

Some Pollutants in the Atmosphere Combine to Form Other Pollutants

- **Primary pollutants**
 - Emitted directly into the air
- **Secondary pollutants**
 - From reactions of primary pollutants
- Air quality improving in developed countries
- Less-developed countries face big problems
 - Indoor pollution: big threat to the poor

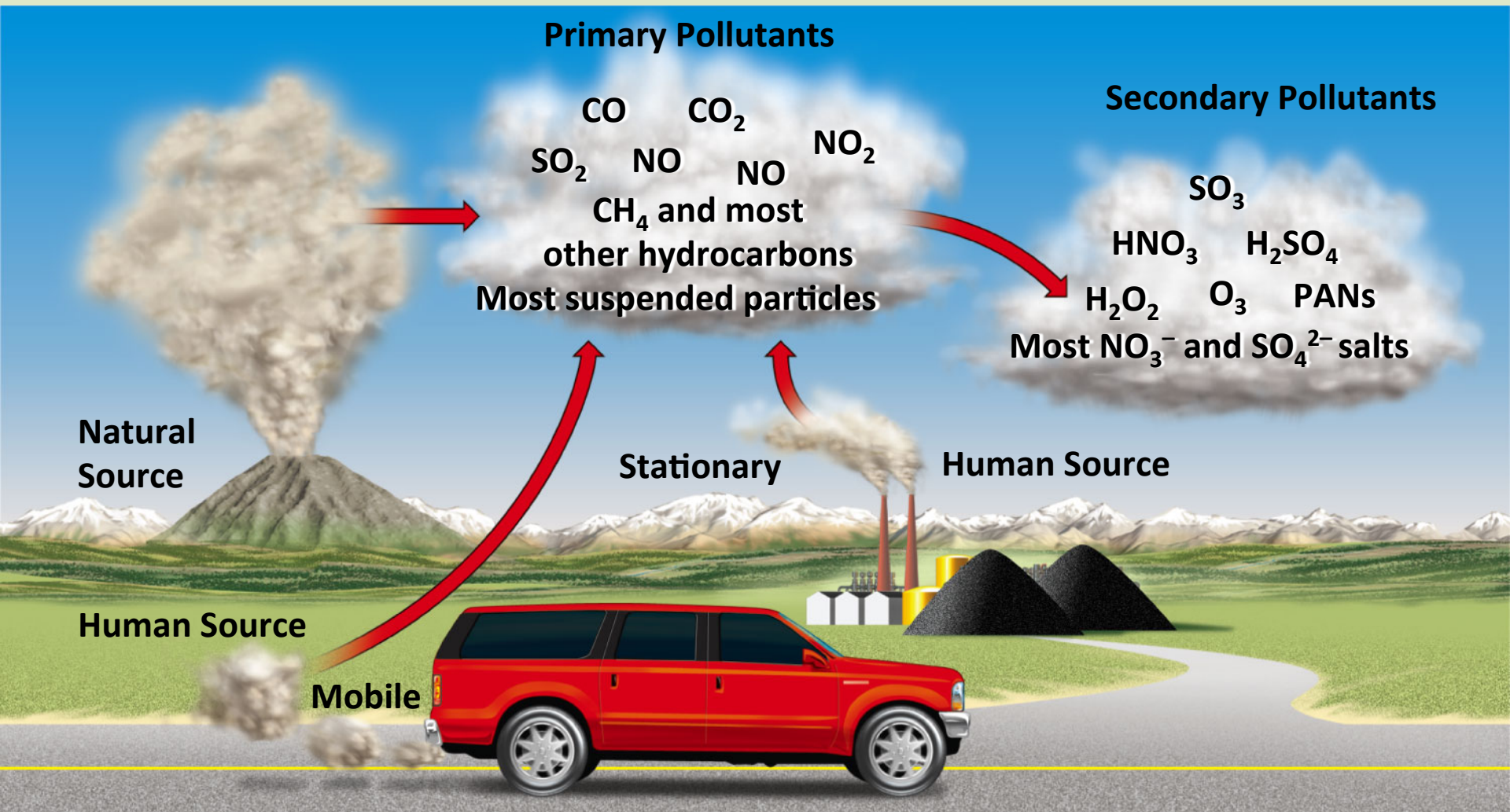


Fig. 18-5, p. 469

What Are the Major Outdoor Air Pollutants? (1)

- **Carbon oxides**

- Carbon monoxide (CO)
- Carbon dioxide (CO₂)
- Sources
- Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (2)

- **Nitrogen oxides (NO) and nitric acid (HNO_3)**
 - Sources
 - Acid deposition
 - Photochemical smog
 - Human health and environmental impact
- **Sulfur dioxide (SO_2) and sulfuric acid (H_2SO_4)**
 - Sources
 - Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (3)

