

ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 14

Environmental Health and Toxicology

Part 2: Environmental Issues and the Search for Solutions

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PowerPoint® Slides prepared by Jay Withgott and Heidi Marcum



Third Edition

Central Case: Lake Apopka alligators

- Alligators in Lake Apopka, Florida, had reproductive problems
- The lake had high levels of agricultural runoff
- Chemical contaminants were disrupting the endocrine systems of alligators during egg development
- Because alligators and humans share the same hormones, chemicals can affect people, too



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The endocrine system is the collection of glands that produce hormones that regulate metabolism, growth and development, tissue function, sexual function, reproduction, sleep, and mood, among other things.

There are many types of environmental hazards



Environmental health = assesses environmental factors that influence human health and quality of life
Natural and human-caused factors are both considered

- **Physical hazards** = occur naturally in our environment
 - Earthquakes, volcanoes, fires, floods, droughts
 - We can't prevent them, but we can prepare for them
 - We increase our vulnerability by deforesting slopes (landslides), channelizing rivers (flooding), etc.
 - We can reduce risk by better environmental choices

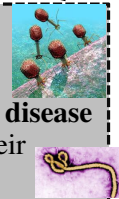


Chemical and biological environmental hazards

- **Chemical** = synthetic chemicals such as pesticides, disinfectants, pharmaceuticals
 - Harmful natural chemicals also exist



- **Biological** = result from ecological interactions
 - Viruses, bacteria, and other pathogens
 - **Infectious (communicable, or transmissible) disease** = other species parasitize humans, fulfilling their ecological roles
 - We can't avoid risk, but we can reduce the likelihood of infection



CULTURE environmental hazards

- **Cultural** = result from the place we live, our socioeconomic status, our occupation, our behavioral choices
 - Smoking, drug use, diet and nutrition, crime, mode of transportation

WHAT IS CULTURE?

The infographic shows a central globe labeled 'Culture' surrounded by various cultural elements: Working Schedules, Language, Medical Care, Religion, Child-rearing Methods, Food, Folk Art, Celebrations, Jokes, Manners, and Clothes and Dressing.

Four types of environmental hazards

(a) Physical hazard

(b) Chemical hazard

(c) Biological hazard

(d) Cultural hazard

a. Physical hazard
 b. Chemical hazard
 c. Biological hazard
 d. Cultural hazard

Disease is a major focus of environmental health

- Despite our technology, disease kills most of us
- Disease has a genetic and environmental basis
 - Cancer, heart disease, respiratory disorders
 - Poverty and poor hygiene can foster illnesses

(a) Leading causes of death across the world

Category	Percentage
Cardiovascular diseases	29.3%
Infectious diseases	14.9 million (26.1%)
Cancers	12.5%
Injuries	9.1%
Maternal and perinatal conditions	5.2%
Other	7.9%
Respiratory and digestive diseases	10.0%

Infectious diseases kill millions

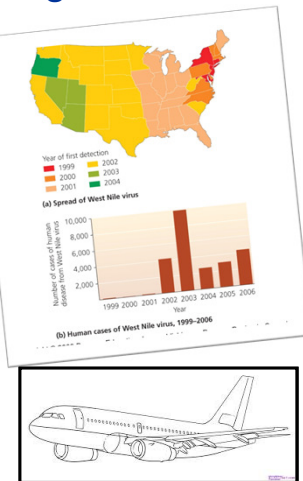
(b) Leading causes of death by infectious disease

Disease	Annual deaths (millions)
Respiratory infections (influenza, pneumonia, etc.)	~3.8
AIDS	~2.8
Diarrheal diseases	~1.8
TB	~1.6
Malaria	~1.4
Childhood diseases (measles, pertussis, tetanus, etc.)	~1.2

- Infectious diseases kill 15 million people per year
 - Half of all deaths in developing countries
 - Developed countries have better hygiene, access to medicine, and money
- **Vector** = an organism that transfers pathogens to a host

