TOXICOLOGY

Environmental health
Toxic substances in the environment
Studying Effects of hazards
Risk Assessment & Risk Management
Philosophical and Policy Approaches
Adapted from K. Sturges
Environmental Health

- We face four types of environmental hazards
  - Physical, Biological, Chemical, Cultural
- For each hazard there is some amount of risk we cannot avoid, yet some risk we can by taking precautions
- Environmental health consists of taking steps to minimize the risks of encountering hazards and alleviate the impacts of hazards we cannot avoid
Environmental Health

- Environmental hazards can be physical, chemical, biological or cultural
  - Physical: occur naturally and pose health hazards
    - Earthquakes, volcanoes, drought, fires, floods, uv radiation (skin cancer) etc
  - Chemical: include synthetic chemicals that our society produces that pose health hazards
    - Pesticides (DDT), can be natural or synthetic
  - Biological: hazard that results from ecological interactions among organisms
    - Mosquitoes transmitting diseases, bacteria, viruses
  - Cultural: hazard that results from the place that we live, socioeconomic status, occupation or behavioral choices
    - Smoking, drug use, diet/nutrition, mode of transportation, crime
Cultural Hazards

- Smoking: 438,000
- Obesity: 112,000
- Alcohol use: 20,700
- Motor vehicle accidents: 43,300
- Other accidents: 65,900
- Suicide: 31,500
- Homicide: 17,700
- Drug use: 28,700
- AIDS: 13,700

Total 2003 deaths = 2,448,000
Total 2003 deaths from cultural hazards = 771,500
Many Health Hazards Exist Indoors

- We spend roughly 90% of our lives indoors which can have hazards
  - Dust, cigarette smoke, plastic emissions, radon, household chemicals, asbestos, lead poisoning, PBDE’s (fire retardants) cleaning products, etc

- Watch Notes Video 1! 😊
Many Health Hazards Exist Indoors

Radon

- Highly toxic radioactive gas that is colorless and undetectable without specialized kits
- Seeps from the ground in areas with certain types of bedrock and can accumulate in basements in homes with poor circulation.
- Cigarette smoke and radon are leading indoor hazards and are the top two causes of lung cancer in developed nations
Many Health Hazards Exist Indoors

- Asbestos
  - A mineral that forms long, thin, microscopic fibers,
  - Trap heat, muffle sound, resist fire- once used to insulate buildings
  - Dangerous when inhaled (the body produces acid to eliminate it but the acid will scar lung tissue)
  - Can cause lung cancer
Many Health Hazards Exist Indoors

- **Lead Poisoning**
  - Heavy metal that can cause damage to the brain, liver, kidney and stomach, learning problems, behavioral abnormalities, anemia, hearing loss and even death
  - Historians attribute the downfall of ancient Rome to chronic lead poisoning (the elite regularly drank wine sweetened with mixtures prepared in leaden vessels)
  - Historians also believe Beethoven suffered from lead poisoning
  - Today- results from drinking water that passes through lead pipes (in older homes) and lead paint (paints pre 1978 contained lead)
Many Health Hazards Exist Indoors

- Lead con’t
  - Most dangerous in its presence in paint
  - Until 1978 most paints contained lead
  - In the US lead based paint and leaded gasoline have been phased out
  - However in 2007 millions of toys exported from China were found to contain lead based paint
    - Many recalled
    - China agreed to limit and monitor the use of lead based paint
Many Health Hazards Exist Indoors

- PBDE’s (polybrominated diphenyl ethers)
  - Fire retardants used in computers, televisions, plastics and furniture
  - Released during production and disposal of products and can evaporate at very slow rates throughout its lifetime
  - Persist and accumulate in living tissue
  - Acts as a hormone/endocrine disruptor
  - Europe has phased them out and has seen a fewer concentration of PBDEs in breast milk
Disease Is a Major Factor of Env. Health

- Despite technological advances we still battle with disease
  - Infectious diseases account 26% of deaths worldwide each year
  - Malaria has killed about 2 million people per year and has probably killed more than all of the wars ever fought.
- Causes the vast majority of deaths worldwide
  - Cancer, heart disease, and respiratory disorders
Causes of Mortality

Total number of mortalities = 8.0 million

**Developed countries**
Population = 896 million

- Cancers: 33%
- Injuries: 7%
- Cardiovascular: 3%
- Other & unknown causes: 24%

Total number of mortalities = 26.9 million

**Least developed countries**
Population = 2.3 billion

- Communicable diseases: 54%
- Other & unknown causes: 13%
- Injuries: 19%
- Cardiovascular: 8%

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Disease Is a Major Factor of Env. Health

- Over half of the world’s deaths result from noninfectious diseases such as cancer and heart disease
- Life style trends alter the prevalence of noninfectious diseases (both good and bad)
  - Fewer Americans smoke cigarettes
  - Americans exercise less and have fattier diets so obesity has doubled
Disease Is a Major Factor of Env. Health

