Unit 1:
HAZARDOUS MATERIALS AND HUMAN HEALTH

In this unit, you will learn:

- **Why hazardous materials are a concern**
- **What hazardous materials are**
- **How hazardous materials affect the body**
- **How hazardous materials enter and move through the** environment

HAZARDOUS MATERIALS IN THE UNITED STATES

In the years since World War II, new technologies have developed at a stunning pace. Nearly every household in our consumer society has grown accustomed to daily use of manufactured products that offer us increased convenience and efficiency. Detergents. Toilet bowl cleaners. Air fresheners. Specialized glues. Caulks. Insecticides.

Many of these products make use of materials that do not exist in nature. This year alone, over 1,000 new synthetic chemicals will enter our communities. Some will require careful handling during manufacture, transport, storage, use, and disposal in order to avoid causing harm to people, other living things, and the environment.

Many of these chemicals are not "biodegradable" (that is, able to be broken down into their components by microorganisms); for such chemicals in particular, the potential for adverse health effects can continue for decades or even centuries.

We are becoming increasingly aware of the limited space that our planet has to offer for the disposal of toxic products. According to 1987 data based on industry reports of toxic discharges compiled by EPA, over seven billion pounds of toxic substances were released directly into our environment (air, land, and water) by industry manufacturers alone. Numerous small businesses, such as printing industries and vehicle maintenance shops, also released

While hazardous materials attract us by promising to make our lives easier, they often confront us with complex problems—many of which have no easy or immediate solutions.

toxic chemicals not included in these estimates. Few communities are eager to have hazardous waste deposited in their "backyard." A lone barge loaded with garbage made headlines in 1987 as it sailed the seas seeking a place to leave its unwanted cargo.It seemed an apt expression of our country's dilemma.

Naturally occurring toxic substances can also pose problems. For example, ponds near a wildlife refuge in California became contaminated by selenium, an element commonly found in alkaline desert soil. The high level of selenium was the result of irrigation methods used at nearby farms. Water removed the selenium from the soil, dissolved it, and carried enough of the element to non-farm portions of the refuge to threaten wildlife. As waterfowl ingested (ate) the selenium, deformities were found more frequently in developing embryos. Naturally occurring substances have sometimes led to expensive cleanup operations comparable to those required for human-created hazardous waste.

Sometimes, the challenge posed by hazardous materials glares at us in headlines and stories like these:

- In Bhopal, India, 44 tons of methyl isocyanate gas spewed into the atmosphere, killing at least 1,700 persons and injuring tens of thousands.
- In a small Kentucky community, tank cars containing toxic substances derailed and burned. The fire caused a column of toxic smoke 3,000 feet high that forced 7,500 area residents to evacuate.
- In Florida, vandals broke the valves of chemical tanks at a local swimming pool supply company. The chemicals mixed to form a toxic acid, and a poisonous cloud of vapors sent 45 persons to the hospital.
- In Louisiana, up to 41,000 pounds of hydrobromic acid fouled part of the Mississippi River after two ships collided.
- In Pennsylvania, a garbage truck operator found his load on fire and dumped it in a residential driveway: mixed chemicals, discarded by a high school science department, released cyanide vapors that sent 100 persons to the hospital.
- Two New Jersey workers were killed and five injured by vapors inhaled as they cleaned a chemical mixing vat at a local company.

Often, however, problems posed by hazardous materials are less clear-cut. Many of the effects attributed to toxic substances, such ascertain types of cancer, have multiple causes. In any single case of illness or death, it is difficult to point the finger at a specific instance of exposure to a particular hazardous material. In fact, one study found traces of over two hundred industrial chemicals and pesticides in members of an American sample group. Determining at what exposure level each of these common substances becomes harmful to human health is not oniy a scientific question but also a social, political, and economic issue.

Our legal system seeks to control these materials at every level of government—Federai, State and local—but it is hampered by funding imitations, debates over emerging technology, iack of definitive research in certain areas, and competing rights and interests. Laws and regulations at ail three levels of government address various aspects of the hazardous materiais problem by specifying how chemicais must be stored, what empioyees are toid about chemicals they handie at work, how chemicals are labelled, what containers are needed to transport specific chemicals, and what emissions levels are acceptable from industries. in each instance, the ***local*** government's roie in regulating its own hazardous materiais problems is critical.

Because Americans are exposed to toxic substances from so many sources, it is often difficult to trace a health effect to a particular source.

In 1986 the Emergency Planning and Community Right-to-Know Act made history by requiring a local farm, industry, or small business that stores a certain quantity of "extremely hazardous substances," as defined by an EPA list, to report them to the State Emergency Response Commission (SERC). This law, also known as the Superfund Amendments and Reauthorization Act of 1986, or just "Title ill," includes provisions intended to heip local-level planners work with industry to identify and reduce risks from toxic chemicals, and, if necessary, to seek corrective action through legal remedies. it also creates new opportunities for citizens to identify and alter potentially hazardous conditions in their communities. it is based on the assumption that the more citizens know about local chemical hazards, the better equipped they and their local governments will be to make wise decisions about how risks associated with hazardous materials are managed in their communities.

But the hazardous materiais challenge facing our country is not posed simply by chemicals reieased into the environment (intentionally or accidentally) by industries. Each individual household creates hazardous waste which, when combined with that from other homes in the same community, presents local government with a potentially serious threat to the local environment and public health. Furthermore, automobiles emit nitrous oxides (one source of "acid rain") and severai air toxics. By becoming informed about hazardous materials laws, issues, and protective actions, local citizens can contribute to reducing their community's hazardous materials threat,

WHAT ARE HAZARDOUS MATERIALS?

Hazardous materials, as discussed in this course, maybe defined as follows:

Substances or materiais which, because of their chemical, physical, or biological nature, pose a potential risk to life, health, or property if they are released.

A "release" may occur by spilling, leaking, emitting toxic vapors, or any other process that enables the material to escape its container, enter the environment, and create a potential hazard. Hazards are classified in many different ways. The following introduces several common terms:

ABSORPTION

INJECTION

Absorption and injection are two routes of entry that occur through direct skin contact with a hazardous material.

1. ***Explosive*** substances release pressure, gas and heat suddenly when they are subjected to shock, heat or high pressure. Fourth of July celebrations use many types of explosive substances that require careful storage and handling to avoid injury.

