Chapter 5

Environmental Pollutants and Their Fate
Pollutants and Their Fate

• Our environment contains a multitude of chemicals that affect many species and ecosystems.
• Ecotoxicology can be viewed as a study of the harmful effects of chemicals on ecosystems.
• It deals with the delivery, transport, transformation, and effects of pollutants on the physical environment and on the species that live here.
• Pollutants enter ecosystems through discharges into the atmosphere, contamination of land, and entry into water.
Chemical Pollution: Links to...

- Loss of parental attention in birds
- Decreased fertility in invertebrates, fish, reptiles, birds, and mammals
- Decreased hatching success in fish, turtles, and birds
- Abnormal thyroid function in birds and mammals
- Feminization in males and masculinization in females in birds, fish, and invertebrates
- Altered immune function in birds and mammals
Table 5-2 Examples of Threatened (T) or Endangered (E) Animal Species

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Species Group</th>
<th>Range</th>
<th>Listing Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abalone, white</td>
<td><em>Haliotis sorenseni</em></td>
<td>Snails</td>
<td>North America</td>
<td>T</td>
</tr>
<tr>
<td>Acornshell, southern</td>
<td><em>Epioblasma othcaloogensis</em></td>
<td>Clams</td>
<td>U.S.A. (AL, GA, TN)</td>
<td>E</td>
</tr>
<tr>
<td>Addax</td>
<td><em>Addax nasomaculatus</em></td>
<td>Mammals</td>
<td>North Africa</td>
<td>E</td>
</tr>
<tr>
<td>Akepa, Hawaii (honeycreeper)</td>
<td><em>Loxops coccineus coccineus</em></td>
<td>Birds</td>
<td>U.S.A. (HI)</td>
<td>E</td>
</tr>
<tr>
<td>Ala balik (trout)</td>
<td><em>Salmo platycephalus</em></td>
<td>Fishes</td>
<td>Turkey</td>
<td>E</td>
</tr>
<tr>
<td>Albatross, Amsterdam</td>
<td><em>Diomedea amsterdamensis</em></td>
<td>Birds</td>
<td>Indian Ocean, Amsterdam Island</td>
<td>E</td>
</tr>
</tbody>
</table>
Unfortunate Lessons Learned

• Environmental pollutants can relocate from their original source through interface transport processes.
• An interface is that theoretical boundary between air and water, air and soil, and soil and water.
• Unfortunately, plants and animals are located in or on these compartments and form a biological interface as well that can be adversely affected.
DDT
(dichlorodiphenyltrichloroethane)

• A chlorinated hydrocarbon developed in the 1930s by the chemist Paul Muller.
• DDT was a very effective insecticide and did not easily degrade in the environment.
• Effectiveness and persistence were deemed to be very favorable aspects for adopting its use on a global scale.
• It became very popular during WWII and was instrumental in the reduction of disease vectors like malaria
• It is responsible for saving millions of lives.
DDT (dichlorodiphenyltrichloroethane)

- Wide use in post WWII United States and abroad because of its cost-effectiveness.
- Ubiquity = long-term detrimental effects?
- Rachel Carson’s *Silent Spring*, published in 1962, launched modern environmental movement
- Experimental studies suggested that DDT may produce reproductive, teratogenic, neurological, and other effects in laboratory animals.
Unintended Consequences

• An unfortunate consequence of DDT’s withdrawal from the world market was a spike in global malaria infection rates.

• Today, malaria infects 300 to 500 million people annually:
  – more than 2.7 million people, primarily children under 5, die from malaria each year.

• As a result, all but the most ardent anti-DDT activists have stepped back from the global ban to support the WHO in its call for limited reintroduction.
Minamata Bay

- Mercury poisoning in 1956 among the residents of the Minamata Bay region on the island of Kyushu, Japan
- It was linked to a local plastics factory that was dumping mercury into the bay
- Fish and shellfish consumption resulted in exposure to high levels of methylmercury
- Microorganisms biotransformed mercury into methylmercury.
Minamata Bay, cont.

