelting of sulfide ores.
  - SO$_2$ in the atmosphere can be converted to sulfuric acid (H$_2$SO$_4$) and sulfate salts (SO$_4^{2-}$) that return to earth as a component of acid deposition.
**MAJOR AIR POLLUTANTS**

- *Suspended particulate matter (SPM):*
  - Consists of a variety of solid particles and liquid droplets small and light enough to remain suspended in the air.
  - The most harmful forms of SPM are fine particles (PM-10, with an average diameter < 10 micrometers) and ultrafine particles (PM-2.5).
  - According to the EPA, SPM is responsible for about 60,000 premature deaths a year in the U.S.
**Natural Sources Pollute: Dust Storms**

- **Dust storms** = Hundreds of millions of tons of dust are blown westward across the Atlantic Ocean by trade winds every year
  - From Africa to the Americas
  - Unsustainable farming and grazing, erosion and desertification
Natural sources pollute: volcanoes

- Release large quantities of particulate matter, sulfur dioxide & other gases
  - Can remain for months or years
  - Aerosols = reflect sunlight back into space and cool the atmosphere and surface
**Natural Sources Pollute: Fires**

- Pollutes atmosphere with soot and gases
- Over 60 million ha of forests and grasslands burn per year
- Severe fires are caused by human interaction
  - Cleared forests, harsh droughts, and climate change (El Niño)
MAJOR AIR POLLUTANTS

- Ozone ($O_3$):
  - Is a highly reactive gas that is a major component of photochemical smog.
  - It can
    - Cause and aggravate respiratory illness.
    - Can aggravate heart disease.
    - Damage plants, rubber in tires, fabrics, and paints.
MAJOR AIR POLLUTANTS

- **Volatile organic compounds (VOCs):**
  - Most are hydrocarbons emitted by the leaves of many plants and methane.
  - About two thirds of global methane emissions come from human sources.
  - Other VOCs include industrial solvents such as trichlorethylene (TCE), benzene, and vinyl chloride.
    - Long-term exposure to benzene can cause cancer, blood disorders, and immune system damage.
Some primary air pollutants may react with one another or with other chemicals in the air to form secondary air pollutants.
Burning fossil fuels produces industrial smog

- **Smog** = unhealthy mixtures of air pollutants over urban areas
- **Industrial (gray air) smog** = industries burn coal or oil
  - Occurs in cooler, hilly areas
  - Government regulations in developed countries reduced smog
  - Coal-burning industrializing countries face significant health risks
PHOTOCHEMICAL (BROWN AIR) SMOG

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

Photochemical smog

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

(a) Formation of photochemical smog
CASE STUDY: SOUTH ASIA’S MASSIVE BROWN CLOUD

- A huge dark brown cloud of industrial smog, caused by coal-burning in countries such as China and India, stretches over much of southeastern Asia.
  - In areas beneath the cloud, photosynthesis is reduced interfering with crop development.
  - Fine particles and droplets in the cloud appear to be changing regional climates (including rainfall).
    - May have contributed to floods in 2002 and 2005 which killed thousands of people.
Photochemical smog is a mixture of air pollutants formed by the reaction of nitrogen oxides and volatile organic hydrocarbons under the influence of sunlight.

\[
\text{VOCs} + \text{NO}_x + \text{heat} + \text{sunlight} \rightarrow \text{ground level ozone (O}_3\text{)} + \text{other photochemical oxidants} + \text{aldehydes} + \text{other secondary air pollutants}
\]
SUNLIGHT PLUS CARS EQUALS PHOTOCHEMICAL SMOG

- Mexico City is one of the many cities in sunny, warm, dry climates with many motor vehicles that suffer from photochemical smog.
FACTORS IN AIR POLLUTION

- Reduction:
  1. Heavy particles settle out
  2. Rain/snow wash away
  3. Salt sea spray
  4. Wind
  5. Chemical Reaction

- Increase:
  1. Urban buildings block wind
  2. Hills & Mountains block
  3. Urban Heat Island
  4. VOC’s from plants
  5. Pollution migrates north
  6. Temperature Inversions
**THERMAL INVERSION**