2. ***Flammable*** and ***combustible*** substances are easy to ignite. Paint thinners, charcoal lighter fluid, and silver polish are all highly flammable. Related hazards are posed by ***oxidizers***, which will lend oxygen readily to support a fire, and ***reactive*** materials, which are unstable and may react violently if mishandled.

3. ***Poisons*** (or toxic materials) can cause injury or death when they enter the bodies of living things. Such substances can be classified by chemical nature (for example, heavy metals and cyanides) or by toxic action (such as irritants, which inflame living tissue, and corrosives, which destroy or irreversibly change it). One special group of poisons includes ***etiological*** (biological) ***agents.*** These are live microorganisms, or toxins produced by these microorganisms, that are capable of producing a disease.

4. ***Radioactive materials*** are a category of hazardous materials that release harmful radiation. They are not addressed specifically in this course.

These categories are not mutually exclusive. For example, acids and bases are listed as corrosive materials, but can also act as poisons.

HOW HAZARDOUS MATERIALS HARM THE BODY

Toxic substances can enter our bodies in any of four ways, called ***routes of entry.*** These are:

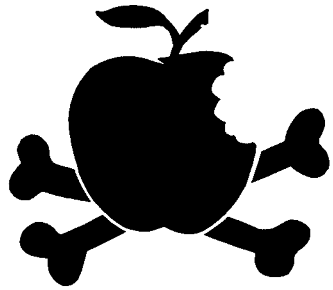
- Absorption
- injection
- Ingestion
- Inhalation

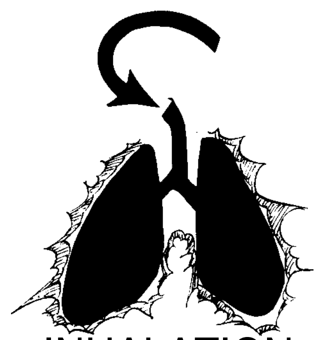
1. Absorption (through the skin or eye)

If a child were to walk barefoot through contaminated soil, the contaminant would contact the skin of the foot. This could cause mild skin irritation, or more serious problems like burns, sores, or ulcers on the outer layers of the skin. Contact with a substance may also occur by spilling it on the skin or brushing against a contaminated object.

Depending on the substance and the condition of the skin, the contaminant might also be absorbed through the skin and poison the body. While some chemicals are not absorbed easily unless the skin is cut, others are absorbed quite readily regardless of the skin's condition. When you are using a material that bears instructions recommending the use of gloves, this is to prevent skin contact or absorption through the skin (also called ***dermal*** exposure).

When you work with chemicals, it is particularly important never to put your hand to your eye. Eyes are particularly sensitive to toxic substances: since capillaries are near the surface, the substance can enter the bloodstream more readily. Eye contact with toxic substances can cause irritation, pain, or even blindness.





When we ingest (eat) or inhale a substance, the body tries to filter it out through interns/defenses. If there is enough of the substance, these filters are overwhelmed.

2. **Injection**

The most familiar example of injection is that of shots given to administer medicine, in which the skin is punctured with needles so that a substance can enter the body. Injection can also occur accidentally. For example, if the skin were cut by a contaminated can or a piece of glass that had been in contact with a contaminant, the contaminated substance could be injected into the body. This is a very powerful means of exposure because the contaminant enters the bloodstream ***immediately.***

3. **Ingestion**

If we eat a substance that contains a harmful material, that substance enters our bodies by means of our digestive system. An example of inadvertent ingestion is a battery factory employee who eats lunch in the work area and ingests inorganic lead that has contaminated a sandwich. A more common instance is the child who puts a toxic substance in his or her mouth out of curiosity. We may also ingest residue from chemicals that have been added to our food to kill germs or parasites.

4. **Inhalation**

It is also possible to be contaminated by toxic substances when we breathe them into our lungs. The amount of air inhaled in a workday can be extremely large, so if we work or live in a contaminated area, we can be exposed to significant quantities of a substance in this way.

Some chemicals have excellent warning properties that let us know when they are in the atmosphere. There is the well-known "rotten egg" smell of hydrogen sulfide, for example. But at high concentrations of this gas, our sense of smell is quickly lost. Many toxic substances, such as carbon monoxide, are both colorless and odorless, providing us with no sensory clues that we are being exposed to anything unusual.

PATHWAYS OF EXPOSURE

if we consider these routes of entry, it is possible to think of a number of ways in which contaminants escaping into the environment from their ***source*** may reach a living plant or animal, or ***receptor.*** Each specific route a chemical might travel from a source to a receptor is called an ***exposure pathway.***

The pathway may be either ***direct or indirect.*** If an open toxic waste dump were near you, you could inhale the vapors from the toxic material, or your skin could contact toxic contaminants if you walked through the substance. These are ***direct*** means of exposure. The substance can also reach you by ***indirect*** pathways. For example, toxic vapors or particles from a site at which hazardous waste has been illegally discarded could be carried in the air to a cornfield and deposited on the crop as it rains. You ingest some of the toxic chemical as you eat the corn; or perhaps a farm animal eats the corn and you later eat meat from that animal.

Another pathway might be through drinking water. When rain falls and passes through polluted soil, it carries chemicals deeper into the earth as well as horizontally across the surface of the soil. If they are able to move far enough—which depends on the geology of that particular area—they could contaminate the groundwater. The contaminants could also be carried along the land by means of ***surface runoff,*** water that moves along the top of the soil, until they reach a recreational pond where children swim. Now there would be another opportunity for dermal contact.

ASSESSING RISK

How much risks associated with any particular source depends on the characteristics of the source, the availability of pathways for it to reach the receptor, and the characteristics of the receptors. No single piece of information alone is sufficient, and incomplete information can be highly misleading. Among the key questions that must be asked in determining risk are the following:

1. What are the ***hazardous properties*** of the substance? What effects can it have on living things or on the environment? (To answer this question it is often necessary to consider the state of research on the substance, and how much is really known about it.)