- **Particulates**

- Suspended particulate matter (SPM)
 - Fine
 - Ultrafine
- Sources
- Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (4)

- **Ozone (O_3)**
 - Sources
 - Human and environmental impact
- **Volatile organic compounds (VOCs)**
 - Hydrocarbons and terpenes
 - Sources
 - Human and environmental impact

Chemical Reactions That Form Major Outdoor Air Pollutants

Table 18-1 Chemical Reactions That Form Major Air Pollutants

Pollutant	Chemical Reaction
Carbon monoxide (CO)	$2\text{C} + \text{O}_2 \rightarrow 2\text{CO}$
Carbon dioxide (CO ₂)	$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
Nitric oxide (NO)	$\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$
Nitrogen dioxide (NO ₂)	$2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$
Sulfur dioxide (SO ₂)	$\text{S} + \text{O}_2 \rightarrow \text{SO}_2$

Case Study: Lead Is a Highly Toxic Pollutant (1)

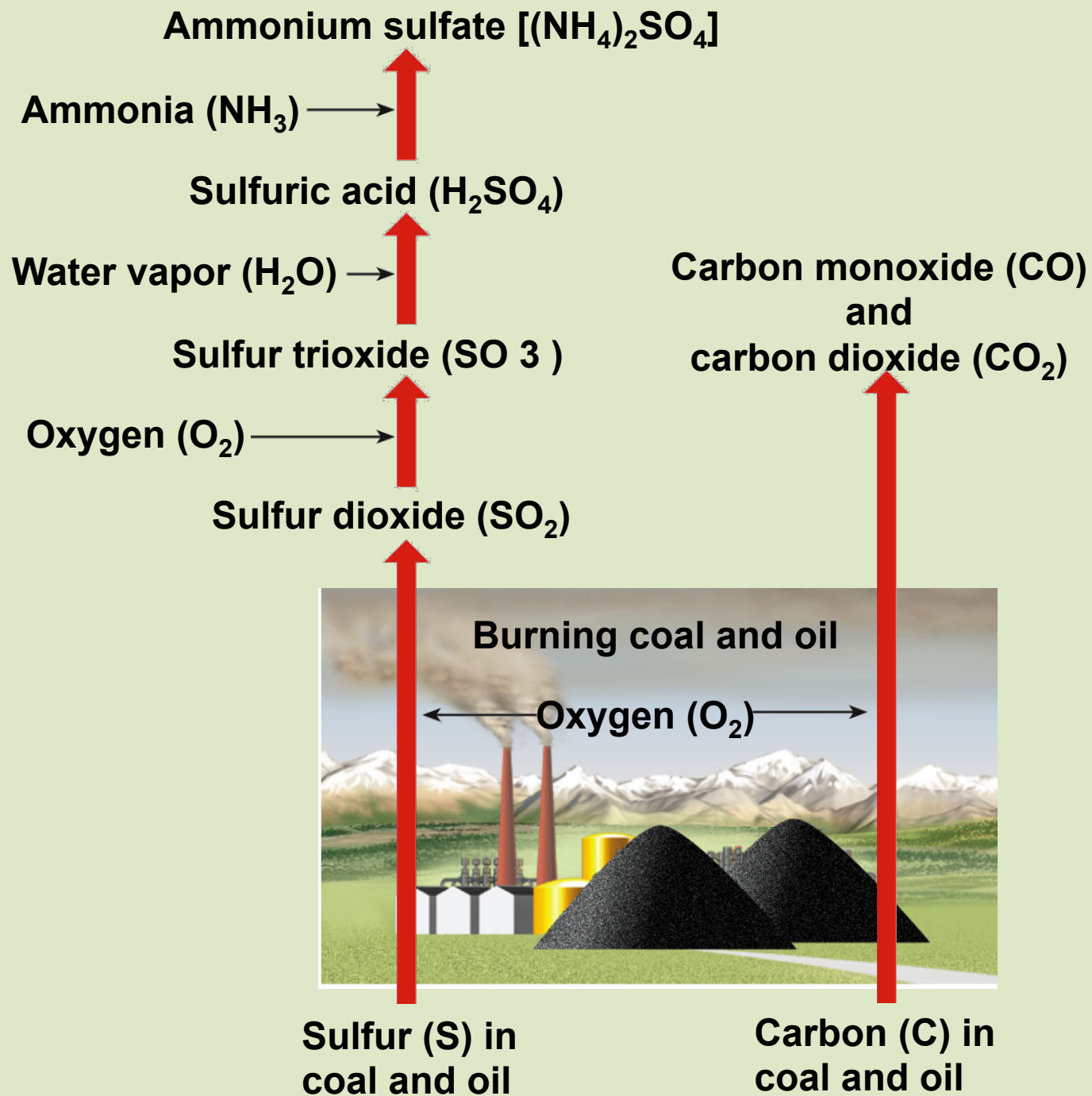
- In air, water, soil, plants, animals
- Does not break down in the environment
- Human health and environmental impact
 - Children most vulnerable
 - Can cause death, mental retardation, paralysis

