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19

Air Pollution

Overview of Chapter 19

- Atmosphere as a Resource
- Types and Sources of Air Pollution
- Effects of Air Pollution
- Controlling Air Pollution in the US
- Ozone Depletion in the Stratosphere
- Acid Deposition
- Air Pollution Around the World
- Indoor Air Pollution

Forest burning in Sumatra

- Fires are set to clear forests for planting
- Burning results in severe air pollution
- Silviculture (commercial production of forest products)
- Smoke is full of small particles that can lodge in lungs and cause illness/disease

ROMEO GACAD/AFP/Getty Images

Atmosphere as a Resource

- Atmospheric Composition
  - Nitrogen 78.08%
  - Oxygen 20.95%
  - Argon 0.93%
  - Carbon dioxide 0.04%
- Ecosystem services
  - Blocks UV radiation
  - Moderates the climate
  - Redistributes water in the hydrologic cycle

SPL/Science Source

Air Pollution - Terminology

- Air Pollution
  - Chemicals added to the atmosphere by natural events or human activities in high enough concentrations to be harmful
- Two categories
  - Primary Air Pollutant
    - Harmful substance emitted directly into the atmosphere
  - Secondary Air Pollutant
    - Harmful substance formed in the atmosphere when a primary air pollutant reacts with substances normally found in the atmosphere or with other air pollutants

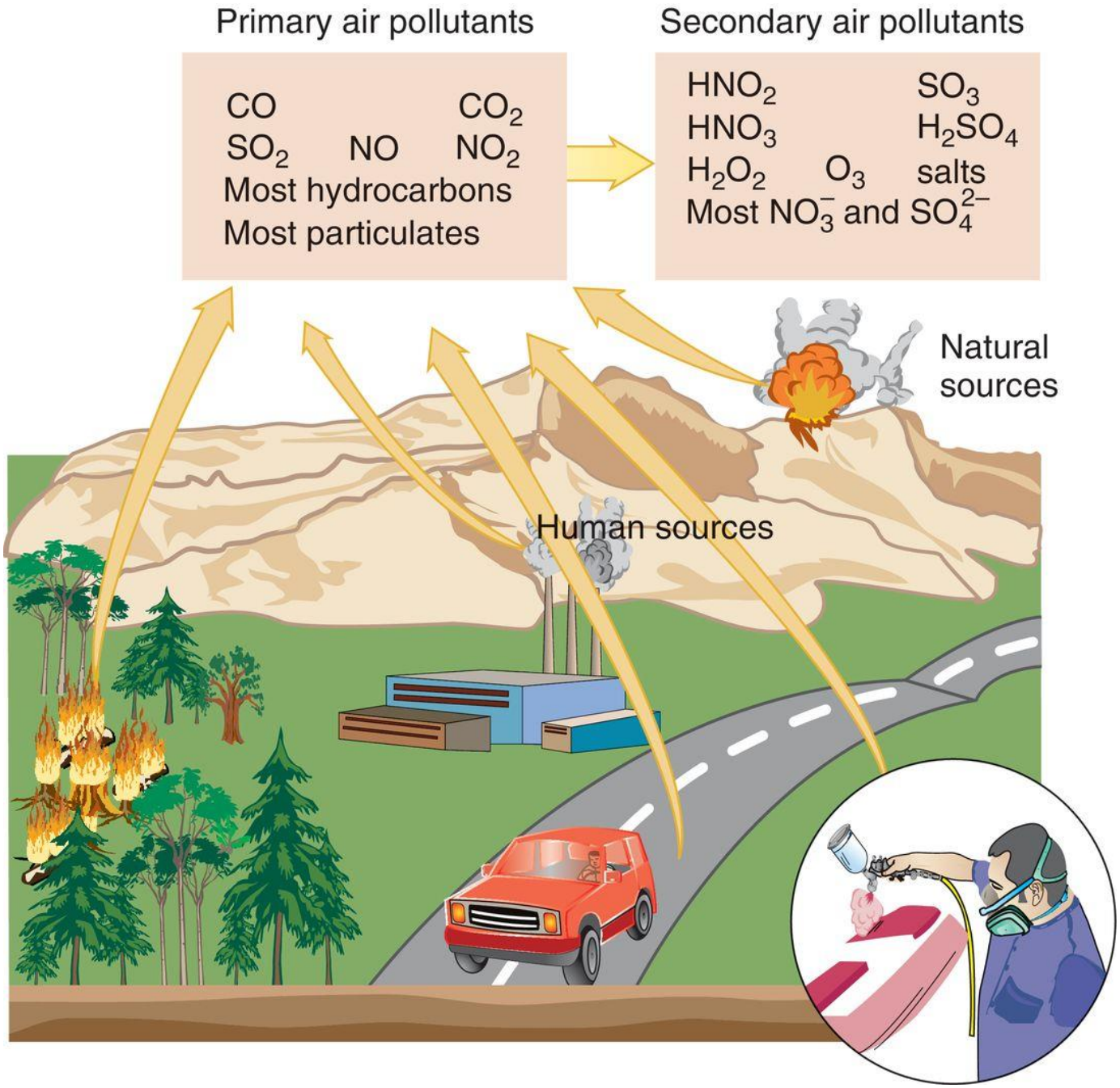
Major Air Pollutants

Table 19.1 Major Air Pollutants

Pollutant	*Composition*	*Primary or Secondary*	*Characteristics*
Particulate Matter			
Dust	Variable	Primary	Solid particles
Lead	Pb	Primary	Solid particles
Sulfuric acid	H_2SO_4	Secondary	Liquid droplets
Nitrogen Oxides			
Nitrogen dioxide	NO_2	Primary	Reddish-brown gas
Sulfur Oxides			
Sulfur dioxide	SO_2	Primary	Colorless gas with strong odor
Carbon Oxides			
Carbon monoxide	CO	Primary	Colorless, odorless gas
Carbon dioxide*	CO_2	Primary	Colorless, odorless gas
Hydrocarbons			
Methane	CH_4	Primary	Colorless, odorless gas
Benzene	C_6H_6	Primary	Liquid with sweet smell
Ozone	O_3	Secondary	Pale-blue gas with acrid odor
Air Toxics			
Chlorine	Cl_2	Primary	Yellow-green gas

*Discussed in Chapter 20.

Source: Environmental Protection Agency. Compiled by authors.


Primary air pollutants
CO
CO_2
SO_2
NO
NO_2
Most hydrocarbons
Most particulates
Secondary air pollutants
HNO_2
SO_3
HNO_3
H_2SO_4
H_2O_2
O_3
salts
Most NO_3^- and SO_4^{2-}
Natural sources
Human sources

Major Classes of Air Pollutants

- Particulate Material
- Nitrogen Oxides
- Sulfur Oxides
- Carbon Oxides
- Hydrocarbons
- Ozone

Particulate Material

- Thousands of different solid or liquid particles suspended in air
  - Includes: soil particles, soot, lead, asbestos, sea salt, and sulfuric acid droplets
- Dangerous
  - May contain materials with toxic/carcinogenic effects
  - Small particles can become lodged in lungs

Nitrogen and Sulfur Oxides

- Nitrogen Oxides
  - Gases produced by the chemical interactions between atmospheric nitrogen and oxygen at high temperature
  - Greenhouse gases that cause difficulty breathing
- Sulfur Oxides
  - Gases produced by the chemical interactions between sulfur and oxygen
  - Causes acid precipitation

Carbon Oxides and Hydrocarbons

- Carbon Oxides
  - Gases carbon monoxide (CO) and carbon dioxide (CO_2)
  - Greenhouse gases
- Hydrocarbons
  - Diverse group of organic compounds that contain only hydrogen and carbon (ex: CH_4 - methane)
  - Some are related to photochemical smog and greenhouse gases