2. How ***much*** of the substance exists at the source, and in what

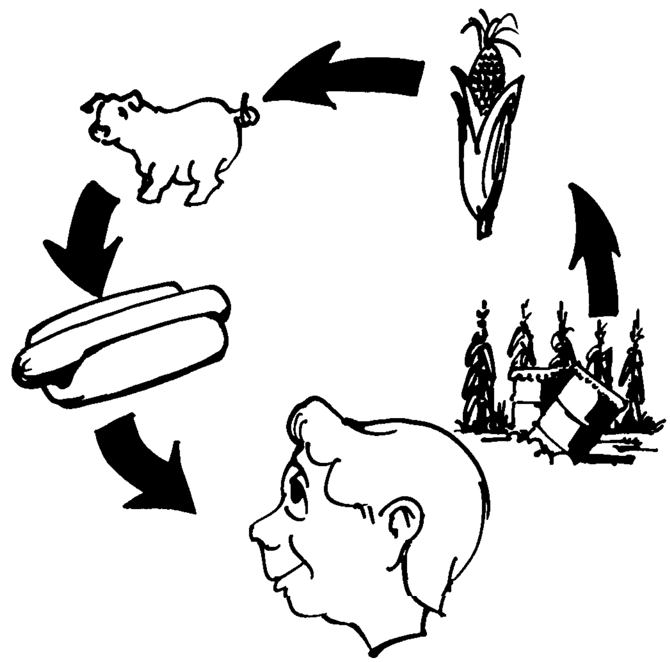
concentration? A higher quantity or concentration of a toxic substance is more dangerous. However, the risk posed by a highly concentrated toxic substance entering the environment depends on the pathways available to it, and to what extent the concentration is reduced by the time it reaches receptors.

3. In what ***form*** is the substance? Whether the substance is in large blocks or tiny particles, or whether it is a liquid or a vapor, will be important in determining not only how it might travel, but also how it could contact and enter the body.

4. What are the ***chemical and physical characteristics*** of the substance? These characteristics determine in what environmental pathways it is likely to move and how rapidly. They include, for example, whether the substance can easily dissolve in water.

5. How is the substance ***contained?*** If the chemical is in old, rusting containers that can leak, the danger is clearly greater than if the container is solid and appropriate to the substance.

6. What ***pathways of exposure*** exist? When scientists study the risk in any particular situation, they look at all the ways a contaminant could reach the population at risk and make measurements to see how much of it is moving through each identified path. For example, if the source is near a stream, water samples would be taken at several places to see what level of contamination exists at different distances from the source.



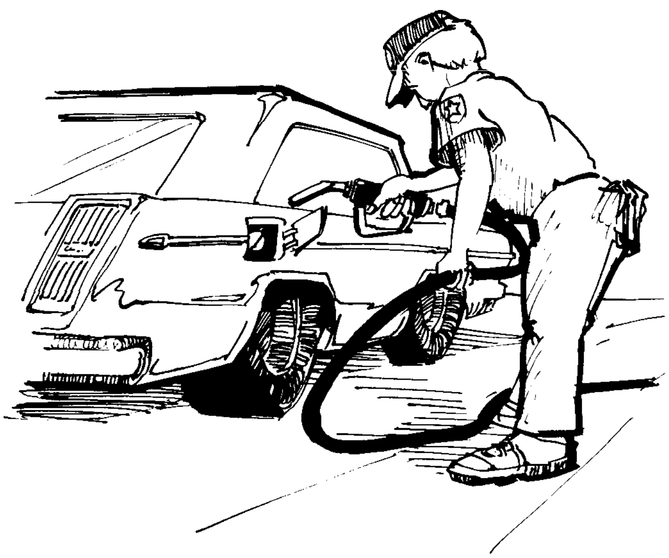
A possible exposure pathway involving the food chain: toxic fumes and particles from a waste dump are carried through the air to a cornfield; corn grown in this field is fed to an animal which is later processed for human consumption.

7. Where is the population ***located*** in relation to the source? Distance is a critical factor. For example, if you are far downstream from a place where toxic waste is entering a waterway, you may have little risk because the substance is so diluted. Closer to the source there might be a high enough concentration to pose a real problem.

8. What are the ***characteristics*** of people who are at risk? The susceptibility of any individual to a toxic substance varies depending on age, weight, sex, and individual sensitivity.

9. How long does the exposure to the chemical last? Its ***duration*** is another key factor in determining risk. Are receptors exposed for only a few hours at a high level (such as when a contaminated air plume passes over a home), or at a low level over a number of years (such as when groundwater supplying a well becomes contaminated)?

The analysis of a situation to determine the level of risk inherent in that situation is called ***risk assessment.*** A risk assessment is conducted by scientists from many different disciplines and uses data about a chemical's effects combined with research into the particular situation to get a clear picture of the risk posed. A decision will then be made as to what" action, if any, is needed to remedy the situation. This is called ***risk management.***



TOXIC MATERIALS IN THE BODY

A poison, or toxic substance, may be defined as ***a chemical that, In relatively small amounts, produces injury when it comes in contact with susceptible tissue.*** Clearly, the phrase "relatively small amounts" is less than precise, but this uncertainty is necessary because of the wide variance in the amount of each chemical needed to have an effect. A substance is generally not thought of as toxic if it is unreasonable to expect that a person would be exposed to the amount necessary to cause injury. A "susceptible" tissue is defined as that part of the body which is injured after exposure to that particular substance.

Chronic exposure is the exposure to a hazardous substance over a long period of time.

Toxic Effects

We can be overexposed to poisons in either of two ways. The first method is called ***acute*** exposure, which means that a dose of a chemical enters the body in a short time. For example, if a carpenter spilled furniture stripper in a small area without adequate ventilation and inhaled the vapors, the carpenter would experience acute exposure. if the same carpenter used this stripper regularly and breathed in a little of it eight hours a day for forty years, ***chronic*** exposure would result. This type of exposure occurs when a person is repeatedly exposed to the same toxic substance over a long period.

Exposure to a toxic substance can produce either immediate or long-term effects. A reaction to a poison can occur at the time of exposure, and might include vomiting, eye irritation, or other symptoms that often may be readily linked to a chemical exposure. These are ***immediate*** effects.

Long-term effects may occur years after a single serious exposure, or as the result of chronic exposure. These effects are often more difficult to trace to their cause, and can include organ damage, respiratory diseases, and other illnesses.

Certain toxic substances produce their long-term effects by altering the genetic code, or DNA, which tells the body's cells to perform certain activities. Three categories of effects can result from such substances:

1. A ***carcinogenic*** effect is an increase in an individual's risk of contracting cancer.

2. A ***mutagenic*** effect is a permanent change in the genetic material (DNA), which may be passed along to later generations.

3. A ***teratogenic*** effect is an increased risk that a developing embryo will have physical defects.

Determining what level of exposure causes these effects requires laboratory research under controlled conditions. Even then, results must be ***extrapolated*** from laboratory animals to humans. That is, scientists must make assumptions and apply formulas to decide what their experiments tell them about ***human*** exposures.

