Chapter 10: Environmental Health, Pollution and Toxicology
Overview

- Some Basics
- Categories of Pollutants
- General Effects of Pollutants
- Risk Assessment
Disease

- Disease is often due to an imbalance resulting from poor adjustment between the individual and the environment
  - Continuum from state of health to disease
  - Gray zone in-between
  - Due to exposure to chemicals in the environment we may be in the midst of an epidemic of chronic disease
Disease

- Seldom have a one-cause-one-effect relationship with the environment
- Depends on several factors
  - Physical environment
  - Biological environment
  - Lifestyle
Disease

- Chances of experiencing serious environmental health problems and disease depends on
  - Water we drink
  - Air we breathe
  - Soil we grow crops in
  - Rocks we build our homes on
Disease

- Natural processes can release harmful materials into the soil, water or air
- Lake Nyos in Cameroon, Africa
  - Experienced sudden release of carbon dioxide
  - Killed 1,800 people in nearby town
Terminology

- **Polluted environment**
  - Impure, dirty, or otherwise unclean
- **Pollution** refers to the occurrence of unwanted change in the environment
  - Introduction of harmful materials
  - Production of harmful conditions
- **Contamination**
  - Similar to pollution
  - Implies making something unfit for a particular use through the introduction of undesirable materials
Terminology

- **Toxic**
  - Materials (pollutants) that are poisonous to people and other living things
  - Toxicology - science that studies chemicals that are known to be or could be toxic

- **Carcinogen**
  - Particular kind of toxin that increases the risk of cancer
  - These are the most feared and regulated toxins in our society
Terminology

- **Synergism**
  - The interaction of different substances resulting in a total effect greater than the sum of the effects of the separate substances
  - E.g., sulfur dioxide and coal dust - great damage to lungs
Terminology

- **Point sources**
  - Smokestacks, pipes discharging into waterways, stream entering the ocean, accidental spills, etc.

- **Non Point sources** (Area sources)
  - More diffused over the land
  - Include urban and agricultural runoff, and mobile sources such as automobile exhaust
Measuring the Amount of Pollution

- Units for the amount or concentration of a particular pollutant or toxin varies widely
  - Waste water reported in millions of gallons
  - Emissions of nitrogen oxides reported in tons per year
  - Others given by a volume, mass of weight
    - ppm, ppb, mg/kg or %
Categories of Pollutants

- Infectious Agents
- Environmentally transmitted infectious disease
- Toxic Heavy metals
- Organic Compounds
- Persistent Organic Pollutants
- Hormonally Active Agents
- Thermal Pollution
- Particulates
- Asbestos
- Electromagnetic Fields
- Noise Pollution
Infectious Agents

- Infectious disease
  - Spread from the interactions between individuals and food, water, air or soil
  - Can travel globally via airplanes
  - New diseases emerging and previous ones reemerging
  - Diseases that can be controlled by manipulating the environment
    - classified as environmental health concerns
Environmentally Transmitted Infectious Diseases

- **Legionellosis**
  - Occurs where air-conditioning systems have been contaminated by disease-causing organisms

- **Giardiasis**
  - Protozoan infection of the small intestine spread via food, water, or person-to-person contact

- **Salmonella**
  - Food-poisoning bacterial infection spread via water or food
Environmentally Transmitted Infectious Diseases

- Malaria
  - Protozoan infection transmitted by mosquitoes
- Lyme disease
  - Transmitted by ticks
- Cryptosporidiosis
  - Protozoan infection transmitted via water or person-to-person contact
- Anthrax
  - Bacterial infection
Toxic Heavy Metals

- Heavy metals that pose health hazards to people and ecosystems
  - Mercury, lead, cadmium, nickel, gold, platinum, silver, bismuth, arsenic, selenium, vanadium, chromium, and thallium
- Each may be found naturally in soil and water
Toxic Heavy Metals

- Often have direct physiological effects
  - Stored and incorporated in living tissue
    - Fatty body tissue
- Body burden
  - Heavy metal content in our bodies
Toxic Pathways

- Chemical elements can become concentrated
- Biomagnification - Accumulation or increase in concentration of a substance in living tissue as it moves through the food chain
- Ex: Cadmium, mercury
Deposition of inorganic mercury into pond from air (dust) and runoff of surface water and groundwater Hg$^{++}$

