TOPIC 6

N.I.M.B.Y. — There Is No Away in Throwing

Figure 3.26 Bulldozers pack down trash at a municipal landfill site.

In the past, pollution was primarily a local problem. With the advent of industrialization, the invention of motorized vehicles, and the population explosion, there was a huge increase in the production of goods and services. This was accompanied by a tremendous growth in waste by-products.

The acronym N.I.M.B.Y. (Not in My Backyard) is familiar to most people these days. It is an expression that summarizes people's growing awareness of the problems associated with waste production and storage. Human beings produce over 1000 billion kg of solid waste every year and it must be removed and stored. We may not even realize that wastes are entering our "backyard." Solid wastes are the easiest of the wastes to notice and the least mobile, but what about the wastes in our air and water?

Blowing in the Wind

In previous Topics, you have seen how acid precipitation results from pollutants entering the atmosphere, travelling great distances, and then creating environmental problems when they fall to the ground. In the past, natural sources such as forest fires and volcanic eruptions introduced the majority of pollutants into the atmosphere. While this is still true for most of the southern hemisphere, human activities are now the biggest source of airborne pollutants in the northern hemisphere. Besides the carbon, nitrogen, and sulfur oxides that you have learned about, soot from combustion of fossil fuels and dust from wind erosion accelerated by agriculture are the most common pollutant particles. In weaker concentrations are heavy metals such as lead, nickel, and copper, which result from industry or combustion processes. At one point in the early 1970s, the concentration of airborne lead in the northern hemisphere was about a thousand times higher than normal. Due to the wind patterns in the northern hemisphere, airborne particles and gas pollutants tend to concentrate at higher latitudes and are eventually washed out of the atmosphere by rain and snow.

DidYouKnow?

Inuit people living on Broughton Island in the high Arctic have higher concentrations of polychlorinated biphenyls (PCBs) in their blood than any other known population. These highly toxic organic chemicals result from industrial fires and are known to bioaccumulate in the food chain.

Figure 3.27 Air pollution from heavily industrialized regions in Europe and America are transported by circumpolar winds to the Arctic, where high levels of smog accumulate. The average transit time from Russia to Canada is only about three days.

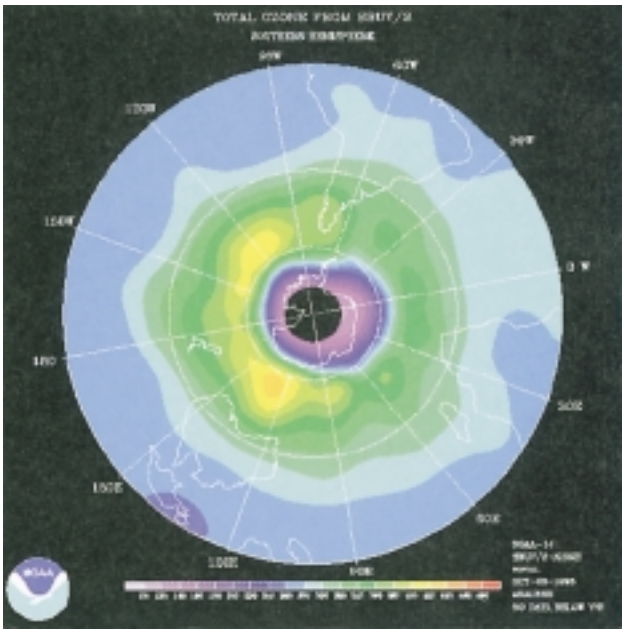


Figure 3.28 Ozone depletion over the South Pole is shown in this satellite image from October 5, 1995. Outside the polar vortex, green and yellow areas show raised ozone levels. Over Antarctica (outlined in white), however, stratospheric ozone levels are reduced by 80 percent or more from normal levels. The dark spot over the South Pole is a function of the measuring system.

Stratospheric Ozone and CFCs

Chlorofluorocarbons (CFCs) are yet another human-made pollutant that has far-reaching effects. Until recently, CFCs were used as:

- an agent in forming Styrofoam™
- propellants in aerosol cans
- coolants in air conditioners and refrigerators

Cheap, non-toxic, and stable, CFCs seemed ideal for these purposes. The discovery of a hole in the protective ozone layer over the Antarctic in 1985 (the result of the ultraviolet breakdown of the CFCs) was a real shock.

Ozone at Earth's surface is an irritating toxin, but ozone high in the stratosphere prevents ultraviolet radiation from reaching the surface of Earth. Without this protection, biological organisms at the surface experience damage to cells. In the stratosphere, ultraviolet light reacts with the CFC molecules to produce chloride ions. These chloride ions act as a catalyst for the breakdown of ozone ($O_{3(g)}$) gas to normal oxygen gas ($O_{2(g)}$). In 1997 the ozone hole over the Antarctic was larger in area than the continental United States, ozone levels over the Arctic were 40 percent lower than normal, and about 10 percent of all stratospheric ozone worldwide was destroyed! Since then, an 81-country agreement to stop the production and use of CFCs has helped. Unfortunately, the most useful property of CFCs for us — their stability — is also the biggest problem. Even though CFCs are no longer widely used, they will persist in the atmosphere for many years.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

What is the state of the ozone layer at this moment? Go to the web site above, and click on Web Links to find out where to go next. How does it compare to the information in Figure 3.28? Write your answer in your notebook.