Ozone

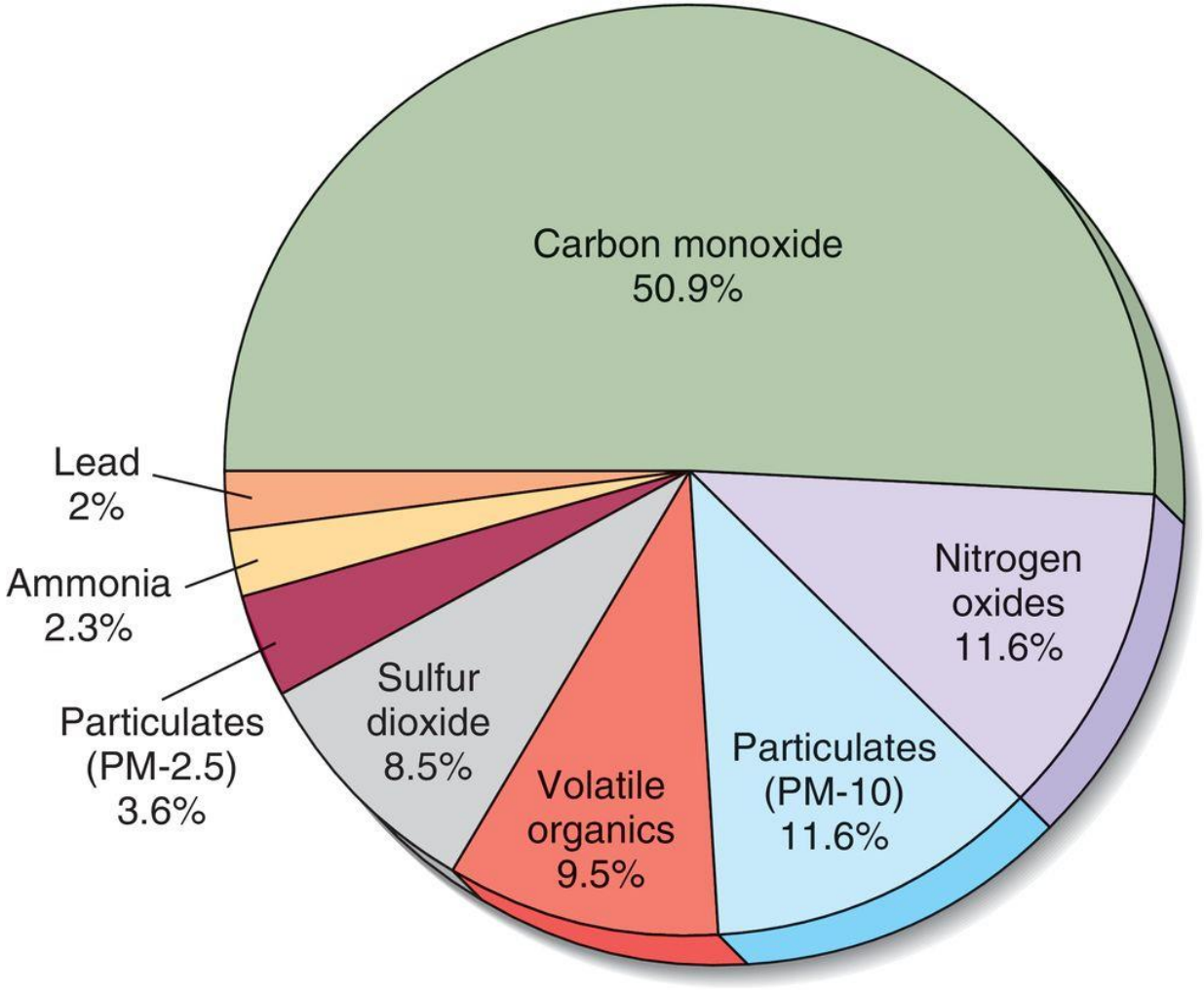
- Tropospheric Ozone
  - Man-made pollutant in the lower atmosphere
  - Secondary air pollutant
  - Component of photochemical smog
- Stratospheric Ozone
  - Essential component that screens out UV radiation in the upper atmosphere
  - Man- made pollutants (ex: CFCs) can destroy it

Ozone Damage to Grape Leaves

TED SPIEGEL/National GeographicCreative

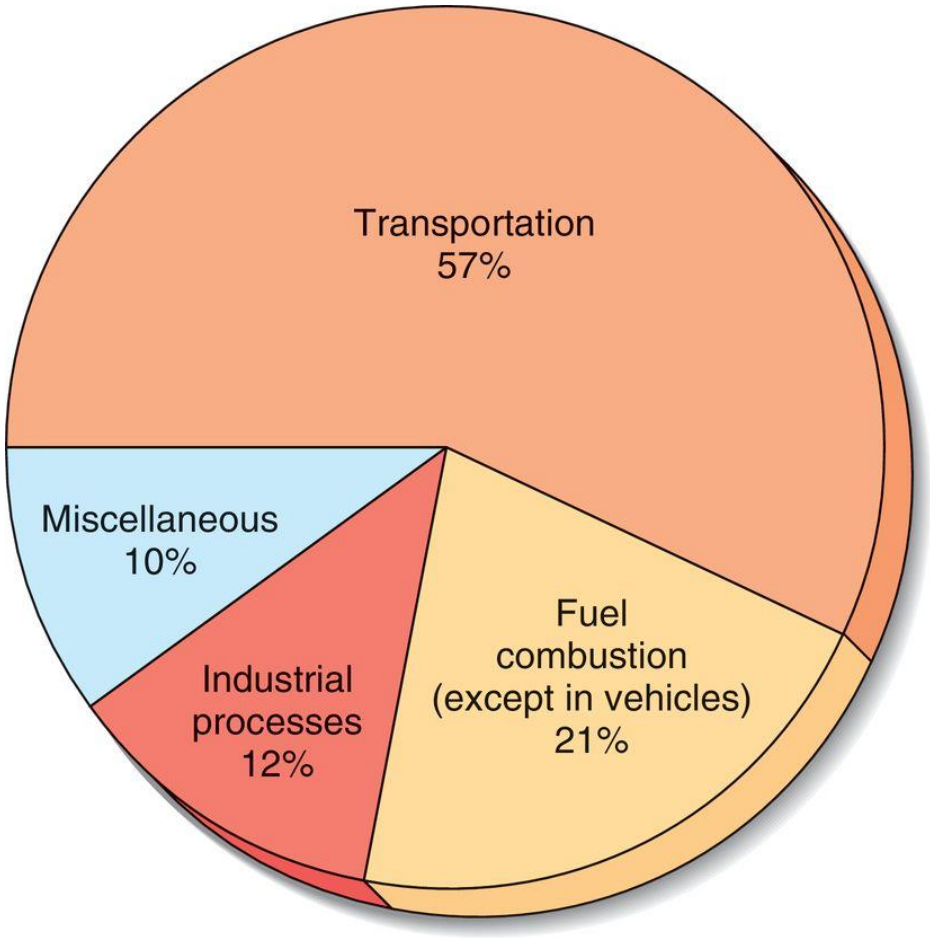
TED SPIEGEL/National Geographic Creative

Air Pollutants



Sources of Outdoor Air Pollution

- Two main sources
  - Transportation
  - Industry
- Intentional forest fires is also high

