10

Environmental Health and Toxicology

Chapter Objectives

This chapter will help students:

Identify the major types of environmental health hazards and explain the goals of environmental health

Describe the types, abundance, distribution, and movement of toxicants in the environment

Discuss the study of hazards and their effects, including epidemiology, animal testing, and dose-response analysis

Assess risk assessment and risk management

Compare philosophical approaches to risk, and how these relate to policy

Lecture Outline

I. Central Case: Alligators and Endocrine Disruptors at Lake Apopka, Florida

A. In 1985, Louis Guillette discovered bizarre reproductive problems in American alligators in Lake Apopka.

B. He developed the hypothesis that certain chemical contaminants in Lake Apopka were disrupting the endocrine system of alligators during development in the egg.

C. Guillette and his co-workers found that Lake Apopka alligators had abnormally low hatchling rates starting in the years after a pesticide spill. The lake also received high levels of chemical runoff from agriculture.

D. Guillette's results showed that atrazine and nitrates (both fertilizer

ingredients) act as endocrine disruptors, causing smaller penises and lower testosterone levels in juvenile male alligators.

E. Many scientists suspect that chemical contaminants could be affecting people just as they have alligators.

II. Environmental Health

1. The study and practice of **environmental health** assesses environmental factors that influence human health and quality of life, and seeks to prevent adverse effects on human health and ecological systems.

A. We face four types of environmental hazards.

1. *Physical hazards* occur naturally in our environments and can pose health hazards. These include discrete events such as earthquakes, fires, floods, and droughts, and also include ongoing natural phenomena such as ultraviolet radiation from the sun, which can cause skin cancer.

2. *Chemical hazards* include many of the synthetic chemicals that our society produces, such as disinfectants and pesticides, and also include chemicals produced naturally by organisms.

3. *Biological hazards* result from ecological interactions among organisms, such as becoming sick from a virus, bacterial infection, or other pathogen. If this illness can spread to other humans, then it is an **infectious disease**, also called *communicable* or *transmissible disease* (e.g., malaria, cholera, flu).

4. *Cultural hazards* result from where we live, our socioeconomic status, our occupation, or our behavioral choices. Choosing to smoke, poor diet, and living in proximity to toxic waste are all cultural hazards.

B. Disease is a major focus of environmental health.

1. Many major killers such as cancer, heart disease, and respiratory disorders have genetic bases but are also influenced by environmental factors.

2. Malnutrition can foster a wide variety of illnesses, as can poverty, poor hygiene, lifestyle choices, and lack of exercise.

3. Infectious disease involves a pathogen that attacks us directly, or an infection may occur through a *vector*.

C. Environmental health hazards exist both indoors and outdoors.

1. Indoor environmental health threats include radon, lead poisoning, and asbestos.

2. A recently recognized hazard is a group of chemicals known as polybrominated diphenyl ethers (PBDEs). These chemicals appear to be endocrine disruptors, affecting thyroid hormones in animals, and have been banned in Europe.

D. Toxicology is the study of poisonous substances.

1. **Toxicology** studies the effects of poisonous substances on humans and other organisms.

2. A **toxicant**, or toxic agent, must be compared to other substances to determine the *toxicity*, or the degree of harm that it can inflict.

3. With toxins, "the dose makes the poison"—meaning that the quantity received is an important factor in the damage done.

4. **Environmental toxicology** deals specifically with toxic substances that come from or are discharged into the environment, and includes the study of health effects on humans, other animals, and ecosystems.

III. Toxic Agents in the Environment

A. Synthetic chemicals are ubiquitous in our environment.

1. Thousands of synthetic chemicals have been manufactured and many have found their way into soil, air, and water.

2. Every one of us carries traces of numerous industrial chemicals in our bodies.

3. Very few of these chemicals have been tested for harmful effects.

B. *Silent Spring* began the public debate over synthetic chemicals.

1. Rachel Carson was a naturalist, author, and government scientist.

2. Using scientific studies, medical case histories, and other data, she showed that DDT, and artificial pesticides in general, were hazardous to people, wildlife, and the environment.

3. Carson's book was a bestseller and generated significant social changes in views and actions toward the environment.

4. The United States still manufactures and exports DDT to countries that do use it, especially for mosquito control. Certain species of mosquitoes are vectors for malaria, which in those countries is considered to be a greater risk than the toxic effects of the pesticide.