Many diseases are increasing

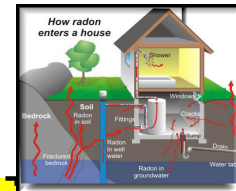
- Tuberculosis, acquired immunodeficiency syndrome (AIDS), and the West Nile virus
- Our mobility spreads diseases
- Diseases are evolving resistance to antibiotics
- Climate change will expand the range of diseases
- To predict and prevent diseases, experts deal with complicated interrelationships



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Environmental health hazards exist indoors

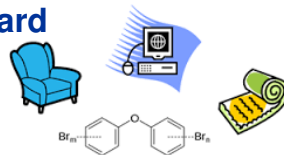
- **Radon** = a highly toxic, radioactive gas that is colorless and undetectable
 - Can build up in basements
- **Lead poisoning** = from lead pipes
 - Damages organs; causes learning problems, behavior abnormalities, and death
- **Asbestos** = insulates, muffles sounds, and resists fire
 - **Asbestosis** = scarred lungs may cease to function



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A recently recognized hazard



- **Polybrominated diphenyl ethers (PBDEs)** = has fire-retardant properties
 - Used in computers, televisions, plastics, and furniture
 - Persist and accumulate in living tissue
 - **Endocrine disruptors** = compounds that mimic hormones and interfere with the functioning of animals' endocrine (hormone) systems
 - Affect brain and nervous system development, and may cause cancer

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Toxicology is the study of poisonous substances

- **Toxicology** = the study of the effects of poisonous substances on humans and other organisms
- **Toxicity** = the degree of harm a toxicant can cause
 - “The dose makes the poison” = toxicity depends on the combined effect of the chemical and its quantity
 - Analogous to pathogenicity or virulence = the degree of harm of biological hazards that spread disease
- **Toxicant** = any toxic agent



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Environmental toxicology

Deals with toxic substances that come from or are discharged into the environment

Studies the health effects on humans, other animals, and ecosystems

- Focus mainly on humans, using other animals as test subjects
- Can serve as indicators of health threats



Don't forget, chemicals have given us our high standard of living



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Toxic agents in the environment

- The environment contains countless natural chemicals that may pose health risks
- But, synthetic chemicals are also in our environment
 - Every human carries traces of industrial chemicals



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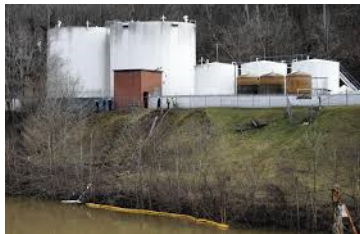
80% of U.S. streams contain at least trace amounts of 83 wastewater contaminants

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Elk River Chemical Spill (West Virginia 2014)

crude 4-methylcyclohexanemethanol (MCHM)

Chemical foam used to wash coal and remove impurities that contribute to pollution during combustion.



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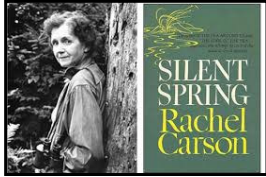
Very few chemicals have been thoroughly tested

- 100,000 chemicals are on the market today
 - 72,000 industrial
 - 8,700 food additives
 - 2,000 new chemicals introduced per year
- We don't know the effects, if any, they have



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Silent Spring began public debate over chemicals

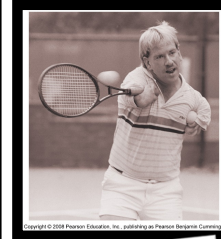


- Rachel Carson published *Silent Spring* in 1962
 - Brought together studies to show DDT risks to people, wildlife, and ecosystems
 - In the 1960s, pesticides were mostly untested and were sprayed over public areas, assuming they would do no harm
- The book generated significant social change



