Impacts on the Environment and Human Health

10

HAZARDS TO HUMAN HEALTH

Environmental Risk

Environmental risk is defined as the probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by vulnerabilities and that can be avoided. Understanding how people accept risk requires an understanding of how choices are accepted and measured.

There are four classes of risk:

- **HIGH RISK**—(e.g., driving while intoxicated)
- **LOW RISK**—(e.g., earthquakes occurring on the east coast of the United States)
- **VERY LOW RISK**—(e.g., a meteorite striking the United States)
- **MIXED RISK**—outcomes that increase in frequency against a background of occurrences (e.g., additional cases of cancer beyond the number that is normally expected)

Environmental Risk Analysis

Environmental risk analysis is the comparing of the risk of a situation to its related benefits. It is the overall process that allows one to evaluate and deal with the consequences of events based on their probability. Environmental risk assessment can be thought of as containing the following key stages:

- Identification of the hazard
- Evaluation of the likelihood of the hazard
- Identification of the consequences if the hazard were to occur

DOSE-RESPONSE RELATIONSHIPS

The dose-response relationship describes the change in effect on an organism caused by differing levels of exposure (or doses) to a drug or a chemical after a certain exposure of time. This may apply to individuals (e.g., a small amount has no significant effect whereas a large amount is fatal) or to populations (e.g., how many people or organisms are affected at different levels of exposure). Studying dose-response, and developing dose-response models, is central to determining "safe" and "hazardous" levels and dosages for drugs, potential pollutants, and other substances to which humans or other organisms are exposed, and the conclusions are often the basis for public policy.

Acute Effect

Acute health effects are characterized by sudden and severe exposure and rapid absorption of a substance. Normally, a single large exposure is involved. Acute health effects, such as carbon monoxide poisoning are often reversible.

Adverse Effect

An undesired, harmful effect.

Chronic Effect

Chronic health effects are characterized by prolonged or repeated exposures over many days, months, or years. Symptoms may not be immediately apparent and are often irreversible. Examples include lead or mercury poisoning, asbestosis, or cancer.

EC_{50}

The dose required for an *individual* to experience 50% of the maximum effect.

ED_{50}

The dose required for 50% of the *population* to obtain the therapeutic effect.

Effective Concentration

The concentration of a substance that causes a defined response.

Effective Dose

The dose of a drug or substance that will have a therapeutic or desired effect.

Lethal Dose

Since resistance varies from one individual to another, the "lethal dose" represents a dose (usually recorded as dose per kilogram of subject body weight) at which a given *percentage* of subjects will die.

LD_{50}

The dose of a pollutant or drug that kills 50% of the members of a tested population. It is the most common indicator of toxicity.

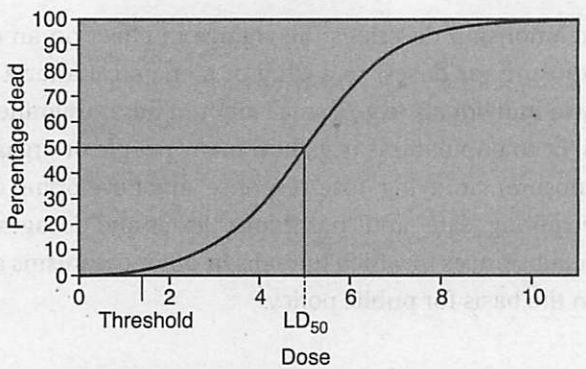


Figure 10.1 LD_{50} dose-response curve

Therapeutic Effect

The consequence of a test, the results of which are judged to be desirable and beneficial whether the result was expected, unexpected, or even an unintended consequence of the treatment.

Toxic

Relating to or caused by a poison.

Toxic Dose

The amount of a substance that may be expected to produce a toxic effect.

TD_{50}

The dose at which toxicity occurs in 50% of cases.

HAZARDOUS CHEMICALS IN THE ENVIRONMENT

A hazardous waste is a waste with properties that make it dangerous or potentially harmful to human health or the environment. Hazardous wastes can be liquids, solids, contained gases, or sludges. The Environmental Protection Agency has separated hazardous wastes into the categories that follow.

Corrosive

Corrosive wastes are strong acids or strong bases (e.g., battery acid) that are capable of corroding metal containers, such as storage tanks, drums, or barrels.

Discarded Commercial Products

Discarded commercial products are specific commercial chemical products in an unused form. Some pesticides and some pharmaceutical products become hazardous when discarded.

Ignitable

Ignitable wastes can create fires under certain conditions, are spontaneously combustible, or have a flash point (e.g., waste oil and used solvents).

Mutagens

Mutagens are physical or chemical agents that cause changes in genetic material (e.g., DNA). Many mutagens can also cause cancer and are known in this case as "carcinogens."

Nonspecific Source

This category includes wastes from common manufacturing and industrial processes (e.g., solvents used in cleaning or degreasing operations).

Radioactive

Radioactive wastes are usually a by-product of nuclear power generation and other applications of nuclear fission, such as research and medicine. Radioactive waste is hazardous to most forms of life and the environment, and is regulated by government agencies to protect human health and the environment.

Low-level radioactive wastes contain low levels of radiation and remain dangerous for a relatively short time (i.e., hundreds of years or less). They can be stored in shielded barrels on-site until they can be disposed of at a hazardous waste landfill.

High-level radioactive wastes contain high levels of radiation and remain dangerous for a very long time (i.e., tens of thousands of years). Storage typically involves sealing the radioactive waste in a steel cylinder, which is then placed in a concrete cylinder, which acts as a radiation shield and must be cooled before it can be sent to hazardous waste sites that are especially designed to handle radioactive material. These sites must:

- Be located in areas that do not experience much rain (to minimize the chance of infiltration into the water table should there be leakage)
- Be at least 2,000 feet (about 600 meters) below Earth's surface
- Be fairly close to the source of the waste so that transportation times and risks are minimized
- Not be located near areas that could be problematic, such as areas near volcanoes or areas that are prone to earthquakes, hurricanes, or tornadoes.
- Be located in remote locations so as not to be near areas of human habitation

Some of the effects of being exposed to sublethal amounts of radiation are cancer, sterility, DNA and chromosomal damage, damage to the immune system, birth defects in children, internal bleeding, and, with high-level exposure, death.