C. Toxicants come in different types.

1. **Carcinogens** are chemicals or types of radiation that cause cancer.

2. **Mutagens** are chemicals that cause mutations in the DNA of organisms.

3. Chemicals that cause harm to the unborn are called **teratogens**.

4. **Neurotoxins** assault the nervous system.

5. **Allergens** overactivate the immune system, causing an immune response when one is not necessary.

6. **Endocrine disruptors** are toxicants that interfere with the *endocrine system*.

D. Endocrine disruption may be widespread.

1. The idea that synthetic chemicals might be altering the hormones of animals was presented in the 1996 book *Our Stolen Future*.

2. One common type of endocrine disruptor involves the feminization of male animals.

3. To date, endocrine effects have been most widely found in nonhuman animals, but scientists attribute the striking drop in sperm counts among men worldwide to endocrine disruptors.

4. Because the *endocrine system* is geared to respond to minute concentrations of hormones in the bloodstream, it may be especially vulnerable to effects from environmental contaminants.

5. Manufacturers of herbicides would lose many millions of dollars if their products were banned or restricted.

6. Many everyday household plastic products contain bisphenol-A, an estrogen mimic, but the plastic industry protests that the chemical is safe despite research showing birth defects in lab mice.

E. Toxicants may concentrate in surface water or groundwater.

1. Water runoff often carries low amounts of toxicants from large areas of land and concentrates them in small volumes of surface water.

2. Many chemicals are soluble in water, and thus are very accessible to organisms. This is why aquatic animals such as fish, frogs, and stream invertebrates are especially good indicators of pollution.

F. Airborne toxicants can travel widely.

G. Some toxicants persist for a long time.

1. DDT and PCBs have long persistence times, while Bt toxin has a very short persistence.

2. Some toxicants have *breakdown products* that are just as toxic as the original chemical, or more so (e.g., DDT breaks down into DDE, a highly persistent and toxic compound).

H. Toxicants may accumulate and move up the food chain.

1. Fat-soluble toxicants such as DDT and DDE are absorbed and stored in fatty tissues and may build up in animals in a process called **bioaccumulation**.

2. Toxicants that bioaccumulate in the tissues of one organism may then be transferred to other organisms in the food chain, in a process called **biomagnification**.

3. An example is polar bears in Arctic Norway who are suffering from PCB contamination because of biomagnification, resulting in high cub mortality.

I. Not all toxicants are synthetic.

1. Chemical toxicants also exist naturally in the environment around us and in the foods we eat.

2. Scientists are actively debating just how much risk is posed by natural toxicants.

IV. Studying Effects of Hazards

1. Wildlife studies use careful observations in the field and the lab.

2. Human studies rely on the direct study and treatment of sickened individuals.

3. **Epidemiological studies** involve large-scale comparisons among groups of people, usually contrasting a group known to have been exposed to some toxicant and a group that has not.

4. Manipulative experiments are needed to truly nail down causation. However, this is not possible with human subjects and so they are substituted with animals.

A. Dose-response analysis is a mainstay of toxicology.

1. The standard method of testing lab animals in toxicology is called dose-response analysis.

2. The *dose* is the amount of toxicant the test animal receives, and the *response* is the type or magnitude of negative effects the animal

exhibits as a result. The response is generally quantified by measuring the proportion of animals exhibiting negative effects.

3. Once a **dose-response curve** is plotted, scientists can calculate a convenient shorthand gauge of a substance's toxicity—the amount of toxicant it takes to kill half the population of study animals used **(LD_{50})**.

4. Nonlethal health effects are determined by the level of toxicant at which 50% of the population is affected **(ED_{50})**.

5. Common sense suggests that the greater the dose, the stronger the response will be. However, sometimes responses occur only above a certain dose, called the *threshold* dose.

6. Sometimes responses decrease with dose. Some dose-response curves are U-shaped, J-shaped, or shaped like an inverted U; these curves appear to apply to endocrine disruptors.

B. Individuals vary in their responses to hazards.

C. The type of exposure can affect the response.

1. The toxicity of many substances varies according to whether the exposure is in high amounts for short periods of time—**acute exposure**—or in lower amounts over long periods of time—**chronic exposure**.