Infectious Diseases
- Malaria, AIDS, West Nile, etc
- Accounts for nearly 15 million deaths worldwide
- Infectious diseases are a greater problem in developing countries (accounts for $\frac{1}{2}$ of all deaths)
- Due to poor sanitation, hygiene and access to medicine
Disease Is a Major Factor of Env. Health

- Fighting Infectious Diseases
  - Access to healthcare
    - Developing nations- open clinics, immunize children, provide prenatal/post natal care, making medicine available
  - Education campaigns
    - Both developed and developing
Toxicology

- Toxicology - the study of poisonous substances
- We are exposed to more and more synthetic chemicals that can pose threats to human health at varying degrees
- Toxicologists assess and compare substances to determine their toxicity (the degree of harm a chemical substance can inflict)
- A toxic substance, or poison, is called a toxicant
- “The dose makes the poison”
  - The toxicity of a substance depends not only on the chemical but also on its quantity
Toxicology

- Environmental toxicology-
  - Studying how various toxins effect the health of humans, animals, ecosystems, etc
  - We need to take this information and weigh it against any benefits we may obtain
  - With some hazards there is some tradeoff between risk and reward
Toxic Substances in the Environment

- Synthetic chemicals are all around us
  - Artificial/man made
  - Each year in the US we manufacture 250lbs of chemical substances for every man, woman, and child
  - They find their way into the soil, air and water
  - A 2002 study found that 80% of US streams contain at least trace amounts of 82 waste water contaminants including antibiotics, detergents, drugs, steroids, plasticizers, disinfectants, solvents, and perfumes
Toxic Substances in the Environment

- We carry traces of hundreds of industrial chemicals in our bodies.
- A 2009 study found 232 chemicals in the umbilical cords of 10 newborn babies.
- Not all synthetic chemicals pose health risks.
- 100,000 synthetic chemicals are on the market and few have been thoroughly tested.
  - We simply don’t know the effects.
Toxic Substances in the Environment

- Toxicants come in different types:
  - Carcinogens - cause cancer
  - Mutagens - cause mutations in DNA
  - Teratogens - cause harm to the unborn
    - Thalidomide - used to treat nausea during pregnancy caused birth defects in thousands of babies banned in the 1960s
  - Allergens - over activates the immune system
    - Allergenic synthetic chemicals have increased asthma in recent years
  - Neurotoxins - attack the nervous system (venoms, lead, mercury, minimata disease)
  - Endocrine disruptors - interfere with the endocrine system
Birth defects caused by Thalidomide
Toxic Substances in the Environment

- Endocrine disruptors
  - Hormones stimulate growth, development and sexual maturity
  - Hormone-disrupting toxicants (endocrine disruptors) block the action of the hormones or accelerate their breakdown
  - Some “mimic” the hormone
    - Bisphenol A – mimics the female sex hormone estrogen
(a) Normal hormone binding

(b) Hormone mimicry
Toxic Substances in the Environment

Endocrine Disruptors

- Mainly affect nonhuman animals but the striking drop of the sperm count in men is attributed to endocrine receptors
  - Danish researchers reported in 1992 the number and motility of sperm had declined by 50% since 1938
  - Concerns about increased rates of testicular cancer linked to endocrine receptors
  - Breast cancer linked to endocrine receptors (excess estrogen feeds tumor development in older women)
Toxic Substances in the Environment

- **Case Study: Alligators and Endocrine Disrupters**
  - A study showed alligators in Lake Apopka had odd reproductive disorders
  - Males had low levels of testosterone and females had elevated levels of estrogen
    - Feminizes male
  - Lake Apopka suffered a spill of DDT and dicofol (pesticide) in 1980 and juvenile alligators declined thereafter
  - Chemical runoff from pesticides and nitrates can also act as endocrine disrupters
Toxic Substances in the Environment

- Toxicants concentrate in water
  - Move in the form of runoff
- If chemicals persist in soil they can leach into groundwater and contaminate water supplies
- Aquatic animals are great indicators of water pollution because water soluble chemicals enter organisms’ tissues through drinking or absorption
Toxic Substances in the Environment

- Toxicants can travel in the air
  - Pesticide drift
  - Despite being applied in mainly tropical and temperate zones, contaminants appear in Arctic bears, Antarctic penguins and people living in Greenland.
Toxic Substances in the Environment

- Polar Bears in the Svalbard Islands near the North Pole have the highest levels of PCB contamination of any wild animal tested.
- Caused by global distillation:
  - When pollutants that evaporate and rise high into the atmosphere at lower latitudes, or are deposited into the ocean, are carried to the poles.
FIGURE 14.15 In a process called global distillation, pollutants that evaporate and rise high into the atmosphere at lower latitudes ①, or are deposited in the ocean, are carried toward the poles ② by atmospheric currents of air and oceanic currents of water. This process concentrates pollutants near the poles ③. Thus, polar organisms take in more than their share of toxicants ④, despite the fact that relatively few synthetic chemicals are manufactured or used near the poles.
Toxic Substances in the Environment