Reactive

Reactive wastes are wastes that are unstable under normal conditions. Reactive wastes can cause explosions, gases, toxic fumes, or vapors when heated, compressed, or mixed with water. Examples are lithium batteries and explosives.

Source Specific

Source specific wastes are wastes from specific industries (e.g., petroleum refining or pesticide manufacturing). Examples of source specific wastes include certain sludges and wastewater from treatment and production processes.

Teratogens

Teratogens are substances found in the environment that can cause birth defects (e.g., drinking alcohol [ethanol], radioactive compounds, dioxin, mercury, tobacco, and excessive caffeine).

Toxic

Toxic wastes are wastes that are harmful or fatal when ingested or absorbed (e.g., lead or mercury). When toxic wastes are disposed of on land, these toxins may leach and pollute the groundwater.

RELEVANT LAWS

FEDERAL HAZARDOUS SUBSTANCES ACT (1960): This act requires that certain hazardous household products display cautionary labels to alert consumers to the potential hazards of these products.

HAZARDOUS MATERIALS TRANSPORTATION ACT (HAZMAT) (1975): This act governs the transportation of hazardous materials and wastes. It covers containers, labeling, and marking standards.

TREATMENT, DISPOSAL, AND CLEANUP OF CONTAMINATED SITES

Reduction and cleanup of hazardous wastes can occur by producing less waste, converting the hazardous material to less hazardous or nonhazardous substances, and placing the toxic material into perpetual storage.

Brownfields

"Brownfield" is a term that is used in urban planning to describe land that was previously used for industrial or commercial use. Such land may have been contaminated with hazardous waste or pollution. Once cleaned up, that area is available for business developments, such as a retail park. Land that has high concentrations of hazardous waste or pollution, such as a Superfund site, does not fall under the brownfield classification. Generally, brownfield sites exist in a city's or a town's industrial section, areas with abandoned factories or commercial buildings, or other previously polluting operations. Small brownfields may also be found in many older residential neighborhoods. For example, many older dry-cleaning establishments or gas stations once produced high levels of subsurface contaminants during prior operations, and the land they occupied might sit idle for decades as a brownfield. Typical contaminants found on contaminated brownfields include hydrocarbon spillages, solvents, pesticides, heavy metals such as lead (e.g., paints), and asbestos.

Reclamation of brownfields has several advantages:

- It reduces urban sprawl by creating open spaces that can be turned into parks, recreational areas, and wildlife sanctuaries.
- It reduces the event of contaminated wastes making their way into streams, rivers, and lakes through urban runoff.
- It reduces the amount of contaminated material entering aquifers and affecting the quality of groundwater.
- It reduces the number of abandoned buildings, which decreases urban blight, thereby increasing property values and tax revenues.
- It makes land available for businesses to expand or develop in new areas, which creates jobs.

The reclamation of brownfields creates a range of questions that must be answered before proceeding:

- Will the cost and time to clean up a brownfield be prohibitive?
- What does a city do with the contaminated material that is removed from a brownfield?

- How will workers who clean up the brownfield, as well as the people living near the brownfield, be protected from the hazardous materials as they are removed?
- What short-term and long-term health effects are associated with cleaning up brownfields?

The remediation of brownfields may include the following techniques:

- **BIOREACTORS**—a device that supports a biologically-active environment to hasten either aerobic or anaerobic decomposition.
- **BIOVENTING**—microorganisms are used to biodegrade organic constituents in the groundwater system.
- **COMPOSTING**—the process of converting a mixture of various organic vegetable matter, such as dead leaves or manure, for use as a fertilizer for soil.
- ***IN SITU* OXIDATION**—injecting or otherwise introducing strong chemical oxidizers (e.g., ozone) directly into the contaminated soil or groundwater to destroy chemical contaminants so as to remediate a variety of organic compounds, including some that are resistant to natural degradation.
- **LAND-FARMING**—contaminated soils, sediments, or sludges are periodically turned over (tilled) to aerate the mixture.
- **PHYTOREMEDIATION**—deep-rooted plants are used to soak up metals in soils into the plant structure as the plant grows. After they reach maturity, the plants—which now contain the heavy metal contaminants in their tissues—are removed and disposed of as hazardous waste.
- **RHIZOFILTRATION**—filtering water through a mass of roots to remove toxic substances or excess nutrients.

Incineration

Burning hazardous wastes does reduce the volume of, and may detoxify, some hazardous pollutants, but it can release air pollutants and toxic ash (e.g., lead, mercury, and dioxins).

Reduce—Recycle

- **REDUCING** is lessening the amount of hazardous wastes by substituting and using products that are more "Earth friendly," (e.g., substituting Puron® for Freon® in air conditioning systems). Freon's® molecular structure contains chlorine, which seriously degrades the stratospheric ozone layer. Puron® substitutes fluorine for chlorine, and has less of an impact on the stratospheric ozone layer. Another method is replacing mercury thermometers with alcohol-based thermometers.
- **RECYCLING** involves collecting, processing, and selling products made from old materials (e.g., requiring that when buying a new lead-acid battery, the old battery must be turned in, or requiring that used motor oil be collected and reprocessed).
- **REUSING** hazardous wastes is generally not recommended at the consumer level due to the potential issues of exposure, contamination, and safety. Reusing hazardous wastes at the industrial level, with government regulations coupled with strict oversight and monitoring for compliance, is a viable solution.

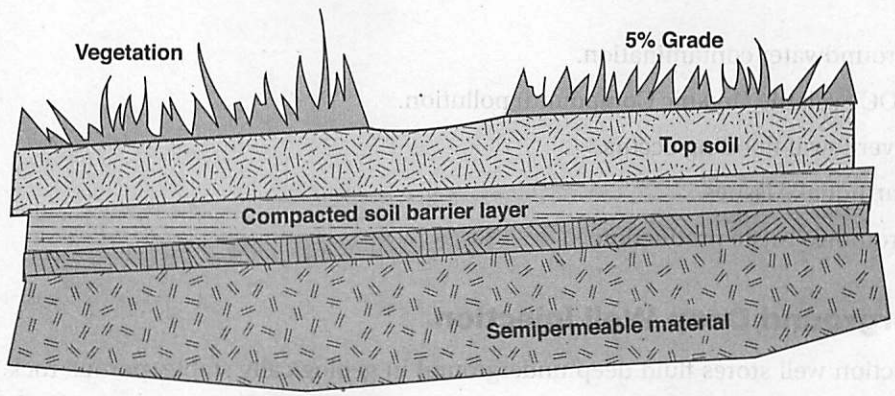
PERPETUAL STORAGE

Each perpetual storage technology attempts to place the hazardous waste material in a highly condensed or concentrated form, such that the wastes are isolated from the environment for extended periods of time. The following sections discuss the current methods used to isolate and store hazardous wastes.

