

# Chapter 8:

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# Environmental Health, Pollution, and Toxicology



Keith Wood/Getty Images

# Overview

- Some Basics
- Categories of Pollutants and Toxins
- Measuring the Amount of Pollution
- Old and New Environmental Health Problems
- General Effects of Pollutants

## **Case Study: Toxic Air Pollution and Human Health: Story of a Southeast Houston Neighborhood**

This case study addresses the problems caused by emissions from petrochemical processing and their effects on nearby residents, particularly children. Studies demonstrated that the areas near the Houston Ship Channel and the petrochemical plants along it were releasing benzene and 1,3-butadiene, and those areas with highest concentrations had the highest incidence of childhood leukemia. Since the residents moved in after the plants were built, and the plants are within legal limits of emission, it presents a difficult legal and ecological problem and an interesting source for discussion, as would the fact that Texas has no air standards for toxins emitted by the petrochemical industry.

# Environmental Health

- Human health and disease determined by or related to environmental factors such as:
  - Toxic chemicals
  - Toxic biological agents
  - Radiation

# Environmental Health

- Also included are direct and indirect adverse health effects resulting from:
  - Housing
  - Urban development
  - Land use
  - Pesticides
  - Transport systems

# Disease

- An impairment of an individual's health
- Seldom has a one-cause/one-effect relationship with the environment
- Depends on several factors
  - Physical environment
  - Biological environment
  - Human-made environment
  - Lifestyle

# Disease

- Due to modern medicine in highly developed societies
  - Infectious diseases greatly reduced
  - United States and Western Europe
- Acute or chronic health problems due to overexposure to chemicals directly or indirectly released into the environment via:
  - Agriculture
  - Urbanization
  - Industrialization

# ● Environmental Health

- Environmental health is a broad field encompassing factors of the environment that can cause or promote disease. Disease is an impairment of an individual's well being and ability to function. The incidence of a disease depends on several factors, including the physical and biological environments and lifestyle. A "gray zone" of sub-optimum health exists between total health and full-blown disease; exposure to pollutants, such as in Houston in the Case Study, may produce ill effects without leading to a demonstrable disease in strict medical terms. Symptoms such as headache, which can be caused by chemical exposure, are nonspecific and can be attributed to other causes.



# Terminology

- Polluted environment
  - Impure, dirty, or otherwise unclean
- Pollution refers to the occurrence of unwanted change in the environment
  - Introduction of harmful materials
  - Production of harmful conditions
- Contamination
  - Similar to pollution
  - Implies making something unfit for a particular use through the introduction of undesirable materials

# Terminology

## ■ Toxic

- Materials (pollutants) that are poisonous to people and other living things
- Toxicology—science that studies chemicals that are known to be or could be toxic

## ■ Carcinogen

- Particular kind of toxin that increases the risk of cancer
- These are the most feared and regulated toxins in our society

# Terminology

- Synergism

- The interaction of different substances resulting in a total effect greater than the sum of the effects of the separate substances
  - Sulfur dioxide and coal dust—great damage to lungs

# Terminology

## ■ Point sources

- Smokestacks, pipes discharging into waterways, stream entering the ocean, accidental spills, etc.

## ■ Nonpoint sources, or area sources

- More diffused over the land
- Include urban and agricultural runoff, and mobile sources such as automobile exhaust

This southern California urban stream flows into the Pacific Ocean at a coastal park. The stream water often carries high counts of fecal coliform bacteria. As a result, the beach is a point source of pollution for the beach, which is sometimes closed to swimming following runoff events.



