Ch 14

Environmental Health and Toxicology

Part 2: Environmental Issues and the Search for Solutions

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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
• Policy and regulation in the U.S. and internationally
Central Case: Lake Apopka alligators

- Alligators in Lake Apopka, Florida, had reproductive problems
- The lake had high levels of agricultural runoff
- Chemical contaminants were disrupting the endocrine systems of alligators during egg development
- 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
  - Natural and human-caused factors are both considered

- **Physical hazards** = occur naturally in our environment
  - Earthquakes, volcanoes, fires, floods, droughts
  - We can’t prevent them, but we can prepare for them
  - We increase our vulnerability by deforesting slopes (landslides), channelizing rivers (flooding), etc.
  - We can reduce risk by better environmental choices
Chemical and biological environmental hazards

- **Chemical** = synthetic chemicals such as pesticides, disinfectants, pharmaceuticals
  - Harmful natural chemicals also exist

- **Biological** = result from ecological interactions
  - Viruses, bacteria, and other pathogens
  - **Infectious** (communicable, or transmissible) **disease** = other species parasitize humans, fulfilling their ecological roles
  - We can’t avoid risk, but we can reduce the likelihood of infection
Cultural environmental hazards

- **Cultural** = 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
  - Poverty and poor hygiene can foster illnesses
Infectious diseases kill millions

• 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
- Our mobility spreads diseases
- Diseases are evolving resistance to antibiotics
- Climate change will expand the range of diseases
- To predict and prevent diseases, experts deal with complicated interrelationships
Environmental health hazards exist indoors

- **Radon** = a highly toxic, radioactive gas that is colorless and undetectable
  - Can build up in basements

- **Lead poisoning** = from lead pipes
  - Damages organs; causes learning problems, behavior abnormalities, and death

- **Asbestos** = insulates, muffles sounds, and resists fire
  - **Asbestosis** = scarred lungs may cease to function
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
  - Endocrine disruptors = compounds that mimic hormones and interfere with the functioning of animals’ endocrine (hormone) systems
  - Affect brain and nervous system development, and may cause cancer
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 toxicant can cause
  - “The dose makes the poison” = toxicity depends on the combined effect of the chemical and its quantity
  - Analogous to pathogenicity or virulence = the degree of harm of biological hazards that spread disease

- **Toxicant** = any toxic agent
Environmental toxicology

• Deals with toxic substances that come from or are discharged into the environment

• Studies the health effects on humans, other animals, and ecosystems
  - Focus mainly on humans, using other animals as test subjects
  - Can serve as indicators of health threats

• Don’t forget, chemicals have given us our high standard of living
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

80% of U.S. streams contain at least trace amounts of 83 wastewater contaminants
Very few chemicals have been thoroughly tested

- 100,000 chemicals are on the market today
  - 72,000 industrial
  - 8,700 food additives
  - 2,000 new chemicals introduced per year

- We don’t know the effects, if any, they have
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

- **Carcinogens** = cause cancer
- **Mutagens** = cause DNA mutations
  - Can lead to severe problems, including cancer
- **Teratogens** = cause birth defects
- **Allergens** = overactivate the immune system
- **Neurotoxins** = assault the nervous 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 the hormones of animals
  - This book integrated scientific work from various fields
  - Shocked many readers and brought criticism from the chemical industry
Evidence for hormone disruption

- Frogs also have gonadal abnormalities
  - Male frogs became feminized from atropine concentrations well below EPA guidelines

- PCB-contaminated human babies were born weighing less, with smaller heads
Male sperm counts are dropping

- Scientists attribute the shocking drop in men’s sperm counts to endocrine disruptors
  - The number and motility of sperm has dropped 50% since 1938
- Testicular cancer, undescended testicles, and genital birth defects are also increasing
Endocrine disruption research is controversial

- Research results are uncertain, which is inherent in any young field
- Negative findings pose economic threats to chemical manufacturers
  - Banning a top-selling chemical could cost a company millions of dollars
  - Bisphenol-A, found in plastics, can cause birth defects, but the plastics industry protests that the chemical is safe
- Studies reporting harm are publicly funded, but those reporting no harm are industry funded
Toxins may concentrate in water