Capping

Landfill capping is a containment technology that forms a barrier between the contaminated media and the surface, thereby shielding humans and the environment from the harmful effects of its contents and hopefully limiting the migration of the contents. A cap must restrict surface water infiltration into the contaminated subsurface to reduce the potential for contaminants to leach from the site. In 1976, Congress passed the Resource Conservation and Recovery Act (RCRA), tightening the regulatory oversight of existing landfills and establishing basic standards for covering landfills (e.g., landfill caps and containing leachate). Hazardous waste caps consists of three layers:

1. An upper topsoil layer
2. A compacted soil barrier layer
3. A low permeability layer made of a synthetic material, covering two feet of compacted clay



Source: Sandia National Laboratory

Figure 10.2 Landfill cap

Landfills

Hazardous waste landfills are excavated or engineered sites where nonliquid hazardous waste is deposited for final (permanent) disposal. These units are selected and designed to minimize the chance of a release of hazardous waste into the environment. Design standards for hazardous waste landfills require a double liner, a double leachate collection and removal system, a leak detection system, and wind dispersal controls. They also may utilize sealed drums as liquid wastes may not be placed in a hazardous waste landfill. Operators of hazardous waste landfills must also comply with inspections, monitoring, release response plans, and closure and post-closure plans (e.g., monitoring leachate, preventing storm water run on and run off).

Salt Formations, Caves, and Mines

Salt dome and bed formations, underground caves, and mines are geologic repositories. The absence of flowing water within natural salt formations prevents dissolution and the subsequent spreading of the waste products. Rooms and caverns in the salt can be sealed, thus isolating the waste from the biosphere.

Surface Impoundments

Surface impoundments are natural topographic depressions, man-made excavations, or diked areas formed primarily of earthen materials that are used for temporary storage and/or for the treatment of liquid hazardous waste. Examples include holding, storage, settling, aeration pits, ponds, and lagoons. Hazardous waste surface impoundments are required to be constructed with a double liner system, a leachate collection and removal system, and a leak detection system.

PROS

- Low initial startup and operating costs.
- Built quickly, wastes can be retrieved, and, if lined, can store wastes for long periods of time.

CONS

- Groundwater contamination.
- VOC (Volatile Organic Compound) pollution.
- Overflow if flooding occurs.
- Earthquake issues.
- Promotes waste production.

Underground Deep Well Injection

An injection well stores fluid deep underground in geologically stable, porous rock formations, such as sandstone or limestone, or into or below the shallow soil layer. The fluid may be water, wastewater, brine (saltwater), or water mixed with chemicals.

PROS

- Low cost.
- Wastes can be retrieved.
- Requires simple technology.

CONS

- Can cause leaks.
- Can cause earthquake issues.
- Can cause groundwater contamination.

Waste Piles

Waste piles are noncontainerized piles of solid, nonliquid hazardous waste that are used for temporary storage or treatment. When closing a waste pile, all waste residue and contaminated soils and equipment must be removed or decontaminated.

PROS

- Fairly easy to identify leaks.
- Provides a temporary storage area to remove wastes from sensitive areas.

CONS

- Shipping materials to facilities can result in accidents.

BIOACCUMULATION—BIOMAGNIFICATION

Bioaccumulation

Bioaccumulation is the *increase in the concentration of a pollutant within an organism.* The rate at which a given substance bioaccumulates depends upon:

- The mode of uptake (along with food, gills, contact with skin, etc.)
- The degree of fat solubility of the pollutant
- The rate that the substance is eliminated from the organism
- The transformation of the substance by metabolic processes
- The lipid (fat) content of the organism

Biomagnification

Biomagnification is the *increasing concentration of a substance in the tissues of organisms at successively higher trophic levels within a food chain.* As a result of biomagnification, organisms at the top of the food chain generally suffer greater harm from a persistent toxin or pollutant than those at lower levels. For biomagnification to occur:

- The pollutant must be long-lived. If it is short-lived, it will be broken down before it can become dangerous.
- The pollutant must be mobile. If it is not mobile, it will stay in one place and be less likely to be taken up by many organisms.
- The pollutant must be soluble in fats. If the pollutant is soluble in water, it will be excreted. In mammals, milk that is produced by females is often tested since the milk is high in fat and because the young are often more susceptible to damage from toxins.
- The pollutant must be biologically active (chemicals that have adverse effects in small amounts).