Prof. Ed Keller

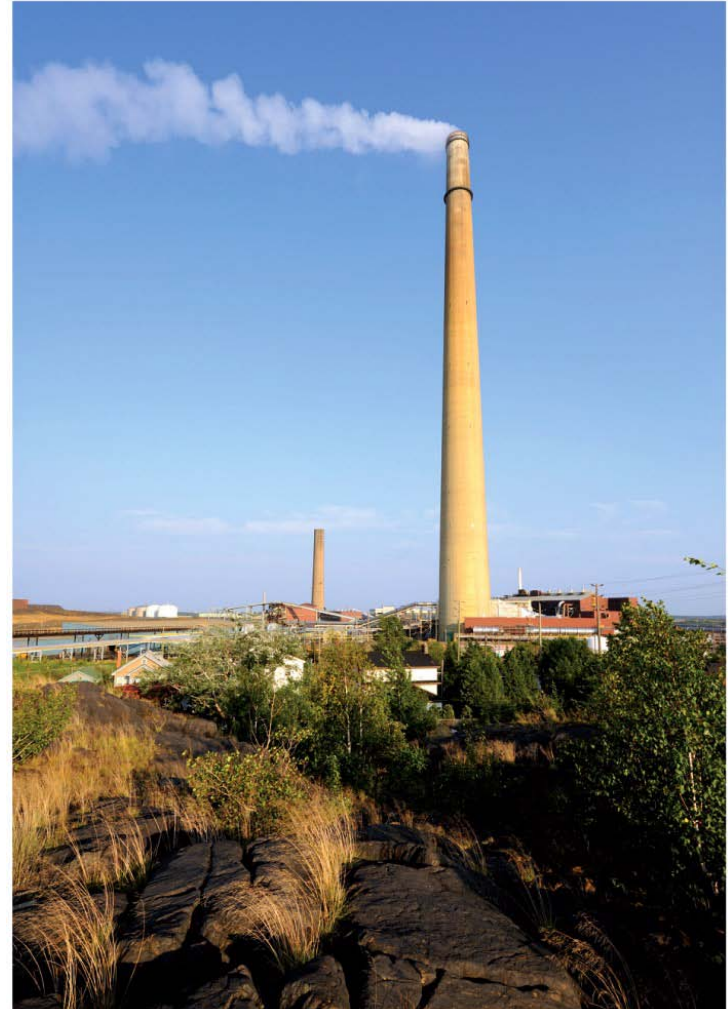


(a) Lake St. Charles, Sudbury, Ontario, prior to restoration.

**Point Source Pollution** Note high stacks (smelters) in the background and lack of vegetation in the foreground, resulting from air pollution (acid and heavy-metal deposition). (b) Recent photo showing regrowth and restoration.



Bill Brooks/Masterfile



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## Point Source Pollution

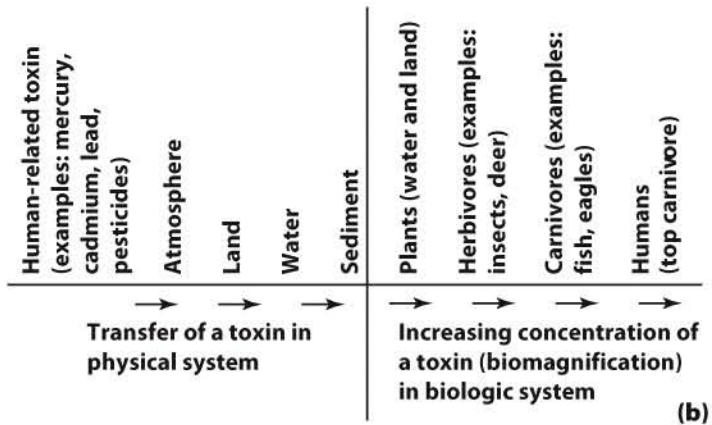
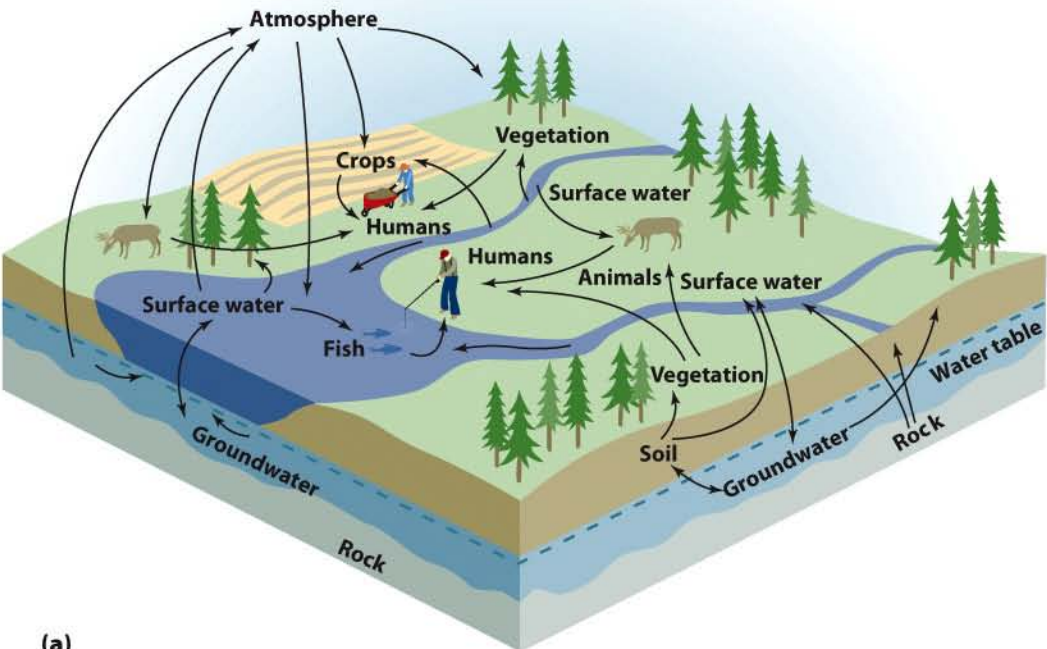
- As a point source example, the text discusses the smelters that refine nickel and copper ores at Sudbury, Ontario. New regulations in 1969 forced the operators of Sudbury smelters to improve local air quality, which was accomplished by raising the heights of the smokestacks (dilution is the answer to pollution).
- However, the  $\text{SO}_x$  emissions were carried over great distances and caused acid rain. As a result of years of pollution, nickel has been found to contaminate soils 50 km from the stacks. This and the acid rain have devastated the surrounding vegetation. The Ontario government then set standards to reduce emission to about 14% of earlier levels. The environment now is recovering, and this is a positive example of pollution reduction.