2. Acute exposure is easier to recognize but chronic exposure is more common, and is more difficult to detect and diagnose.

D. Mixes may be more than the sum of their parts.

1. Interactive impacts may arise when toxicants are mixed together, and when these impacts are more than or different from the simple sum of their constituent effects, they are called **synergistic effects**.

2. Traditionally, environmental health has tackled the effects of single hazards one at a time, and single-substance tests have received priority. This is changing, but scientists will never be able to test all possible combinations.

V. Policy Approaches

A. **Risk** is expressed in terms of probability.

1. Exposure to a toxin causes some probability of harm, a statistical chance that damage will result. The probability depends on the toxin, its strength, the frequency and duration of the encounter, the sensitivity of the organism, and other factors.

B. Our perception of risk may not match reality.

C. Risk assessment analyzes risk quantitatively.

1. The quantitative measurement of risk and the comparison of risks involved in different activities or substances together are termed **risk assessment**.

2. Assessing risk for a chemical substance involves several steps.

D. **Risk management** combines science and other social factors.

1. In most developed nations, risk management is handled largely by government agencies.

2. Scientific assessments of risk are considered in light of economic, social, and political needs and values.

3. In environmental health and toxicology, comparing costs and benefits is often difficult because the benefits are economic and the costs often pertain to health.

E. Two approaches exist for determining safety.

1. One approach is to assume that substances are harmless until shown to be harmful; the *innocent-until-proven-guilty* approach. This approach encourages technological innovation but may put some dangerous substances into wide use.

2. The other approach is to assume that substances are harmful until shown to be harmless. This enables us to identify toxicants before they are released into the environment, but may also impede technological and economic advance.

F. Philosophical approaches are reflected in policy.

1. Most nations follow a blend of the two approaches, but there is marked variation.

2. At present, European nations are following the precautionary principle.

3. The United States is largely following the innocent-until-proven-guilty approach.

4. In the United States, the tracking and regulation of synthetic chemicals is shared among several federal agencies.

5. The EPA also regulates diverse chemicals under the Toxic Substances Control Act (TSCA) of 1976.

a. TSCA was the first law to require screening of substances before they entered the marketplace.

b. Many public health and environmental advocates view TSCA as being too weak.

G. We regulate toxicants internationally.

1. An international treaty, the Stockholm Convention, aims first to end the use and release of 12 persistent organic pollutants (POPs) called the "dirty dozen." It appears to be on its way to ratification.

2. In 2007, the EU's REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) program shifted the burden of testing chemical safety from national governments to industry.

VI. Conclusion

1. International agreements such as the Stockholm Convention represent a hopeful sign that governments will act to protect the world's people, wildlife, and ecosystems from toxic chemicals and other environmental hazards.

2. A society's philosophical approach to risk management will determine what policy decisions are made.

Key Terms

acute exposure
allergens
bioaccumulation
biomagnification
carcinogens
chronic exposure
dose-response curve
ED_{50}
endocrine disruptors
environmental health
environmental toxicology
epidemiological studies
infectious disease
LD_{50}
mutagens
neurotoxins
risk
risk assessment
risk management
synergistic effects
teratogens
toxicant
toxicology

Teaching Tips

1. Assign students to read selections from *Our Stolen Future* (Colburn, Dumanoski, and Myers, Dutton Publishing, 1996) and/or *Silent Spring* (Rachel Carson, 1962). There is a website that accompanies *Our Stolen Future* at

www.ourstolenfuture.org, which provides links to current research on the effects of endocrine disruptors. The "Online Ethics Center for Engineering and Science" at Case Western Reserve University provides information about Rachel Carson with a summary of the book at http://onlineethics.org/moral/carson/index.html. It also has links to the information in Spanish.

2. Ask students to conduct Internet research for updates on the Lake Apopka alligator issue presented as the central case study in this chapter. Is current research being done? If so, what are the results showing? There is a Frontline video and accompanying website that examined this issue in 1998 called "Frontline: Fooling with Nature" (www.pbs.org/wgbh/pages/frontline/shows/nature/). A paper published in 2005 in *Biology of Reproduction* (http://www.biolreprod.org/cgi/content/abstract/73/5/1004) gives further evidence of the problem.