Case Study: Lead Is a Highly Toxic Pollutant (2)

- Reduction of lead (Pb)
 - Unleaded gasoline
 - Unleaded paint
- Still problems
 - 15-18 million children have brain damage
 - Need global ban on lead in gasoline and paint

Burning Coal Produces Industrial Smog

- Chemical composition of **industrial smog**
- Reduction of this smog in urban cities of the United States
- China and smog
 - Human deaths
 - Need strong standards, especially for coal burning



Science Focus: Mercury's Toxic Effects

- Mercury is one of the most harmful pollutants faced by fish and wildlife. Toxic mercury is released from coal burning power plants across the country and accumulates in rivers, lakes, and forests.
 - Mercury is a highly potent neurotoxin that impacts the function and development of the central nervous system in both people and wildlife. Exposure to mercury is particularly dangerous for pregnant and breastfeeding women, as well as children, since mercury is most harmful in the early stages of development.
 - Scientists have found alarming levels of mercury accumulation in a wide range of wildlife species, causing dangerous reproductive and neurological problems.
 - Fish have difficulty schooling and decreased spawning success.
 - Birds lay fewer eggs and have trouble caring for their chicks.
 - Mammals have impaired motor skills that affect their ability to hunt and find food.

Science Focus: Mercury's Toxic Effects (1)

- Hg: teratogen and potent neurotoxin
 - Once airborne, persistent and not degradable
 - 1/3 from natural sources
 - 2/3 from human activities
 - Enters the food chain: biomagnification
- How are humans exposed?
 1. Inhalation: vaporized Hg or particulates
 2. Eating fish with high levels of methylmercury
 3. Eating high-fructose corn syrup

Science Focus: Mercury's Toxic Effects (2)

- Effects of Hg on humans
 - Damage nervous system, kidneys, lungs
 - Harm fetuses and cause birth defects
- Who is most at risk?
 - Pregnant women
 - 75% of exposure comes from eating fish

Solutions

Mercury Pollution

Prevention

Phase out waste incineration

Remove mercury from coal before it is burned

Switch from coal to natural gas and renewable energy resources



Control

Sharply reduce mercury emissions from coal-burning plants and incinerators

Label all products containing mercury

Collect and recycle batteries and other products containing mercury

50. The majority of atmospheric mercury is produced by

- (A) medical waste incinerators
- (B) volatilization of lead-based paint
- ☒ (C) coal-burning power plants
- (D) runoff from thermometer factories
- (E) municipal waste incinerators

Sunlight Plus Cars Equals Photochemical Smog

- **Photochemical Smog**
 - Chemical composition
 - Sources
- VOCs + NO_x + Heat + Sunlight yields
 - Ground level O₃ and other photochemical oxidants
 - Aldehydes
 - Other secondary pollutants
- Human health and environmental impact