# Toxic Pathways

- Chemical elements can become concentrated
- Biomagnification
  - Accumulation or increase in concentration of a substance in living tissue as it moves through the food chain
  - Ex: Cadmium, mercury



Potential complex pathways. (a) for toxic materials through the living and nonliving environment. Note the many arrows into humans and other animals, sometimes in increasing concentrations as they move through the food chain (b).

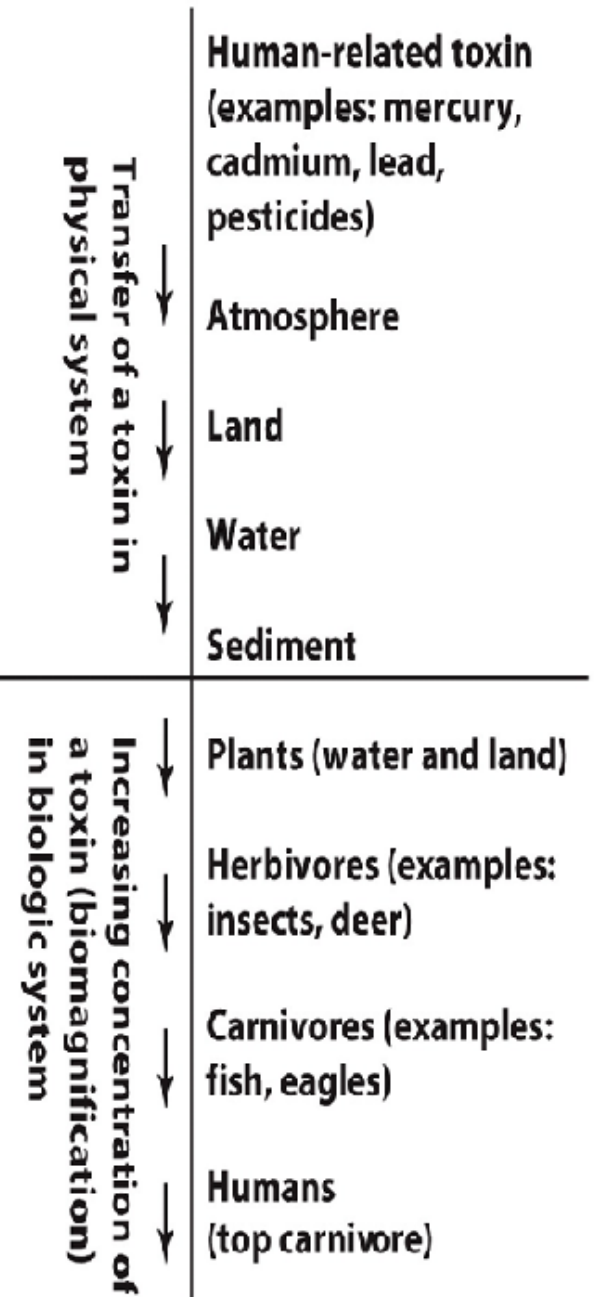


(a)  
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# Categories of Pollutants

- Infectious agents
- Toxic heavy metals
- Organic compounds
- Hormonally active agents
- Nuclear radiation
- Thermal pollution
- Particulates
- Asbestos
- Electromagnetic fields
- Noise pollution



# Infectious Agents

- Infectious disease
  - Spread from the interactions between individuals and food, water, air or soil
  - Constitute some of the oldest health problems that people face
  - May be caused by bacteria, virus, or fungus

# Environmentally Transmitted Infectious Diseases

- Legionellosis

- Occurs where air-conditioning systems have been contaminated by disease-causing organisms

- Giardiasis

- Protozoan infection of the small intestine spread via food, water, or person-to-person contact

- Salmonella

- Food-poisoning bacterial infection spread via water or food

# Environmentally Transmitted Infectious Diseases

- Malaria
  - Protozoan infection transmitted by mosquitoes
- Lyme disease
  - Transmitted by ticks
- Cryptosporidiosis
  - Protozoan infection transmitted via water or person-to-person contact
- Anthrax
  - Bacterial infection spread by terrorist activity

# Toxic Heavy Metals

- Heavy metals that pose health hazards to people and ecosystems
  - Mercury, lead, cadmium, nickel, gold, platinum, silver, bismuth, arsenic, selenium, vanadium, chromium, and thallium
- Each may be found naturally in soil and water
- Each has uses in our modern industrial society
- Each is also a by-product of the mining, refining, and use of other elements