3. Certain facilities in the United States are required to report their releases of toxic substances to the state and the EPA. These data are compiled and reported in the *Toxic Releases Inventory (TRI) Public Data Release Report*, and are made available to the public via the Internet. Ask students to find information about toxic releases in their neighborhood by accessing the TRI Explorer at www.epa.gov/triexplorer. TRI Explorer is a searchable online database that lets users quickly get information about releases and transfers of toxic chemicals. Have your students check their zip code or their county, or have each group choose a county near you.

4. A recent issue that has generated a good deal of controversy is contaminants in children's candy. In April of 2004, the *Orange County Register* conducted an investigation and published a 6-part story about lead in candy, imported mostly from Mexico. The story includes a number of candies that you might not think are imported, and some candies that are manufactured in the United States by major companies. The story, sidebars, and news reports since the initial story are all available at the newspaper's website (www.ocregister.com/investigations/2004/lead/index.php) and include coverage of environmental contaminants, local and international laws and regulations, risk assessment, and the pitting of manufacturers against health officials. Divide your students into groups and have them each take one aspect of the story:

   How lead gets into candies

   Allowable levels of lead

   Effects of lead in the body (in children, adults, and during pregnancy)

   Current estimates of numbers of people affected

   Treatments for lead poisoning

   Regulations on lead in Mexico, and their enforcement

Regulations on lead in the United States, and their enforcement

What some states and cities are doing

What is being done in your area

Have each group make a poster or PowerPoint presentation to present to the class. Hang the posters or PowerPoint printouts in school hallways, place them on a class website, or give a public presentation of the information.

5. It's approaching the middle of the semester and you are thinking of giving a mid-term exam, or at least a mid-term grade so that students know where they stand. What about having students give the course some mid-term feedback as well? The website for the Office of Educational Development at the University of California, Berkeley (http://teaching.berkeley.edu/teaching.html) has a link to a Standard Mid-semester Evaluation form, and a second link to Responding to Mid-semester Evaluations. The students spend 5 minutes in class writing an anonymous evaluation of the course and their progress, which can help you fine-tune your planning for the rest of the semester. The second paper includes tips on dividing student responses into things you might change this semester, things you might change in future semesters, and things that are either structural or that you cannot change.

6. If your classroom has the capacity to project an online search of the Internet onto a larger screen, go to the website www.scorecard.org; type in the zip code for the college and begin to query the site. Students can select information ranging from what toxic chemicals are stored in the vicinity of the school to learning which facilities have released toxics into the environment and what the nature of the hazard presents in terms of human health and environmental quality. The exercise itself will generate rich classroom discussion.

7. Use the above site and assign students to prepare a written report based on information they learn by typing their home zip code into the website's search capacity. It is easy to shrug off; "other people have this pollution in their communities, but I don't have it in mine."

Additional Resources

Websites

1. *EXTOXNET*, a cooperative effort of University of California at Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho (http://extoxnet.orst.edu).

   This website provides information for the public about pesticides, including Pesticide Information Profiles (PIPs), Toxicology Information Briefs (TIBs), and Toxicology Issues of Concern (TICs).

2. *Indoor Air Quality*, U.S. Environmental Protection Agency (www.epa.gov/iaq).

   This Web resource provides information about indoor air pollutants, potential effects, and ways to minimize pollutant concentrations.

3. *Report on Carcinogens*, 11th Edition, 2005, U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program (http://ntp.niehs.nih.gov/index.cfm?objectid=72016262-BDB7-CEBA-FA60E922B18C2540).

   This report is an informational scientific and public health document that identifies and discusses substances that may pose a carcinogenic hazard to human health.

4. *Toxicology Tutor*, National Library of Medicine, National Institute of Health (www.sis.nlm.nih.gov/ToxTutor/Tox1/index.html).

   This online tutorial introduces the basics of toxicology written at the introductory college level.

5. *Science and Environmental Health Network,* a virtual organization with 501(c)(3) status, (www.sehn.org).

   This organization has a wealth of information about synthetic chemicals and their impact on human health and environmental quality. The network also provides detailed information on the "Precautionary Principle" and how it relates to environmental quality.

6. *Agency for Toxic Substances and Disease Registry*, Centers for Disease Control, United States Department of Health and Human Services (www.atsdr.cdc.gov).

   This website contains summaries of various toxic materials for the public in documents called ToxFAQs.