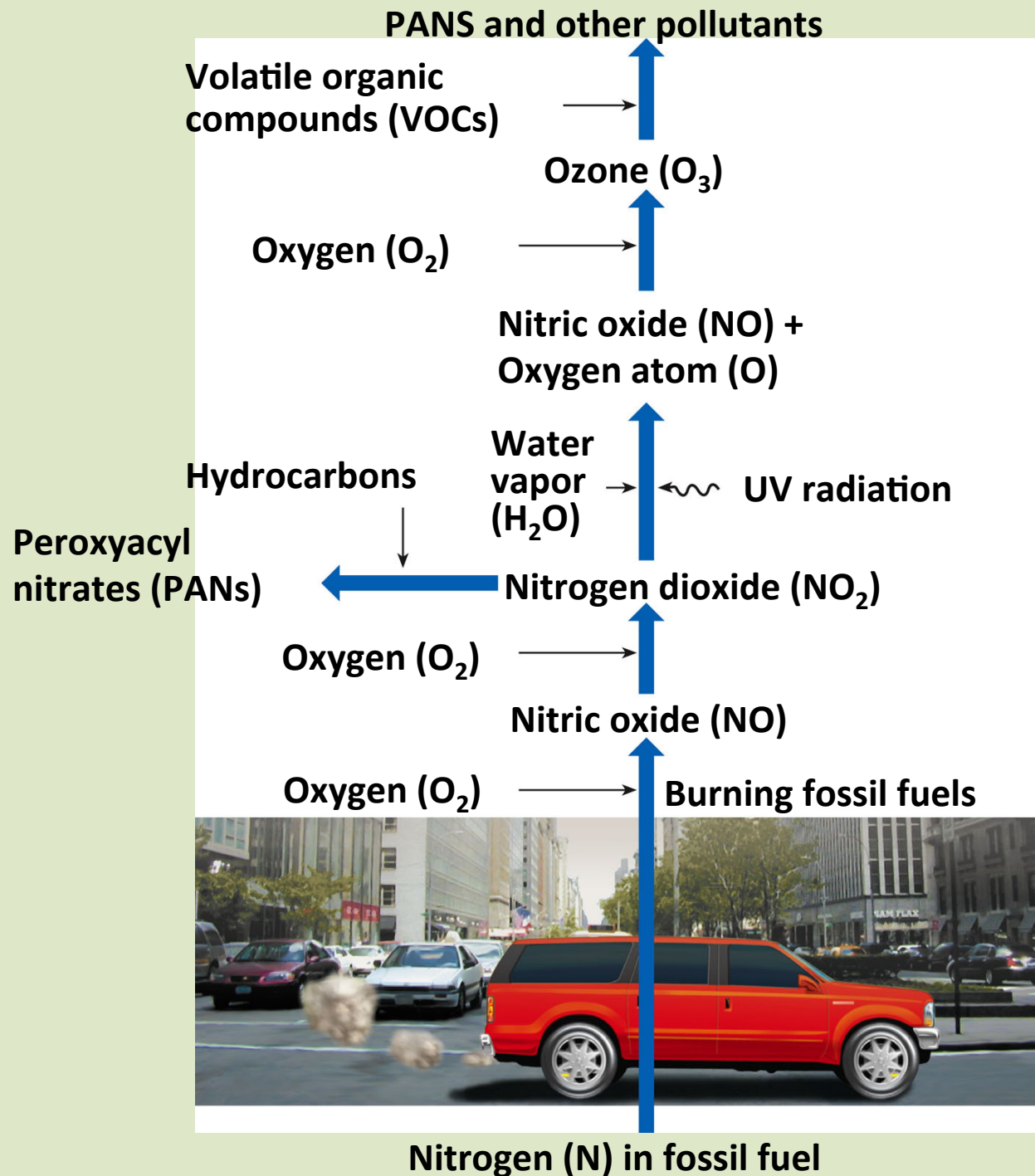


Fig. 18-11, p. 475

Global Outlook: Photochemical Smog in Santiago, Chile



Fig. 18-12, p. 475

A Temperature Inversion



Fig. 18-13, p. 476

30. Of the following cities, which regularly experiences the worst levels of photochemical smog that is enhanced by thermal inversions?

- (A) New York City, New York
- ☒ (B) Los Angeles, California
- (C) Portland, Oregon
- (D) Atlanta, Georgia
- (E) Philadelphia, Pennsylvania

68. Important factors that contribute to smog formation in the Los Angeles basin include which of the following?

- I. Ample summer sunshine
- II. Sea-level elevation
- III. High concentration of automobiles

- (A) I only
- (B) III only
- ☒ (C) I and III only
- (D) II and III only
- (E) I, II, and III

71. Which of the following are direct products of the use of hydrocarbon fuels in automobile engines?

- (A) O, N, and CO
- (B) CO, Ar, and O₃
- (C) CO₂, H₂O, and O₃
- (D) CO₂, O₃, and Pb
- ☒ (E) CO₂, NO_x, and VOCs

45. Which of the following best illustrates point-source pollution?

- (A) Toxic sediments in the delta of a major river
- (B) Increase in NO_x in a traffic-clogged city
- (C) Dust blowing off unpaved roads
- (D) Smoke emitted from forest fires
- ☒ (E) Smokestack emissions from a large smelting company

57. Ground-level ozone in most major United States cities results primarily from

- (A) burning coal
- (B) burning fuel for cooking
- (C) producing electric power
- (D) industrial emissions
- ☒ (E) motor-vehicle exhaust

Acid Disposition Is a Serious Regional Air Pollution Problem

- **Acid deposition**, acid rain
 - Chemical sources
 - Formation
 - Local versus regional problems
 - Effects of prevailing winds
 - Buffers
 - Where is the worst acid deposition?