- 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
Airborne pesticides from farms
- Industrial pollutants drifting from cities, factories and powerplants
- Feedlots, where cattle, hogs, or chickens are raised in dense concentrations
  - Voluminous amounts of methane, hydrogen sulfide, and ammonia
  - People living or working nearby have high rates of respiratory problems
LEGISLATION
LEGISLATION ADDRESSES POLLUTION

- Congress passed a series of laws starting in 1955
- The Clean Air Act of 1970
  - Sets standards for air quality, limits on emissions
  - Provides funds for pollution-control research
  - Allows citizens to sue parties violating the standards
- The Clean Air Act of 1990
  - Strengthens standards for auto emissions, toxic air pollutants, acidic deposition, stratospheric ozone depletion
  - Introduced emissions trading
CLEAN AIR ACT HISTORY

- In 1963, the Clean Air Act was first passed with regulatory language.
- Grants were provided for air pollution control agencies and established a pollution abatement conference procedure.
- In 1965, Congress added Title II, The Motor Vehicle Air Pollution Control Act which provided emission standards.
CLEAN AIR ACT OF 1970

- EPA had the authority to establish regulatory goals and standards
- Standards for 50 industrial processes were developed
- 189 Pollutants were initially regulated
- Permit requirements were established
- Criminal sanctions for non-compliance were established
CLEAN AIR ACT (CONTINUED)

- National Ambient Air Quality Standards (NAAQS): primary and secondary standards for each pollutant to protect public health
- Air Quality Control Regions (AQCR) were established
- State Implementation Plans (SIPs): states were given the task of setting the regulatory structure to achieve the NAAQS
CLEAN AIR ACT (CONTINUED)

- Attainment: If an area has achieved the NAAQSs for a parameter, it is considered to be in attainment status
- Nonattainment Areas: Those areas where the NAAQSs have not been achieved
- Title V
NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

- NESHAP is the toxic equivalent to the NAAQSs
- If a NESHAP is set for a pollutant, a facility must apply for governmental approval for operation
  - Asbestos, Benzene, Beryllium, Coke oven emissions, Inorganic Arsenic, Mercury, Radionuclides, and Vinyl Chloride
NESHAP (CONTINUED)

- New Source or changes to an existing source must be approved by the EPA prior to bringing the process on-line
The EPA sets standards

Environmental Protection Agency (EPA) sets nationwide standards for emissions of toxic pollutants

- NAAQs: primary standards to protect human health and secondary standards to protect from property damage.
- NESHAP: 188 compounds, Toxic Release Inventory

States monitor air quality and develop, implement, and enforce regulations within their borders

- If a state’s plans for implementation are not adequate, the EPA can take over enforcement
**Using the Marketplace to Reduce Outdoor Air Pollution**

- To help reduce SO$_2$ emissions, the Clean Air Act authorized and emission trading (cap-and-trade) program.
  - Enables the 110 most polluting power plants to buy and sell SO$_2$ pollution rights.
  - Between 1990-2002, the emission trading system reduced emissions.
  - In 2002, the EPA reported the cap-and-trade system produced less emission reductions than were projected.
TRADING PLACES

- With a “cap and trade” provision of the CAA, companies can trade or sell their SO$_2$ rights.
FALLING SHORT

The CAA has reduced emissions, but there are still gaps in the legislation

- The government cleans rather than prevents.
- Insufficient Emissions Standards on vehicles
- Fuel Efficiency Ratings
- Ocean going vessels
- Airports are exempt
- CO$_2$ not even covered
- No Indoor Air Quality regulations
- Enforcement
AREAS IN THE U.S. FAIL AIR QUALITY STANDARDS
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 used emitted by vehicle engines and industrial processes
In 2006, the U.S. emitted 137 million tons of the six major pollutants
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
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 SO$_2$ emissions
- **Scrubbers** = technologies that chemically convert or physically remove pollutants before they leave the smokestacks
- Phaseout of leaded gasoline
- Improved technologies and federal policies
TOXIC SUBSTANCES ALSO POLLUTE