Methylation

Methyl mercury (CH$_3$Hg)$^+$

Biomagnification (bioaccumulation)

Deposition of mercury in sediments
Organic Compounds

- Organic compounds
  - compounds of carbon produced naturally by living organisms or synthetically by human industrial practices

- Synthetic organic compounds
  - Used in industrial processes, pest control, pharmaceuticals, and food additives
  - Over 20 million currently in use
    - 1 million more added each year!
Persistent Organic Pollutants

- Persistent Organic Pollutants (POPs) may produce a hazard for decades or hundreds of years
  - First produced when their harm was not known
  - Now banned or restricted
<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>EXAMPLE OF USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Atrazine</td>
<td>Herbicide</td>
</tr>
<tr>
<td>DDT</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Endrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>PCBs</td>
<td>Liquid insulators in electric transformers</td>
</tr>
<tr>
<td>Dioxins</td>
<td>By-product of herbicide production</td>
</tr>
</tbody>
</table>

*a* Banned in the United States and many other countries.

*b* Degraded in the environment. It is persistent when reapplied often.

*c* Restricted or banned in many countries.

Persistent Organic Pollutants

- POPs are defined by several properties:
  - Carbon-based molecular structure, often containing highly reactive chlorine
  - Most are synthetic chemicals
  - Do not easily break down in the environment
  - Polluting and toxic
Persistent Organic Pollutants

- POP characteristics (continued)
  - Soluble in fat and likely to accumulate in living tissue
  - Occur in forms that allow them to be transported by wind, water, and sediments for long distances
Hormonally Active Agents

- Hormonally Active Agents (HAAs) are a type of POP
- Have potential to cause developmental and reproductive abnormalities in animals, including humans
  - Include a wide variety of chemicals, herbicides, pesticides, phthalates, and PCBs
Hormonally Active Agents

- Evidence of effect on developmental and reproductive growth:
  - Wild Leopard Frogs across US
    - Gonadal abnormalities and hermaphroditism
  - Alligator populations in Florida
    - Exposed to DDT - genital abnormalities and low egg production
Hormonally Active Agents

- Major disorders studied in wildlife have centered on abnormalities including:
  - Thinning of eggshells of birds
  - Decline in populations of various animals and birds
  - Reduced viability of offspring
  - Changes in sexual behavior
Hormonally Active Agents

- In humans, scientists are researching:
  - HAAs (environmental Estrogens) as a linked to breast cancer
  - PCBs with neurological behavior
  - Phthalates with endocrine and hormone disruption
Endocrine System

- One of two main systems that regulate and control growth, development, and reproduction
- Composed of a group of hormone secreting glands
  - Thyroid, pancreas, pituitary, ovaries and testes
  - Hormones are transported by blood stream and act as chemical messengers
Hormonally Active Agents

- The National Academy of Sciences
  - Recommends that there should be continued monitoring of wildlife and human populations for abnormal development and reproduction
Thermal Pollution

- Occurs when heat released into water or air produces undesirable effects
  - Also called heat pollution
  - Acute event or long term, chronic release
  - Heated water released into rivers changes temp. and dissolved oxygen content
    - Changes river’s species composition
Thermal Pollution

- Heating river water changes natural conditions and disturbs the ecosystem
  - Fish spawning cycles may be disrupted
  - Fish may have heightened susceptibility to disease
- Physical stress on fish
  - Easier prey
- Change in type and availability of food
Thermal Pollution

- Solutions to chronic thermal heating
  - Release of heat into air in cooling towers
  - Artificial lagoons
  - Used to heat buildings

(a) Evaporation chamber (dripping water)
- Air inlet
- Cool water outlet to pond, lake, or rivers

(b) Area where transfer of heat from water in small pipes to surrounding air occurs
- Hot water inlet from power plant
- Cool water outlet
- Air inlet
Particulates

- Small particles of “dust” released into the atmosphere by many natural processes and human activities
  - Modern farming
  - Burning oil and coal
  - Dust storms
  - Volcanic eruptions
Asbestos

- A term for several minerals that take the form of small, elongated particle or fibers
  - Used for fire prevention
  - Insulation
- Inhalation leads to asbestosis and cancer
- 95% of asbestos now in use in US chrysolite (white asbestos)
- Another type crocidolite (blue asbestos)
  - Exposure can be very hazardous
Electromagnetic Fields