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Types of toxicants

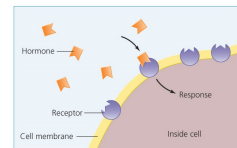


- **Carcinogens** = cause cancer
- **Mutagens** = cause DNA mutations
 - Can lead to severe problems, including cancer
- **Teratogens** = cause birth defects
- **Allergens** = overactivate the immune system
- **Neurotoxins** = assault the nervous system
- **Endocrine disruptors** = interfere with the endocrine (hormone) system

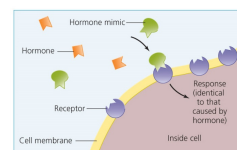
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Endocrine disruption may be widespread

- Theo Colburn wrote *Our Stolen Future* in 1996
 - Synthetic chemicals may be altering the hormones of animals
 - This book integrated scientific work from various fields
 - Shocked many readers and brought criticism from the chemical industry



(a) Normal hormone binding



(b) Hormone mimicry

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"Now that we know better [about the risks of hormone disrupting chemicals], we must have the courage to be cautious, for the stakes are very high. We owe that much, and more, to our children."

- Theo Colborn (1927-2014), *Our Stolen Future*

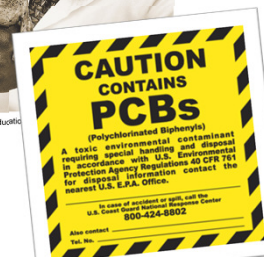


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Evidence for hormone disruption



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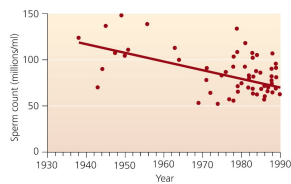


- Frogs also have gonadal abnormalities
 - Male frogs became feminized from atropine concentrations well below EPA guidelines
- PCB-contaminated human babies were born weighing less, with smaller heads

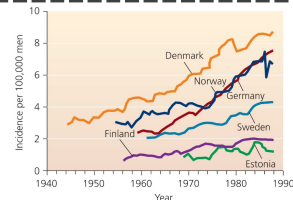
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Male sperm counts are dropping

- Scientists attribute the shocking drop in men's sperm counts to endocrine disruptors
 - The number and motility of sperm has dropped 50% since 1938
- Testicular cancer, undescended testicles, and genital birth defects are also increasing



(a) Declining sperm count in men, based on 61 studies
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(b) Increasing incidence of testicular cancer
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Endocrine disruption research is controversial



- Research results are uncertain, which is inherent in any young field
- Negative findings pose economic threats to chemical manufacturers
 - Banning a top-selling chemical could cost a company millions of dollars
 - Bisphenol-A, (BPA) found in plastics, can cause birth defects, but the plastics industry protests that the chemical is safe



Studies reporting harm are publicly funded, but those reporting no harm are industry funded

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Toxins may concentrate in water

- Runoff carries toxins from large land areas to small volumes of surface water
- Chemicals can leach into the soil
- Chemicals enter organisms through drinking or absorption
 - Aquatic organisms are effective pollution indicators

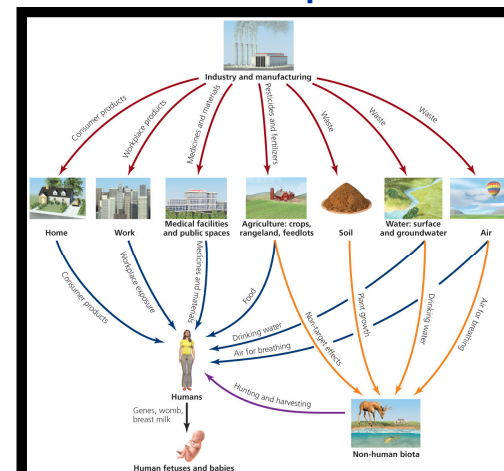


Overland runoff from disturbed areas often contain excessive sediment in addition to water. (USGS)