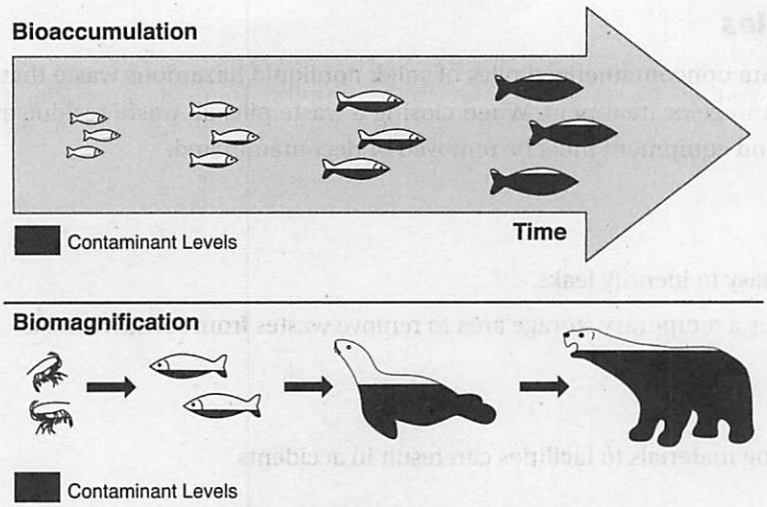


Figure 10.3 Bioaccumulation vs. biomagnification

CASE STUDY

METHYLMERCURY: Mercury is a well-known environmental pollutant. There are many sources of mercury in the environment, both natural and human made. Natural sources include volcanoes, natural mercury deposits, and volatilization from the ocean. The primary human-related sources include coal combustion, waste incineration, and metal processing. Best estimates suggest that human activities have about doubled or tripled the amount of mercury in the atmosphere, and it is increasing by about 1.5% per year. Like many environmental contaminants, mercury undergoes bioaccumulation. The bioaccumulation effect is generally compounded the longer an organism lives, so that larger predatory game fish will likely have the highest mercury levels. Adding to this problem is the fact that mercury concentrates in the muscle tissues and fat of fish. Humans generally intake mercury in two ways: (1) as methylmercury (CH_3Hg^+) from fish consumption, or (2) by breathing vaporous mercury in the ambient air. The ultimate source of mercury for most aquatic ecosystems is deposition from the atmosphere, primarily associated with rainfall.

Methylmercury toxicity causes neurological malfunctions, and, especially in a fetus, impaired neurological development. Other symptoms include peripheral vision impairment, loss of coordination, muscle weakness, and speech and hearing impairments. Furthermore, the fetal brain has been shown to be very sensitive to methylmercury; developmental impairments, such as a reduced ability in thinking, attention span, memory, and most motor skills, are common signs of methylmercury poisoning.

ENVIRONMENTAL ECONOMICS

Environmental economics is an area of economics that deals with the relationship between the economy and the environment. Environmental economists study the economics of natural resources from both sides—their extraction and use and the waste products returned to the environment.

Cap and Trade

"Cap and trade," also known as "emission trading," is a market approach that is used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. With cap and trade policies, the government sets a limit or "cap"

on the amount of a pollutant that can be emitted. Companies or other groups are then issued emission permits and are required to hold an equivalent number of allowances or credits, which represent the right to emit a specific amount of pollutants. The total amount of allowances and credits cannot exceed the cap, which limits total emissions to that level. Companies that need to increase their emission allowance must then buy credits from those who pollute less. The transfer of allowances is referred to as a "trade." In effect, the buyer is paying a charge for polluting while the seller is being rewarded for having reduced emissions by more than what was needed. Therefore, those who can reduce emissions more cheaply will do so, achieving pollution reduction at the lowest cost to society.

Cost-Benefit Analysis

A cost-benefit analysis is a technique for deciding whether to make a change. To use this technique, one adds up the value of the benefits of a course of action and subtracts the costs associated with it.

Costs are either one-time or ongoing while benefits are most often received over time. Time is factored into a cost-benefit analysis by calculating a payback period—the time for the benefits of a change to repay its costs.

A cost-benefit analysis is often carried out using only financial costs and benefits. For example, a cost-benefit analysis of a new road would measure the cost of building the road and subtract that cost from the economic benefit of improving transport links. It would not measure either the cost of environmental damage or the benefit of quicker and easier travel to work. A more sophisticated approach is to attempt to put a financial value on intangible costs and benefits, which is highly subjective.

A cost-benefit analysis applies to three economic situations:

- It can help judge whether public services that are provided by the private sector are adequate.
- It can be used when judging and assessing inefficiencies (market failures) in the private sector and their impact on the health, safety, and environmental needs of the county.
- It helps in determining how to meet societal needs in a cost-effective manner in areas that only the government can address (e.g., defense, preservation of scenic areas, environmental protection, etc.).

Framework of Cost-Benefit Analysis

Step	Description
Cost-benefit	Determine an action and levels of action that achieve the greatest net economic benefit. Exploring options and determining incremental levels of remediation provide the most benefit for the least cost.
Cost-effectiveness	Implementing a specific environmental, health, or safety objective at the least cost. Emphasis is on achieving the objective. Flexible regulatory guidelines are adapted to find the lowest cost to solve a problem.
Health or environmental protection standards	Reducing risk to the public whatever the cost.
Risk-benefit	Balancing health or environmental protection with the costs of providing the protection.
Technology	To achieve results that are predictable and certain.

Ecotaxes (Green Taxes)

Ecotaxes are intended to promote ecologically sustainable activities by providing economic incentives. They can complement or reduce the need for regulatory (command and control) approaches. Often, an ecotax may attempt to maintain overall tax revenue by proportionately reducing other taxes (green tax shift).

Examples of ecotaxes are:

- Taxes on the use of fossil fuels by the amount of greenhouse gases produced
- Duties on imported goods produced by ecologically unsound methods
- Taxes on mineral, energy, and forestry products that were produced by ecologically-unsound methods
- Fees for camping, fishing, hiking, and hunting
- Taxes on technologies and products that are associated with substantial negative externalities
- Waste disposal taxes
- Taxes on effluents, pollution, and other hazardous wastes

Environmental Full-Cost Accounting

Environmental full-cost accounting is a method of cost accounting that traces direct costs and allocates indirect costs by collecting and presenting information about the possible environmental, social, and economic costs and benefits or advantages (i.e., the "triple bottom line"). Full-cost accounting embodies several key concepts that account for costs rather than outlays:

- Hidden costs and externalities
- Overhead and indirect costs
- Past and future outlays
- Costs according to the life cycle of the product

External Costs

External costs are costs that are NOT included in what a business bases its prices on. These include:

- The cost of disposing of the product at the end of its useful life
- The environmental degradation caused by the emissions, pollutants, and wastes from production
- The cost of health problems caused by harmful materials and ingredients
- Social costs associated with increasing unemployment due to increasing automation

Even though external costs are not included in the price of the product, they still have to be paid. Society ends up paying them through taxes, accident compensation, medical payments, insurance payments, and through losses in environmental quality and natural capital.

Products and services that include external costs (e.g., organic produce, clean technology, natural products, and renewables) are usually more expensive than those that don't. Consumers will tend to buy the least expensive goods so "clean" products are at a price disadvantage.

One way to include external costs is to add a tax directly to those products or activities that have them (i.e., external costs should be directed at the users). The restructuring of taxes, which is often called "tax shifting," would mean that "environmentally friendly" products (e.g., recycled metals) are not taxed while items that harm the environment or human health (e.g., coal and cigarettes) are.