# Toxic Heavy Metals

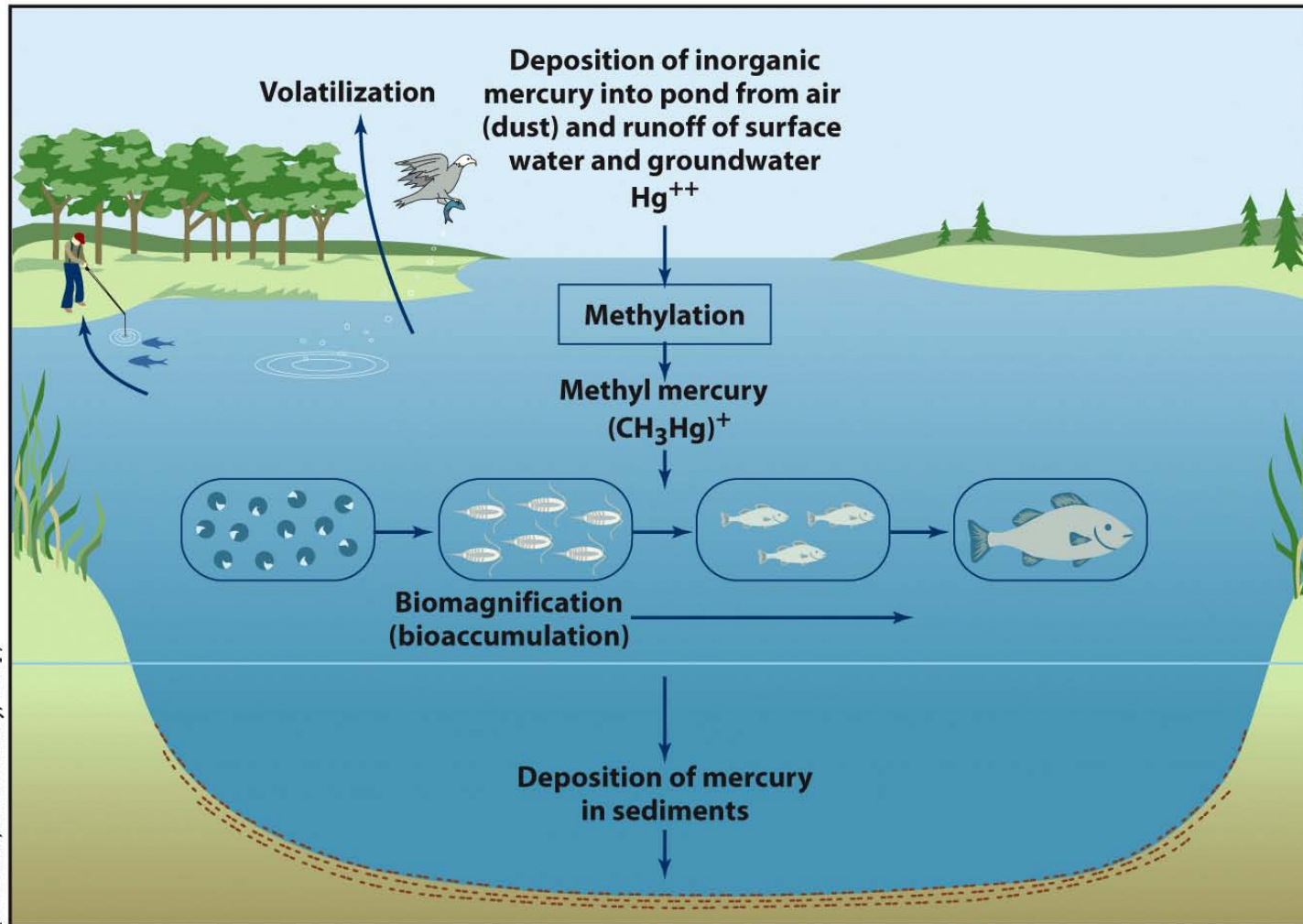
- Often have direct physiological effects
  - Stored and incorporated in living tissue
  - Particularly fatty body tissue
  - Sometimes permanently

# Toxic Heavy Metals

- Body burden
  - Heavy metal content in our bodies
  - For an average human body (70 kg) body burden is about
    - 8 mg of antimony
    - 13 mg of mercury
    - 18 mg of arsenic
    - 30 mg of cadmium
    - 150 mg of lead



Mercury in aquatic systems provides a specific example of biomagnification. Hg is present in coal in small amounts and is released into the atmosphere when coal is burned. The Hg is then deposited onto the land surface and makes its way into rivers and lakes. The Hg is methylated by bacteria in sediments and in this form is far more toxic than elemental mercury. Methyl mercury enters the food chain and biomagnifies at each trophic level.



