Chapter 15
ENVIRONMENTAL HEALTH AND TOXICOLOGY

15.1 BASICS

● Disease seldom has a one-cause, one-effect relationship with the environment. Rather, the incidence of a disease depends on several factors, including the physical and biological environments and lifestyle. Environmental risks are both anthropogenic and natural. The Lake Nyos CO₂ release in Cameroon in 1986 killed more than 1,800 people and is an example of how risky nature can be.

● Terminology: pollution refers to the occurrence of an unwanted environmental change caused by the introduction of harmful materials or the production of harmful conditions (e.g. heat); contamination implies making something unfit for use by the introduction of undesirable materials; toxicology is the science that studies chemicals that are known to be or could be toxic; a carcinogen is a toxin that increases the risk of cancer; and a synergism is an interaction between two or more substances such that the combined effect differs from that of either substance alone.

● Units of reporting concentrations of pollutants varies depending on the chemical and the circumstance. The unit ppm is equivalent to 1 mg/kg. A ppm can also be expressed as a percent. 100 ppm = 0.01%. The unit ppb is 1 ug/kg. Units may be based on dry mass or on volume. Review metric units.

Case Study: Demasculinization and Feminization of Frogs in the Environment

● This is a case study of freak abnormalities beginning to appear in common species around us. A variety of pollutants are the suspected causative agents. In the case of the leopard frogs in the Midwest, 10-92 percent of male frogs exhibit gonadal abnormalities that are thought to be caused by the common herbicide Atrazine. The atrazine is believed to activate a gene that turns testosterone to estrogen. Atrazine is one of a growing group of chemicals that are referred to as xenoestrogens or compounds that mimic or alter the activity of estrogen, also known as hormonally active agents (HAAS). This example dramatizes the importance of evaluating the role of human-made chemical in the environment.

A CLOSER LOOK 15.1: SUDBURY

● New regulations in 1969 forced the operators of the 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 SO₂ 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.
15.2 CATEGORIES OF POLLUTANTS

- Diseases can be classified as being infectious or noninfectious. There are infectious diseases that have no known reliable vaccines such as HIV, hantavirus and Dengue fever. Diseases that can be controlled by manipulating the environment are classified as environmental health concerns. In developing countries the greatest mortality is from infectious disease, not from toxins or carcinogens. Some examples of environmentally transmitted diseases are legionellosis (Legionnaires’ disease), giardiasis (protozoan), salmonella, malaria, Lyme borreliosis, cryptosporidiosis (protozoan) and anthrax (a terrorist threat).
- The major heavy metals that pose health hazards to people and ecosystems include Hg, Pb, Cd, Ni, Pt, bismuth, arsenic, selenium, vanadium, chromium and thallium. Heavy metals often have direct physiological toxic effects. Some are stored in living tissue. They tend to store in fatty tissue.
- The content of heavy metals in our bodies is referred to as the **body burden** (see the web link). Mercury (Hg), thallium and lead are very toxic to humans and their properties are well known.
- Toxins can make their way into the human body through numerous pathways. These may involve **biomagnification**. For example, an element like Cd can enter the environment via the ash from burning coal. The ash is collected and placed into a landfill where it can migrate and be taken up by plants and then into the rest of the food chain. Mercury in aquatic systems provides another 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 deposits 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. Several major incidents of methyl mercury poisoning have been recorded, including the famous Minamata Bay case in which a number of people have died from consuming tainted fish from the bay where chemical maker Chisso Corp. had been pouring tons of mercury compounds since the 1930s.
- Organic compounds (molecules containing both carbon and hydrogen atoms) may be natural or synthetic. Synthetic organics are used for many purposes such as pharmaceuticals, pesticides, and food additives (see Table 15.1). They also include the HAAs that were discussed earlier. We have produced over 20 million synthetic chemicals, and new ones are appearing at a rate of about 1 million per year, though most of these are not produced commercially. Some of these compounds persist in the environment (POPs). POPs have the following characteristics: they often contain a highly reactive chlorine atom, they are usually synthetic, they do not easily or quickly degrade, they are polluting and toxic, they are fat soluble, and they occur in forms that allow them to be transported by wind, water and sediments. PCBs once used in the electronics industry is a notorious example of a toxic POP that has made its way into the food chain, biomagnifies, and is still present years after its production was stopped.
- The HAAs deserve closer inspection and further study. Pesticides, including herbicides, are found in alarming concentrations in the environment and in the tissues of all organisms including man. There is evidence that these compounds are affecting the reproductive systems of numerous organisms, possibly including man. The data on declining sperm counts in humans is controversial and not conclusive. These compounds
are suspected as playing a role in breast cancer. Plastics that are chlorine-based leak plasticizers (phthalates) are also suspect, and little is known about them.