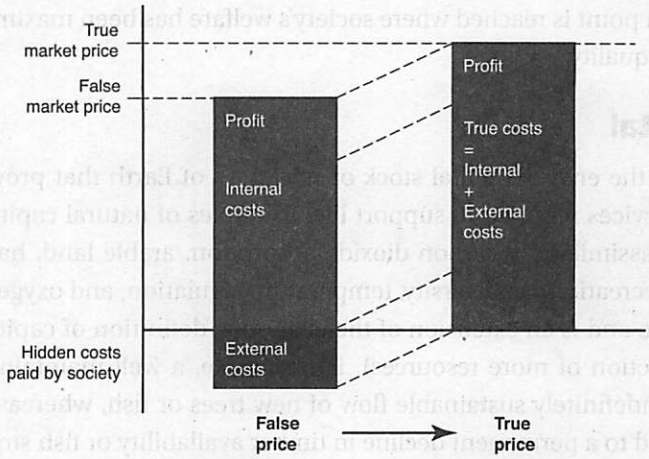


Figure 10.4 True pricing

Gross Domestic Product (GDP)

The gross domestic product is one of the primary indicators used to gauge the health of a country's economy. It represents the total dollar value of all goods and services produced over a specific time period.

Gross National Product (GNP)

The gross national product is the total value of all final goods and services produced within a nation in a particular year, plus the income earned by its citizens. GNP, like GDP, is a measure of the economic condition of a country, under the assumption that a higher GNP leads to a higher quality of living.

Internal Costs

Internal costs are the costs that a business bases its prices on (e.g., materials, marketing, energy, labor, and equipment).

Marginal Costs

The "marginal cost" is the cost of producing one more unit of something. Just as it is possible to have an environment that is "too dirty," it is also possible to have an environment that is "too clean" (e.g., it is not efficient to reduce pollution to zero as the cost of this reduction would probably exceed the benefits). Waterways and the atmosphere have a natural capacity to assimilate at least some pollution with no associated ill-effects on the environment. To not benefit from this natural assimilative capacity would be wasteful.

If the marginal cost of pollution abatement exceeds the marginal benefit from the reduction, then the benefit of reducing pollution is not worth the expense. Consequently, further attempts to clean up the environment would result in a reduction in society's welfare.

If the marginal benefit of reducing pollution were greater than the marginal cost of reducing pollution, then society would benefit from a reduction in pollution. The benefit would be equal to the amount by which the marginal benefit of the cleanup exceeded the marginal cost of the cleanup.

If the marginal cost of pollution abatement is equal to the marginal benefit from pollution abatement, then a point is reached where society's welfare has been maximized with respect to environmental quality.

Natural Capital

Natural capital is the environmental stock or resources of Earth that provide goods, flows, and ecological services required to support life. Examples of natural capital include minerals, water, waste assimilation, carbon dioxide absorption, arable land, habitat, fossil fuels, erosion control, recreation, biodiversity, temperature regulation, and oxygen. Natural capital has financial value and is an extension of the economic definition of capital (resources that enable the production of more resources). For example, a well-maintained forest or river may provide an indefinitely sustainable flow of new trees or fish, whereas overuse of those resources may lead to a permanent decline in timber availability or fish stocks.

Natural capital also provides people with essential services, like water catchment, erosion control, and crop pollination by insects, which in turn ensures the long-term viability of other natural resources. Since the continuous supply of services from the available natural capital assets is dependent upon a healthy, functioning environment, the structure and diversity of habitats and ecosystems are important components of natural capital. "Natural capital asset checks" help decision-makers understand how changes in the current and future performance of natural capital assets will have an impact on human well-being and the economy.

Current world business practices, development patterns, environmental modifications, exploitation of resources from other countries, and government policies are degrading or decreasing stocks of natural capital. This not only has financial implications, such as increased market prices due to resource depletion, but also environmental implications as services provided by ecosystems are damaged and unable to function effectively (e.g., as greenhouse gas emissions increase and areas responsible for carbon sequencing decrease, global temperatures rise, weather patterns change, sea levels increase, terrestrial and aquatic ecosystems readjust, and land usability patterns change).

SUSTAINABILITY—RESILIENCY

Sustainability is the capacity to endure; it is how biological systems remain diverse and productive. It is a function of the endurance of systems and processes.

Resiliency is the capacity of an ecosystem to absorb disturbance and still retain its basic structure and viability. It focuses on how much ecological systems can withstand the negative effects from human disturbances and still deliver ecological services for current and future generations.

The three broad criteria for ecological sustainability are:

- Renewable resources should provide a sustainable yield—the rate of consumption should not exceed the rate of replacement.
- For nonrenewable resources, there should be an equivalent development of renewable substitutes.
- Waste generation should not exceed the assimilative capacity of the environment.

Ecological Footprint

The "ecological footprint" is a measure of human demand on Earth's ecosystems. It is a standardized measure of demand for natural capital (world's stocks of natural assets, which include air, geology, soil, water, and all living things) that may be contrasted with the planet's ecological capacity to regenerate. It represents the amount of biologically productive land and sea area that is necessary to supply the resources a human population consumes, and to assimilate associated waste.

Figure 10.5 below shows the ecological footprints of various countries on Earth measured in global hectares per person. One global hectare represents the average productivity of all biologically productive areas measured in hectares on Earth in a given year.