- Electromagnetic Fields (EMFs)
  - Part of everyday urban life
    - Electric motors
    - Transmission lines
    - Appliances
  - Controversy as to whether they pose a health risk
  - Children may be at greater risk
Noise Pollution

- Unwanted sound
- Sound is a form of energy that travels as waves
  - We hear sounds when waves vibrate our eardrum
  - Loudness a measure of intensity of energy
    - Measured in units of decibels
<table>
<thead>
<tr>
<th>SOUND SOURCE</th>
<th>INTENSITY OF SOUND (dB)</th>
<th>HUMAN PERCEPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of hearing</td>
<td>0</td>
<td>Very quiet</td>
</tr>
<tr>
<td>Rustling of leaf</td>
<td>10</td>
<td>Very quiet</td>
</tr>
<tr>
<td>Faint whisper</td>
<td>20</td>
<td>Very quiet</td>
</tr>
<tr>
<td>Average home</td>
<td>45</td>
<td>Quiet</td>
</tr>
<tr>
<td>Light traffic (30 m away)</td>
<td>55</td>
<td>Quiet</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>65</td>
<td>Quiet</td>
</tr>
<tr>
<td>Chain saw (15 m away)</td>
<td>80</td>
<td>Moderately loud</td>
</tr>
<tr>
<td>Jet aircraft flyover at 300 m</td>
<td>100</td>
<td>Very loud</td>
</tr>
<tr>
<td>Rock music concert</td>
<td>110</td>
<td>Very loud</td>
</tr>
<tr>
<td>Thunderclap (close)</td>
<td>120</td>
<td>Uncomfortably loud</td>
</tr>
<tr>
<td>Jet aircraft takeoff at 100 m</td>
<td>125</td>
<td>Uncomfortably loud</td>
</tr>
<tr>
<td>Rocket engine (close)</td>
<td>180</td>
<td>Traumatic injury</td>
</tr>
</tbody>
</table>

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Noise Pollution

- Environmental effects of noise depend on
  - Energy
  - Pitch
  - Frequency
  - Time pattern
  - Length of exposure
- Very loud noise can cause pain
- Any sound above 80dB can cause hearing loss
  - Rock concert = 110dB
Voluntary Exposure

- Sometimes referred to as exposure to personal pollutants
  - Tobacco
    - 30% of cancers tied to smoking
  - Alcohol and other drugs
General Effects of Pollutants

- Remember that pollutants also affect wildlife
- Almost every part of the human body is affected by one pollutant or another.
Concept of Dose and Response

- Five centuries ago, the physician and alchemist Paracelsus wrote that “everything is poisonous, yet nothing is poisonous.”

- For Example
  - Selenium required in small amounts by living things
  - May be toxic in high concentrations
Concept of Dose and Response

- The effect of a chemical on an individual depends on the dose
  - Dose response
  - Dose dependency can be represented by a generalized dose response curve
The diagram illustrates the relationship between concentration and benefit/harm to life. It shows four main regions:

1. **Increasing benefit** (AB): As concentration increases, benefit also increases from point A to point B.
2. **Maximum benefit (plateau)** (BC): The benefit reaches its peak at point C, where it remains constant.
3. **Decreasing benefit** (CD): Beyond point C, benefit decreases as concentration continues to increase.
4. **Toxic** (DE): This region indicates harmful effects, with points D and E representing the toxic range.

The graph includes points A, B, C, D, E, and F, with the axes labeled as follows:

- **Beneficial to life** (vertical axis)
- **Harmful to life** (vertical axis)
- **Increasing concentration** (horizontal axis)

The diagram highlights the critical concentration range where maximum benefit is achieved, distinguishing between beneficial and toxic effects.
Concept of Dose and Response

- Doses that are beneficial, harmful, or lethal may differ widely for different organisms and are difficult to characterize.
- Ex: Fluoride and dental health
  - Fluorine forms fluoride compounds that prevent tooth decay and promote healthy bone structure (1–5ppm)
  - Toxic effects are noticed at concentrations of 6–7 ppm
Fluoride concentration (ppm)

Beneficial to life

Harmful to life

Maximum benefits for tooth and bone development

Excessive bone formation

Toxic
How **individuals** will respond to a chemical is not known

- Predictions made about how a percentage of the **population** will respond to a specific dose