Another way to classify poisons is by their physiological effects. This classification includes the following major groups:

1. ***Irritants*** are chemicals that inflame living tissue at the site of contact, causing pain and swelling. Household cleaners that contain ammonia produce a gas that irritates the eyes and the mucous membranes of the respiratory tract. Watery eyes and a stinging sensation in the throat will result from exposure to sufficient concentrations of these chemicals over a long enough period.

2. ***Asphyxiants*** are chemicals that prevent the cells of the individual from receiving life-giving oxygen. Carbon monoxide is a well-known asphyxiant, which chemically "ties up" the hemoglobin in the blood so that the body's metabolism slows and stops.

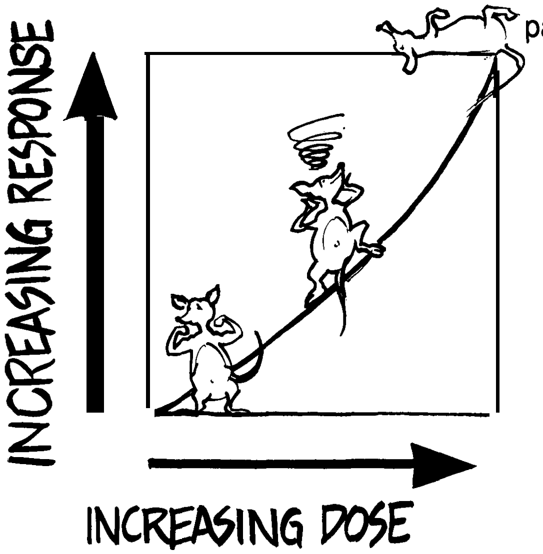
3. ***Central Nervous System (CNS) Depressants*** affect the nervous system. This broad category includes vapors from most anesthetic gases, depressants, and organic solvents (a general category that includes most household cleaners as well as many paints, glues, and adhesives). Some CNS depressants produce a feeling of dizziness or giddiness. More severe effects (including death) can also result.

4. ***Systemic Toxicants*** dramatically affect specific organ systems. For example, mercury vapor, which Victorian hat-makers had to inhale regularly when mercury was used in making hats, causes a serious nervous system disorder which could lead to insanity. (The "Mad Hatter" in Alice in Wonderland suffered from an occupational illness.)

Exposure to a toxic substance over a short period of time—such as in an accident—is known as acute exposure.

Many chemicals can have multiple effects. For example, xylene, commonly used in paint, is both an irritant and a CNS depressant.

Symptoms of toxic exposure include a broad range of reactions: chronic coughs, difficulty in breathing, skin ulcers, diarrhea, irregular heartbeat, headaches, dizziness, chest pain, sore eyes and skin, difficulty in sleeping, lack of appetite, weight loss, nausea, tremors, and many others. However, the same symptoms can result from many other causes as well. Tracing a particular reaction to a specific source can be a challenge to even the most experienced environmental toxicologists, allergists, and industrial hygiene specialists. This is further complicated by the fact that many effects are delayed, and are apparent only later in life. The individual experiencing the symptom may no longer live near the original source, or may not even know that the exposure occurred.



*At low enough exposure levels, a toxic substance will produce no observable harmful effects. As the dose increases, so does the potential for harm. For every substance-even table **salt**— there is a lethal dose.*

Internal Defenses

When the body is exposed to a poison, its internal defenses try to remove the unwanted substances. The primary internal defense is excretion of the contaminant with other wastes in the feces or urine. Prior to excretion, wastes are ***filtered***, primarily by the liver and kidneys. As a result, these two organs are both subject to damage from toxic substances, storing in their tissues what they are unable to breakdown. Portions of the lungs contain cilia, which try to remove particles so that they can be coughed out. Particles that are too large or cannot be removed for other reasons sometimes remain as deposits in the lower part of the lungs, where they can cause toxic effects such as fibrosis or cancer.

Other body defenses against toxic substances are ***breathing*** and ***sweating.*** When an intoxicated person has the smell of alcohol on his or her breath, the smell indicates that the body is ***exhaling*** material it has no use for. ***Tears*** also remove contaminants that enter the eyes. However, these defenses contribute only a small amount to the body's ***detoxification*** (that is, its attempt to rid itself of toxic substances).

The body's ability to defend itself against toxic substances varies with the individual. Small children are liable to be more affected by the same amount of a substance than are larger or older persons. Elderly individuals also may have less ability to remove toxicants from the body. Gender can be a factor in toxic responses; for example, some cancers are sex-linked (such as prostate and ovarian cancers). Personal hygiene and the overall health of an individual can also adversely affect the body's ability to process certain toxic substances. For example, a smoker is likely to be much more susceptible to lung cancer if he or she has also been exposed to high levels of radon gas.

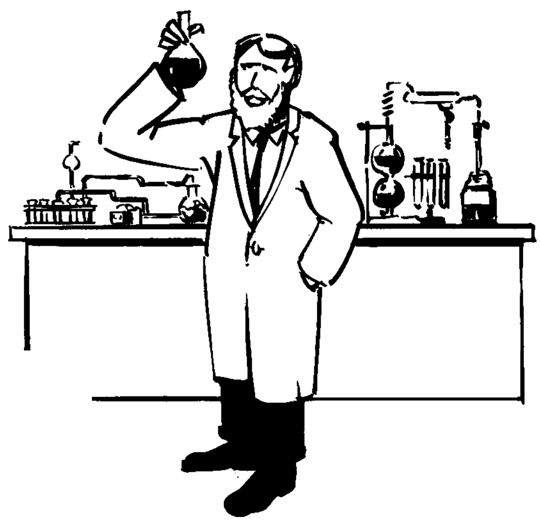
Certain people also have allergies to substances that can cause them to react violently, even fatally, to a situation that would pose no apparent risk to another individual. Chemicals that cause strong allergic reactions in some perople are called ***sensitizers.*** For example, epoxy resins and polyester resins cause many people to have a ***sensitivity reacation*** and become ill.

Exposure to a poison becomes a problem when the material is of a type that inner defenses cannot breakdown and remove, or when there is more of it than the body can handle. In these instances, ***antidotes*** are available for a limited number of substances. However, only about 20 antidotes are in existence for the thousands of poisons in the world—and each antidote may work for only a few poisons.