1 ha = 2.5 acres = 10,000 m^2

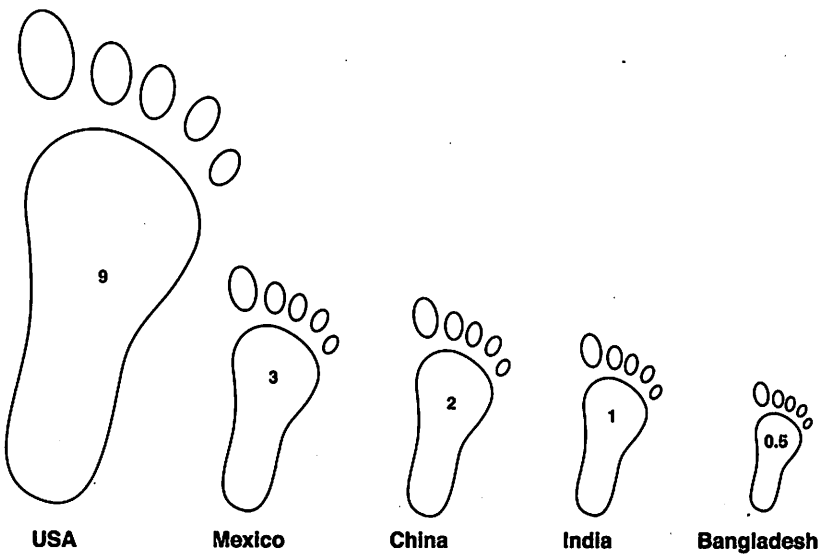


Figure 10.5 Ecological footprints of various countries on Earth measured in global hectares per person

MULTIPLE-CHOICE QUESTIONS

1. About 70% of U.S. hazardous wastes come from

   (A) agricultural pesticides
   (B) smelting, mining, and metal manufacturing
   (C) nuclear power plants
   (D) chemical and petroleum industries
   (E) households

2. Which act established federal authority for emergency response and cleanup of hazardous substances that have been spilled, improperly disposed of, or released into the environment?

   (A) Resource Recovery Act
   (B) Resource Conservation and Recovery Act
   (C) Solid Waste Disposal Act
   (D) Superfund
   (E) Hazardous Materials Transportation Act

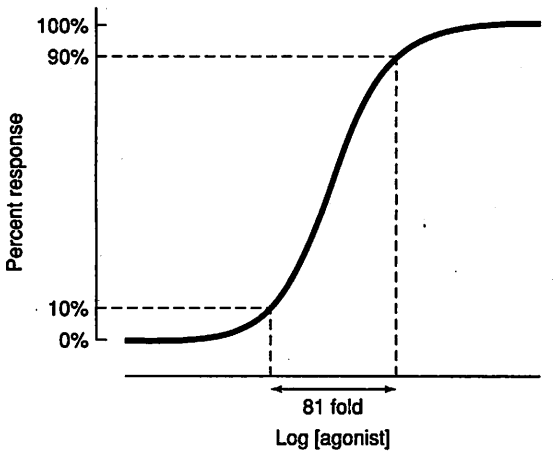
3. Effects produced from a long-term, low-level exposure are called

   (A) acute
   (B) chronic
   (C) pathological
   (D) symptomatic
   (E) synergistic

4. Which of the following techniques is NOT an example of bioremediation?

   (A) Land farming
   (B) Composting
   (C) Rhizofiltration
   (D) Phytoremediation
   (E) All are examples of bioremediation.

5. The following dose-response curve shows that



(A) larger amounts of agonist produce a corresponding increase in response
(B) 80% more agonist is required to achieve 80% more response
(C) 81 times more agonist is needed to achieve a 90% response than a 10% response
(D) an 80% high response is achieved with a tenfold increase in agonist
(E) None of the above are true.

6. A dose that is represented as LD_{50}

(A) shows a response in 50% of the population
(B) kills half of the study group
(C) is a dose that has an acceptable risk level of 50%
(D) is a dose that has a threshold response of 50%
(E) is a dose that is administered to 50% of the population

7. Problem(s) associated with risk management include

(A) people making a risk assessment vary in their conclusions of long-term versus short-term risks and benefits
(B) some technologies benefit some groups and harm others
(C) there is consideration of the cumulative impacts of various risks rather than consideration of each impact separately
(D) there may be a conflict of interest in those carrying out the risk assessment and the review of the results
(E) All of the above are true.

8. Currently, the single-most significant threat to human health is

(A) toxic chemicals
(B) accidents
(C) pathogenic organisms
(D) pollution
(E) nontransmissible diseases such as cancer and cardiovascular disease

9. The accumulation of DDT by peregrine falcons, brown pelicans, and other predatory birds during the 1960s is an example of

   (A) bioaccumulation
   (B) bioremediation
   (C) acute exposure
   (D) biomagnification
   (E) a case-controlled study

10. A concentration of 30 ppm would be equivalent to

   (A) 0.3%
   (B) 0.03%
   (C) 0.003%
   (D) 0.0003%
   (E) 0.00003%

11. Preserving the value of a resource for the future is a(n)

   (A) aesthetic value
   (B) cultural value
   (C) existence value
   (D) use value
   (E) option value

12. It costs a copper smelter $200 to reduce emissions by 1 ton and $250 for each additional ton while it costs an electric company $100 to reduce its emissions by 1 ton and $150 for each additional ton. What is the least expensive way of reducing total emissions by 2 tons?

   (A) Legislate that both firms must reduce emissions by 1 ton
   (B) Charge both firms $251 for every ton they emit
   (C) Allow each firm to buy a $151 permit to pollute
   (D) File an injunction to halt production until the firms reduce emissions by 2 tons
   (E) None of the above

13. In economic analysis, the optimum level of pollution

   (A) is always zero
   (B) is where the marginal benefits from further reduction equals the marginal cost of further reduction
   (C) occurs when demand crosses the private cost supply curve
   (D) should be determined by the private market without any government intervention
   (E) None of the above

14. Externalized costs of nuclear power include all of the following EXCEPT

(A) disposing of nuclear wastes
(B) government subsidies
(C) costs associated with Three Mile Island
(D) Price-Anderson Indemnity Act
(E) All are external costs.

15. Which of the following is NOT part of a cost-benefit analysis?

(A) Judging whether public services provided by the private sector are adequate
(B) Judging and assessing inefficiencies in the private sector and their impact on health, safety, and environmental need
(C) Determining external costs to society
(D) Meeting societal needs in a cost-effective manner
(E) All are part of a cost-benefit analysis.