- Runoff carries toxins from large land areas to small volumes of surface water
- Chemicals can leach into the soil
- Chemicals enter organisms through drinking or absorption
  - Aquatic organisms are effective pollution indicators
Routes of chemical transport
Airborne toxicants travel widely

- Because chemicals can travel by air, their effects can occur far from the site of chemical use
- **Pesticide drift** = airborne transport of pesticides
- Synthetic chemical contaminants are found globally
  - They appear in arctic polar bears, Antarctic penguins, and people living in Greenland
Some toxicants persist for a long time

- Toxins can degrade quickly and become harmless
  - Or, they may remain unaltered and persist for decades
  - Rates of degradation depends 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
  - DDT degrades into DDE, which is also highly persistent
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 and brown pelicans

http://epa.gov/region02/superfund/hudson/returningarivertohealth.html
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

- Some scientists feel that natural toxicants dwarf our intake of synthetic chemicals
  - Natural defenses against toxins are effective against synthetic ones, too
  - Critics say natural toxins are more readily metabolized and excreted, and synthetic chemicals persist and accumulate
Wildlife studies

- Museum collections provide data from times before synthetic chemicals were used.
- Measurements from animals in the wild can be compared to controlled experiments in the lab.
- Scientists can first measure effects in the lab, then look for correlations in the wild.
- Conspicuous mortality events can trigger research:
  - Many sea otters died and washed ashore.
  - Research showed they died from parasites carried in sewage runoff containing cat litter.
Human studies

- Case histories = studying sickened individuals directly
  - Autopsies
  - Don’t tell about future risks
- Epidemiology = large-scale comparisons between groups of people
  - Studies between exposed and unexposed people last for years
  - Yield accurate predictions about risk
- Animals are used as test subjects
  - Some people object to animal research
  - New techniques (human cell cultures, bacteria, etc.) may replace some live-animal testing
Dose-response analysis

- Dose-response analysis = measuring 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 of the animal
  - Dose-response curve = the plot of dose given against response
Dose response curves

- **LD$_{50}$/ED$_{50}$** = the amount of toxicant required to kill (affect) 50% of the subjects

- **Threshold** = the dose level where certain responses occur
  - Organs can metabolize or excrete low doses of a toxicant
  - Some toxicants 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 in 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
  - Fetuses, infants, and young children are more sensitive

- 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
  - Hard 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

• We can’t 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
Risk assessment

- **Risk** = the probability that some harmful outcome will result from a given action
  - Exposure to environmental health threats doesn’t automatically produce an effect
  - Rather, it causes some probability (likelihood) of harm

- **Probability entails**
  - Identity and strength of threat
  - Chance and frequency that an organism will encounter it
  - 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
Analyzing risk quantitatively

• **Risk assessment** = the quantitative measurement of risk and the comparison of risks involved in different activities or substances
  - It is a way of identifying and outlining problems

• Several steps:
  - Scientific study of toxicity
  - Assessing an individual or population’s likely extent of exposure to the substance, including frequency, concentrations, and length of exposure

• Studies are often performed by industry-associated scientists, which may undermine the study’s objectivity
Risk management

- Combines decisions and strategies to minimize risk
- Scientific assessments are considered with economic, social, and political needs and values
- Developed nations have federal agencies to manage risk
  - The U.S. has the Centers for Disease Control (CDC), the EPA, and the Food and Drug Administration (FDA)
- Comparing costs and benefits is hard
  - Benefits are economic and easy to calculate
  - Health risks (costs) are hard-to-measure probabilities of a few people being affected
The process of risk management
One approach to determining safety

• **Innocent until proven guilty approach:** product manufacturers must prove a product is safe
  - Benefits: now slowing down technological innovation and economic advancement
  - Disadvantage: putting into wide use some substances that may later on 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