Across Canada

Since the largest ozone depletion happens around the Poles, what better place for Hans Fast and other scientists to study this phenomenon than in the Canadian North? The location of the Arctic Stratospheric Ozone Observatory at Eureka, Nunavut, was no accident. Scientists needed to find a place with low enough latitude that the Sun was visible in early spring when ozone destruction is at its highest. There had to be enough Sun for scientists to use certain instruments for measuring ozone and the gases that affect ozone. The observatory also needed to be far from sources of pollution but close enough to a base station where scientists could live. Eureka has it all — its latitude is 80°N and it has a weather station that scientists can use for support.

About ten scientists study ozone at the observatory every winter and spring, but not at the same time. Hans visits the observatory every fall and spring to make sure everything is running smoothly. He also measures atmospheric gases that control the concentration of atmospheric ozone. Scientists at the observatory battle temperatures of –40° to –50°C in February and March. With such low temperatures, Hans and other scientists observe the atmosphere through hatches in the roof. Electric heater wires and heaters keep instruments mounted on the roof from freezing. These instruments measure the concentration of ozone and variations of tiny particles that are related to ozone destruction. Spectrometers also measure the concentration of atmospheric gases that have chemical reactions with ozone.

The results of all these tests show that the ozone layer in the Arctic is getting thinner. But since harmful substances have been reduced over the past ten years, Hans and other scientists think this will improve. Hans says that it'll be another few decades of measurements and observation before they can verify their predictions.

Controlling Water Pollution in Surface Waters

As you have learned, pollutants entering the general environment eventually find their way into our lakes and rivers as they are washed from the soil or out of the atmosphere. Most countries in the world have now enacted legislation to control the dumping of waste products into surface waters. Targeting point sources especially, these controls have greatly reduced the amounts of pollutants entering surface waters.

Most surface water pollution is due to everyday activities such as washing clothes or watering lawns. The resulting waste water is channeled away either through storm sewers for surface runoff or sanitary sewers for sewage. The law requires that the nitrates and phosphates from household detergents and other cleaning agents be removed before the water is returned to a watercourse. Sewage must also be treated to reduce the amount of organic material contained and to destroy disease-causing bacteria and viruses. As illustrated in Figure 3.29, chlorinating the waste water has been the method of choice for destroying bacteria and viruses, but recently high-intensity ultraviolet light has been used as well. What can be done about the problem of run-off from streets and yards, which carries fertilizers, pesticides, oils, and other chemicals into our surface watercourses? In addition, chlorinating waste water may result in the formation of cancer-causing agents. Is this an acceptable risk?