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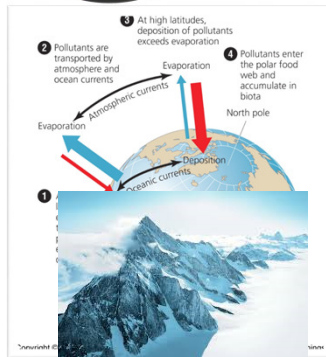
Routes of chemical transport



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Airborne toxicants travel widely

- Because chemicals can travel by air, their effects can occur far from the site of chemical use
- **Pesticide drift** = airborne transport of pesticides
- Synthetic chemical contaminants are found globally
 - They appear in arctic polar bears, Antarctic penguins, and people living in Greenland

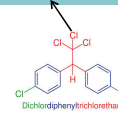


Some toxicants persist for a long time

- Toxins can degrade quickly and become harmless
 - Or, they may remain unaltered and persist for decades
 - Rates of degradation depends on temperature, moisture, and sun exposure
- Persistent chemicals have the greatest potential for harm
- **Breakdown products** = toxicants degrade into simpler products
 - May be more or less harmful than the original substance

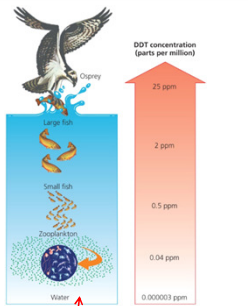


DDT degrades into DDE, which is also highly persistent



Dichlorodiphenyldichloroethylene

Toxicants can accumulate and biomagnify

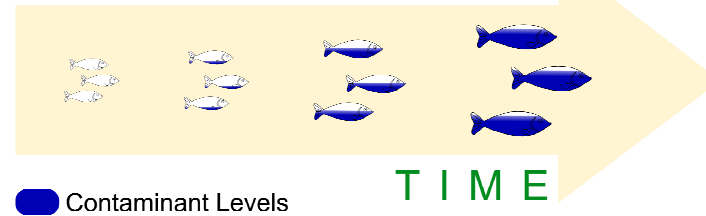


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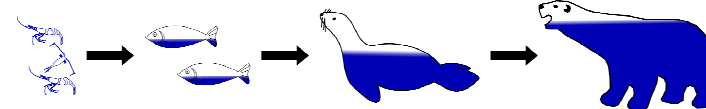


- Some toxicants can be excreted or metabolized
 - Fat-soluble toxicants are stored in fatty tissues
- **Bioaccumulation** = toxicants build up in animal tissues
- **Biomagnification** = toxicants concentrate in top predators
 - Near extinction of peregrine falcons and brown pelicans

Bioaccumulation



Contaminant Levels



Contaminant Levels

Biomagnification

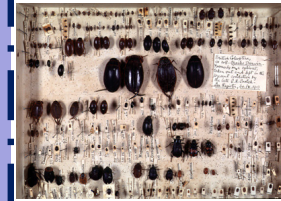
Not all toxicants are synthetic

- Chemical toxicants also exist naturally and in our food
 - Don't assume natural chemicals are all healthy and synthetic ones are all harmful
- Some scientists feel that natural toxicants dwarf our intake of synthetic chemicals
 - Natural defenses against toxins are effective against synthetic ones, too
 - Critics say natural toxins are more readily metabolized and excreted, and synthetic chemicals persist and accumulate

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Wildlife studies

- Museum collections provide data from times before synthetic chemicals were used
- Measurements from animals in the wild can be compared to controlled experiments in the lab
- Scientists can first measure effects in the lab, then look for correlations in the wild
- Conspicuous mortality events can trigger research
 - Many sea otters died and washed ashore
 - Research showed they died from parasites carried in sewage runoff containing cat litter



Human studies

- Case histories = studying sickened individuals directly
 - Autopsies
 - Don't tell about future risks
- Epidemiology = large-scale comparisons between groups of people
 - Studies between exposed and unexposed people last for years
 - Yield accurate predictions about risk