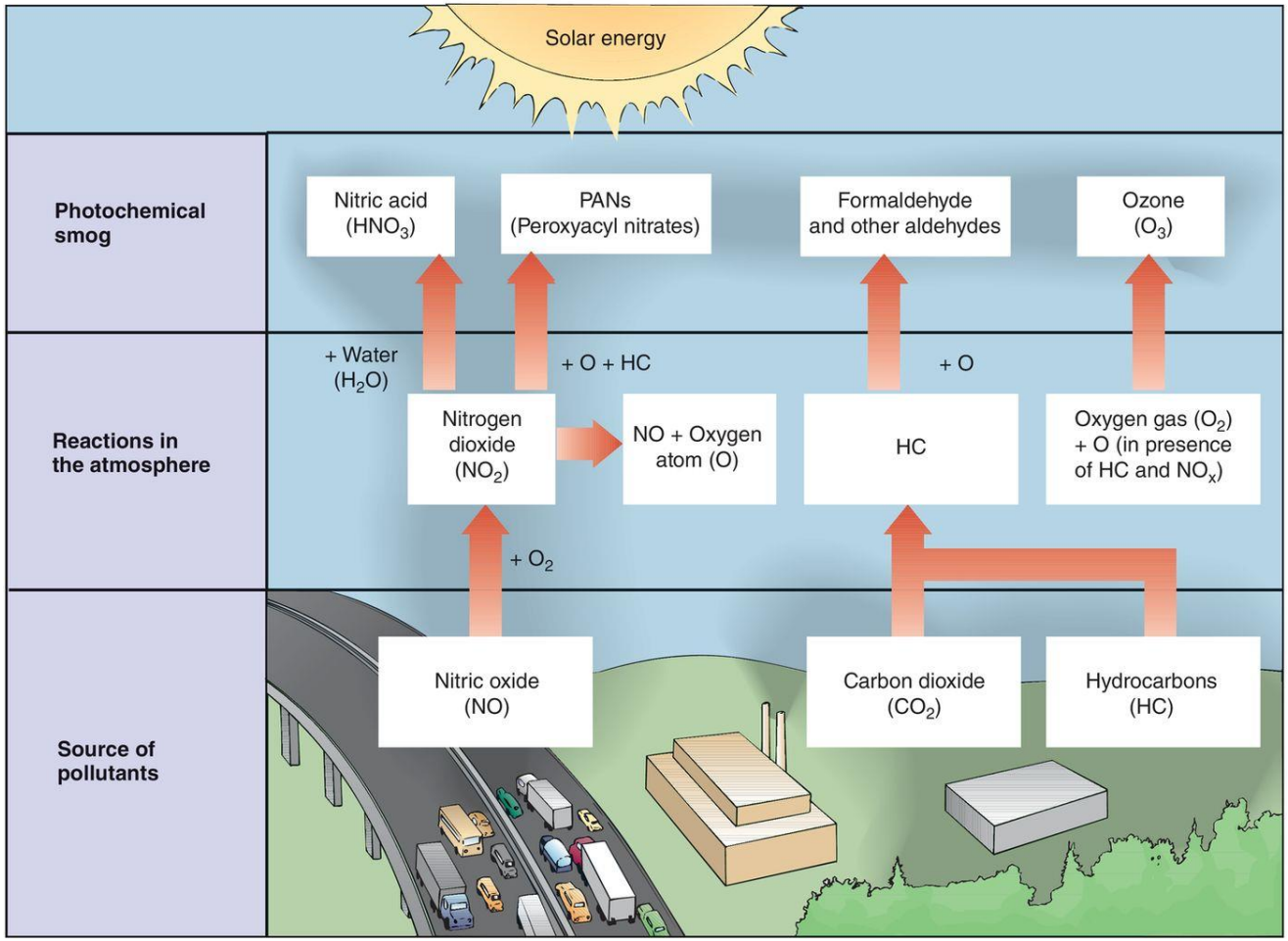


Urban Air Pollution

- Industrial Smog – sulfur oxides and PM
- Photochemical Smog (ex: Los Angeles below)
  - Brownish-orange haze formed by chemical reactions involving sunlight, nitrogen oxide, and hydrocarbons

Jodi Cobb/National Geographic Creative

Formation of Photochemical Smog

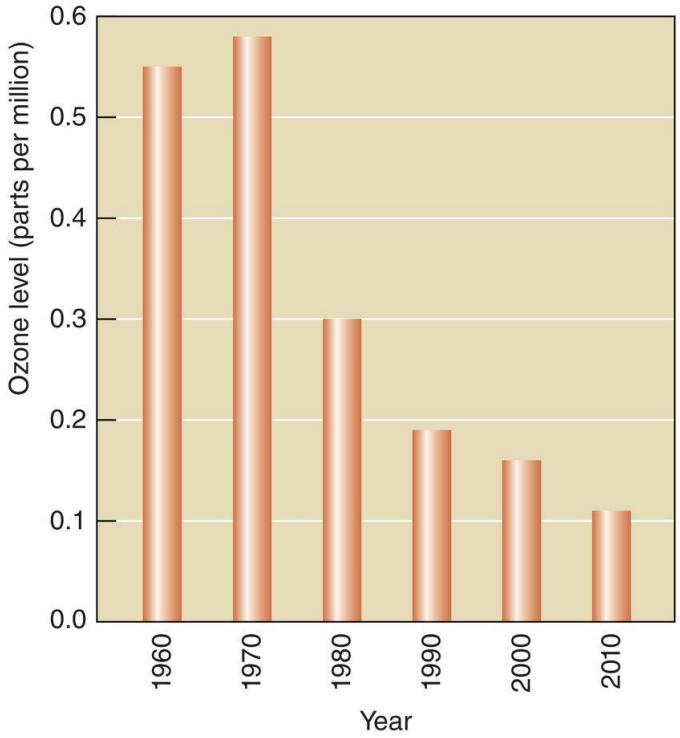


Efforts to Reduce Ozone in S. California

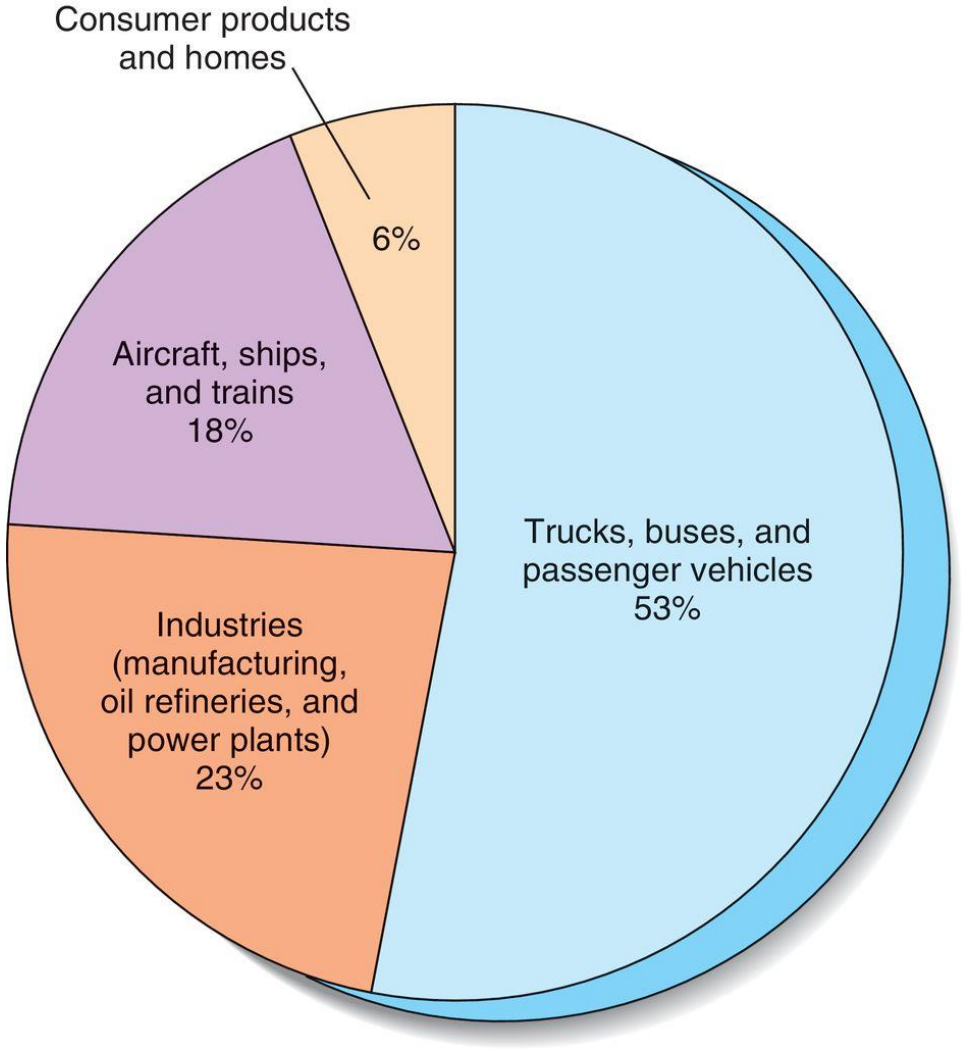
- Volatile organic compounds (VOCs)
  - Contributes to smog
  - Ex: compounds released from paints, cleaning products, dry cleaners, bakeries
- Temperature inversions
  - Temperature increases with altitude (usually reverse)
  - Pollution is trapped in high concentrations near surface and is not distributed

Efforts to Reduce Ozone in S. California

- CA consolidated efforts to improve air quality (1977)
- Improvements due to a few major regulations



Sources of Smog in Los Angeles



Effects of Air Pollution

- Low level exposure
  - Irritates eyes
  - Causes inflammation of respiratory tract
- Can develop into chronic respiratory diseases
  - Emphysema
  - Chronic bronchitis

Health Effects of Pollutants

Table 19.2 Health Effects of Several Major Air Pollutants

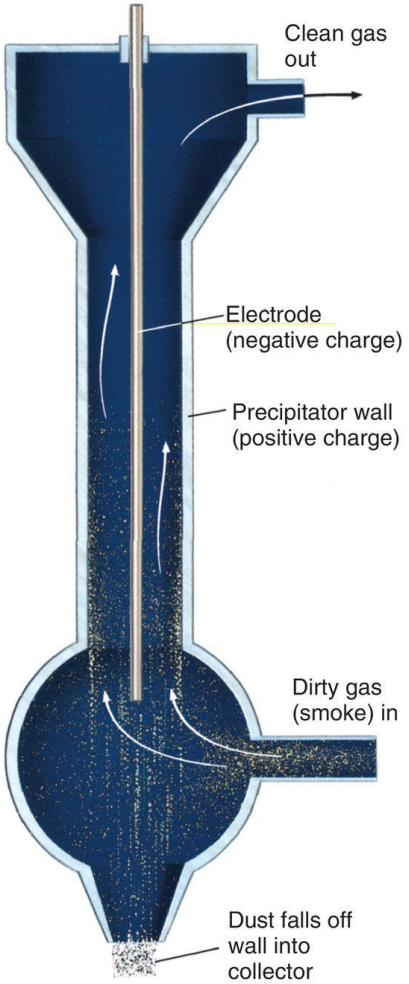
Pollutant	*Source*	*Effects*
Particulate matter	Industries, electric power plants, motor vehicles, construction, agriculture	Aggravates respiratory illnesses; long-term exposure may cause increased incidence of chronic conditions such as bronchitis; linked to heart disease; suppresses immune system; some particles, such as heavy metals and organic chemicals, may cause cancer or other tissue damage
Nitrogen oxides	Motor vehicles, industries, heavily fertilized farmland	Irritate respiratory tract; aggravate respiratory conditions such as asthma and chronic bronchitis
Sulfur oxides	Electric power plants and other industries	Irritate respiratory tract; same effects as particulates
Carbon monoxide	Motor vehicles, industries, fireplaces	Reduces blood's ability to transport oxygen; headache and fatigue at lower levels; mental impairment or death at high levels
Ozone	Formed in atmosphere (secondary air pollutant)	Irritates eyes; irritates respiratory tract; produces chest discomfort; aggravates respiratory conditions such as asthma and chronic bronchitis