• Hundreds of people exhibited serious neurological problems:
  – difficulty walking, swallowing, speaking, and hearing.
  – Post mortem brain analysis revealed that many had a marked loss of brain weight and volume (brain atrophy).
  – Children born to exposed mothers had a high rate of birth defects, including severe brain damage, mental impairment, and delayed development.
Minamata Bay

- Epidemiological experts were called on to investigate:
  - exposures to manganese and selenium were first suspected
  - mercury contamination proven following investigation
Case in Point

The Minamata Bay incident is not the only episode of industrial pollution in Japan. Kamioka Mines in Japan’s Toyama Prefecture released significant amounts of cadmium into the Jinzu River as a byproduct of zinc purification. The water from the Jinzu was used for drinking water, bathing, and rice paddy irrigation. Cadmium was incorporated into the rice grains, and people who consumed the contaminated rice began to bioaccumulate the cadmium.
Case in Point

Cadmium mimicked zinc, calcium, and sulfur in the undernourished citizens, softening their bones and entering their tissues. Local physicians documented a cluster of new bone and joint pain diseases in the area. The symptoms were particularly pronounced in post-menopausal women. Although the syndrome, dubbed “itai itai” for the cries of pain uttered by the sufferers, was initially noted in 1912, it wasn’t linked to the zinc mines until 1946, when Dr. Noboru Hagino overlaid a map of the river and tributaries with an epidemiological map plotting cases of itai-itai.
In response to citizen complaints, Mitsui Mining and Smelting Company designed a retention basin to trap the mining wastes. Twenty-nine plaintiffs filed suit against the Mitsui Mining and Smelting Company in 1968. The company was found guilty in 1971. After a failed appeal, Mitsui was ordered to pay for medical care and monitoring of the water quality, and to pay reparations to the survivors diagnosed with itai-itai.
Pollution versus Contamination

- *pollutant* is commonly taken to refer to any chemical as producing or having the potential to produce actual environmental harm.
- *contaminant* has no implication of harm associated with its presence in a system.
EPA Categorized Pollutants

- Agricultural Chemicals
- Air Pollutants
- Biological Contaminants
- Carcinogens
- Chemicals
- Extremely Hazardous Substances
- Microorganisms
- Radiation
- Soil Contaminants
- Toxic Substances (Persistent Bioaccumulative Toxic Pollutants, Persistent Organic Pollutants)
- Pollutants
Pollution versus Contamination

- *The Third National Report on Human Exposure to Environmental Chemicals* is part of a long-range biomonitoring project conducted by the CDC at the National Center of Environmental Health (NCEH).
- Attempting to quantify exposure to 148 common environmental chemicals
- Defines an environmental chemical as “a compound or chemical element present in air, water, food, soil, dust, or other environmental media.”
- The findings for each of the 148 chemicals in the report are summarized individually.
Did You Know?

- According to the EPA, the open air burning of backyard waste is currently the main source of dioxins in the United States.
Ecosystems and Compartments

• An ecosystem comprises populations and communities residing in a defined area.
• Ecosystems are aquatic (marine and freshwater) or terrestrial.
• They can be viewed as being composed of a number of compartments:
  – An abiotic compartment (nonliving): contains air, water, soils, and sediments
  – A biotic compartment (living): composed of animal and plant life
The Environment Viewed as Compartments and Ecosystems

• The Atmosphere
  – Fate of a Chemical in Air
• The Hydrosphere
• Soils
• The Biosphere
Atmosphere

• Composed of a number of layers:
  – troposphere
  – stratosphere
  – mesosphere
  – thermosphere

• Principal concern is the troposphere, which extends from the surface of the earth to an altitude of about 10 km
Atmosphere

• This atmospheric air contains:
  – “trace amounts” of chemicals such as carbon monoxide, sulfur dioxide, hydrogen sulfide, nitric acid, ammonia, formaldehyde, lead, oxides of nitrogen, particulates, and many others pollutants
  – most of the atmospheric water, and this is where we observe clouds, storms, and other conditions of weather
  – gases necessary to maintain life
Fate of a Chemical in the Air