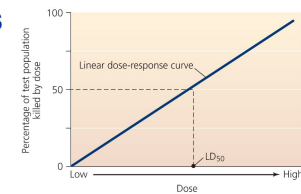


- Animals are used as test subjects
 - Some people object to animal research
 - New techniques (human cell cultures, bacteria, etc.) may replace some live-animal testing

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Dose-response analysis

Dose-response analysis = measuring how much effect a toxicant produces at different doses



(a) Linear dose-response curve
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- Animal testing
- **Dose** = the amount of toxicant the test animal receives
- **Response** = the type or magnitude of negative effects of the animal
- **Dose-response curve** = the plot of dose given against response

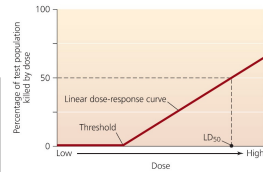


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Dose response curves

Lethal Dose

LD₅₀/ED₅₀ = the amount of toxicant required to kill (affect) 50% of the subjects



(b) Dose-response curve with threshold
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- **Threshold** = the dose level where certain responses occur
 - Organs can metabolize or excrete low doses of a toxicant
 - Some toxicants show a J-shaped, U-shaped, or inverted curve
- Scientists extrapolate downward from animal studies to estimate the effect on humans
 - Regulatory agencies set allowable limits well below toxicity levels in lab studies

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Lethal Dose 50 (LD₅₀)

- LD₅₀
 - Amount of toxicant it takes to kill half the population of study organisms used
- High LD₅₀ – Low Toxicity
- Low LD₅₀ – High Toxicity

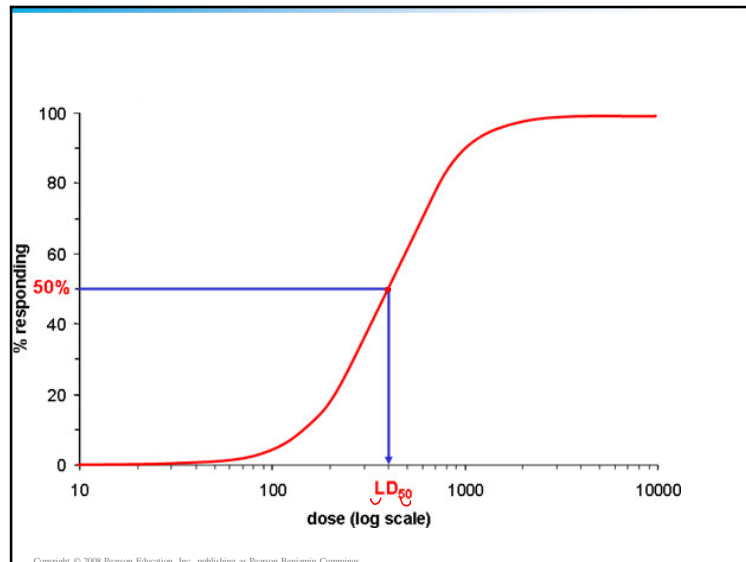


Effective Dose 50 (ED₅₀)

- Effective dose is used to document nonlethal effects of a toxicant
 - Ex: what level of toxicant causes 50% of lab rats to lose their hair

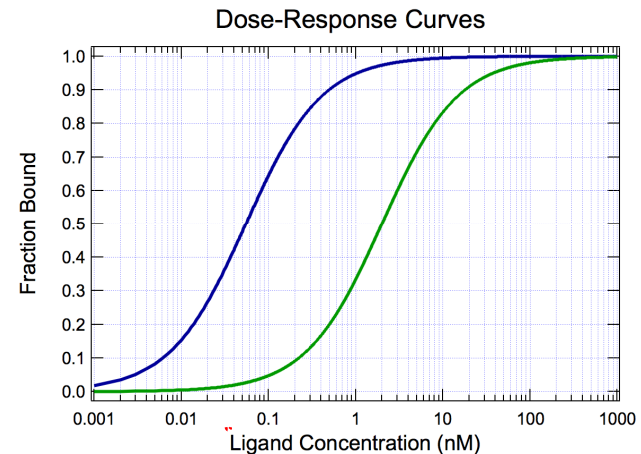
[LD50 Video](#)