Clearly, the safest barrier to toxic exposure is the ***prevention*** of exposure. This is why it is so important for the citizen to be aware of the threat posed by hazardous materials in their own home and community, and to learn to minimize or eliminate unnecessary exposure.

STUDIES OF TOXIC EFFECTS

Scientists determine what levels of exposure in human beings will produce observable symptoms by two types of studies. ***Epidemiological*** studies use data on how toxic substances affect human populations. This type of study might compare the number of workers exposed to a certain substance who develop lung cancer to those who develop it in the rest of the population. Other ***clinical*** studies test the effects of concentrated doses of substances on animals or animal tissue.

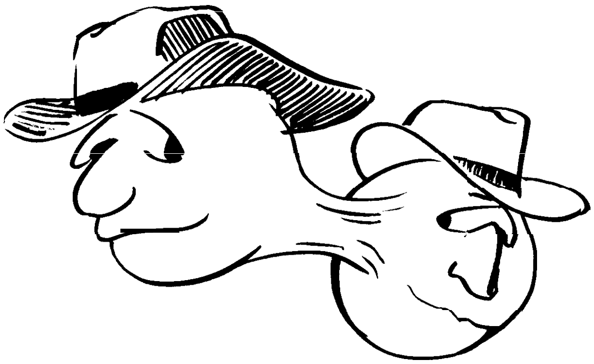


Scientists conduct two kinds of studies-epidemiological and clinical—to determine what levels of exposure to a hazardous substance will produce observable symptoms.

A basic principle of research on toxic substances is that the seriousness of the effect a poison has on the body increases as the ***dose*** increases. Theoretically, there is **a threshold** for exposure to each poison. Beneath the threshold, the dose is so small that no harmful effect will occur. As the dose increases, there is a point at which there is an effect, but the animal can compensate for it by internal healing, and no permanent injury will occur.

Beyond that, there is a dose at which the animal cannot repair itself from the damage and disease results. Finally, at the upper limit of the curve, death occurs.

Death would occur if sufficient quantities of any substance were taken into the body. For example, if a large group of people with similar characteristics ate half a pound of table salt, half of them would probably die. Through experiments, scientists try to establish the particular dosage of chemical (in mass per kilogram of body weight) that will result in the death of half the test animals: that is the ***Lethal Dose for* 50%** or ***LD*** $_{50}$. They also try to establish the point at the other end of the curve at which there is no observable effect from the substance on the animal. This is called the ***NOAEL: No Observable Adverse Effect Level.***

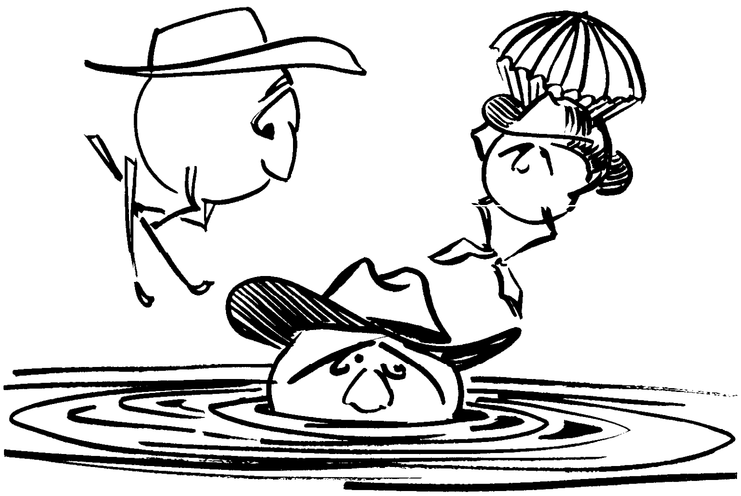


Once the LD_{50} for a substance has been established by repeated experiments with animals, it must be ***extrapolated*** to determine what the LD_{50} would be for h-umans. This means adjusting the results to apply to human body weight and similar characteristics. But a toxic substance often has different effects on different species, so tests on animals cannot predict the exact effect that the substance will have on a human population. As a result, scientists are usually quite conservative in their estimates, which means that they assume that the smallest dose that causes an effect in animals will also cause an effect in humans. In addition, scientists study the effect of a substance on human populations wherever statistics are available.

A toxic substance will sometimes combine with another substance to create a new chemical. The potential for harm of this new chemical can be greater or lesser than that of its individual components.

Another uncertainty associated with the LD_{50} concept is that most LD_{50} data is gained from acute exposure (single dose) testing rather than by chronic exposure. Extrapolation from these studies is complicated by the fact that chemicals are sometimes distributed differently in the body when the exposure is chronic; for example, a different target organ may be attacked, or the material may be excreted more easily.

Given these uncertainties, it is understandable why there is often considerable debate about what constitutes a "safe" level of exposure. For most substances, agency experts extrapolate conservatively from the NOAEL to set exposure limits for humans. The Occupational Safety and Health Administration (OSHA) uses "Permissible Exposure Limits," or ***PELs***, while the American Conference of Government Industrial Hygienists (ACGIH) uses "Threshold Limit Values," or ***TLVs***, to define the workroom air concentration that is considered a safe upper limit of exposure. For carcinogens and mutagens, however, there is considered to be no such "safe" exposure limit for regulatory purposes. Every exposure carries some risk.



The movement of contaminants within a medium such as air, groundwater, or soil is known as transport.

HAZARDOUS MATERIALS IN THE ENVIRONMENT

Hazardous materials can enter the environment either from a specific source that can be pinpointed, known as a ***point source***, or from sources that are more spread out, known as ***area sources.*** A factory smokestack and the flow of toxic waste from a pipe to a stream are point sources, while the liquid runoff from afield in which pesticides were used is considered an area source.

Contaminants behave differently in the environment depending on their ***physical state.*** A solid may stick to surfaces, scatter, or form a dust cloud; a liquid may seep into the ground, flow along the ground, or vaporize and become a gas; a gas will expand and be carried by the wind. Some chemicals are ***volatile,*** meaning that they evaporate easily. Such a chemical may enter a stream as a liquid but rapidly become an ***air*** pollution problem.

Anon-volatile chemical entering the same stream at the same point may behave quite differently. A ***soluble*** chemical is one which will dissolve readily in water, and would be carried by the stream. Soluble chemicals tend to be ***mobile***, meaning that they will move rapidly in the ground because they can be easily dissolved in groundwater. Another chemical might be more likely to ***adsorb*** to soil particles, becoming attached to particles' surfaces. Such a chemical would attach to particles in the stream and eventually settle at the bottom. If the chemical were a ***persistent*** one, which resists breakdown in the environment, it might remain there for some time in the same form, while a less persistent one might be broken down by bacteria. This breakdown is called ***biodegradation,*** and is an important risk management concept. Sometimes it is possible to ***increase*** biodegradation so that materials lose their harmful properties more readily.