Audiovisual Materials

1. *Cleaning Up Toxics at Home and Business*, 1990, produced by the League of Women Voters and distributed by The Video Project (www.videoproject.com).

   This two-video program gives practical advice on how to protect our families, co-workers, and customers from toxic hazards found in our homes and business.

2. *Global Dumping Ground*, 1990, video produced by Maryann Sargent and distributed by The Video Project (www.videoproject.com).

   This film investigates how toxic exports have become a big business and a health hazard to the citizens of foreign nations.

3. *Witness to the Future*, 1996, produced by Branda Miller and distributed by The Video Project (www.videoproject.com).

This program tells the stories of three citizens whose experiences with toxic waste transformed them into environmental activists.

4. *NOW, with Bill Moyers: Are We Poisoning Our Children?* (May, 2002).

   Bill Moyers interviews parents, scientists, and government officials about children's exposure to toxic materials. Voice of Dr. Sandra Steingraber, noted ecologist and author, states that "our children are the canaries in the coal mine."

5. *Drumbeat for Mother Earth*, 2002, video produced by the Indigenous Environmental Network and Greenpeace and distributed by Bullfrog Films (http://bullfrogfilms.com).

   This video program describes how toxic chemicals are the greatest threat to the survival of indigenous peoples.

6. *One Night in Bhopal*, 2004, video distributed by Films for the Humanities and Sciences (www.films.com).

   This video program describes the Union Carbide methyl isocyanate disaster outside of Bhopal, India in 1984 and details its protracted consequences.

Weighing the Issues: Facts to Consider

A Circle of Poison?

Facts to Consider: This question requires an individual response. The selling of DDT to other countries does not lessen the harmful effects of the pesticide. Perhaps products should not be exported if they are banned domestically. Synthetic chemicals can travel great distances in the environment—far from their place of application—so exporting these chemicals to one country may mean harmful effects in other countries that did not agree to their use. On the other hand, other countries might have different priorities. In a developing country, DDT may be the pesticide of choice because it is effective and inexpensive. Tropical countries may deem the problem for which they will use the chemical greater than the effect of the chemical on the human population or on ecosystems. This is the case with malaria control programs in many tropical developing countries. In any case, since pesticide sales are permitted from the United States to other countries, it would seem proper that all available information the U.S. has about the negative effects of such substances, and how to minimize these impacts, should be disseminated publicly in the countries to which it is sold.

The Precautionary Principle

Facts to Consider: Responses may vary about whether proof of safety should be required and whether manufacturers should bear the burden of this proof. Many may argue that if substances are permitted to go to market without proof of safety, some dangerous chemicals may do great harm before

their effects are discovered. Others will argue that the cost of these chemicals will increase due to the additional research needed prior to their commercial release. Some students may point out that the research is being done by chemical manufacturers, and the problem lies with the public's inability to access this research, as has been the case in nicotine research by some of the major tobacco companies in the United States. Adopting the precautionary principle would certainly reduce the number of chemicals on the market. In the long run, manufacturers might develop new chemicals that have less toxic effects, or consumers might buy more of the chemicals that remain available, reducing or eliminating loss of revenue to manufacturers.

The Science behind the Story

Pesticides and Child Development in Mexico's Yaqui Valley

Observation: A study in 1990 of Yaqui who lived and worked on some of the larger farms in the valley showed high levels of multiple pesticides in mothers' breast milk and the umbilical cord blood of newborns. Anthropologist Elizabeth Guillette was interested in the possible effects of pesticides on children, and conducted her team's study in 1994.

Hypothesis: In Mexico's agricultural Yaqui Valley, children who live on farms in areas of heavy pesticide use will develop more slowly than children who live in the foothills above the valley near farms with little or no pesticide use.

Experiment: Guillette and her team studied 50 preschoolers. Thirty-three of the children lived in Yaqui River Valley farming communities where farmers applied pesticides up to 45 times from planting to harvest. The rest of the children lived in the village of Tescopaco, in the Sierra Madre Occidental foothills above the valley. Here, farmers chose not to use pesticides, and farmed crops using traditional agricultural methods of the Yaqui culture. Guillette developed tests that assessed children for coordination, memory, and other skills that measure healthy child development.

Results: The children from the high-pesticide Yaqui River Valley performed poorly on the tests compared to the children from low or no pesticide use areas in the foothills.