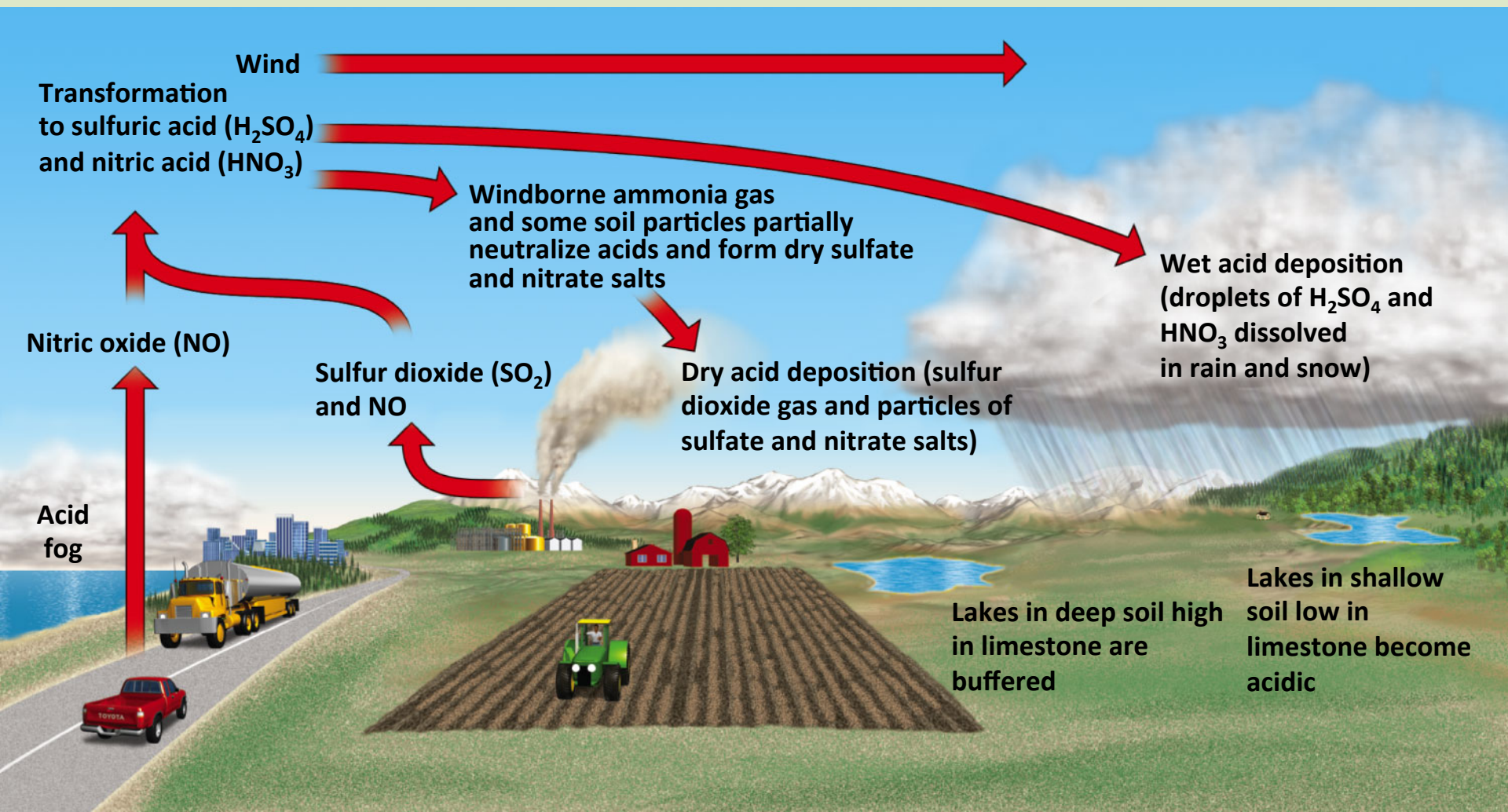


Fig. 18-14, p. 477

Acid Deposition Has a Number of Harmful Effects (1)

- Human health
 - Respiratory disorders
 - Toxins in fish
- Release of toxic metals
- Aquatic ecosystems affected
 - Lowers pH and kills organisms

Acid Deposition Has a Number of Harmful Effects (2)

- Leaching of soil nutrients
- Lower crop yields
- Forest damage
- Damage to buildings, statues, and monuments