# Organic Compounds

- Organic compounds
  - Compounds of carbon produced naturally by living organisms or synthetically by human industrial practices
- Synthetic organic compounds
  - Used in industrial processes, pest control, pharmaceuticals, and food additives
  - Over 20 million currently in use
    - 1 million more added each year!

# Persistent Organic Pollutants

- Persistent organic pollutants (POPs) may produce a hazard for decades or hundreds of years
  - First produced when their harm was not known
  - Now many are banned or restricted

**Table 8.1 SELECTED COMMON PERSISTENT ORGANIC POLLUTANTS (POPs)**

CHEMICAL	EXAMPLE OF USE
<b>Aldrin<sup>a</sup></b>	<b>Insecticide</b>
<b>Atrazine<sup>b</sup></b>	<b>Herbicide</b>
<b>DDT<sup>a</sup></b>	<b>Insecticide</b>
<b>Dieldrin<sup>a</sup></b>	<b>Insecticide</b>
<b>Endrin<sup>c</sup></b>	<b>Insecticide</b>
<b>PCBs<sup>a</sup></b>	<b>Liquid insulators in electric transformers</b>
<b>Dioxins</b>	<b>By-product of herbicide production</b>
<sup>a</sup> Banned in the United States and many other countries.	
<sup>b</sup> Degrades in the environment. It is persistent when reapplied often.	
<sup>c</sup> Restricted or banned in many countries.	
<p><i>Source:</i> Data in part from Anne Platt McGinn, "Phasing Out Persistent Organic Pollutants," in Lester R. Brown et al., <i>State of the World 2000</i> (New York: Norton, 2000).</p>	

# Persistent Organic Pollutants

- POPs are defined by several properties
  - Carbon-based molecular structure, often containing highly reactive chlorine
  - Most are synthetic chemicals
  - Do not easily break down in the environment
  - Polluting and toxic

# Persistent Organic Pollutants

- Additional POP characteristics
  - Soluble in fat and likely to accumulate in living tissue
  - Occur in forms that allow them to be transported by wind, water, and sediments for long distances

# Dioxin

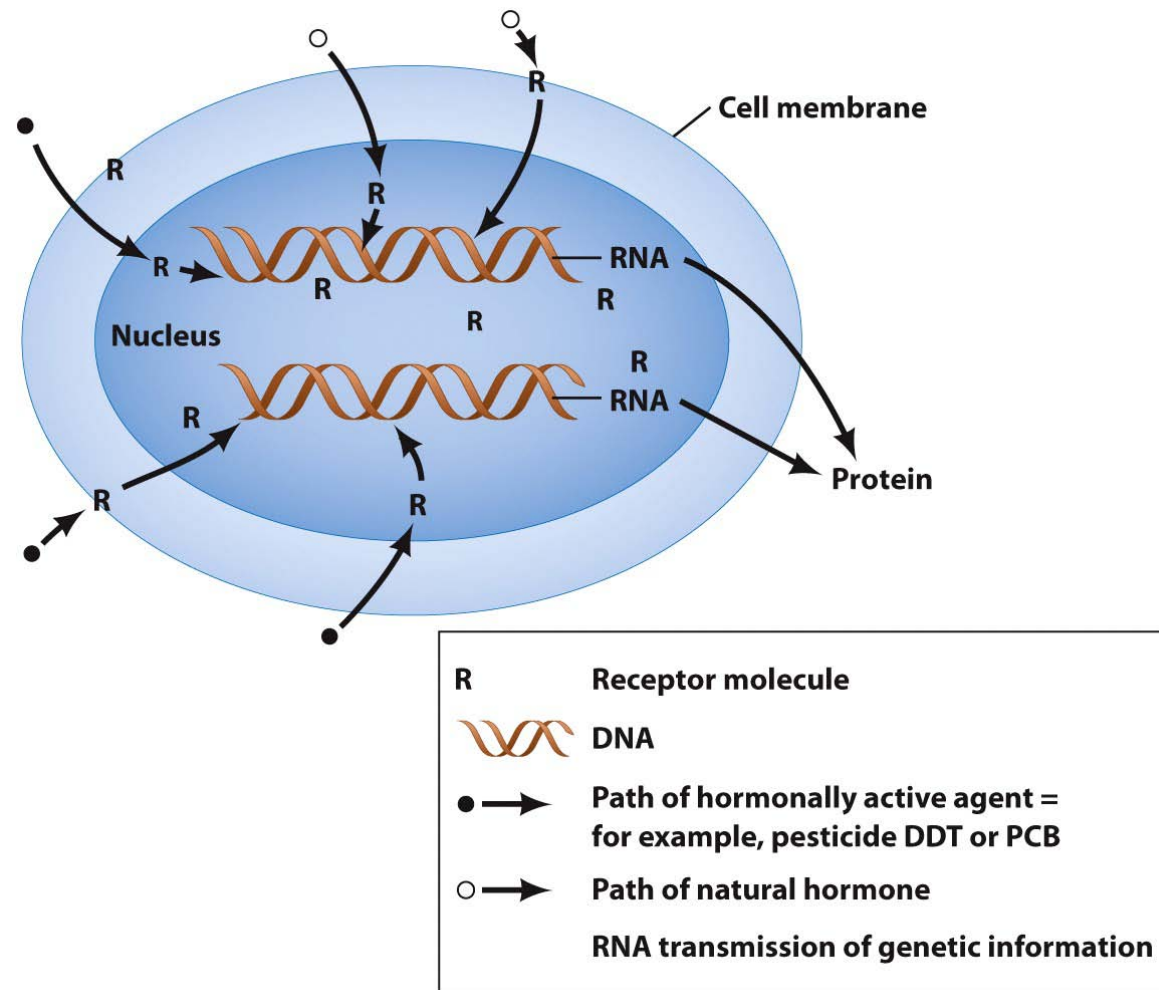
- Dioxin is a colorless chlorinated hydrocarbon that is very toxic. Dioxin is produced as a byproduct of several industrial processes, including the production of chlorinated herbicides. Dioxin is an expected carcinogen, but its actions in the human body are not well known. Studies of animals suggest that fish, birds and other animals are extremely sensitive to its effects. The EPA has set an acceptable intake of dioxin at 0.006 pg/kg/day, though this level is controversial. Dioxin is stable, long-lived, and is accumulating in the environment. There is no known remediation technology that is economical, safe and reliable.