- **Toxic air pollutants** = substances known to cause cancer; reproductive defects; or neurological, development, immune system, or respiratory problems
  - Some are produced naturally: hydrogen sulfide
  - Most are produced by humans: smelting, sewage treatment, industry
- Not monitored as closely as the six criteria pollutants
  - Monitoring is improving
RECENT POLICIES HAVE BEEN CONTENTIOUS

- President G.W. Bush has pushed proposals that would overturn key aspects of legislation
  - New source reviews = old utility plants have to install the best available technology when upgrading
    - The Bush administration proposed abolishing this requirement and dropped lawsuits against violators

- Clear Skies Initiative = establishes a market-based can-and-trade program for some pollutants
  - Stopped in the Senate, because it would increase pollution
  - The EPA had skewed its analysis to promote the legislation
INDUSTRIALIZING NATIONS FACE INCREASING POLLUTION

- Outdoor pollution is increasing
- Factories and power plants do not control emissions
- Citizens burn traditional fuels (wood and charcoal)
- China has the world’s worst air pollution
  - 80% of Chinese cities have emissions above the safety threshold
  - Asian brown cloud = a 2-mile thick layer of pollution that reduces sunlight, affects climate, decreases productivity, and kills thousands each year
SYNTHETIC CHEMICALS DEPLETE STRatospheric OZONE

- **Ozone layer** = ozone in the lower stratosphere
  - 12 ppm concentrations effectively block incoming damaging ultraviolet radiation

- **Chlorofluorocarbons (CFCs)** = chemicals that attack ozone
  - 1 million metric tons/year were produced
  - Releases chlorine atoms that split ozone
The hole in the ozone

- **Ozone hole** = ozone levels over Antarctica had declined by 40-60%
  - Depletion also in the Arctic and globally
  - Causes skin cancer, harms crops and decreases ocean productivity
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 addresses 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
  - Nations can ask for exemptions to the ban
THE MONTREAL PROTOCOL IS A SUCCESS

- Considered the biggest environmental success story
  - Policymakers included industry in helping solve the problem
  - Implementation of the plan allowed an adaptive management strategy that changed strategies in response to new scientific data, technological advances, and economic figures
- The Montreal Protocol can serve as a model for international environmental cooperation
ACID DEPOSITION

- Acid rain and it’s effects.
ACID DEPOSITION

- Sulfur dioxides, nitrogen oxides, and particulates can react in the atmosphere to produce acidic chemicals that can travel long distances before returning to the earth’s surface.
  - Tall smokestacks reduce local air pollution but can increase regional air pollution.
Acid deposition consists of rain, snow, dust, or gas with a pH lower than 5.6.
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
ACID DEPOSITION

- Air pollution is one of several interacting stresses that can damage, weaken, or kill trees and pollute surface and groundwater.
ACID DEPOSITION

- Acid deposition contributes to chronic respiratory disease and can leach toxic metals (such as lead and mercury) from soils and rocks into acidic lakes used as sources for drinking water.

THINKING ABOUT ACID DEPOSITION AND MERCURY

Do you live in or near an area where government officials have warned people (especially pregnant women) not to eat fish caught from some of their waters because of mercury contamination?
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
ACID DEPOSITION

Figure 19-8

Potential problem areas because of sensitive soils
Potential problem areas because of air pollution: emissions leading to acid deposition
Current problem areas (including lakes and rivers)

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ACID DEPOSITION

- pH measurements in relation to major coal-burning and industrial plants.

Figure 19-7
Many regions of acidification are downwind of major sources of pollution.
EFFECTS OF ACID DEPOSITION

- Nutrients are leached from topsoil
- Soil chemistry is changed
- Metal ions (aluminum, zinc, etc.) are converted into soluble forms that pollute water
- Widespread tree mortality
- Affects surface water and kills fish
- Damages agricultural crops
- Erodes stone buildings, corrodes cars, erases writing on tombstones
ACID DEPOSITION HAS NOT BEEN GREATLY REDUCED