• TRI estimates that about half of atmospheric pollutants result from industrial discharges.
• Pollutants reach the atmosphere directly or through transport from other compartments.
• Airborne chemicals can enter into chemical reactions, such as oxidation and photolysis.
• This ability to enter into chemical reactions results in the production of other pollutants.
Fate of a Chemical in the Air Depends On

- Input (e.g., rate, type of pollutant, source, etc.)
- Dispersion (e.g., mixing from the wind and turbulence)
- Transport (e.g., vertical and horizontal by wind)
- Reactions and formation of secondary pollutants (e.g., chemical reactions such as oxidation, hydrolysis, and photolysis, and physical reactions such as absorption and adsorption)
- Removal (e.g., through precipitation)
The Hydrosphere

• Water covers approximately 70% of the surface of the earth.
• Water provides humans with chemical necessary for survival, source of nourishment, a means to travel
• Cultures developed along oceans, rivers, and lakes.
  – More than 50% of the population of the United States resides in cities surrounding seaports and lakes.
• Water has enabled us to thrive as an agricultural and industrial society.
The Hydrosphere, cont.

• Inevitable contamination of waters from:
  – manufacturing plant discharges
  – accidental chemical spills
  – domestic sewage
  – agricultural, urban and rural runoff
  – atmospheric deposition
The Hydrosphere, cont.

• Chemical contaminants move within that medium because of water turbulence and diffusion.

• Chemicals in the water can interact:
  – with the sediments
  – with the suspended particulates in the water column
  – with the plants and animals residing there
Soil

• Soil is a complex mixture of organic matter, inorganic matter such as silica and clay, water, and air.

• The composition of soils can vary greatly.
  – Agricultural soil may be quite different from a typical urban soil due to the addition of organic matter, fertilizer, and pesticides for optimal plant growth.
Soil

- Chemicals can be put into the soil directly from deliberate or accidental (unintentional) means or indirectly as the result of their translocation from water and air.
  - The direct and deliberate addition of chemicals into the soil would include the addition of agrochemicals such as fertilizer and pesticides
  - The direct but unintentional addition could be from chemical leaks or spills.
Soil, cont.

- Chemicals can move about in this medium, undergo chemical reactions, and be transported to plant and animal life.
- Surface chemicals can move vertically and have the potential to reach groundwater.
Biosphere

• Chemicals reach plant and animal life:
  – they may be directly absorbed through the lungs, skin, or gills
  – or indirectly through the consumption of food
• The direct absorption of chemicals from the environmental medium can result in *bioaccumulation* or *bioconcentration*.
Biosphere, cont.

• The *bioavailability* of the chemical refers to that portion present within the medium that is potentially available for direct uptake by the organism.

• If a chemical is in high concentration in the sediment of a lake and a fish spends most of its time residing in the water column, then the bioavailability is low. This depends on many factors, including sediment turbulence and the fish’s dependence for food from sedimentary organisms. Depending on the physicochemical properties, a chemical may be concentrated in the fish.
Biosphere, cont.

• A very lipophilic and environmentally persistent chemical such as DDT can be stored and accumulated in fatty tissue compartments. This is bioconcentration.

• The bioconcentration factor (BCF) is equal to the concentration of the pollutant in the fish divided by its concentration in the water.
  – The BCF is calculated from the ratio of the toxicant concentration in the whole animal (or a particular tissue) at steady state, to its concentration in its environment.
Toxicity in a Population

• The toxicity of chemicals on a population depends on many factors.

• Ecosystems are complex and made up of a multitude of animals and plants. The level of effect(s) of any chemical, on any one particular population of species, may be different from another in that community.
Toxicity in a Population: Factors

- Species
- Age
- Gender
- Exposure route
- Form and activity of the chemical
- Concentration or dose
- Bioavailability
- Primary route of exposure
- Ability to be absorbed
- Metabolism
- Distribution within the body
- Excretion
- Presence of other chemicals
Figure 5-2 Factors affecting population growth.
Figure 5-3 Graphical representation of the majority of responses to toxic insult.