# Hormonally Active Agents

- Persistent organic chemicals that interact with the hormone systems of organisms
- Have potential to cause developmental and reproductive abnormalities in animals, including humans
  - Include a wide variety of chemicals, herbicides, pesticides, phthalates, and PCBs



Idealized diagram of hormonally active agents (HAAs) binding to receptors on the surface of and inside a cell. When HAAs, along with natural hormones, transmit information to the cells' DNA, the HAAs may obstruct the role of the natural hormones that produce proteins that in turn regulate the growth and development of an organism.



# Hormonally Active Agents

- Evidence of effect on developmental and reproductive growth
  - Wild leopard frogs across U.S.
    - Gonadal abnormalities (disorder of reproductive system)
  - Alligator populations in Florida
    - Exposed to DDT—genital abnormalities, low egg production etc.



Mother Daughter Press/Getty Images

Wild leopard frogs in America have been affected by human-made chemicals (the herbicide atrazine) in the environment.

# Hormonally Active Agents

- Major disorders studied in wildlife have centered on abnormalities including:
  - Thinning of eggshells of birds
  - Decline in populations of various animals and birds
  - Reduced viability of offspring
  - Changes in sexual behavior

# Hormonally Active Agents

- In humans, scientists are researching:
  - HAAs (environmental estrogens) as a link to cancer
  - PCBs and neurological behavior
  - Phthalates and endocrine and hormone disruption

# Hormonally Active Agents

- The National Academy of Sciences
  - Recommends that there should be continued monitoring of wildlife and human populations for abnormal development and reproduction
  - As an example, consider the exposure of frogs to a common herbicide in A Closer Look 8.2.

# Nuclear Radiation

- Introduced here as a category of pollution
- Excessive exposure is linked to serious health problems, including cancer

# Thermal Pollution

- Occurs when heat released into water or air produces undesirable effects
  - Also called heat pollution
  - Acute event or long-term, chronic release
  - Heated water released into rivers changes temperature and dissolved oxygen content
    - Changes river's species composition