- New technologies such as scrubbers have helped
- $\text{SO}_2$ emissions are lower
- But, $\text{NO}_x$ emissions are higher
- Acid deposition’s effects are worse than predicted
  - The Clean Air Act cannot restore ecosystems
  - More must be done to control acid deposition
Acid Deposition Solutions

**Prevention**
- Reduce air pollution by improving energy efficiency
- Reduce coal use
- Increase natural gas use
- Increase use of renewable energy resources
- Burn low-sulfur coal
- Remove SO\(_2\) particulates & NO\(_x\) from smokestack gases

**Cleanup**
- Add lime to neutralize acidified lakes
- Add phosphate fertilizer to neutralize acidified lakes
- Remove NO\(_x\) from motor vehicular exhaust
- Tax emissions of SO\(_2\)
AIR POLLUTION IS A BIG KILLER

Each year, air pollution prematurely kills about 3 million people, mostly from indoor air pollution in developing countries.

- In the U.S., the EPA estimates that annual deaths related to indoor and outdoor air pollution range from 150,000 to 350,000.
- According to the EPA, each year more than 125,000 Americans get cancer from breathing diesel fumes.
Air Pollution is a Big Killer

- Spatial distribution of premature deaths from air pollution in the United States.

Figure 19-16
PREVENTING AND REDUCING AIR POLLUTION

The Clean Air Acts in the United States have greatly reduced outdoor air pollution from six major pollutants:

- Carbon monoxide
- Nitrogen oxides
- Sulfur dioxides
- Suspended particulate matter (less than PM-10)
Environmental scientists point out several deficiencies in the Clean Air Act:

- The U.S. continues to rely on cleanup rather than prevention.
- The U.S. Congress has failed to increase fuel-efficiency standards for automobiles.
- Regulation of emissions from motorcycles and two-cycle engines remains inadequate.
- There is little or no regulation of air pollution from oceangoing ships in American ports.
PREVENTING AND REDUCING AIR POLLUTION

- Airports are exempt from many air pollution regulations.
- The Act does not regulate the greenhouse gas CO$_2$.
- The Act has failed to deal seriously with indoor air pollution.
- There is a need for better enforcement of the Clean Air Act.
Executives of companies claim that correcting these deficiencies would cost too much, harm economic growth, and cost jobs.
To help reduce SO$_2$ emissions, the Clean Air Act authorized and emission trading (cap-and-trade) program.

- Enables the 110 most polluting power plants to buy and sell SO$_2$ pollution rights.
- Between 1990-2002, the emission trading system reduced emissions.
- In 2002, the EPA reported the cap-and-trade system produced less emission reductions than were projected.
There are a of ways to prevent and control air pollution from coal-burning facilities.

- **Electrostatic precipitator**: are used to attract negatively charged particles in a smokestack into a collector.
- **Wet scrubber**: fine mists of water vapor trap particulates and convert them to a sludge that is collected and disposed of usually in a landfill.
ELECTROSTATIC PRECIPITATOR

- Can remove 99% of particulate matter
- Does not remove hazardous ultrafine particles.
- Produces toxic dust that must be safely disposed of.
- Uses large amounts of electricity
Wet Scrubber

- Can remove 98% of SO$_2$ and particulate matter.
- Not very effective in removing hazardous fine and ultrafine particles.
**Solutions**

**Stationary Source Air Pollution**

**Prevention**
- Burn low-sulfur coal
- Remove sulfur from coal
- Convert coal to a liquid or gaseous fuel
- Shift to less polluting fuels

**Dispersion or Cleanup**
- Disperse emissions above thermal inversion layer with tall smokestacks
- Remove pollutants after combustion
- Tax each unit of pollution produced
In 2003, fourteen states and a number of U.S. cities sued the EPA to block new rules that would allow older coal-burning power plants to modernize without having to install the most advanced air pollution controls.
SOLUTIONS: REDUCING OUTDOOR AIR POLLUTION

There are a of ways to prevent and control air pollution from motor vehicles.