Some toxicants persist

- Some chemicals degrade quickly and become harmless while others persist for many months, years or even decades
  - Persistent: DDT and PCBs (polychlorinated biphenyls—byproducts of chemicals used in transformers and electrical equipment)
  - Short persistence: Bt toxin used in GM crops (naturally occurring soil bacterium that produces a protein that kills many caterpillars and larvae of some flies and beetles)
Toxic Substances in the Environment

- Persistent synthetic chemicals exist today because we have designed them to persist
  - Chemicals in plastic are used specifically because they resist breaking down
Toxic Substances in the Environment

Toxicants may accumulate and move up the food chain

- Some of the toxicants that are absorbed, inhaled or consumed break down into harmless by products
- Some toxicants may build up in animal tissue—bioaccumulation
- Toxicants that bioaccumulate can pass up the food chain from prey to predator
  - Concentrations of toxicant are greatly magnified
    - Biomagnification
Toxic Substances in the Environment

- Bioaccumulation results in the animal’s having a greater concentration of the substance than exists in the surrounding environment
  - Takes place on all trophic levels
- Biomagnifications - caused by the consumption of organisms in which bioaccumulation has occurred - magnifies the concentration of the toxicant
Toxic Substances in the Environment

- Biomagnification occurred famously with DDT
  - Birds of prey ended up with high concentrations of DDT
  - Water → algae → plankton → to small fish → larger fish → fish eating birds
- DDT causes the birds’ eggshells to grow thinner so eggs were breaking while in the nest
  - Peregrine falcon almost wiped out
  - Bald Eagle virtually eliminated in the lower 48 states
  - Brown pelican vanished from the Atlantic Coast
Studying Effects of Hazards

- Dose-response analysis
  - Scientists quantify the toxicity of a substance by measuring the strength of its effects of the number of animals affected at different doses
  - Dose: the amount of substance the test animal receives
  - Response: type or magnitude of negative effects the animal exhibits as a result
  - Dose-response curve: dose on the x-axis and the response on the y-axis
Studying Effects of Hazards

Factors determining the harm caused by exposure to a chemical include:
- The amount of exposure (dose).
- The frequency of exposure.
- The person who is exposed.
- The effectiveness of the body’s detoxification systems.
- One’s genetic makeup.
Studying Effects of Hazards

- Children are more susceptible to the effects of toxic substances because:
  - Children breathe more air, drink more water, and eat more food per unit of body weight than adults.
  - They are exposed to toxins when they put their fingers or other objects in their mouths.
  - Children usually have less well-developed immune systems and detoxification processes than adults.
Studying Effects of Hazards

- LD-50
  - Lethal Dose - 50%
  - The amount of the substance it takes to kill half of the population of study animals used
    - High LD50 indicates low toxicity
    - Low LD50 indicates high toxicity
Studying Effects of Hazards

• If a scientist wants to measure a nonlethal health effect (what level of toxicant causes 50% of mice to lose their hair) is called the effective dose 50

  • Threshold - the amount of toxicant at which it begins to affect a population of test animals
Studying Effects of Hazards

- The type of exposure can affect the response
  - Acute exposure - high exposure for short amt of time (oil spill, nuclear accident, accidental ingestion), easier to recognize
  - Chronic exposure - low exposure for long periods (smoking causing lung cancer, alcohol abuse leads to kidney/liver damage)
Risk Assessment and Risk Management

- Risk can be measured in terms of probability - a quantitative description of the likelihood of a certain outcome.

- Our perception of risk may not match reality.
  - We feel more at risk when we are not in control of the situation.
    - You feel safer driving a car but statistics show that is a greater risk than flying in an airplane.
    - Accounts for anxiety over nuclear power, toxic waste and pesticide residue - invisible/barely understood.
Risk Assessment and Risk Management

- Risk Management - consists of decisions and strategies to minimize risk
  - In the USA we have the EPA, CDC and FDA
  - Have to assess costs and benefits of addressing risk in various ways before making decisions
    - Eliminating plastic linings in our food and drink cans could do more harm than good because the linings help prevent metal corrosion and the contamination of food by pathogens
Philosophical and Policy Approaches

- Innocent until proven guilty approach
  - Assume that substances are harmless until shown to be harmful
  - Avoids long, complicated and expensive testing
- Precautionary principal
  - Assume that substances are harmful until shown to be harmless
  - May impede the pace of technological and economic advances
<table>
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<th>Sequence of events</th>
<th>“Innocent until proven guilty” approach</th>
<th>Precautionary principle approach</th>
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<td>Industrial research and development</td>
<td>Limited testing; most products brought to market</td>
<td>Rigorous testing; only the safest products brought to market</td>
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<tr>
<td>Pre-market testing by industry, government, and academic scientists</td>
<td>Some products harm human health</td>
<td>Minimal impact on human health</td>
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<tr>
<td>Consumer use of products</td>
<td>Rigorous testing demanded</td>
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<td>Post-market testing by industry, government, and academic scientists</td>
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<td>Regulations and bans of unsafe products</td>
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