The process of chemical breakdown, or biodegradation, can cause materials to lose their harmful properties and, in effect, "disappear."

Contaminants enter any of the various ***media***—air, groundwater, surface water, or soil—and move as a mass along with the general flow of that medium. This movement of contaminants within a medium is called ***transport.*** Substances in transport also tend to spread out as they move, becoming diluted to a varying extent by the medium. This generally reduces the concentration, and therefore lowers the level of hazard.

Once a toxic substance is released into a medium, a number of different processes can occur:

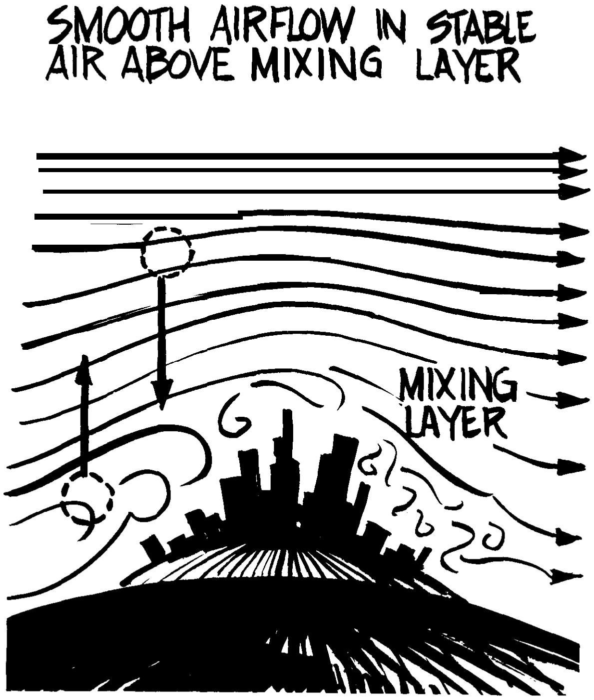
1. The substance moves in a pathway determined by its own characteristics, and those of the medium that is carrying it.

2. The substance spreads out or disperses, reducing the level of hazard. This means of reducing risk is not always reliable or consistent, however. For example, there may be periods of low flow in streams when the volume of water is reduced and less dilution occurs.

3. The material may change chemically or break down into other elements or compounds. Sometimes a contaminant will

Certain chemicals tend to become more high/y concentrated as they move through the food chain. This process is known as ***biomagnification.***

combine with another substance to become a more dangerous chemical; at other times, it will be rendered less harmful by the encounter. Some chemicals have a ***synergetic*** effect when they combine that results in a much more dangerous hazard than either would have individually. A chemical may also ***potentate,*** or increase, the toxicity of another chemical; for example, alcohol potentates the effect of many chlorinated hydrocarbons.



In urban locations, a turbulent "mixing area" of air exists which helps diffuse contaminants. This is due in part to the irregular surfaces of various size buildings and hot and cold spots created by contrasting materials such as concrete and grass.

4. A toxic substance may move from one medium to another (for example, evaporating from water into air).

5. Toxic substances can build up in the food chain. Organisms can absorb contaminants such as pesticides in a process known as bioaccumulation. These contaminants are later released into another organism that eats that animal or plant. Certain chemicals also tend to become more concentrated as they move up the food chain. (For example, toxic concentrations may be higher in a bird that ate insects containing poison than in the insects themselves.) This is known as ***biomagnificatlon.*** Often, an important part of understanding a chemical's risk to humans is understanding how a particular contaminant will move through a food chain and how each animal or plant in the chain may be affected.

The way a pollutant is ***transformed*** by chemical reactions and ***transported*** through the environment is called its ***fate.*** As we have seen, the fate of chemicals released at the same site may be extremely different.

The Movement of Contaminants in Different Mediums

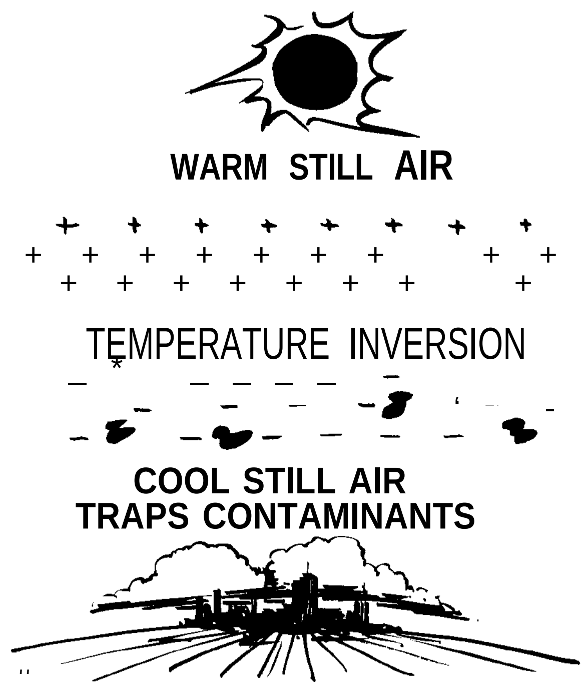
Hazardous substances move and disperse differently, depending on the medium in which they are deposited. Regulators set standards for exposure in each media separately, trying to take the unique features of each one into account. There are four ***transport mediums*** in which contaminants travel.

Air

Hazardous chemicals can enter the atmosphere from a point source (such as an industrial stack), or from an area source (such as the evaporation of volatile compounds from hazardous waste sites). A major factor affecting the level of contaminants in the air is the rate of dispersion, which is affected by both weather and ***topography*** (the shape of the land, including buildings). With a good, strong wind, air pollutants are dispersed more rapidly; when the air is calm, contaminant concentration increases. As a rough rule of thumb, contaminant levels are halved when wind speed is doubled. (This rule of thumb assumes no effect from topographical features.)

Contaminant levels are also affected by the amount of ***vertical mixing*** that occurs. Normally, temperature decreases with height; we have all noticed how much colder the air is on top of a high mountain. In urban areas, under such temperature conditions, a turbulent **mixing *area*** of air exists, characterized by swirls, gusts, updrafts, and downdrafts. This movement is partly attributable to the irregular surfaces of small and tall buildings, and hot and cold spots created by contrasting materials (asphalt or concrete vs. grassy park areas). Polluted air is carried upward and dispersed, while relatively cleaner air moves downward. The net result is that pollutants move up and away from us.

