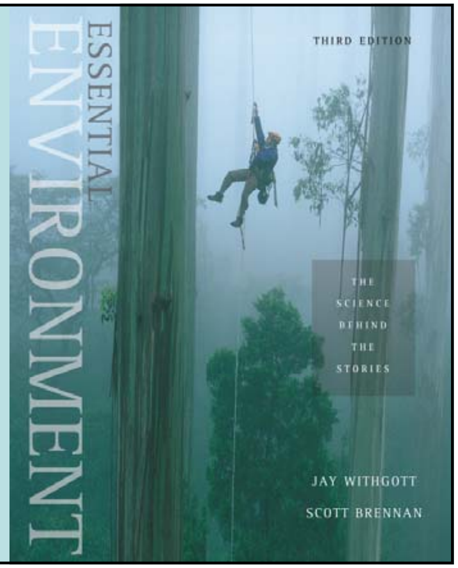
Chapter 10

Environmental Health and Toxicology



This lecture will help you understand:

- Environmental health hazards
- Toxicants in the environment
- Hazards and their effects
- Risk assessment and risk management
- Philosophical approaches to risk

Central Case: Lake Apopka alligators

- In 1985, alligators in Lake Apopka, Florida, had bizarre reproductive problems
  - Non-viable eggs, depressed or elevated hormone levels
- The lake had high levels of agricultural chemicals and fertilizers that were disrupting the endocrine systems of alligators during development in the egg.
  - **Endocrine disruptors**: compounds that mimic hormones and interfere with the functioning of animals' endocrine (hormone) systems
- Because alligators and humans share the same hormones, chemicals can affect people, too.

There are many types of environmental hazards

- **Environmental health**: assesses environmental factors that influence human health and quality of life
- There are 4 major types of environmental hazards:
  - Physical
  - Chemical
  - Biological
  - Cultural
- Much of environmental health consists of taking steps to address the impacts and risks of hazards.
  - We can't avoid risk, but we can minimize its effects.

Chemical and biological environmental hazards

- **Physical hazards**: occur naturally in our environment
  - Earthquakes, volcanoes, fires, floods, droughts
  - Ultraviolet radiation from sunlight damages DNA.
  - We increase our vulnerability by deforesting slopes (landslides), channelizing rivers (flooding), etc.
  - We can reduce risk by making better environmental choices.
- **Chemical hazards**: synthetic chemicals such as pesticides, disinfectants, pharmaceuticals
  - Harmful natural chemicals also exist.

Cultural environmental hazards

- **Biological hazards**: result from ecological interactions
  - Viruses, bacteria, and other pathogens
  - **Infectious** (**communicable**, or **transmissible**) **disease**: other species parasitize humans, fulfilling their ecological roles
  - We can reduce the likelihood of infection.
- **Cultural (lifestyle) hazards**: result from the place we live, our socioeconomic status, our occupation, our behavioral choices
  - Smoking, drug use, diet and nutrition, crime, mode of transportation

Four types of environmental hazards

(a) Physical hazard

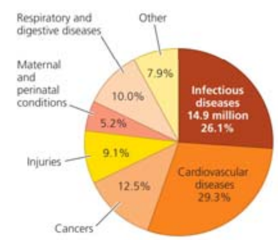
(b) Chemical hazard

(c) Biological hazard

(d) Cultural hazard

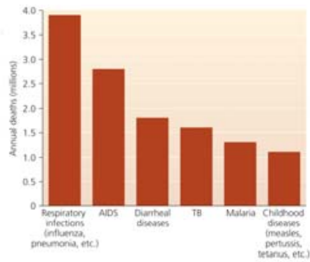
Disease is a major focus of environmental health

- Despite our technology, disease kills most of us.
- Disease has a genetic and environmental basis.
  - Cancer, heart disease, respiratory disorders
  - Malnutrition, poverty, and poor hygiene can foster illnesses.



(a) Leading causes of death across the world

Infectious diseases kill millions



(b) Leading causes of death by infectious disease

- Infectious diseases kill 15 million people per year.
  - Half of all deaths in developing countries
  - Developed countries have better hygiene, access to medicine, and money.
- **Vector**: an organism that transfers pathogens to a host

Many diseases are increasing

- Tuberculosis, acquired immunodeficiency syndrome (AIDS), and the West Nile virus are increasing.
  - Our mobility spreads diseases.
- Some diseases are evolving resistance to antibiotics.
- Climate change will expand the range of diseases.
- Habitat alteration affects the abundance, distribution, and movement of disease vectors.