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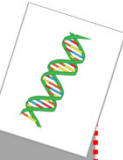
Log graphing paper



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Individuals vary in their responses to hazards

- Different people respond differently to hazards
 - Affected by genetics, surroundings, etc.
 - People in poor health are more sensitive
 - Sensitivity also varies with sex, age, and weight
 - Fetuses, infants, and young children are more sensitive
- Standards for responses are set by the Environmental Protection Agency (EPA)



- Often, standards are not low enough to protect babies

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The type of exposure affects the response

- **Acute exposure** = high exposure for short periods of time to a hazard
 - Easy to recognize
 - Stem from discrete events: ingestion, oil spills, nuclear accident



- **Chronic exposure** = low exposure for long periods of time to a hazard

- Hard to detect and diagnose
- Affects organs gradually: lung cancer, liver damage
- Cause and effect may not be easily apparent



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Mixes may be more than the sum of their parts

- We can't determine the impact of mixed hazards
 - They may act in ways that cannot be predicted from the effects of each in isolation

Synergistic effects = interactive impacts that are more than or different from the simple sum of their constituent effects

Mixed toxicants can sum, cancel out, or multiply each other's effects

New impacts may arise from mixing toxicants



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Risk assessment

Risk = the probability that some harmful outcome will result from a given action

Exposure to environmental health threats doesn't automatically produce an effect

Rather, it causes some probability (likelihood) of harm



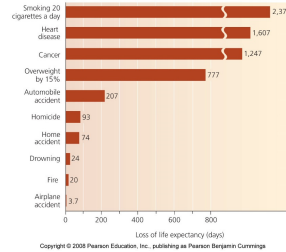
- Probability entails
 - Identity and strength of threat
 - Chance and frequency that an organism will encounter it
 - Amount of exposure to the threat
 - An organism's sensitivity to the threat



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Perceiving risks

- Everything we do involves some risk
- We try to minimize risk, but we often misperceive it
 - Flying versus driving
- We feel more at risk when we cannot control a situation
 - We fear nuclear power and toxic waste, but not smoking or overeating



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Analyzing risk quantitatively

Risk assessment = the quantitative measurement of risk and the comparison of risks involved in different activities or substances
It is a way of identifying and outlining problems

- Several steps:
 - Scientific study of toxicity
 - Assessing an individual or population's likely extent of exposure to the substance, including frequency, concentrations, and length of exposure
- Studies are often performed by industry-associated scientists, which may undermine the study's objectivity

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Risk management

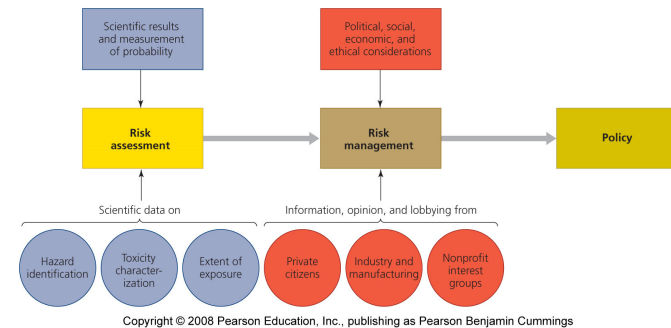
- Combines decisions and strategies to minimize risk
- Scientific assessments are considered with economic, social, and political needs and values
- Developed nations have federal agencies to manage risk
 - The U.S. has the Centers for Disease Control (CDC), the EPA, and the Food and Drug Administration (FDA)

Comparing costs and benefits is hard
Benefits are economic and easy to calculate
Health risks (costs) are hard-to-measure probabilities of a few people being affected