# Thermal Pollution

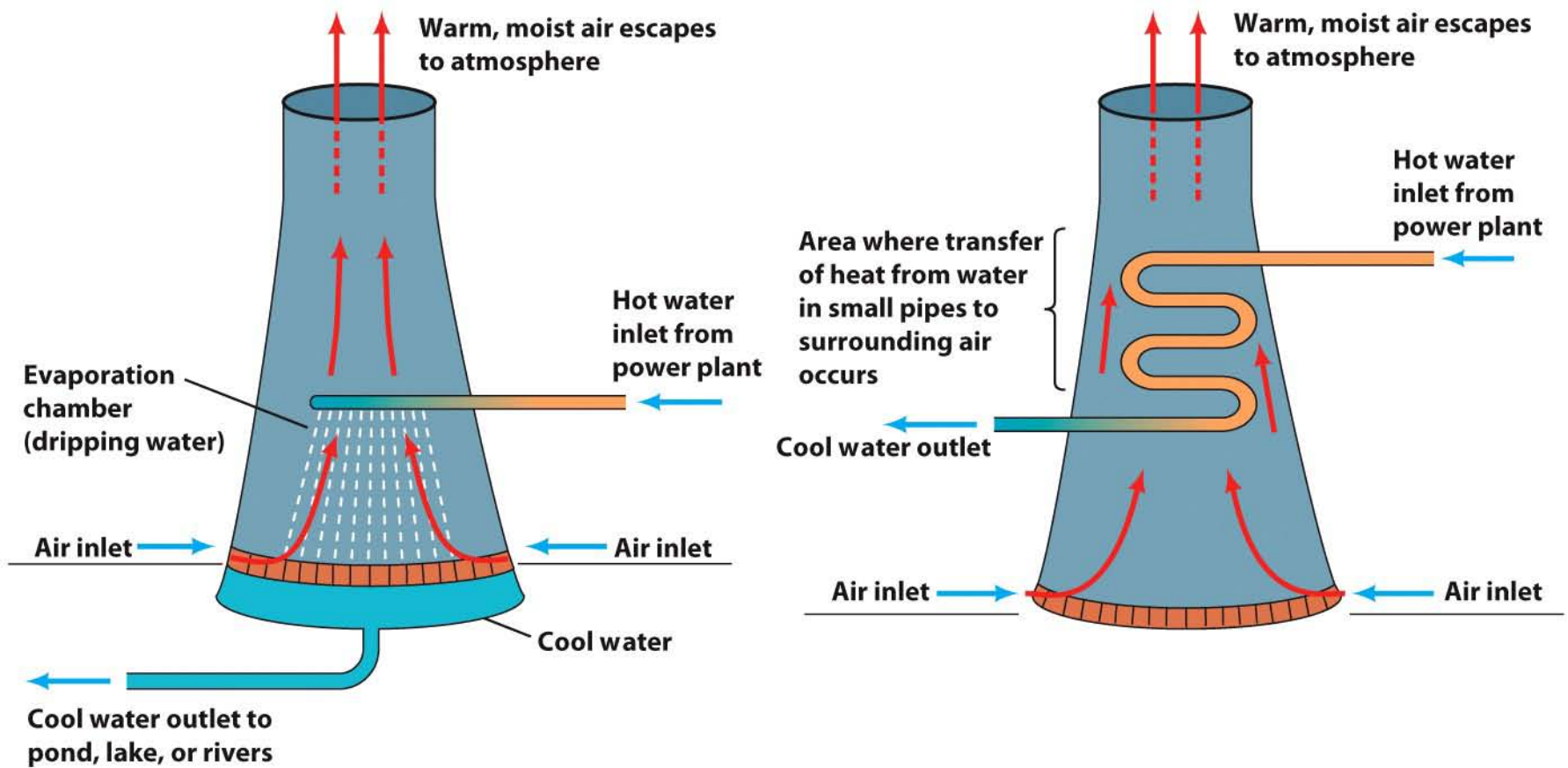
- Heating river water changes natural conditions and disturbs the ecosystem
  - Fish spawning cycles may be disrupted
  - Fish may have heightened susceptibility to disease
  - Physical stress on fish
  - Easier prey
  - Change in type and availability of food



# Thermal Pollution

- Solutions to chronic thermal heating
  - Release of heat into air via cooling towers
  - Artificial lagoons
  - Cogeneration—use waste heat to warm buildings (see Ch. 14)





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Two types of cooling towers. (a) Wet cooling tower. Air circulates through the tower; hot water drips down and evaporates, cooling the water. (b) Dry cooling tower. Heat from the water is transferred directly to the air, which rises and escapes the tower.



Cooling towers emitting steam at Didcot power plant, Oxfordshire, England. Red and white lines are vehicle lights resulting from long exposure time (photograph taken at dusk).

# Particulates

- Small particles of dust released into the atmosphere by many natural processes and human activities
  - Modern farming
  - Burning oil and coal
  - Dust storms
  - Volcanic eruptions





Fires in Indonesia in 1997 caused serious air pollution. The person shown here is wearing a surgical mask in an attempt to breathe cleaner air.

# Asbestos

- A term for several minerals that take the form of small, elongated particles or fibers
  - Used for fire prevention
  - Insulation
- Inhalation leads to asbestosis and cancer
- 95% of asbestos now in use in U.S. is chrysolite (white asbestos)
  - Not particularly harmful
- Another type is crocidolite (blue asbestos)
  - Exposure can be very hazardous

# Electromagnetic Fields

- Electromagnetic fields (EMFs)
  - Part of everyday urban life
    - Electric motors
    - Transmission lines
    - Appliances
  - Controversy as to whether they pose a health risk
  - Children may be at greater risk

# Noise Pollution

- Unwanted sound
- Sound is a form of energy that travels as waves
  - We hear sounds when waves vibrate our eardrum
  - Loudness—a measure of intensity of energy
    - Measured in units of decibels