We are exposed to many hazards

TABLE 14.1 Selected Environmental Hazards

Category	Hazard
Air	Smoking and secondhand smoke
	Chemicals from automotive exhaust
	Chemicals from industrial pollution
	Tropospheric ozone
	Pesticide drift
	Dust and particulate matter
Water	Pesticide and herbicide runoff
	Nitrates and fertilizer runoff
	Mercury, arsenic, and other heavy metals in groundwater and surface water
Food	Natural toxins
	Pesticide and herbicide residues
Indoors	Asbestos
	Radon
	Lead in paint and pipes
	Toxicants in plastics and consumer products

Environmental health hazards exist indoors

- **Radon**: a highly toxic, colorless, undetectable radioactive gas
  - Builds up in basements
  - Can cause lung cancer
- **Lead poisoning**: from lead pipes, paint
  - Damages organs, learning problems, behavior abnormalities, death
- **Asbestos**: insulates against heat, cold, sounds, and fire
  - **Asbestosis**: scarred lungs don't function
  - Also causes a type of lung cancer

Asbestos removal can also be dangerous

A recently recognized hazard

- **Polybrominated diphenyl ethers (PBDEs)**: has fire-retardant properties
  - Used in computers, televisions, plastics, and furniture
  - Persist and accumulate in living tissue
  - Affect thyroid hormones, may cause cancer, and affect brain and nervous system development
  - The European Union banned them in 2003.
  - The U.S. has not addressed this issue.

Toxicology is the study of poisonous substances

- **Toxicology**: the study of the effects of poisonous substances on humans and other organisms
- **Toxicity**: the degree of harm a chemical substance can cause
  - "The dose makes the poison": toxicity depends on the combined effect of the chemical and its quantity
- **Toxicant**: any toxic or poisonous agent
- During the past century, we have produced many new chemicals.
  - Public concern for health and the environment

Environmental toxicology

- Deals with toxic substances that come from or are discharged into the environment
- Focuses mainly on humans, using other animals as test subjects
  - Animals can serve as indicators of health threats.
- Don't forget: chemicals have played a crucial role in giving us our high standard of living.
  - Food, medicine, materials, convenience

Toxic agents in the environment

- The environment contains countless natural chemicals that may pose health risks.
- But synthetic chemicals are also in our environment.
  - Every human carries traces of industrial chemicals.
- Very few chemicals have been thoroughly tested.
  - 100,000 chemicals are on the market today.
  - We don't know the effects, if any, they have.

80% of U.S. streams contain at least trace amounts of 82 wastewater contaminants.

Silent Spring began public debate over chemicals

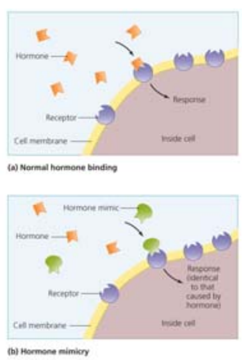
- Rachel Carson published *Silent Spring* in 1962.
  - Brought together studies to show DDT risks to people, wildlife, and ecosystems
  - In the 1960s, pesticides were mostly untested and were sprayed over public areas, assuming they would do no harm.
- The book generated significant social change.

Types of toxicants based on health effects

- **Carcinogens**: cause cancer
- **Mutagens**: cause DNA mutations
  - Can lead to severe problems, including cancer
- **Teratogens**: cause birth defects
- **Neurotoxins**: assault the nervous system
  - Heavy metals, pesticides, chemical weapons
- **Allergens**: overactivate the immune system
- **Endocrine disruptors**: interfere with the endocrine (hormone) system

Endocrine disruption may be widespread

- Theo Colburn wrote *Our Stolen Future* in 1996.
  - Synthetic chemicals may be altering hormones.
  - This book integrated scientific work from various fields.
  - Shocked many readers and brought criticism from the chemical industry

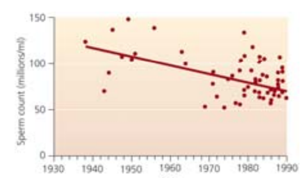


(a) Normal hormone binding

(b) Hormone mimicry

Evidence for hormone disruption

- Frogs also have gonadal abnormalities.
  - Male frogs exposed to very low levels of atrazine became feminized.
  - Levels were below EPA standards for human health.
- The shocking drop in men's sperm counts may be due to endocrine disruptors.



(a) Declining sperm count in men, based on 61 studies

Endocrine disruption research is controversial

- Scientific uncertainty is inherent in any young field.
- Negative findings pose economic threats to chemical manufacturers.
  - Bisphenol-A, used in plastics, causes birth defects, but the plastics industry protests that the chemical is safe.
  - Pthalates affect male fetuses but are still used in toys and makeup in the U.S.