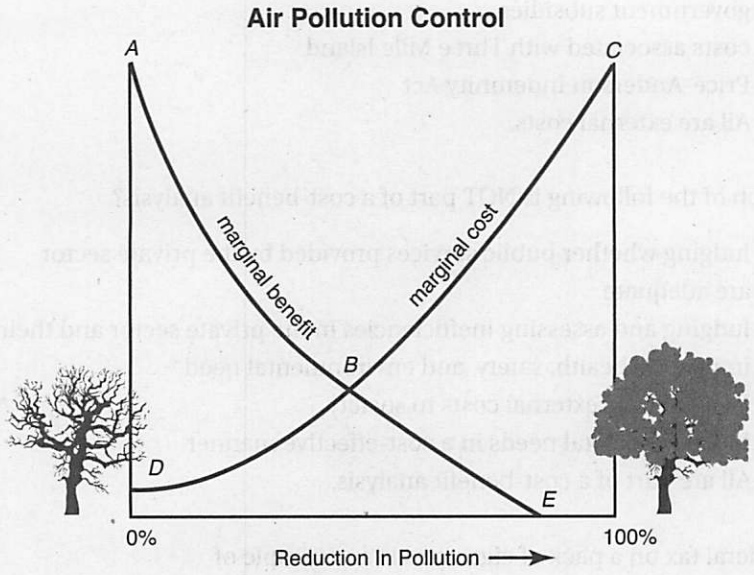
16. A federal tax on a pack of cigarettes is an example of

(A) full-cost pricing
(B) an internal cost
(C) an external cost
(D) a marginal cost
(E) a life cycle cost

17. The threshold dose-response model

(A) cannot be used to determine how toxic a substance is
(B) implies a risk associated with all doses
(C) implies that no detectable harmful effects can occur below a certain dose
(D) is similar to a linear dose-response model
(E) All of the above are true.

18. Which letter on the graph below represents the optimum level of pollution balanced with the most efficient use of available resources to control it?



(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

19. Which of the following is NOT part of risk assessment?

(A) Determining the probability of a particular hazard
(B) Determining types of hazards
(C) Coming up with an estimate on the chances of how many people could be exposed to a particular risk
(D) Informing the public about the chances of risks
(E) All are part of risk assessment.

20. Which factor listed below is generally considered to be the primary cause of reduced human life span?

(A) AIDS
(B) Infectious disease
(C) Cancer
(D) Poverty
(E) Heart disease

FREE-RESPONSE QUESTION

By: Annaliese Berry, B.A.
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In 1989, the oil tanker *Exxon Valdez* struck an offshore reef in Alaska and spilled more than 11 million gallons of crude oil into Prince William Sound. Although Exxon spent $2.2 billion in partially dispersing and removing the oil, many seabirds and mammals died as a result of this catastrophe.

Ironically, environmental accidents such as the *Exxon Valdez* oil spill actually stimulate our nation's economy by causing an increase in the gross domestic product and the gross national product. Using this information, answer the following questions.

(a) Explain what gross domestic product (GDP) or gross national product (GNP) is a measure of and give ONE example of a possible cause for an increase in the GDP or GNP following the *Exxon Valdez* oil spill.

(b) Give ONE valid criticism of GDP and GNP as progress indicators, and provide ONE viable alternative progress indicator. Describe what the viable alternative attempts to measure.

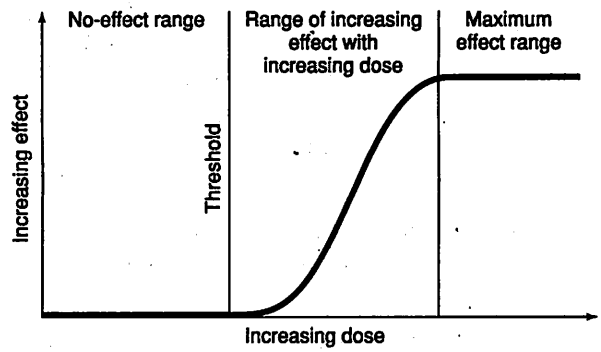
(c) Name and explain one internal cost and one external cost that might be associated with the oil industry. Include in your answer an explanation of what internal and external costs are.

(d) How would internalizing external costs (sometimes called full-cost analysis or true-cost analysis) affect the pricing and economic competitiveness of petroleum products?

When responding to Free-Response Questions, be sure to practice making good arguments in favor of, or against, a particular position on an environmental issue. Make sure you understand that restating the question is a waste of time on a timed test, and doing so will never earn you any points.

MULTIPLE-CHOICE ANSWERS AND EXPLANATIONS

1. **(D)** In 1999, over 20,000 hazardous waste generators produced over 40 million tons of hazardous wastes.
2. **(D)** The Superfund program began in 1980 to locate, investigate, and clean up the most polluted sites nationwide.
3. **(B)** Chronic diseases are of long duration with slow progress. Examples would include congestive heart failure, Parkinson's disease, and cerebral palsy.
4. **(E)** Land farming, composting, rhizofiltration (filtering water through a mass of roots to remove toxic substances or excess nutrients), and phytoremediation (the use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or groundwater) all involve the use of bacteria and enzymes to break down hazardous materials.
5. **(C)** "81 fold" means 81 more times. An agonist is a drug or other chemical that produces a reaction typical of a naturally occurring substance.



6. **(B)** The LD_{50} value is typically expressed in milligrams of material per kilogram of body weight. It indicates the quantity of material that will cause 50% of the subjects to perish.
7. **(E)** Risk assessment is the process of evaluating the likelihood of an adverse health effect. Risk assessment does NOT determine the level of allowable or acceptable risk—that is risk management.
8. **(E)** For most of human history, pathogenic (disease-causing) organisms were the greatest threat to health. Today, cardiovascular diseases, cancer, and other noninfectious diseases have become the major killers.
9. **(D)** Biomagnification is the increase in the concentration of toxic substances as one moves up the food chain. Animals at the top of the food chain receive the highest concentration of toxins and experience the worst effects.
10. **(C)** To change ppm to a percentage, move the decimal place four places to the left and add a % sign.
11. **(E)** An option value is the value that people place on having the option to enjoy something in the future.
12. **(C)** The copper smelter would pay $450 to emit 2 tons of pollutants while the electric company would pay $250 to emit 2 tons of pollutants. Clearly, $151 would be the least expensive option available.

13. **(B)** The marginal benefit of pollution control declines as the level of environmental quality goes up while, at the same time, the marginal cost of pollution tends to increase. The optimal level of pollution from an economic standpoint is where the marginal benefit equals the marginal cost. As long as the marginal benefit exceeds the marginal cost, there is an economic incentive for cleaning up.

14. **(E)** External costs are the costs that are borne by people other than the producer of a good.