- Radiation is a class of pollutant that is discussed in more detail in Chapter 19.
- Thermal pollution occurs when heat released into water or air produces undesirable effects. The release can be acute or chronic. The chronic release of hot water from thermal power plants can raise the temperature of the aquatic environment and have adverse effects on the biota. Solutions to thermal pollution from power plants include cooling ponds and towers (see Fig. 15.8).
- Particulates are small particles of dust (including soot and asbestos fibers) released by natural or anthropogenic sources. Asbestos is a term applied to several fibrous minerals that have been used for decades as a fire retardant and as insulation. Breathing asbestos fibers can cause mesothelioma, a rare lung cancer. About 95% of the asbestos is white asbestos from the mineral chrysolite which is not particularly dangerous, and the movement to remove it from buildings and homes at great expense was probably an overreaction. In contrast, exposure to crocidolite asbestos (blue asbestos) is quite harmful.
- The radiation from electromagnetic fields (EMFs) deserves further study, though no study to date shows any statistically significant health effect associated with EMF exposure.
- Noise pollution. The intensity of the energy carried by sounds waves is measured in units of decibels (dB). The threshold for human hearing is 0 dB, the average level in a home is 45 dB, an automobile is 70 dB, and a jet aircraft taking off is about 120 dB. A 10-fold increase in the strength of a sound adds 10 dB. Permanent loss of hearing can result from extended exposure to 110 dB (the strength of amplified music).
- Voluntary exposure to toxins includes tobacco use, alcohol, and drugs.

A CLOSER LOOK 15.2: MINAMATA BAY

- A vinyl chloride factory on Minamata Bay used Hg in hits production processes and discharged Hg into the bay for years. The Hg was methylated by bacteria in the sediments and entered the marine food chain. Fish from the bay was an important part of the local diet. Eventually, 43 people died and 11 were disabled. This case illustrates four factors that must be considered in evaluating toxins: (1) individuals vary in the response to exposure; (2) pollutants may have a threshold; (3) some effects are reversible; and (4) the chemical form of a pollutant, its activity, and its potential to cause health problems may be changed by ecological and biological processes.

A CLOSER LOOK 15.3: 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. The EPA has set an acceptable intake of dioxin at 0.006 pg/kg, 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.
15.3 GENERAL EFFECTS
● The typical response to a toxin is summarized by a dose-response curve (see Fig. 15.11). Toxicity is dose-dependent, and not every individual responds the same way to the same dose. The dose-response curve is not always simple (see Figs. 15.11 to 15.14).
● The lethality of a toxin is expressed as an LD<sub>50</sub>, the effectiveness is measured as an ED<sub>50</sub> (the concentration that causes a response of some kind in 50% of the exposed population), and TD<sub>50</sub> (the concentration that is toxic to 50% of the population). See Table 15.4 for the LD50s of selected substances.
● Some toxins have thresholds, concentrations or levels below which there are no effects.
● Tolerance is the ability to resist or withstand stress resulting from pollutant exposure. Tolerance can develop in response to repeated exposure, and can be behavioral, physiological, or genetic. Genetic tolerance acts at the population level after generations of exposure.
● Effects and exposures are usually described as being acute or chronic.

15.4 RISK ASSESSMENT
● Risk assessment involves four steps: identification of the hazard, dose-response assessment, exposure assessment (how much exposure to people?), and risk characterization (what is the risk to people from the exposure?). Risk management integrates risk assessment with the technical, legal, political, social and economic issues.

CRITICAL THINKING: LEAD IN THE URBAN ENVIRONMENT
● Pb is one of the most common and oldest forms of pollution. A study of children concluded that attention deficit disorder, aggression and delinquency were related to the concentration of Pb in bones. The study controlled for factors such as maternal intelligence, socioeconomic status and the quality of child rearing. The implication of the study is that Pb toxicity may play a role in urban crime.
Are there other factors besides those mentioned that might explain the effect of Pb?
What are the assumptions and are they reasonable?

Web Resources
http://www.ewg.org/reports/bodyburden/  Researchers at two major laboratories found an average of 91 industrial compounds, pollutants, and other chemicals in the blood and urine of nine volunteers, with a total of 167 chemicals found in the group. Of the 167 chemicals found, 76 cause cancer in humans or animals, 94 are toxic to the brain and nervous system, and 79 cause birth defects or abnormal development.
http://www.personalmd.com/news/a1998060315.shtml  This is a brief account of the death of Professor Karen Wetterhahn who died 10 months after exposure to dimethylmercury.
http://www.phthalates.org/yourhealth/food_packaging.asp  This is information about phthalates from the industry source.