Children and Air Pollution

- Greater health threat to children than adults
  - Air pollution can restrict lung development
  - Children breath more often than adults
- Children who live in high ozone areas are more likely to develop asthma

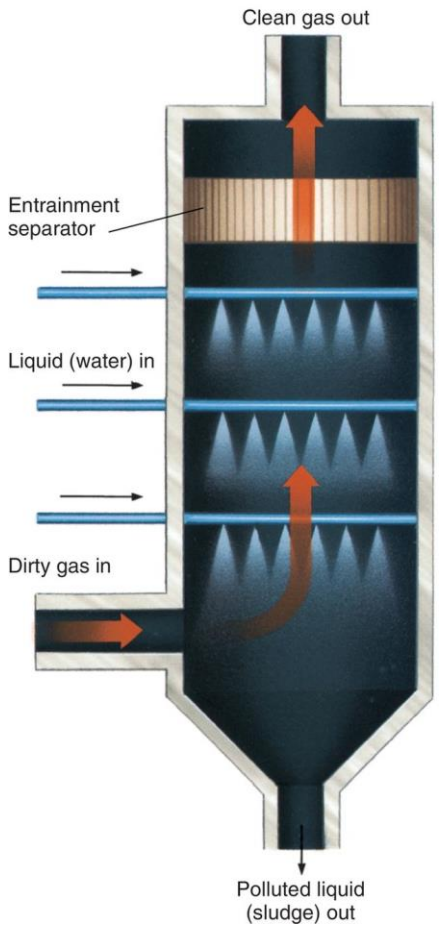
Controlling Air Pollution

- Smokestacks with electrostatic precipitator (right)
  - Electrode imparts negative charge on the air pollutants
  - Negatively charged pollutants are then attracted to positively charged walls- fall into collector

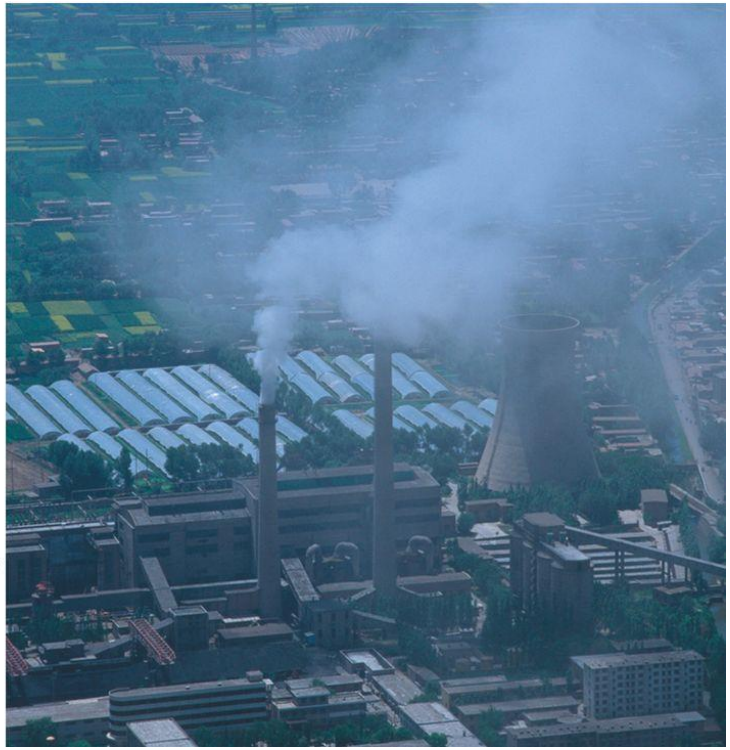


Controlling Air Pollution

- Smokestacks with scrubbers (right)
- Particulate material can also be controlled by proper excavating techniques
- Cars – catalytic converters



Scrubbers



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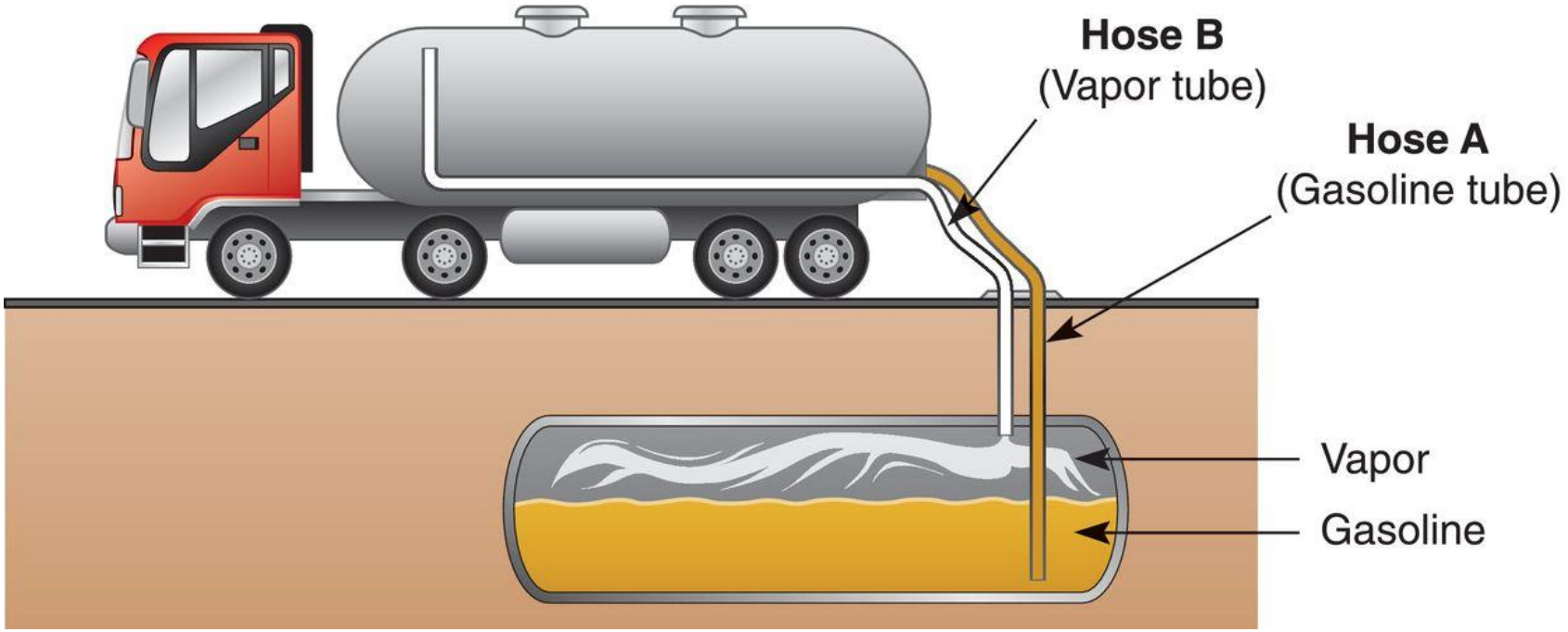
Emissions not controlled-heavily polluted (China)

Harrison Shull/Aurora Photos

Emissions controlled with scrubbers-only steam expelled (North Carolina)