- Because of the Clean Air Act, a new car today in the U.S. emits 75% less pollution than did pre-1970 cars.
- There is an increase in motor vehicle use in developing countries and many have no pollution control devices and burn leaded gasoline.
## Solutions

### Motor Vehicle Air Pollution

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<td>Give buyers large tax write-offs or rebates for buying low-polluting, energy efficient vehicles</td>
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Solutions
Air Pollution

Outdoor

Improve energy efficiency to reduce fossil fuel use
Rely more on lower-polluting natural gas
Rely more on renewable energy (especially solar cells, wind, & solar-produced hydrogen)
Transfer technologies for latest energy efficiency, renewable energy, & pollution prevention to developing countries

Indoor

Reduce poverty
Distribute cheap & efficient cookstoves or solar cookers to poor families in developing countries
Reduce or ban indoor smoking
Develop simple and cheap tests for indoor pollutants such as particulates, radon, and formaldehyde
**How Would You Vote?**

Should the 1990 U.S. Clean Air Act be strengthened?

- **a. No.** Strengthening the Act would be too expensive and would harm the economy.
- **b. Yes.** Strengthening the Act would improve the environment and people's health, save energy, and ultimately save money.
HOW WOULD YOU VOTE?

Should older coal-burning power and industrial plants have to meet the same air pollution standards as new facilities?

- a. No. The private sector should not have to upgrade existing facilities every time the regulations change.
- b. Yes. All facilities should comply with current regulations so that the environment and human health are effectively protected.
Should emissions trading be used to help control emissions of all major air pollutants?

- a. No. Emissions trading has no system for verifying compliance and eliminating "hot spots" of air pollution.
- b. Yes. Emissions trading is an efficient and effective way of reducing air pollution.
INDOOR AIR QUALITY (IAQ)
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 have not been comprehensively tested
- To reduce heat loss and improve energy efficiency, building ventilation systems were sealed off ventilation and windows put in that did not open, trapping pollutants inside
INDOOR AIR POLLUTION

- Indoor air pollution usually is a greater threat to human health than outdoor air pollution.
- According to the EPA, the four most dangerous indoor air pollutants in developed countries are:
  - Tobacco smoke.
  - Formaldehyde.
  - Radioactive radon-222 gas.
  - Very small fine and ultrafine particles.
TOBACCO SMOKE AND RADON

- Some of the most dangerous indoor pollutants in the developed world
- Secondhand smoke from cigarettes is especially dangerous
  - Containing over 4000 dangerous chemicals
  - Causes eye, nose, and throat irritation
  - 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
CASE STUDY: RADIOACTIVE RADON

Radon-222, a radioactive gas found in some soils and rocks, can seep into some houses and increase the risk of lung cancer.

Sources and paths of entry for indoor radon-222 gas.
RADON RISK ACROSS THE U.S.
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
- Unclear health implications due to low concentrations
- Also include pesticides, which are found indoors more often than outdoors due to seepage
- Formaldehyde, which leaks from pressed wood and insulation, irritates mucous membranes and induces skin allergies
Living organisms can pollute indoors

- Tiny living organisms can also pollute
- Includes dust mites and animal dander worsening asthma
- Fungi, mold, mildew, airborne bacteria cause severe allergies, asthma, and other respiratory ailments

**Sick building syndrome** = a sickness produced by indoor pollution with general and nonspecific symptoms
  - Solved by using low-toxicity building materials and good ventilation
INDOOR AIR POLLUTION

- Household dust mites that feed on human skin and dust, live in materials such as bedding and furniture fabrics.
  - Can cause asthma attacks and allergic reactions in some people.
Sources of indoor air pollution

- **Hot showers with chlorine-treated water**
  - Pollutant: Chloroform
  - Health risks: Nervous system damage

- **Old paint**
  - Pollutant: Lead
  - Health risks: Nervous system and organ damage

- **Fireplaces; wood stoves**
  - Pollutant: Particulate matter
  - Health risks: Respiratory problems, lung cancer

- **Pipe insulation; floor and ceiling tiles**
  - Pollutant: Asbestos
  - Health risks: Asbestosis

- **Unvented stoves and heaters**
  - Pollutant: Nitrogen oxides
  - Health risks: Respiratory problems