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The process of risk management



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One approach to determining safety

- **Innocent until proven guilty approach:** product manufacturers must prove a product is safe
 - Benefits: now slowing down technological innovation and economic advancement
 - Disadvantage: putting into wide use some substances that may later on turn out to be dangerous



Industries loves this method

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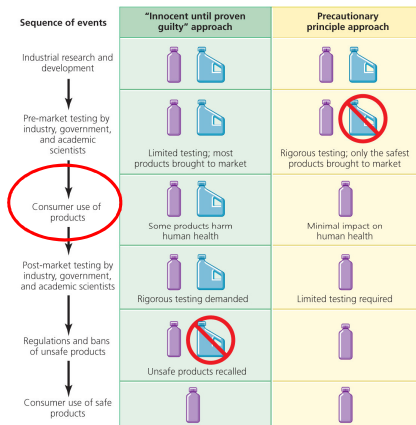
Another approach to determining safety

- **Precautionary principle approach:** the government, scientists, and the public are required to prove a product is dangerous
 - Assume substances are harmful until they are proven harmless
 - Identifies troublesome toxicants before they are released
 - But, this may impede the pace of technology and economic advance



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Two approaches for determining safety



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Philosophy affects policy

- Different nations use different policies; most use a mix between the "innocent until proven guilty" principle and the precautionary principle
 - Europe is shifting more towards the precautionary principle
 - Industries like the "innocent until proven guilty" approach because it allows them to produce more and make more money



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The EPA regulates many substances

- Federal agencies apportion responsibility for tracking and regulating synthetic chemicals
 - FDA: food, food additives, cosmetics, drugs, and medical devices
 - EPA: pesticides
 - Occupational Safety and Health Administration (OSHA): workplace hazards

Many public health and environmental advocates fear it isn't enough
 Many synthetic chemicals are not actually tested
 Only 10% have been tested for toxicity
 Fewer than 1% are government regulated



International regulation

- Nations address chemical pollution with international treaties
- Stockholm Convention on Persistent Organic Pollutants (POPs)** was ratified by 140 nations in 2004
 - Ends the release of the 12 most dangerous POPs
- EU's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Program
 - Aims to evaluate and restrict dangerous chemicals while giving industries a streamlined regulatory system
 - It will cost the chemical industry 2.8 – 5.2 billion euros (U.S. \$3.8 – 7.0 billion), but will save more than 10 times that in health benefits

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Table 1. The twelve priority persistent organic pollutants listed under the Stockholm Convention.

Category	Chemical	CAS#	Stockholm Convention Annex ^a	Use ^b	Soil Half-life (in years)
Pesticides	Aldrin	309-00-2	A	insecticide	N/A
	Chlordane	57-74-9	A	insecticide, termiticide	1
	DDT	50-29-3	B	insecticide	10-15
	Dieldrin	60-57-1	A	insecticide	5
	Endrin	72-20-8	A	insecticide, rodenticide	Up to 12
	Heptachlor	76-44-8	A	insecticide, termiticide	Up to 2
	Hexachlorobenzene	118-74-1	A	fungicide	2.7-22.9
	Mirex	2385-85-5	A	insecticide, termiticide	Up to 10
	Toxaphene	8001-35-2	A	insecticide	100 days up to 12 years
	Category	Chemical	CAS#	Stockholm Convention Annex	By-product (typical formation)
Industrial Chemicals	Hexachlorobenzene	118-74-1	A	by-product of manufacture (chlorinated solvents, pesticides), application of pesticides, incineration of HCB-containing wastes	2.7-22.9
	Polychlorinated biphenyls	1336-36-3	A	Industry manufacture; co-planar PCBs are a by-product of combustion	10 days to 1.5 years
Unintended By-Products	Dioxins	Several	C	by-product	10-12
	Furans	Several	C	by-product	10-12

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