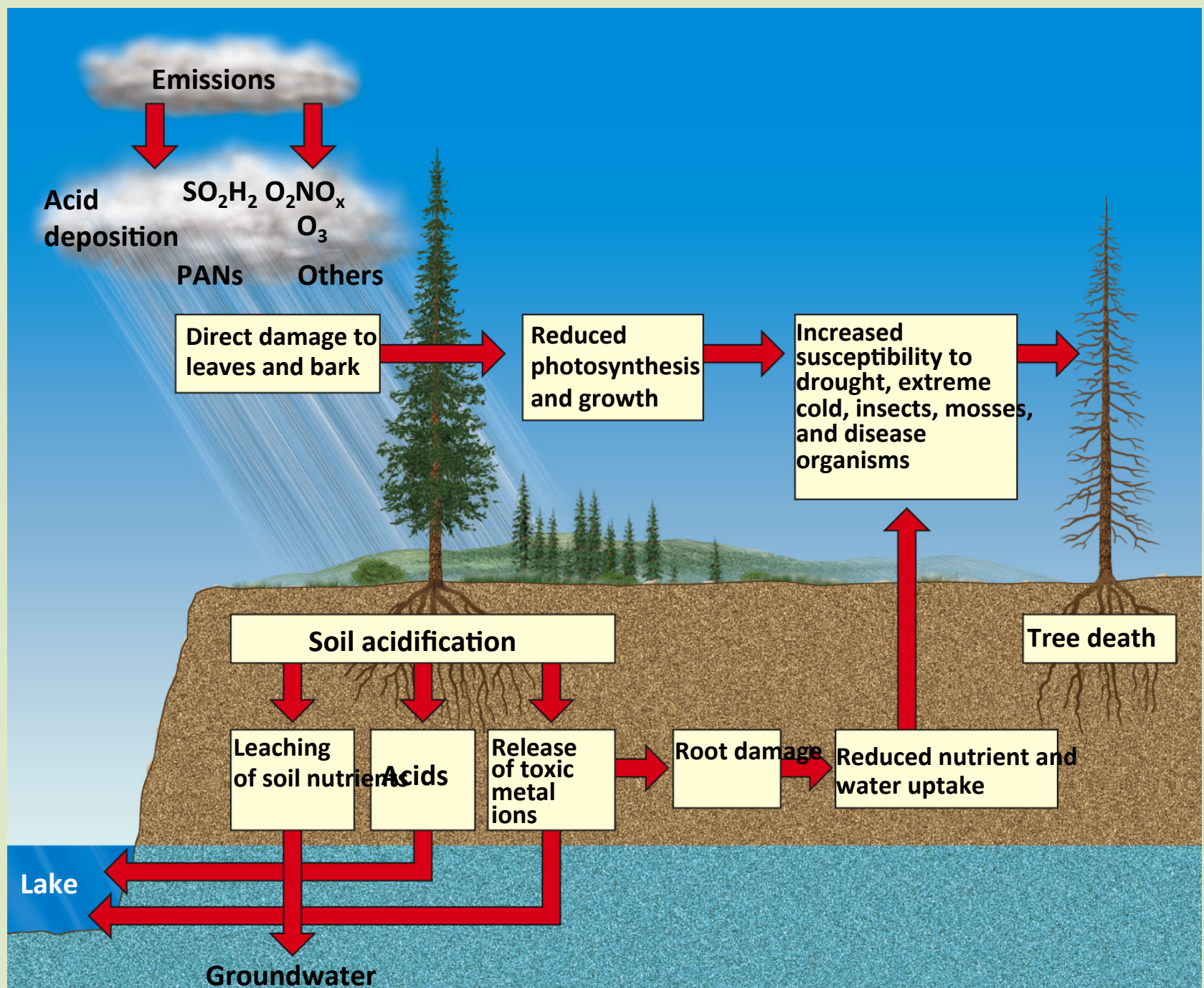


Fig. 18-16a, p. 479

Acid rain is associated with which of the following?

- (A) Formation of the antarctic ozone hole
- (B) Release of PCBs into the atmosphere
- (C) Damage to tropical rain forests
- ☒ (D) The burning of fossil fuels
- (E) The increasing pH of lake waters

Which of the following would be the strongest evidence in support of a scientist's contention that a local area was experiencing acid deposition?

- (A) A sudden die-off of all the fish in a local stream
- (B) A gradual increase in the temperature of a local lake
- (C) An increase in the rate of photosynthesis of aquatic plants in a local lake
- (D) A long-term increase in the pH of a local pond
- ☒ (E) An increase in the concentrations of soluble heavy metals in a local pond

Which of the following actions would be the most effective in decreasing acid rain and acid deposition problems?

- (A) Using higher smokestacks
- ☒ (B) Reducing use of fossil fuels
- (C) Developing acid-resistant crops
- (D) Adding lime to acidified lakes
- (E) Relocating power plants to areas of lower population density

52. Acid deposition would most likely result in which of the following?

- ☒ (A) The release of aluminum ions from soil
- (B) An increase in populations of mollusks
- (C) The death of species tolerant of low pH levels
- (D) An increase in buffering of lake water by sulfates
- (E) An increase in the pH of unbuffered water

Air Pollution Is a Big Killer

- 2.4 million deaths per year world-wide
 - Mostly in Asia; 750,000 in China
 - 150,000 to 350,000 in the United States
 - Role of coal-burning power plants
- EPA: proposed stricter emission standards for diesel-powered vehicles
 - 125,000 die in U.S. each year from diesel fumes
 - Emissions from one truck = 150 cars

Air Pollution Health Effects

Air pollution can contribute to:

- asthma
- chronic bronchitis
- emphysema
- lung cancer
- heart attack and stroke.