Controlling Air Pollution

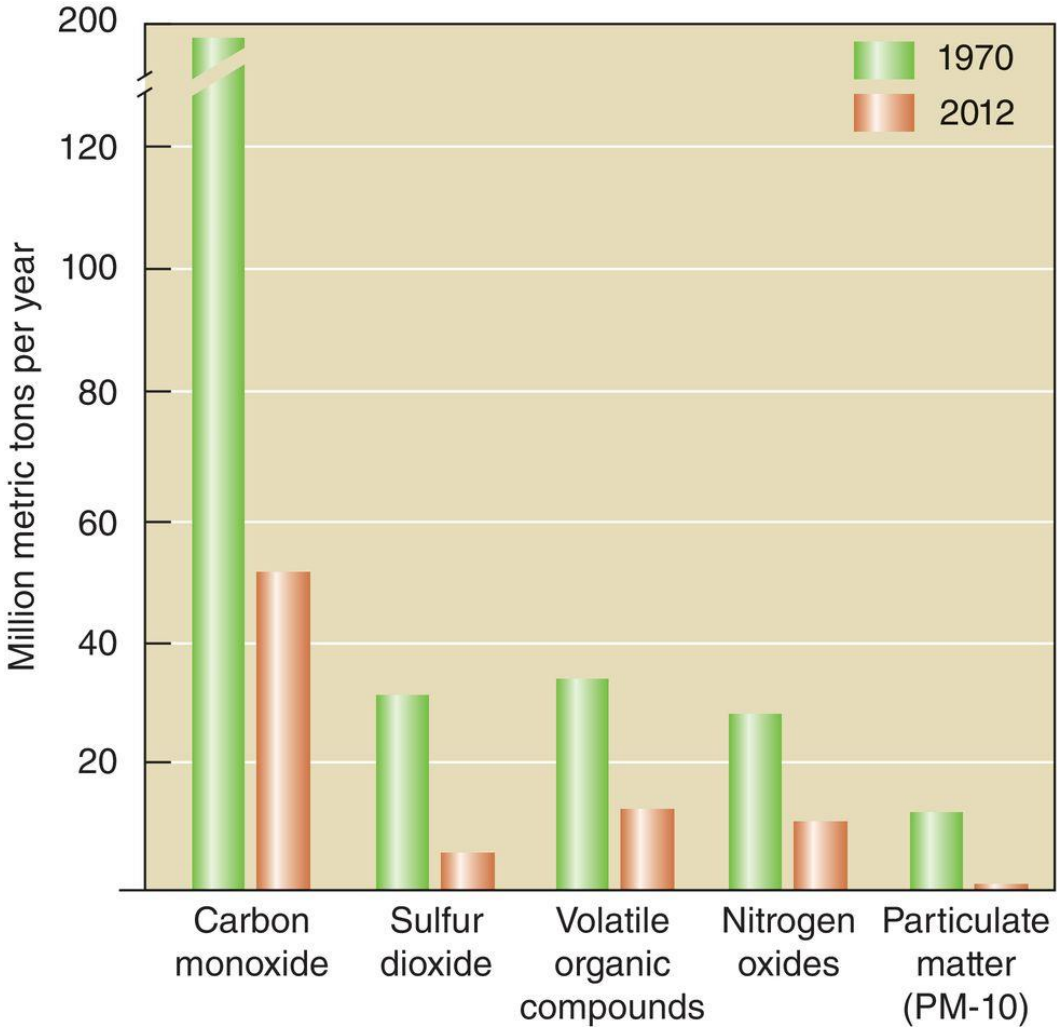
- Phase I Vapor Recovery System for gasoline



The Clean Air Act

- 1955 and significant updates in 1990
- Authorizes EPA to set limits on amount of specific air pollutants permitted
- Focuses on 6 pollutants:
  - lead, particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and ozone
- Act has led to decreases in air pollutants
  - Most dramatic is lead - decreased by 98% since 1970 (due to switch to unleaded gasoline)

The Clean Air Act



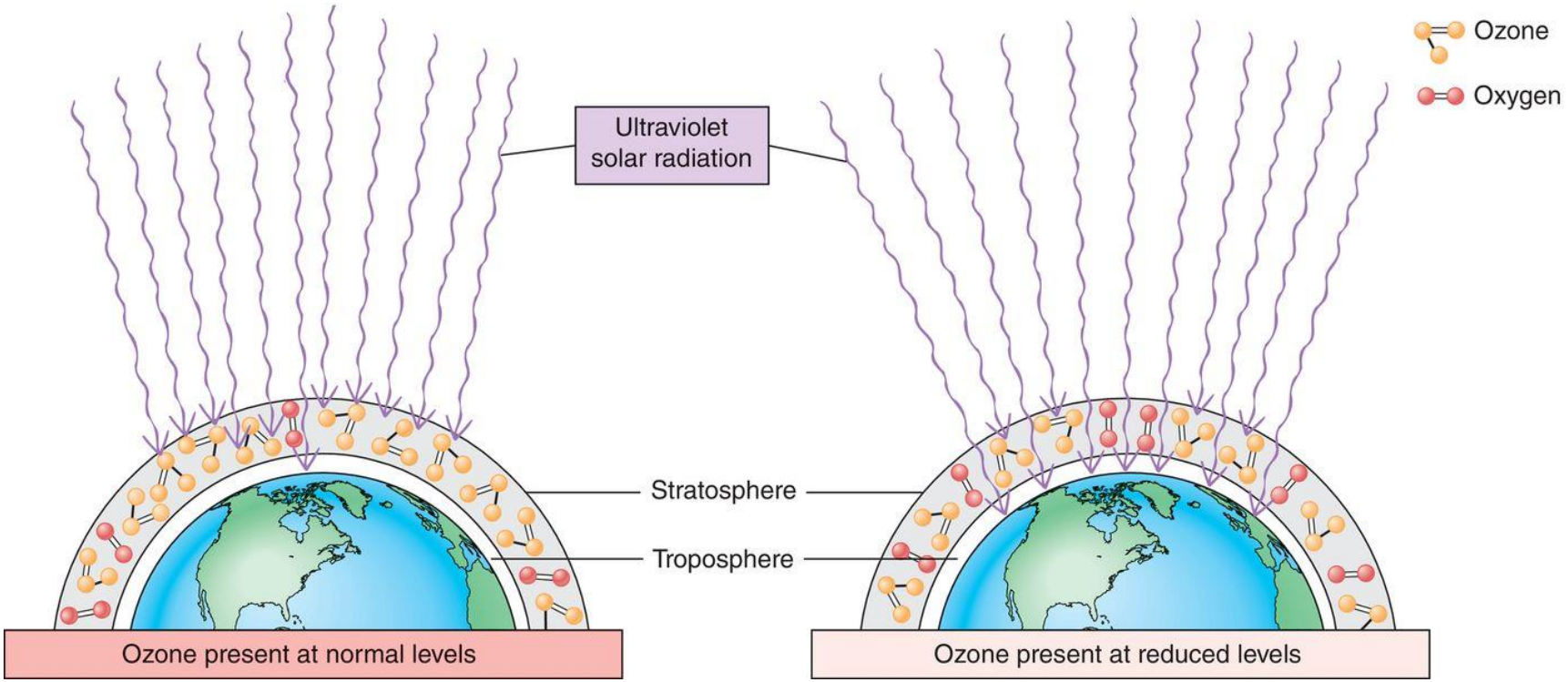
Urban Air Quality

Table 19.3 U.S. Urban Areas with the Worst Air Quality in 1999 (Ozone Nonattainment Areas), and Conditions in the Same Locations in 2009.

	1999	*2013*
Los Angeles South Coast Air Basin, California	Extreme	Extreme
Chicago, Gary, and Lake County, Illinois–Indiana	Very severe	Marginal
Houston, Galveston, and Brazoria, Texas	Very severe	Marginal
Milwaukee and Racine, Wisconsin	Very severe	No longer listed
New York City, northern New Jersey, and Long Island, New York –New Jersey–Connecticut	Very severe	Marginal
Baltimore, Maryland	Severe	Moderate
Philadelphia, Wilmington, Trenton, Pennsylvania–New Jersey –Delaware–Maryland	Severe	Marginal
Sacramento, California	Severe	Severe
San Joaquin Valley, California	Severe	No longer listed
Ventura County (between Santa Barbara and Los Angeles), California	Severe	Serious