**Lethal dose 50, LD-50**

- Dose at which 50% of the population dies
<table>
<thead>
<tr>
<th>AGENT</th>
<th>LD-50 (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride (table salt)</td>
<td>4,000</td>
</tr>
<tr>
<td>Ferrous sulfate (to treat anemia)</td>
<td>1,520</td>
</tr>
<tr>
<td>2,4-D (a weed killer)</td>
<td>368</td>
</tr>
<tr>
<td>DDT (an insecticide)</td>
<td>135</td>
</tr>
<tr>
<td>Caffeine (in coffee)</td>
<td>127</td>
</tr>
<tr>
<td>Nicotine (in tobacco)</td>
<td>24</td>
</tr>
<tr>
<td>Strychnine sulfate (used to kill certain pests)</td>
<td>3</td>
</tr>
<tr>
<td>Botulinum toxin (in spoiled food)</td>
<td>0.00001</td>
</tr>
</tbody>
</table>

* Milligrams per kilogram of body mass (termed mass weight, although it really isn’t a weight) administered by mouth to rodents. Rodents are commonly used in such evaluations, in part because they are mammals (as we are), are small, have a short life expectancy, and their biology is well known.

Dose-Response Curve

- The ED-50 (effective dose 50%)
  - Defined as the dose that causes an effect in 50% of the population of observed subjects
  - Ex: ED-50 of aspirin would be the dose that relieves headaches in 50% of the people
Dose-Response Curve

- The TD-50 (toxic dose 50%)
  - Defined as the dose that is toxic to 50% of the population
  - Often used to indicate responses such as
    - Reduced enzyme activity
    - Decreased reproductive success
    - Onset of specific symptoms
Dose-Response Curve

- For a particular chemical, there may be an entire family of dose–response curves
  - Which dose is of interest depends on what is being evaluated
  - Killing insects vs. pesticide residue
  - Overlap between the therapeutic dose (ED) and the toxic dose (TD)
- Measure of the relative safety of a particular drug is the therapeutic index
  - Defined as the ratio of the LD-50 to the ED-50
    \[ \text{LD/ED} \rightarrow \text{ex. 1,000 mg/0.5 mg is better than 2 mg/1 mg} \]
  - The greater the therapeutic index, the safer the drug
Threshold Effects

- Threshold is a level below which no effect occurs and above which effects begin to occur
  - Concentration below the threshold is safe
  - If there is no threshold dose, then even the smallest amount has a toxic effect
- Evaluating thresholds for toxic pollutants is difficult due to unaccounted for synergistic effects
Toxin B is safer than Toxin A; any dose of A will produce toxic effects.
Ecological Gradients

- Defined as the changes in vegetation with distance from a toxic source
  - Weedy species adapted to harsh conditions may be closer
  - Trees and shrubs will grow further from the toxic source
Tolerance

- The ability to resist or withstand stress resulting from exposure to a pollutant or harmful condition
  - Result from behavioral, physiological, or genetic adaptation
- Three types:
  - Behavioral tolerance
  - Physiological tolerance
  - Genetic tolerance
Tolerance

- Behavioral tolerance
  - Change in behavior to avoid exposure

- Physiological tolerance
  - Body of an individual adjusts to tolerate a higher level of pollutant
  - Many mechanisms including detoxification
    - Toxic chemical is converted to a nontoxic form
  - Internal transport of the toxin to a part of the body where it is not harmful, such as fat cells
Tolerance

- Genetic tolerance-
  - Adaptation
  - Some individuals in a population are naturally more resistant to a toxin than others
    - They survive to reproduce
- Examples
  - Strains of mosquitoes resistant to DDT
  - Antibiotic resistance
Acute and Chronic Effects

- Acute effect is one that occurs soon after exposure
  - Usually to large amounts of a pollutant
- Chronic effect takes place over a long period
  - Often as a result of exposure to low levels of pollutant
Risk Assessment

- The process of determining potential adverse environmental health effects to people exposed to pollutants and potentially toxic materials.
Risk Assessment

- Such an assessment generally includes four steps:
  - Identification of the hazard
  - Dose–response assessment
  - Exposure assessment
  - Risk characterization
- Risk assessment is difficult, costly, and controversial
- Risk management integrates the assessment of risk with technical, legal, political, social, and economic issues