Laws and Regulations Can Reduce Outdoor Air Pollution (1)

- United States
 - Clean Air Acts: 1970, 1977, and 1990 created regulations enforced by states and cities
 - The Clean Air Act (CAA) is the comprehensive federal law that ***regulates air emissions from stationary and mobile sources***. Among other things, this law authorizes EPA to establish National Ambient Air Quality Standards (NAAQS) to protect public health and public welfare and to regulate emissions of hazardous air pollutants.

Laws and Regulations Can Reduce Outdoor Air Pollution (1)

- United States
 - Clean Air Acts: 1970, 1977, and 1990 created regulations enforced by states and cities
 - The Acid Rain Program was created under Title IV of the 1990 Clean Air Act Amendments to reduce the adverse effects of acid deposition through reductions in annual emissions of SO₂ and NO_x. The Act calls for reductions in SO₂, which are largely achieved through a ***market-based cap and trade program*** utilizing emission caps to permanently limit SO₂ emissions from power plants. NO_x reductions under the Acid Rain Program are achieved through a program closer to a more traditional, rate-based regulatory system.

Laws and Regulations Can Reduce Outdoor Air Pollution (1)

- EPA
 - National ambient air quality standards for 6 outdoor pollutants
<https://www.epa.gov/criteria-air-pollutants/naaqs-table>
 - National emission standards for 188 hazardous air pollutants (HAPs)

National Emission Standards for Hazardous Air Pollutants (NESHAP) are stationary source standards for hazardous air pollutants. Hazardous air pollutants (HAPs) are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.

Laws and Regulations Can Reduce Outdoor Air Pollution (1)

- EPA

- Toxic Release Inventory (TRI)

TRI tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. U.S. facilities in different industry sectors must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery and treatment. (A "release" of a chemical means that it is emitted to the air or water, or placed in some type of land disposal.)

[https://www.epa.gov/toxics-release-inventory-tri-program/learn-about-toxics-release-inventory#What is the Toxics Release Inventory?](https://www.epa.gov/toxics-release-inventory-tri-program/learn-about-toxics-release-inventory#What%20is%20the%20Toxics%20Release%20Inventory?)

54. Which of the following is true of the Clean Air Act?

- (A) It was passed by Congress during the early 1950s.
- (B) It regulates the amount of CO₂ emitted by power plants.
- (C) It has remained largely unmodified since it was originally signed into law.
- ☒ (D) It established a cap-and-trade program for SO₂ in 1990.
- (E) It is set to expire in 2015.