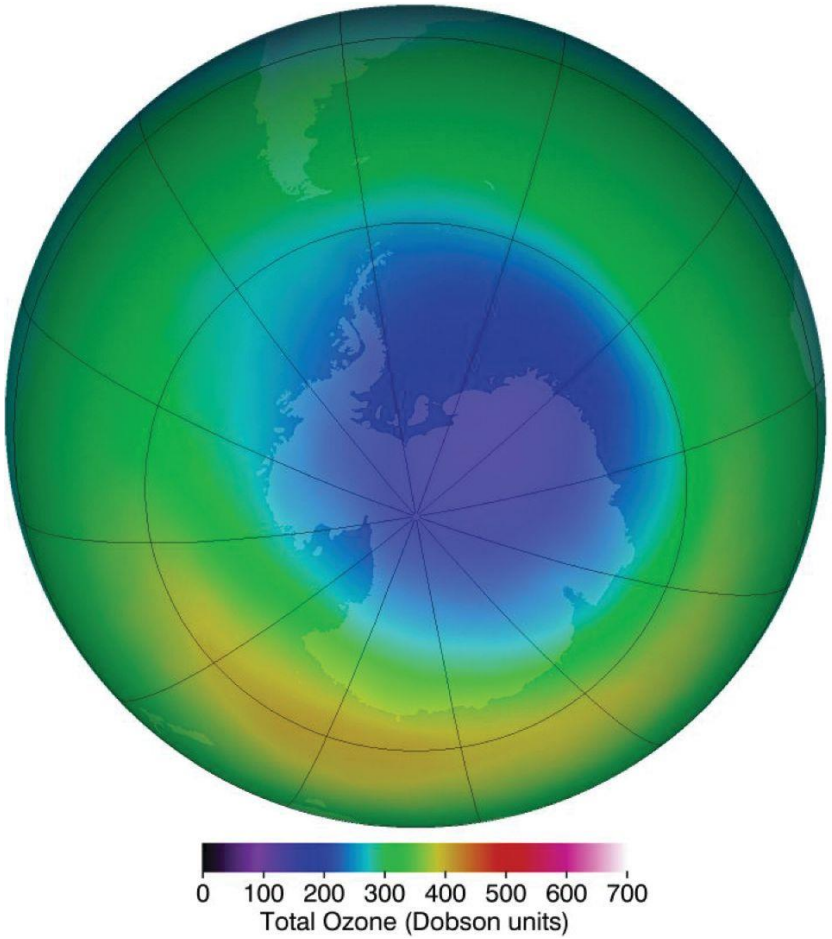
Ozone Depletion in Stratosphere

- Ozone Protects earth from UV radiation



Ozone Depletion in Stratosphere

- Ozone thinning/hole
  - First identified in 1985 over Antarctica
  - Occurs annually between Sept and Nov because:
- Caused by human-produced bromine and chlorine containing chemicals (Ex: CFCs)



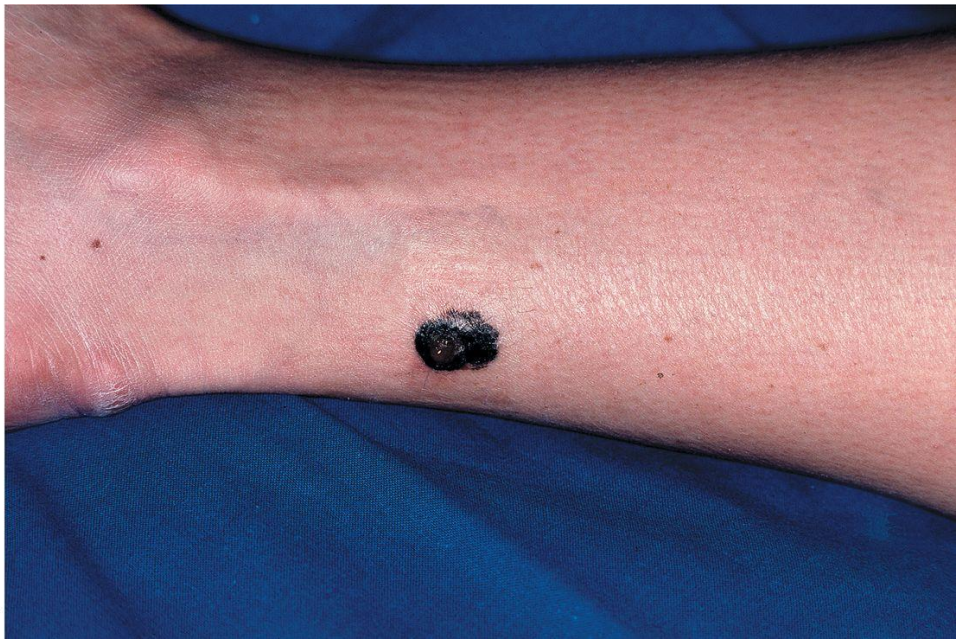
NASA/Ozone Hole Watch/REXFeatures/ AP Photos

Ozone Depletion in Stratosphere

- Hole over Antarctica requires two conditions:
  - Sunlight just returning to polar region
  - Circumpolar vortex- a mass of cold air that circulates around the southern polar region
- Polar stratospheric clouds form
  - Enable chemical reactions that cause Cl and Br to destroy ozone

Effects of Ozone Depletion

- Higher levels of UV-radiation hitting the earth
  - Eye cataracts
  - Skin cancer (right)
  - Weakened immunity
- May disrupt ecosystems
- May damage crops and forests



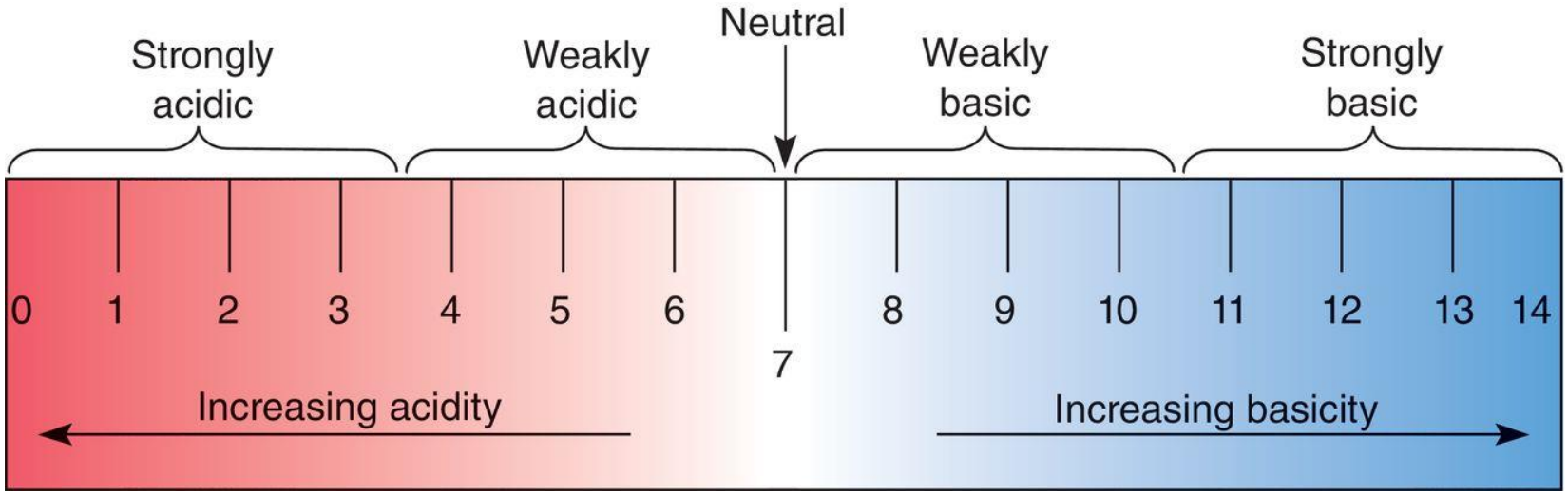
ISM/Phototake

Recovery of Ozone Layer

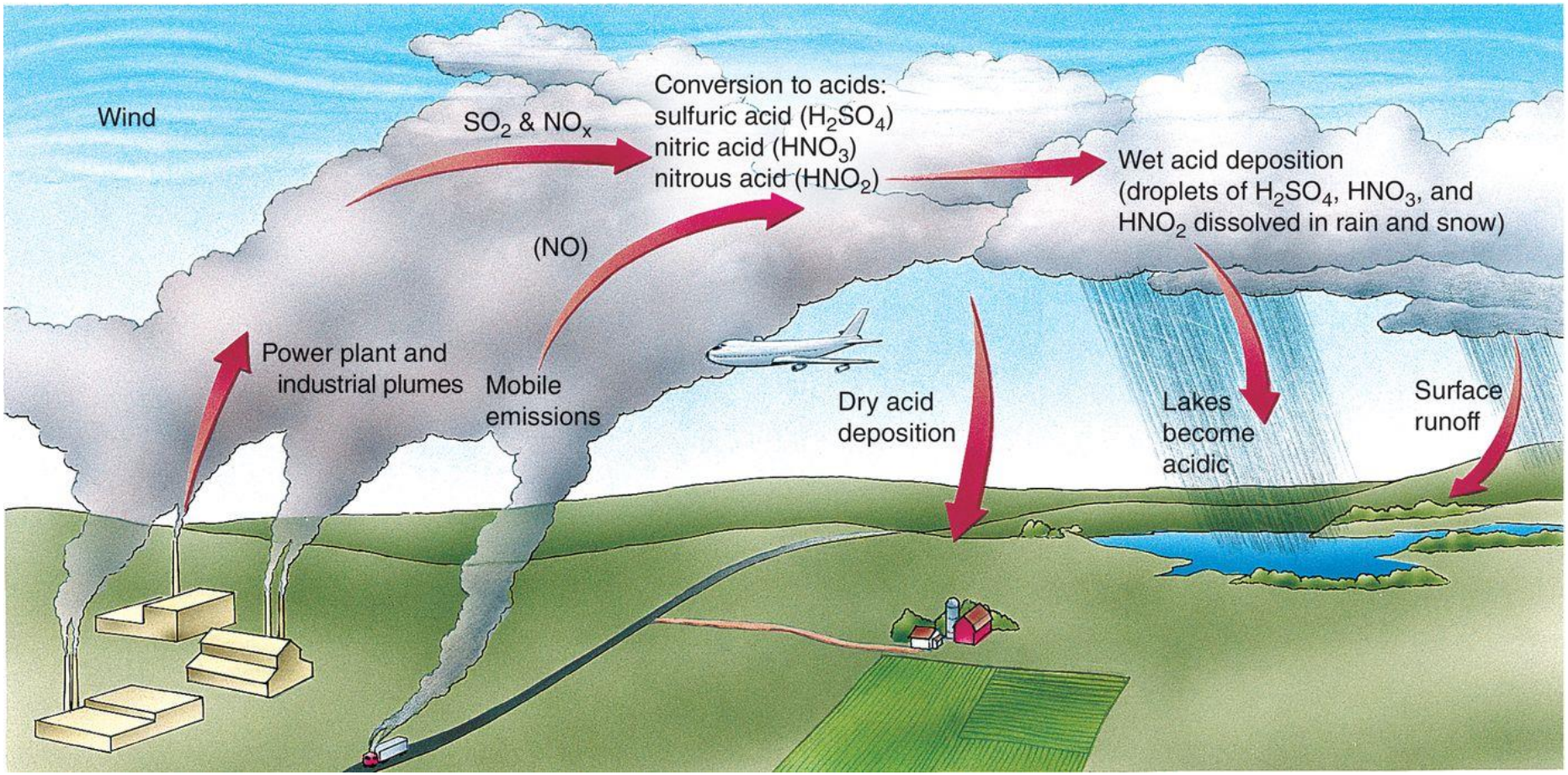
- Montreal Protocol (1987)
  - Reduction of CFCs
  - Started using HCFCs (greenhouse gas)
- Phase out of all ozone destroying chemicals is underway globally
- Satellite pictures in 2000 indicated that ozone layer was recovering
- Full recovery will not occur until 2050