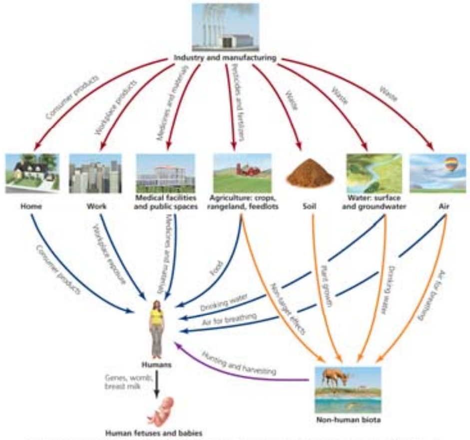
(a) Exposure through toys

(b) Exposure through cosmetics

Toxicants are found in water and air

- Water carries toxicants from land areas to surface water.
  - Chemicals can leach through the soil into groundwater.
  - Chemicals enter organisms through drinking or absorption.
  - Aquatic organisms (fish, frogs, stream invertebrates) are effective pollution indicators.
- Because chemicals can travel by air, their effects can occur far from the site of use.
  - **Pesticide drift**: airborne transport of pesticides
  - Synthetic chemical contaminants are found globally.
    - Arctic polar bears, Antarctic penguins, and people living in Greenland

Routes of chemical transport



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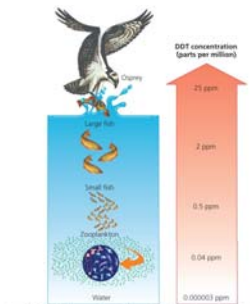
Some toxicants persist

- Toxins can degrade quickly and become harmless.
  - Or they may remain unaltered and persist for decades.
  - Rates of degradation depend on temperature, moisture, and sun exposure.
- Persistent chemicals have the greatest potential for harm.
- **Breakdown products**: toxicants degrade into simpler products
  - May be more or less harmful than the original substance
  - i.e., DDT degrades into DDE, which is also highly persistent and toxic

Toxicants can accumulate and biomagnify



- Some toxicants can be excreted or metabolized.
  - Fat-soluble toxicants are stored in fatty tissues.

  Bioaccumulation: toxicants build up in animal tissues

  Biomagnification: toxicants concentrate in top predators
  - Near extinction of peregrine falcons, bald eagles, and brown pelicans

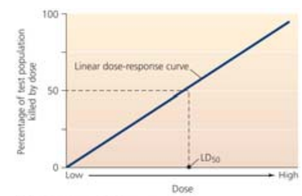
Not all toxicants are synthetic

- Chemical toxicants also exist naturally and in our food.
  - Don't assume natural chemicals are all healthy and synthetic ones are all harmful.
- Scientists are debating just how much risk natural toxicants pose.
  - Plants produce toxins to ward off herbivores.
  - When we consume meat, we take in toxins the animals have ingested.

Studying the effects of hazards

- Animals in the wild are observed to determine the cause of sickness or death.
- In human health studies, researchers study and treat sick individuals.
- **Epidemiological studies**: large-scale comparisons between groups of people
  - Studies between exposed and unexposed people last for years.
- Animals are used as subjects to test toxicity.
  - Rats, mice, other mammals

Dose-response analysis



(a) Linear dose-response curve

- **Dose-response analysis**: measures how much effect a toxicant produces at different doses
  - Animal testing
  - **Dose**: the amount of toxicant the test animal receives
  - **Response**: the type or magnitude of negative effects
  - **Dose-response curve**: the plot of the dose given against the response
    - Looks at lethal doses (**LD_{50}**) or effective doses (ED_{50})

Dose response curves

- **LD_{50}/ED_{50}**: the amount of toxicant required to kill (affect) 50% of the study animals used
  - A *high* LD_{50}/ED_{50} indicates *low* toxicity.
- **Threshold**: the dose level where certain responses occur
  - Organs can metabolize or excrete low doses of a toxicant.
  - Some toxicants that work at extremely low levels show a J-shaped, U-shaped, or inverted curve.
- Scientists extrapolate downward from animal studies to estimate the effect on humans.
  - Regulatory agencies set allowable limits well below toxicity levels from lab studies.

Individuals vary in their responses to hazards

- Different people respond differently to hazards.
  - Affected by genetics, surroundings, etc.
  - People in poor health are more sensitive.
  - Sensitivity also varies with sex, age, and weight.
  - Increased sensitivity in fetuses, infants, and children
- Standards for responses are set by the Environmental Protection Agency (EPA).
  - Often, standards are not low enough to protect babies.