<table>
<thead>
<tr>
<th>Sequence of events</th>
<th>&quot;Innocent until proven guilty&quot; approach</th>
<th>Precautionary principle approach</th>
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<tbody>
<tr>
<td>Industrial research and development</td>
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<td><img src="https://via.placeholder.com/15" alt="Icon" /></td>
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<tr>
<td>Pre-market testing by industry, government, and academic scientists</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Limited testing, most products brought to market</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Rigorous testing, only the safest products brought to market</td>
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<tr>
<td>Consumer use of products</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Some products harm human health</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Minimal impact on human health</td>
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<tr>
<td>Post-market testing by industry, government, and academic scientists</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Rigorous testing demanded</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Limited testing required</td>
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<td>Regulations and bans of unsafe products</td>
<td><img src="https://via.placeholder.com/15" alt="Icon" /> Unsafe products recalled</td>
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<td>Consumer use of safe products</td>
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Different nations use different policies; most use a mix between the “innocent until proven guilty” principle and the precautionary principle

- Europe is shifting more towards the precautionary principle
- Industries like the “innocent until proven guilty” approach because it allows them to produce more and make more money
The EPA regulates many substances

- Federal agencies apportion responsibility for tracking and regulating synthetic chemicals
  - FDA: food, food additives, cosmetics, drugs, and 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

- Nations address chemical pollution with international treaties
- **Stockholm Convention on Persistent Organic Pollutants (POPs)** was ratified by 140 nations in 2004
  - Ends the release of the 12 most dangerous POPs
- EU’s Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Program
  - 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 will save more than 10 times that in health benefits
Conclusion

• International agreements represent a hopeful sign that governments are working to protect society, 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
QUESTION: Review

Which of the following is a biological hazard?

a) Earthquake  
b) Smoking  
c) Virus  
d) A pesticide  
e) All are biological hazards
QUESTION: Review

A “vector” is defined as …

a) A highly toxic, radioactive compound
b) An organism that transfers pathogens to a hose
c) A compound with fire-retardant properties
d) A compound that mimics natural substances
QUESTION: Review

Toxicity is …

a) The study of the effects of poisonous substances
b) Any toxic agent
c) Any substance that causes environmental degradation
d) The degree of harm a substance can cause
QUESTION: Review

A “teratogen” causes…?

a) Cancer
b) Mutations
c) Birth defects
d) Problems in the hormonal system
QUESTION: Review

Why is research into endocrine disrupters controversial?

a) Negative findings threaten the industry’s economics
b) Research is still only beginning
c) Much research is funded by industry
d) All of these are reasons why research is controversial
A human-based study that compares a group of smokers to non-smokers to determine the effects of smoking is …

a) An epidemiological study  
b) A case study  
c) Not likely to be funded  
d) Not going to tell about future risks
Our perception, and the reality, of risk often do not match. Given this graph (reality), and your knowledge of sources of anxiety (perception), which statement is correct?

a) Smoking is very dangerous and we are very anxious about it
b) Smoking is not dangerous, but we are very anxious about it
c) Airplane accidents are dangerous, and we are very anxious about it
d) Airplane accidents are not dangerous, but we are very anxious about it
QUESTION: Interpreting Graphs and Data

If the “low” dose = 5 units of a chemical, the “medium” dose = 10 units, and the “high” dose = 15 units, how much of the chemical is required to kill 50% of the study population?

a) About 5 units
b) About 10 units
c) About 15 units
d) You can’t tell from the graph

From The Science behind the Stories
QUESTION: Viewpoints

Is it unethical for a country that has banned a chemical to manufacture and export it to other countries?

a) Yes; if we won’t have it in the U.S., we shouldn’t make it
b) Yes, but the money we get from selling it will help our economy
c) No; let people decide what they want to do
d) No; in fact, chemicals should not be banned in the U.S. either
**QUESTION: Viewpoints**

Should the government follow the precautionary principle and force industries to prove their products are safe?

a) Absolutely; it is up to industry to prove its chemicals are safe
b) Maybe, if it is not too expensive
c) No; let the government and scientists prove a chemical is dangerous before it is taken off the market
d) No, as long as the product makes money and jobs for the industry, it should be allowed