Acid Deposition

- Sulfur dioxide and nitrogen dioxide emissions react with water vapor in the atmosphere and form acids that return to the surface as either dry or wet deposition
- pH scale



How Acid Deposition Develops

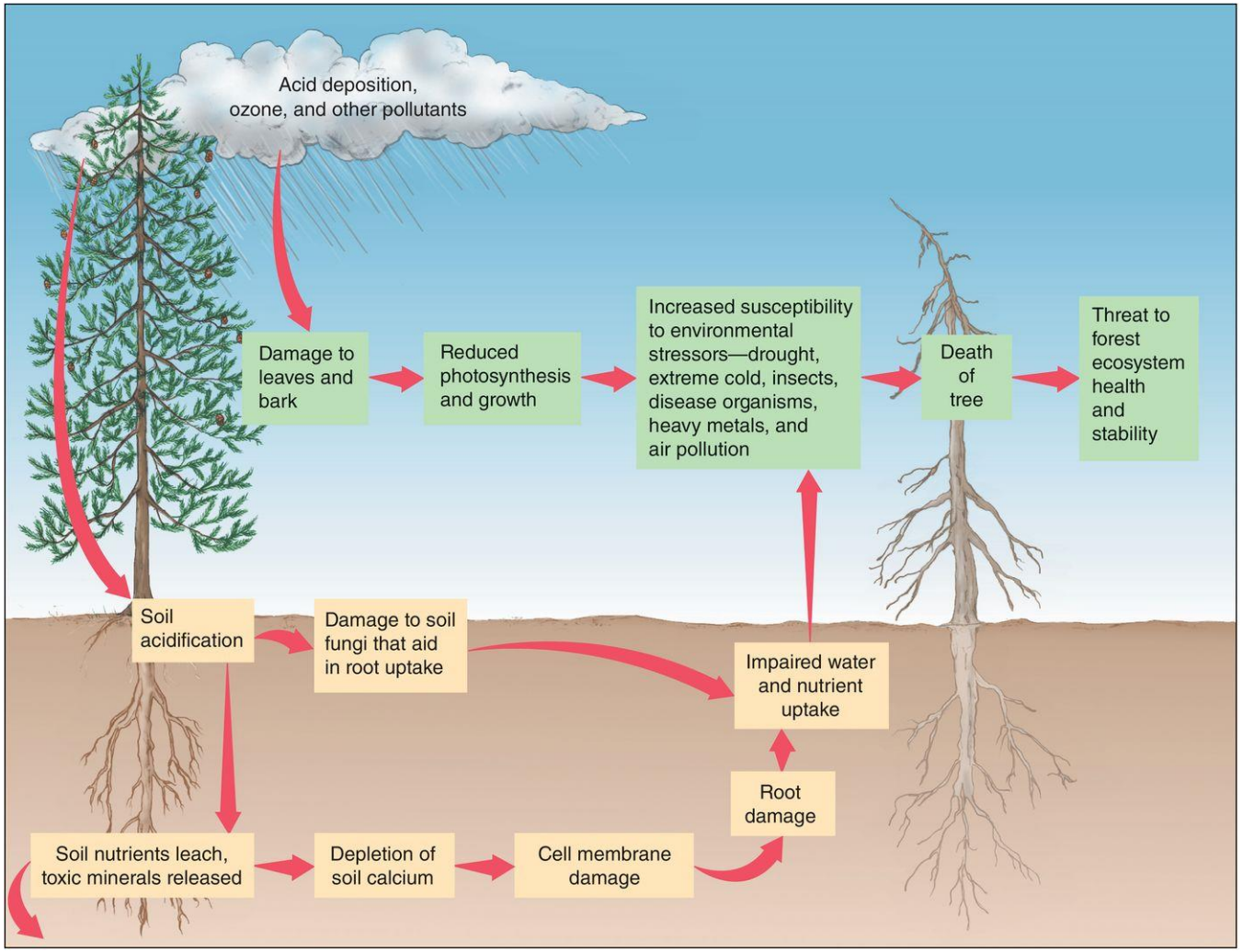


Effects of Acid Deposition

- Declining Aquatic Animal Populations
- Thin-shelled eggs prevent bird reproduction
  - Calcium is unavailable in acidic soil
- Forest decline
  - (right) Black Forest in Germany

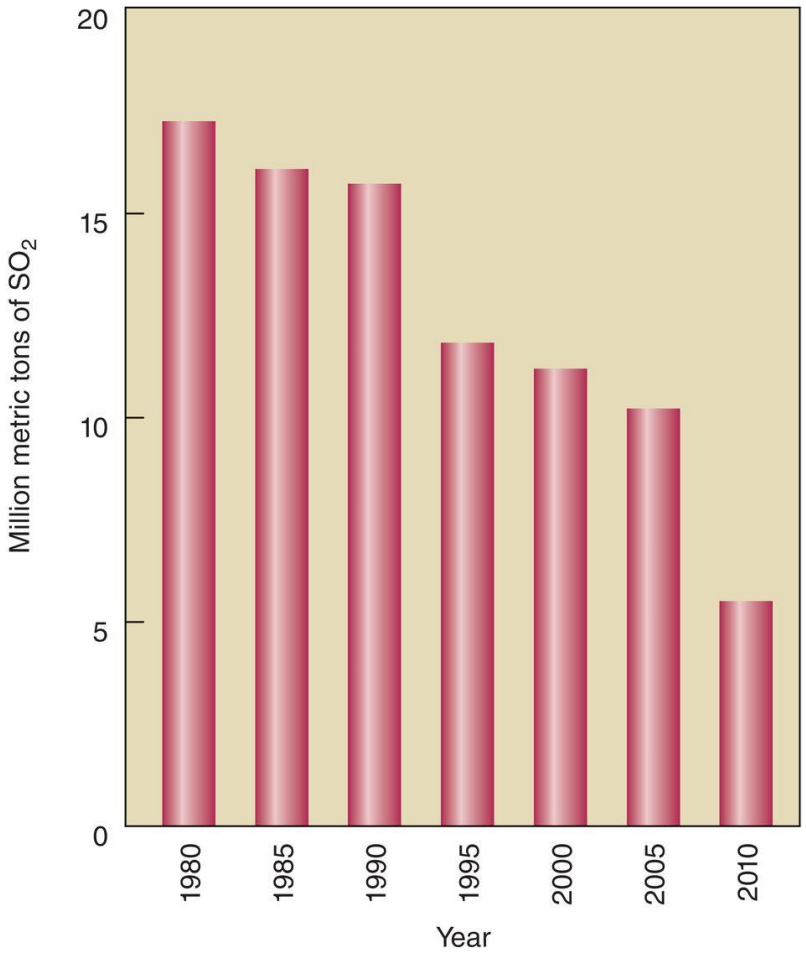
Hans Reinhard/Bruce Coleman, Inc./Photoshot

Acid Deposition and Forest Decline



Managing Acid Deposition

- Acid deposition is cross boundary issue
  - Pollution in one place, problem in another