Under weather conditions in which temperature ***increases*** with height, much less vertical mixing occurs, and pollutants can grow thick in the breathing zone. Such conditions typically occur when a warm air mass moves over a cooler layer of air. In areas with basin-like topography, such as Los Angeles, high-pressure systems can develop in which air above the two-to-three thousand foot level dips and warms, while the air near the earth stays relatively cooler. Hazardous situations called "episodes" can last for days in such areas, often confining persons with respiratory difficulties such as emphysema indoors.



Under certain weather conditions, a "temperature inversion" can occur which traps contaminants and can promote unusually high levels of exposure.

The height of the source can also affect the distribution of pollutants in air. For ground-level releases, the highest concentrations 'are almost always near the source; for elevated sources such as stacks more than 30 feet above ground, however, the highest concentrations may be further downwind from the source. The size of the particles emitted is also relevant; larger particles are more likely to settle out near the source, while small ones will travel further in the air.

Groundwater

Groundwater, defined as water moving through soil and rock, is a common route for chemical movement. The source of groundwater contamination can include surface ***impoundments*** in which hazardous materials are disposed or stored, such as ponds and lagoons, leaking underground storage tanks, or any spill where contaminants can seep downward. The type of soil configuration is crucial in groundwater contamination. Some soil layers, such as clay, are harder for contaminants to move through (less permeable) and can protect the underlyinggroundwater.

While contaminants in rivers or streams are generally churned and diluted by movement as they are in the air, contaminants can move great distances in groundwater without dilution. Also, chemicals in the groundwater last longer; chemicals cannot evaporate, and they resist breakdown in the absence of air and light. It is difficult and sometimes impossible to purify contaminated groundwater.

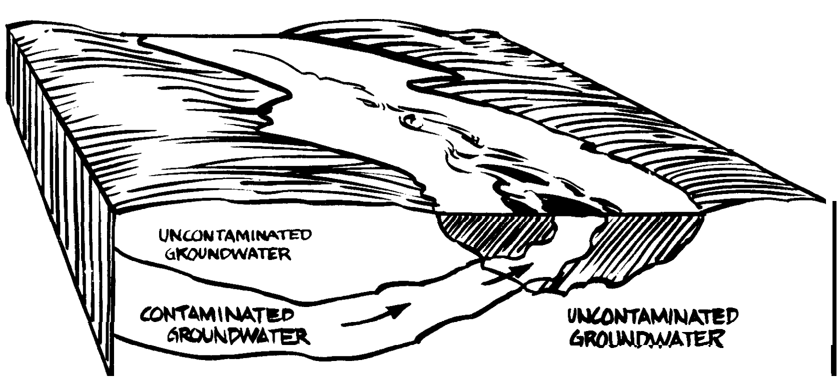
Surface Water

Surface water includes oceans, rivers, lakes, streams, or any above-ground water. It may be contaminated by industrial and sewage discharge pipes, chemical spills, or hazardous waste landfills.

The concentration of chemicals in surface water depends on the amount of the substance entering the water, its properties, and the water's rate of flow. Chemicals that are heavier than water, which include PCBS and dioxin, settle out in the sediment at the bottom and can remain there for long periods, while lighter chemicals will flow with the stream. Exposure to light, oxygen, and organisms will break down some chemicals; others, such as metals, are ***persistent*** and do not break down easily. Substances that are persistent may be transported to estuaries (areas where rivers meet oceans) and accumulate in shellfish and fish,

Soil

Soil may become contaminated through dumping, spills, and other sources. Rainwater leaches some contaminants from the soil and carries them to the ground-water; other contaminants remain near the surface, where they can affect human health by entering the food chain (ingestion), emitting toxic vapors (inhalation), or rubbing onto the skin of children playing in the dirt (dermal absorption). Because contaminated soil is a basic contaminant medium which affects other media, it is of considerable importance.

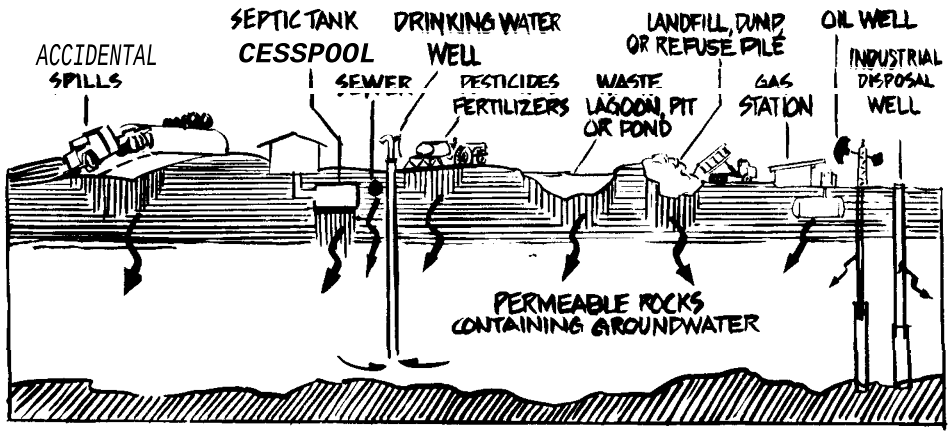


Surface water generally dilutes contaminants as it moves; they tend to break down as they contact air and light. Contaminants resist breakdown in groundwater and do not disperse readily because there is nowhere to go.

Once a contaminant has gained a foothold in one medium, it may be released into others as well. Whether this happens or not depends on the contaminant's characteristics and pathways available in the environment. Contaminants evaporate from the soil or water and enter the air through ***volatilization.*** Contaminants can also ***leach*** from the soil and enter water, or be blown by the ***wind*** and become airborne particles. When it rains, contaminated ***runoff*** from the soil can enter a stream. Therefore, it is impossible to simply place a chemical in one medium and forget about it. Careful thought must be given to how it may be released into other media.