- **Pets**
  - Pollutant: Animal dander
  - Health risks: Allergies

- **Pesticides; paints; cleaning fluids**
  - Pollutants: VOCs and others
  - Health risks: Neural or organ damage, cancer

- **Rocks and soil beneath house**
  - Pollutant: Radon
  - Health risks: Lung cancer

- **Heating and cooling ducts**
  - Pollutants: Mold and bacteria
  - Health risks: Allergies, asthma, respiratory problems

- **Furniture: carpets; foam insulation; pressed wood**
  - Pollutant: Formaldehyde
  - Health risks: Respiratory irritation, cancer

- **Leaky or unvented gas and wood stoves and furnaces; car left running in garage**
  - Pollutant: Carbon monoxide
  - Health risks: Neural impairment, fatal at high doses

- **Gasoline**
  - Pollutant: VOCs
  - Health risks: Cancer

- **Tobacco smoke**
  - Pollutants: Many toxic or carcinogenic compounds
  - Health risks: Lung cancer, respiratory problems

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PM-10

- Particulate Matter less than 10 microns is the technical term for “dust”.
  - PM-10 is the biggest indoor air pollutant in developing countries.
INDOOR AIR POLLUTION IN THE DEVELOPING WORLD

- Stems from burning
  - Wood, charcoal, dung, crop wastes
  - Little to no ventilation

- Fuel burning pollution causes an estimated 1.6 million deaths per year
  - Soot and carbon monoxide
  - Causes pneumonitis, bronchitis, allergies, cataracts, asthma, heart disease, cancer and death
We can reduce indoor air pollution

- In developed countries:
  - Use low-toxicity material
  - Monitor air quality
  - Keep rooms clean
  - Limit exposure to chemicals

- In developing countries:
  - Dry wood before burning
  - Cook outside
  - Use less-polluting fuels (natural gas)
HEALTH RISKS OF AIR POLLUTION
Your respiratory system can help protect you from air pollution, but some air pollutants can overcome these defenses.
HEALTH EFFECTS OF AIR POLLUTION

Normal human lungs (left) and the lungs of a person who died of emphysema (right).
MEASURING IAQ

- Equipment is used to monitor the quality of air
  - CO, CO$_2$, Humidity and Temperature
  - Dust
  - Mold and Bacteria
  - Ozone
DIY

- Homemade Ozone Strips
- Homemade Dust Strips
  - Set up around the school
Indoor Air Pollution

- Little effort has been devoted to reducing indoor air pollution even though it poses a much greater threat to human health than outdoor air pollution.
- Environmental and health scientists call for us to focus on preventing air pollution (especially indoor) in developing countries.
## Solutions

### Indoor Air Pollution

#### Prevention
- Cover ceiling tiles & lining of AC ducts to prevent release of mineral fibers
- Ban smoking or limit it to well-ventilated areas
- Set stricter formaldehyde emissions standards for carpet, furniture, and building materials
- Prevent radon infiltration
- Use office machines in well-ventilated areas
- Use less polluting substitutes for harmful cleaning agents, paints, and other products

#### Cleanup or Dilution
- Use adjustable fresh air vents for work spaces
- Increase intake of outside air
- Change air more frequently
- Circulate a building’s air through rooftop greenhouses
- Use exhaust hoods for stoves and appliances burning natural gas
- Install efficient chimneys for wood-burning stoves

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Fig. 19-20, p. 461

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What Can You Do?
Indoor Air Pollution

• Test for radon and formaldehyde inside your home and take corrective measures as needed.
• Do not buy furniture and other products containing formaldehyde.
• Remove your shoes before entering your house to reduce inputs of dust, lead, and pesticides.
• Test your house or workplace for asbestos fiber levels and for any crumbling asbestos materials if it was built before 1980.
• Don't live in a pre-1980 house without having its indoor air tested for asbestos and lead.
• Do not store gasoline, solvents, or other volatile hazardous chemicals inside a home or attached garage.
• If you smoke, do it outside or in a closed room vented to the outside.
• Make sure that wood-burning stoves, fireplaces, and kerosene- and gas-burning heaters are properly installed, vented, and maintained.
• Install carbon monoxide detectors in all sleeping areas.