The type of exposure affects the response

- **Acute exposure**: high exposure for short periods of time to a hazard
  - Easy to recognize
  - Stem from discrete events: ingestion, oil spills, nuclear accident
- **Chronic exposure**: low exposure for long periods of time to a hazard
  - More common but harder to detect and diagnose
  - Affects organs gradually: lung cancer, liver damage
  - Cause and effect may not be easily apparent.

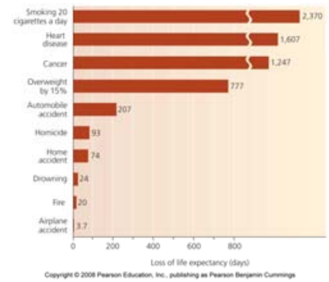
Mixes may be more than the sum of their parts

- It's hard to determine the impact of mixed hazards.
  - They may act in ways that cannot be predicted from the effects of each in isolation.
- **Synergistic effects**: interactive impacts that are more than or different from the simple sum of their constituent effects
  - Mixed toxicants can sum, cancel out, or multiply each other's effects.
  - New impacts may arise from mixing toxicants.
- Single-substance tests receive priority but this is changing.

Risk assessment

- The steps between obtaining scientific data and policy formulation involve assessing and managing risk.
- **Risk**: the probability that some harmful outcome will result from a given action, event, or substance
  - Exposure to a health threat doesn't always produce an effect.
  - Rather, it causes some probability (likelihood) of harm.
- Probability entails:
  - Identity and strength of threat
  - Chance and frequency of an encounter
  - Amount of exposure to the threat
  - An organism's sensitivity to the threat

Perceiving risks



- Everything we do involves some risk.
- We try to minimize risk, but we often misperceive it.
  - Flying versus driving
- We feel more at risk when we cannot control a situation.
  - We fear nuclear power and toxic waste, but not smoking or overeating.

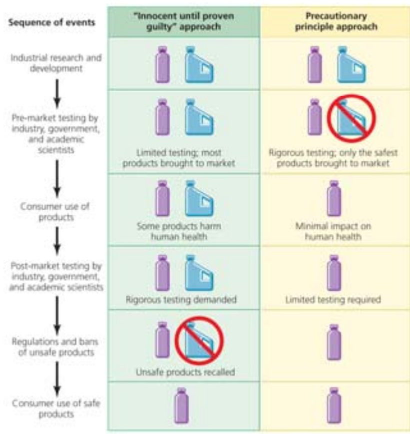
Approaches to determining safety

- Two philosophies categorize a substance as safe or harmful.
  - Are businesses required to prove a product is safe, or are the government, scientists, or citizens required to prove danger?
- **Innocent until proven guilty approach:**
  - Assume products are harmless until proven harmful.
  - Benefits: not slowing down technological innovation and economic advancement
  - Disadvantage: putting into wide use some substances that may turn out to be dangerous

Another approach to determining safety

- **Precautionary principle approach:**
  - The government, scientists, and the public are required to prove a product is dangerous.
  - Assume substances are harmful until they are proven harmless
  - Identifies troublesome toxicants before they are released
  - But this may impede the pace of technology and economic advance

Two approaches for determining safety



Philosophy affects policy

- Most nations use a mix between the "innocent until proven guilty" principle and the precautionary principle.
  - Europe is shifting more toward the precautionary principle.
  - The U.S. generally follows the "innocent until proven guilty" approach.

The EPA regulates many substances

- Federal agencies share responsibility for tracking and regulating synthetic chemicals.
  - FDA: food, food additives, cosmetics, drugs, medical devices
  - EPA: pesticides
  - Occupational Safety and Health Administration (OSHA): workplace hazards
- Many public health and environmental advocates fear it isn't enough.
  - Many synthetic chemicals are not actually tested.
  - Only 10% have been tested for toxicity.
  - Fewer than 1% are government regulated.

International regulation of toxicants

- Nations address chemical pollution with international treaties.
- **Stockholm Convention on Persistent Organic Pollutants (POPs)** is nearing ratification.
  - Ends the release of the 12 most dangerous POPs ("dirty dozen")
- EU's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Program (2007)
  - Aims to evaluate and restrict dangerous chemicals while giving industries a streamlined regulatory system
  - It will cost the chemical industry 2.8–5.2 billion euros (U.S. \$3.8–7.0 billion), but public benefits will exceed 50 billion euros (\$67.0 billion).

Conclusion

- International agreements represent a hopeful sign that governments are working to protect people, wildlife, and ecosystems from toxic chemicals and environmental hazards.
- Once all the scientific results are in, society's philosophical approach to risk management will determine what policies are enacted.
- A safe and happy future depends on knowing the risks that some hazards pose and on replacing those substances with safer ones.