SUMMARY

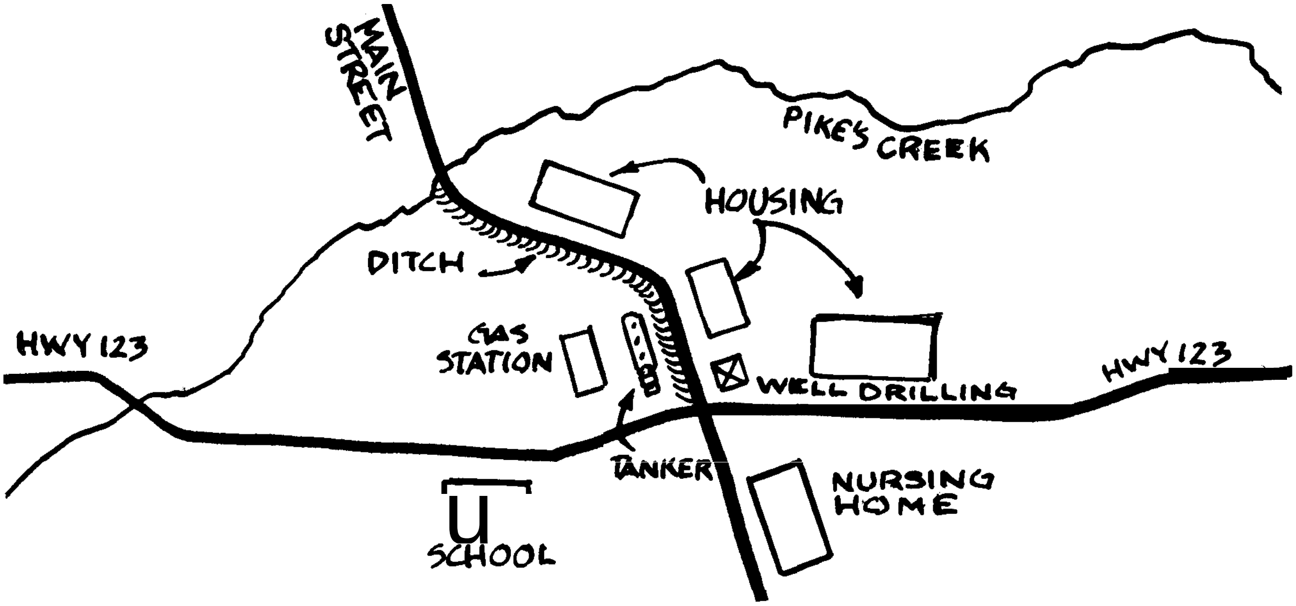
While we often associate our hazardous materials problems with industry, naturally occurring toxic substances, products used in average households, and automobiles all contribute to our country's challenge. Materials may be considered hazardous for different reasons—for example, some are liable to explode or burst into flame easily, while others can poison us. Poisons can enter our bodies by absorption, ingestion, inhalation, or injection, through various environmental pathways in different mediums.



Numerous sources contribute to groundwater contamination. Because groundwater is a source of drinking water for half the Nation's population, and because it is so hard to clean up, protecting this resource from contamination is a major concern.

Predicting how much of a substance will actually reach us from a particular source is complicated. Chemicals often follow complex pathways through the environment, leaving one medium to enter another, and being transformed and transported in different ways by each medium. They may either disperse harmlessly or become concentrated as they move through the food chain.

While our bodies have many internal defenses against poisons, these defenses can be overwhelmed. Whether we are exposed to chemicals all at once or gradually over time, we can reach a threshold at which harmful effects are noticeable—sometimes years after our first exposure. To ensure our health and safety, we should take reasonable precautions to limit our potential exposure to hazardous substances. ■



HAZ MAT TEASER

(answers on page A-1)

The driver of a gasoline tanker unloading at a local service station leaves his truck unattended for a short period of time. When the driver returns to his truck, he finds that the serice station's underground storage tank has overflowed and more than 1,000 gallons of gasoline are covering the ground and flowing down the street.

A strong odor of gasoline covers the entire spill area and extends downwind for several blocks. People who live downwind of the incident notice the gasoline odor and become concerned: a well driller in the area reports the odor to the local 911 dispatch center, a nursing home in the area starts to move patients inside from an outdoor recreation yard, and teachers from a nearby elementary school begin to bring students indoors from recess. The driver of the tanker works furiously to shut off the trucks delivery valves to halt the overflow; in the process, his pants and shoes become drenched with gasoline. Down the street from the service station, the gasoline is running into a roadside drainage ditch and soaking into the ground. Some of the product has also reached a small stream that flows through the area.

1. How would you assess the risk from this incident? What are some of the things to take into account when making your risk assessment?

2. What routes of exposure might affect the people downwind of the spill? What routes of exposure might affect the driver of the tanker?

3. Does the potential of a long-term exposure threat exist? If so, what type of exposure would this be?

4. What transport media (air, surface water, groundwater, soil) are involved in this incident? How are they involved?

5. Do the people in the nursing home and the students in the elementary school face any ***increased*** threats from exposure to gasoline fumes? If so, why?

CHECK YOUR MEMORY

(answers on page A-4)

1. While spraying pesticides, a farmer wears long pants, a long-sleeved shirt, and gloves. The farmer is trying to prevent contaminants from entering the body by:

   a. Dermal absorption c. Ingestion
   b. Injection d. Inhalation

2. Midnight dumpers have been leaving toxic waste in an illegal dump site in the woods. The soil beneath the waste is highly porous. A nearby house has a well which taps into this porous soil. Based on this limited information, through what ***medium*** is the well most likely to become contaminated?

   a. Soil c. Surface water
   b. Air d. Groundwater

3. You spill a toxic substance; you cough, and your eyes water. You are experiencing what type of exposure?

   a. Acute b. Chronic

4. You have just learned that a chemical you work with is a ***teratogen***. What effect does this chemical have?

   a. Increases the risk of cancer
   b. Increases the risk of physical defects in a developing embryo
   c. Causes a permanent change in the genetic material (DNA)
   d. Irritates the lining of the throat

5. When you are about to have a serious operation, the anesthetist is likely to use a substance which is:

   a. A CNS (central nervous system) depressant
   b. An irritant
   c. An asphyxiant
   d. A corrosive

6. Which of these groups would be likely to have the ***most extreme reaction*** to most types of toxic exposure?

   a. Adult women c. Children
   b. Adult men d. Adolescents

7. Groundwater is ***least*** likely to be contaminated under what circumstances?

   a. The waste is confined by an aged underground storage tank
   b. The groundwater is protected by a relatively impermeable protective layer, such as clay
   c. The contaminants are persistent
   d. The contaminants are highly soluble