**Table 8.2 EXAMPLES OF SOUND LEVELS**

<b>SOUND SOURCE</b>	<b>INTENSITY OF SOUND (dB)</b>	<b>HUMAN PERCEPTION</b>
Threshold of hearing	0	
Rustling of leaf	10	Very quiet
Faint whisper	20	Very quiet
Average home	45	Quiet
Light traffic (30 m away)	55	Quiet
Normal conversation	65	Quiet
Chain saw (15 m away)	80	Moderately loud
Jet aircraft flyover at 300 m	100	Very loud
Rock music concert	110	Very loud
Thunderclap (close)	120	Uncomfortably loud
Jet aircraft takeoff at 100 m	125	Uncomfortably loud
	140	Threshold of pain
Rocket engine (close)	180	Traumatic injury

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# Noise Pollution

- Environmental effects of noise depend on
  - Energy
  - Pitch
  - Frequency
  - Time pattern
  - Length of exposure
- Very loud noise can cause pain
- Any sound above 80dB can cause hearing loss
  - Rock concert = 110dB

# General Effects of Pollutants

- Almost every part of the human body is affected by one pollutant or another
  - Lead and mercury affect the brain
  - Arsenic, the skin
  - Carbon monoxide, the heart
  - Fluoride, the bones
- Remember that pollutants also affect wildlife

**Table 8.3 EFFECTS OF POLLUTANTS ON WILDLIFE**

EFFECT ON POPULATION	EXAMPLES OF POLLUTANTS
Changes in abundance	Arsenic, asbestos, cadmium, fluoride, hydrogen sulfide, nitrogen oxides, particulates, sulfur oxides, vanadium, POPs <sup>a</sup>
Changes in distribution	Fluoride, particulates, sulfur oxides, POPs
Changes in birth rates	Arsenic, lead, POPs
Changes in death rates	Arsenic, asbestos, beryllium, boron, cadmium, fluoride, hydrogen sulfide, lead, particulates, selenium, sulfur oxides, POPs
Changes in growth rates	Boron, fluoride, hydrochloric acid, lead, nitrogen oxides, sulfur oxides, POPs

<sup>a</sup> Pesticides, PCBs, hormonally active agents, dioxin, and DDT are examples (see Table 8.1).

Source: J.R. Newman, *Effects of Air Emissions on Wildlife*, U.S. Fish and Wildlife Service, 1980. Biological Services Program, National Power Plant Team, FWS/OBS-80/40, U.S. Fish and Wildlife Service, Washington, DC.

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**Table 8.4 APPROXIMATE LD-50 VALUES (FOR RODENTS) FOR SELECTED AGENTS**

AGENT	LD-50(MG/KG) <sup>a</sup>
Sodium chloride (table salt)	4,000
Ferrous sulfate (to treat anemia)	1,520
2,4-D (a weed killer)	368
DDT (an insecticide)	135
Caffeine (in coffee)	127
Nicotine (in tobacco)	24
Strychnine sulfate (used to kill certain pests)	3
Botulinum toxin (in spoiled food)	0.00001
<sup>a</sup> Milligrams per kilogram of body mass (termed mass weight, although it really isn't a weight) administered by mouth to rodents. Rodents are commonly used in such evaluations, in part because they are mammals (as we are), are small, have a short life expectancy, and have a well-known biology.	
Source: H.B. Schiefer, D.C. Irvine, and S.C. Buzik, <i>Understanding Toxicology</i> (New York: CRC Press, 1997).	

# Acute and Chronic Effects

- Acute effect is one that occurs soon after exposure
  - Usually to large amounts of a pollutant
- Chronic effect takes place over a long period
  - Often as a result of exposure to low levels of pollutant

# Chapter Summary

- Environmental health
  - Broadly defined as human health and disease associated with environmental factors
  - Included are adverse health effects of
    - Urban development
    - Industrialization
    - Land use
- Pollution produces an impure, dirty, or otherwise unclean state
  - Contamination means making something unfit for a particular use through the introduction of undesirable materials

# Chapter Summary

- Toxic materials are poisonous to people and other living things
  - Toxicology is the study of toxic materials
- A concept important in studying pollution problems is synergism
  - The actions of different substances produce a combined effect greater than the sum of the effects of the individual substances



# Chapter Summary

- Common units for expressing the concentration of pollutants are
  - Parts per million (ppm)
  - Parts per billion (ppb)
  - Micrograms of pollutant per cubic meter of air ( $\mu\text{g}/\text{m}^3$ )

# Chapter Summary

- Organic compounds of carbon are produced by living organisms or synthetically by people
  - May have physiological, genetic, or ecological effects when introduced into the environment
  - Organic compounds of serious concern include persistent organic pollutants, such as pesticides, dioxin, PCBs, and hormonally active agents (HAAs)

# Chapter Summary

- Emergence of new diseases
  - From disturbed environments
  - From human environments, including hospitals where sick people are naturally crowded together
  - From large industrial farms where animals are produced for consumption