Air Pollution Around the World

- Air quality is deteriorating rapidly in developing countries
  - Developing countries have older cars
- Shenyang, China
  - Residents only see sunlight a few weeks each year
- 5 worst cities in world
  - Beijing, China and New Delhi, India are tied for first; Santiago, Chile; Mexico City, Mexico; Ulaanbaatar, Mongolia

Case-In-Point Air Pollution in Beijing, New Delhi, and Mexico City

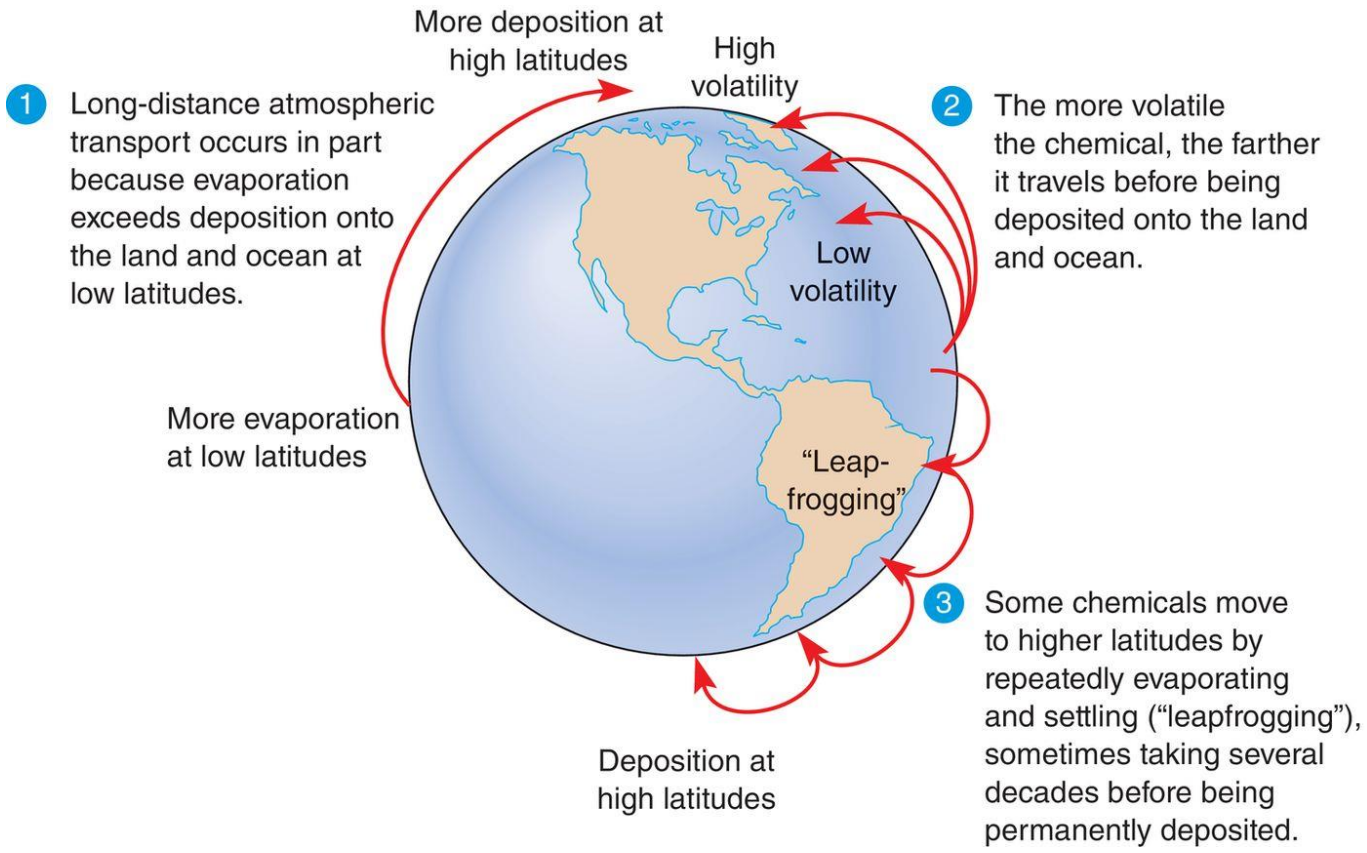
© SHENG LI/Reuters / Corbis

Adam Jones/Science Source

- Liaoning Province, China (right)
- New Delhi, India (left)

Long Distance Transport of Air Pollutants

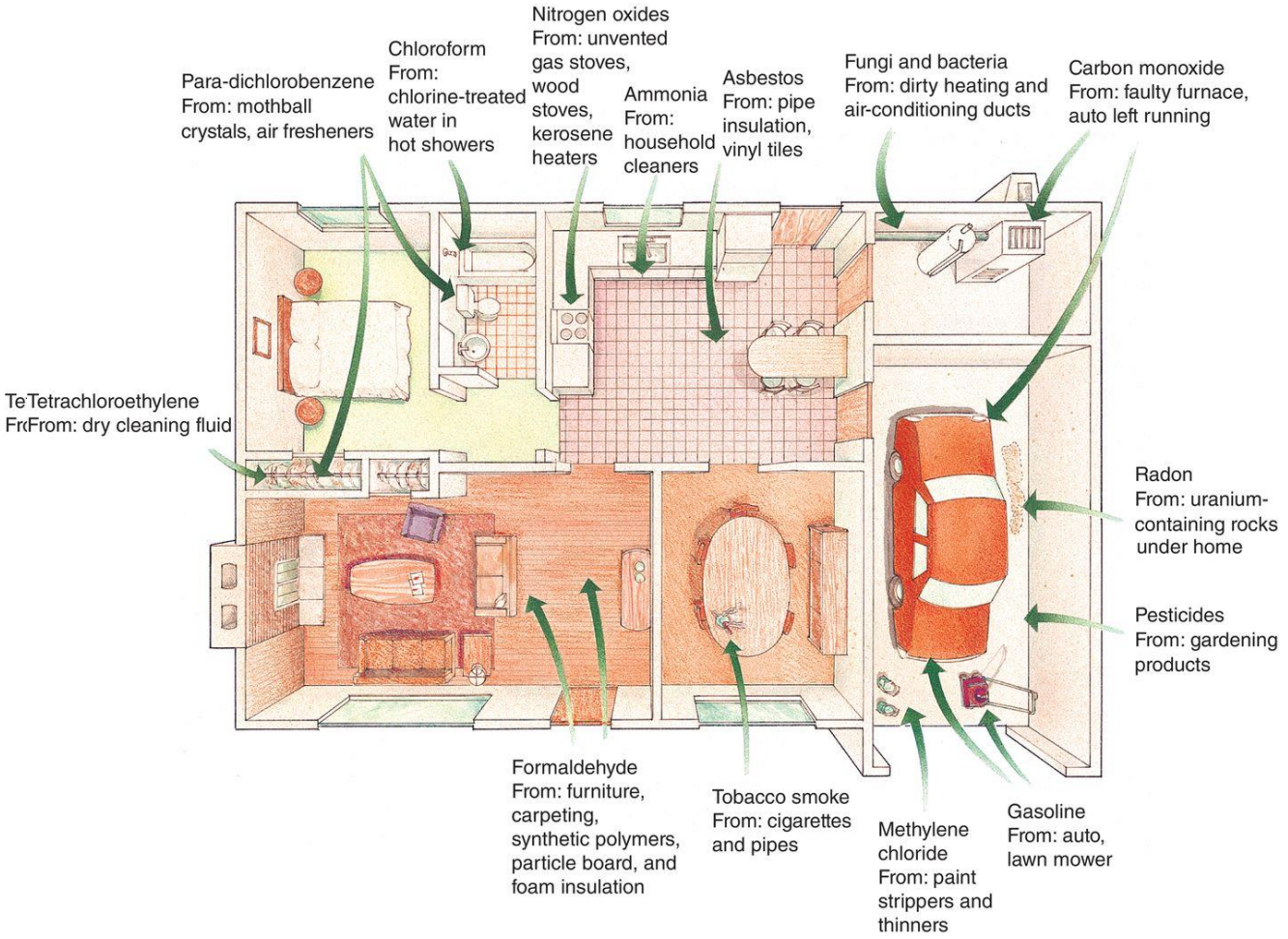
Global Distillation Effect



Indoor Air Pollution

- Pollutants can be 5–100x greater than outdoors
- Radon, cigarette smoke, carbon monoxide, nitrogen dioxide, formaldehyde pesticides, lead, cleaning solvents, ozone, and asbestos

Indoor Air Pollution



Indoor Air Pollution – Tobacco and Radon

- Cigarette smoke
  - Increasing in developing nations
- Radon
  - Natural form of ionizing radiation
  - Damaging to surface tissues if not diluted with air
  - Trapped in houses