Solutions

Stationary Source Air Pollution

Prevention

**Burn low-sulfur coal
or remove sulfur
from coal**

**Convert coal to
a liquid or
gaseous fuel**

Phase out coal use



Reduction or Disposal

**Disperse emissions (which
can increase downwind
pollution) with tall
smokestacks**

**Remove pollutants
from smokestack
gases**

**Tax each unit of
pollution produced**

Solutions

Motor Vehicle Air Pollution

Prevention

Walk, bike, or use mass transit

Improve fuel efficiency

Get older, polluting cars off the road



Cleanup

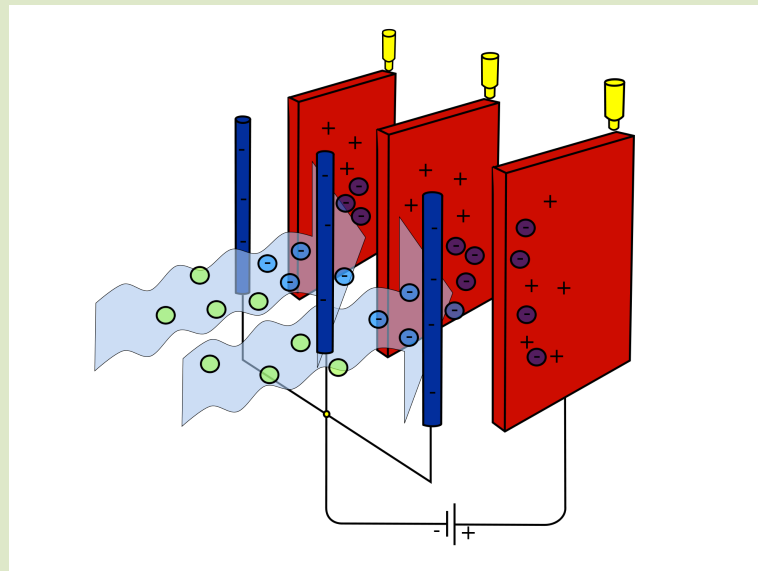
Require emission control devices

Inspect car exhaust systems twice a year

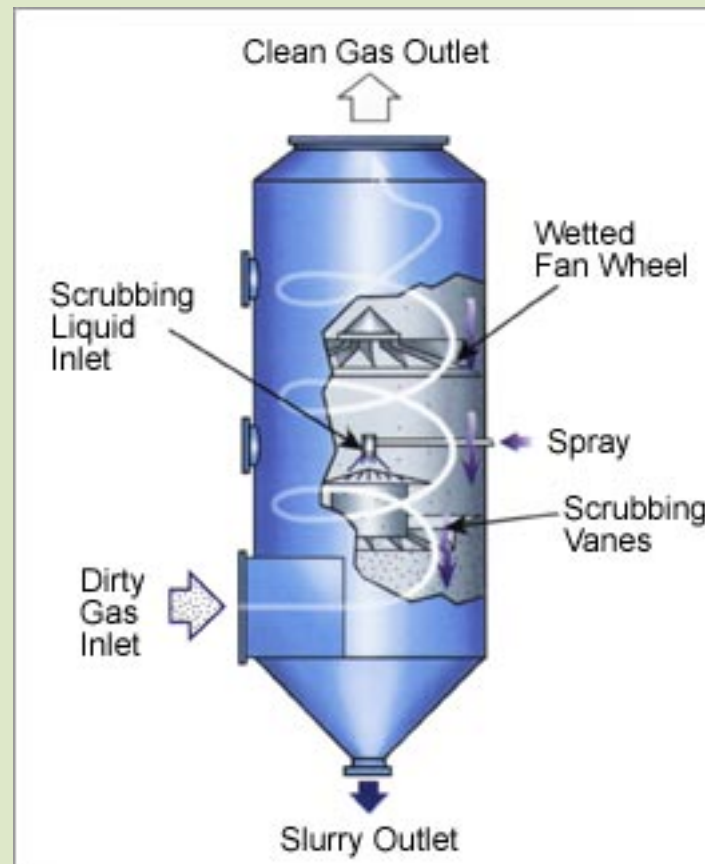
Set strict emission standards

An electrostatic precipitator (ESP) is a filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit. [1]

In contrast to wet scrubbers which apply energy directly to the flowing fluid medium, an ESP applies energy only to the particulate matter being collected and therefore is very efficient in its consumption of energy (in the form of electricity).[citation needed]



An SO₂ scrubber system is the informal name for flue gas desulfurization (FGD) technology, which removes, or "scrubs," SO₂ emissions from the exhaust of coal-fired power plants. A scrubber works by spraying a wet slurry of limestone into a large chamber where the calcium in the limestone reacts with the SO₂ in the flue gas. There are some variations in design of scrubbers. For example, some scrubbers may use other chemicals such as magnesium oxide to react with the SO₂ in the flue gas.



69. Particulates can be removed from smokestack emissions by which of the following methods?

- (A) Irradiation by UV light
- ☒ (B) Electrostatic precipitators
- (C) Catalytic converters
- (D) Liquid chromatography
- (E) Exhaust-stream aeration

Questions 25-28 refer to the following gases.

- (A) Carbon dioxide
- (B) Carbon monoxide
- (C) Methane
- (D) Radon
- (E) Sulfur dioxide

- 25. Is an important precursor to acid rain
- 26. Has a stronger affinity for hemoglobin than oxygen has
- 27. Has been implicated as the cause of as much as 15 percent of lung cancer cases
- 28. Is a flammable gas produced by landfills

Elements that cycle in the environment and that also have a gaseous phase at some point in their cycle include which of the following?

- I. Carbon
- II. Phosphorus
- III. Sulfur

- (A) I only
- (B) III only
- (C) I and II only
- ☒ (D) I and III only
- (E) I, II, and III

- (A) Sulfur dioxide
- (B) Lead
- (C) Ozone
- (D) Hydrocarbons
- (E) Particulates

Most often cited as the causative factor for acid deposition

Implicated in human neurological damage

Considered harmful in the troposphere but beneficial in the stratosphere

Is the major pollutant that electrostatic precipitators are designed to remove from power-plant smokestack emissions

Which of the following is a greenhouse gas that is also a by-product of anaerobic respiration?

- ☒ (A) Methane, CH_4
- (B) Nitrogen, N_2
- (C) Oxygen, O_2
- (D) Nitrogen dioxide, NO_2
- (E) Hydrogen sulfide, H_2S