15. **(C)** Cost-benefit analysis is a technique for deciding whether to make a change and requires adding up the value of the benefits of a course of action and subtracting the costs associated with it.

16. **(A)** Full-cost pricing accounts for the cost of a good when its internal costs and its estimated short- and long-term external costs are included in its market price. The highest combined state-local cigarette tax rate is $7.42 per pack in Chicago, IL, making it the nation's highest while the lowest rate in the nation is in Missouri, at 17 cents per pack.

17. **(C)** The threshold dose-response model has long been recognized as the most important tool in understanding the risk assessment processes used by regulatory and public health agencies worldwide.

18. **(B)** Point *B* represents the point where society has reached the maximum benefit of controlling air pollution at the least cost. Any more money spent on controlling air pollution would not be worth the cost and would take money away from other needs.

19. **(D)** Risk assessment is the process of quantifying the probability of a harmful effect. In most countries, the approval of certain pesticides, industrial chemicals, power plants, and so on is not allowed unless it can be demonstrated through risk assessment that they do not increase the risk, death, or illness above a certain level. Educating the public is not part of risk assessment. That is left up to the media, public interest groups, and special interest groups.

20. **(D)** Poverty is the fundamental issue that affects the human life span. People who are without financial resources suffer from malnutrition, exposure, and disease while those with financial resources are able to obtain proper nutrition, have shelter, and seek medical treatment.

FREE-RESPONSE ANSWER

10 Total Points Possible

(a) Maximum 2 points distributed as follows.

Explain what gross domestic product (GDP) or gross national product (GNP) is a measure of and give ONE example of a possible cause for an increase in the GDP or GNP following the Exxon Valdez *oil spill. (1 point maximum for a correct explanation of either GDP or GNP. 1 point maximum for a possible cause for an increase in the GDP or GNP following the* Exxon Valdez *oil spill.)*

Notable points:

Explanation of GDP or GNP.

Example of how cleaning up the spill or replacing lost equipment/oil causes goods or services to be transacted.

Gross domestic product (GDP) is a measure of the market value of goods and services transacted within a country during a year, so it increases any time products or services are paid for. This means that the additional expense that Exxon (now Exxon-Mobil) incurred by controlling the spill ($2.2 billion) increased the GDP. For example, money was spent to hire boats with skimmers in an attempt to capture and contain floating oil.

(b) Maximum 3 points distributed as follows.

GDP and GNP are economic measures, not direct quality of life measures.

Example of alternative indicator. Examples include the NNP, ISEW, GPI, or NEW. A general alternative is to take into account any standard of living data (literacy rate, percent of population below poverty line, and so on).

Explanation of what example indicator measures.

Give ONE valid criticism of GDP and GNP as progress indicators, and provide ONE viable alternative progress indicator. Describe what the viable alternative attempts to measure. (1 point maximum for providing a valid criticism. 1 point maximum for providing a viable alternative. 1 point maximum for describing what the alternative attempts to measure.)

GDP and GNP have been criticized as progress indicators because economic growth is only indirectly related to quality of life. The GDP and GNP are often stimulated by events that directly lower the quality of life, such as the *Exxon Valdez* oil spill, the Oklahoma City bombing, Hurricane Katrina in New Orleans, or the events of 9/11 in New York City. Alternative progress indicators attempt to capture the quality of life or the standard of living, although these are often harder to define and measure than the flow of dollars. One such indicator is the net national product (NNP), which accounts for the depletion and destruction of natural resources along with changes in the GNP.

(c) Maximum 4 points distributed as follows.

Naming of an internal cost. Costs may be expenses related to cleanup, ship or oil replacement, cost of labor, and so on.

Explanation that internal costs are costs paid for by the organization producing the product.

Name and explain one internal cost and one external cost that might be associated with the oil industry. Include in your answer an explanation of what internal and external costs are. (1 point maximum for correctly explaining what an internal cost is. 1 point maximum for correctly explaining what an external cost is. 1 point maximum for correctly naming an internal cost associated with the oil industry. 1 point maximum for correctly naming an external cost associated with the oil industry.)

An internal cost is a cost that is paid for by the organization producing a product. This cost is typically passed along to the consumers when they purchase the product. One internal cost of the petroleum industry could be the cost of extracting petroleum using oil drills and platforms. An external cost occurs when producing or consuming a good or service imposes a cost upon a third party. If there are external costs in consuming a good (negative externalities), the social cost will be greater than the private cost. The cost of an oil spill consists of both "private" costs to the oil

rig operator(s) and "external" or third-party costs to the government, victims, and natural resources. Examples of external costs might include loss of life and injury to workers and cleanup costs incurred by government agencies.

Naming of an external cost such as water pollution left behind after a spill, air or water pollution from operating tankers, or an increase of CO_2 in the atmosphere when the petroleum products are consumed.

(d) *Maximum 1 point.*

How would internalizing external costs (sometimes called full-cost analysis or true-cost analysis) affect the pricing and economic competitiveness of petroleum products? (1 point maximum for providing a correct explanation.)

Internalizing external costs would mean that organizations producing a product would pay for any harmful effects (the external costs) of their products. This would allow the market price of a product to reflect the full cost of producing and cleaning up the product. It would also increase the price of any product that has external costs. A product with high external costs would become substantially more expensive and less economically competitive. In the energy industry, sources of power such as oil and gas have relatively high external costs and could become more expensive than lower-impact sources of energy, such as wind power.

Explanation that external costs are harmful effects of the product that are not paid for by the organization.

Price of product would increase as external costs are paid for by the producer and passed along to the consumer.

Petroleum products would become less economically competitive.

UNIT VII

Global Change

(10%–15%)

Areas on Which You Will Be Tested

A. STRATOSPHERIC OZONE—formation of stratospheric ozone, ultraviolet radiation, causes of ozone depletion, effects of ozone depletion, strategies for reducing ozone depletion, and relevant laws and treaties.

B. GLOBAL WARMING—greenhouse gases and the greenhouse effect, impacts and consequences of global warming, reducing climate change, and relevant laws and treaties.

C. LOSS OF BIODIVERSITY

1. Habitat loss—overuse, pollution, introduced species, and endangered and extinct species.
2. Maintenance through conservation.
3. Relevant laws and treaties.