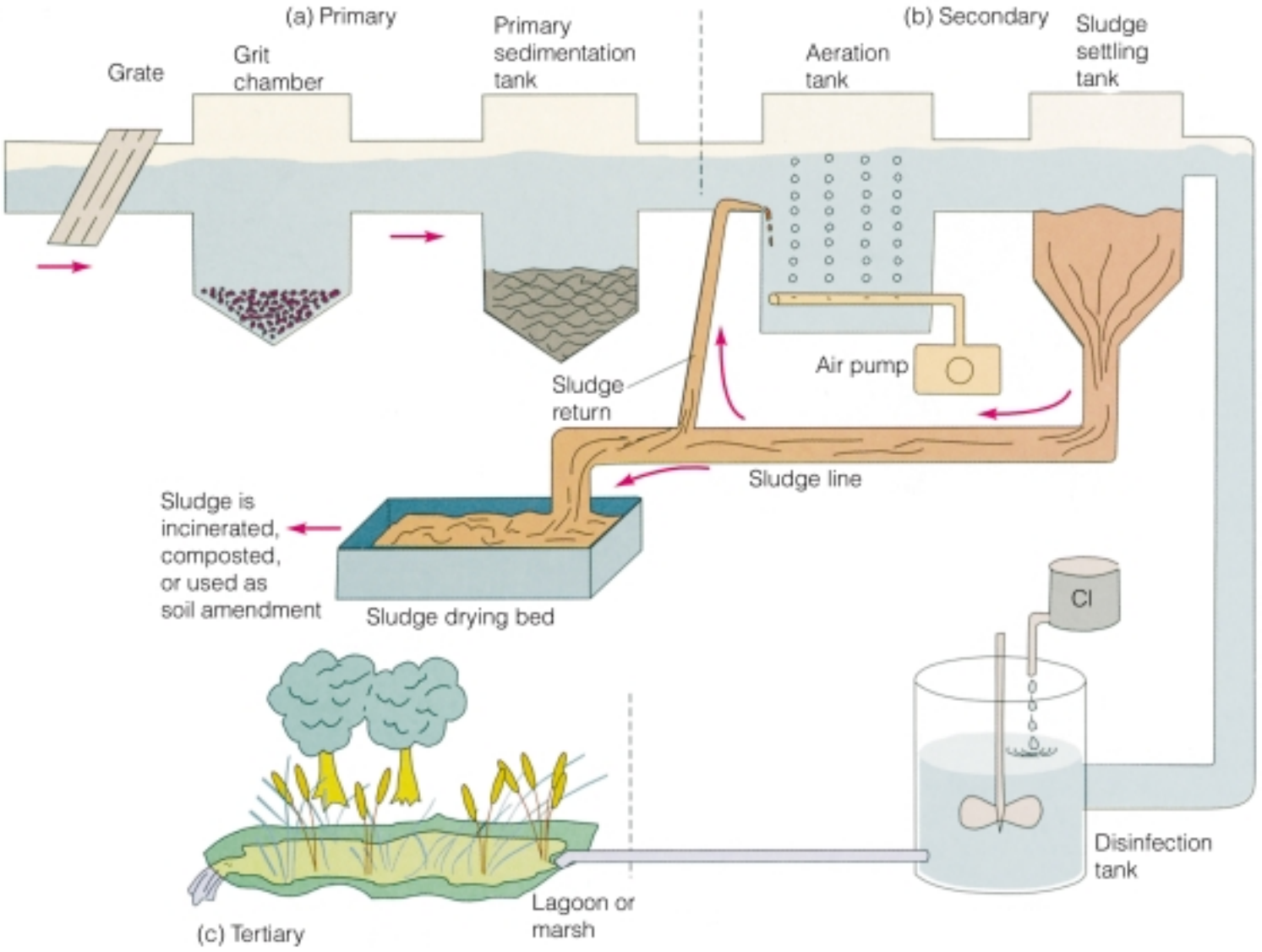


Figure 3.29 (a) *Primary treatment* physically separates large solids and suspended sediments. (b) *Secondary treatment* removes much of the organic compounds by bacterial decomposition. The resulting sludge is removed, and the remaining liquid effluent is treated by chlorinating or exposure to ultraviolet light to kill any disease organisms that have survived. (c) During *tertiary treatment*, percolation through soil into ground water, passage through a trickling bed evaporator and/or a lagoon or marsh removes the nitrates and phosphates that remain. A careful choice of the plants growing in the marsh can even remove some of the heavy metals within the effluent.

DidYouKnow?

According to Environment Canada, approximately 57 percent of Canadians are served by waste water-treatment plants, compared with 74 percent of Americans, 86.5 percent of Germans, and 99 percent of Swedes.

Figure 3.30 The water hyacinth plant removes many pollutants from water. Water hyacinths can be used at waste water-treatment facilities to clean water before it flows back into streams and aquifers.

Controlling Water Pollution in Ground Water

Most people think only of surface waters — oceans, lakes, rivers, and glaciers when they think of the effects of water pollutants. This is not where the attention of almost 8 million Canadians should be! About 26 percent of Canadians rely on ground water for their domestic water supplies. **Ground water** is water that filters down through soil and fills the spaces between particles of rock and soil, and the cracks and fractures in underlying rock. Like all water, ground water tends to flow down towards rivers, lakes, or the sea, but the rate at which ground water moves depends on how permeable the rock and soil formations are. Typically, ground water moves at an average of 15 m per year, although it is not unusual to find locations where a flow rate of a few centimetres per century is normal. There are some areas of this permeable material that can produce useful amounts of water when a well is drilled into them. These are referred to as **aquifers**. One common feature of aquifers is that the water is naturally filtered as it moves through and is usually free from bacterial contamination. Unfortunately, other contaminants dissolve into water and can become concentrated in aquifers. Problems with contamination are multiplying because of the increased use of toxic herbicides, pesticides, and solvents in industry and agriculture. Ground water contamination is very difficult, if not impossible, to clean up, so the best option is to avoid producing contaminants in the first place.

DidYouKnow?

The ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT states that:

"109(1) No person shall knowingly release or permit the release into the environment of a substance in an amount, concentration or level or at a rate of release that causes or may cause a significant adverse effect."

"112 Where a substance that may cause, is causing or has caused an adverse effect is released into the environment, the person responsible for the substance shall, as soon as that person becomes aware or ought to have become aware of the release, (a) take all reasonable measures to (i) repair, remedy and confine the effects of the substance, and (ii) remove or otherwise dispose of the substance in such a manner as to effect maximum protection to human life, health and the environment, and (b) restore the environment to a condition satisfactory to the Director."

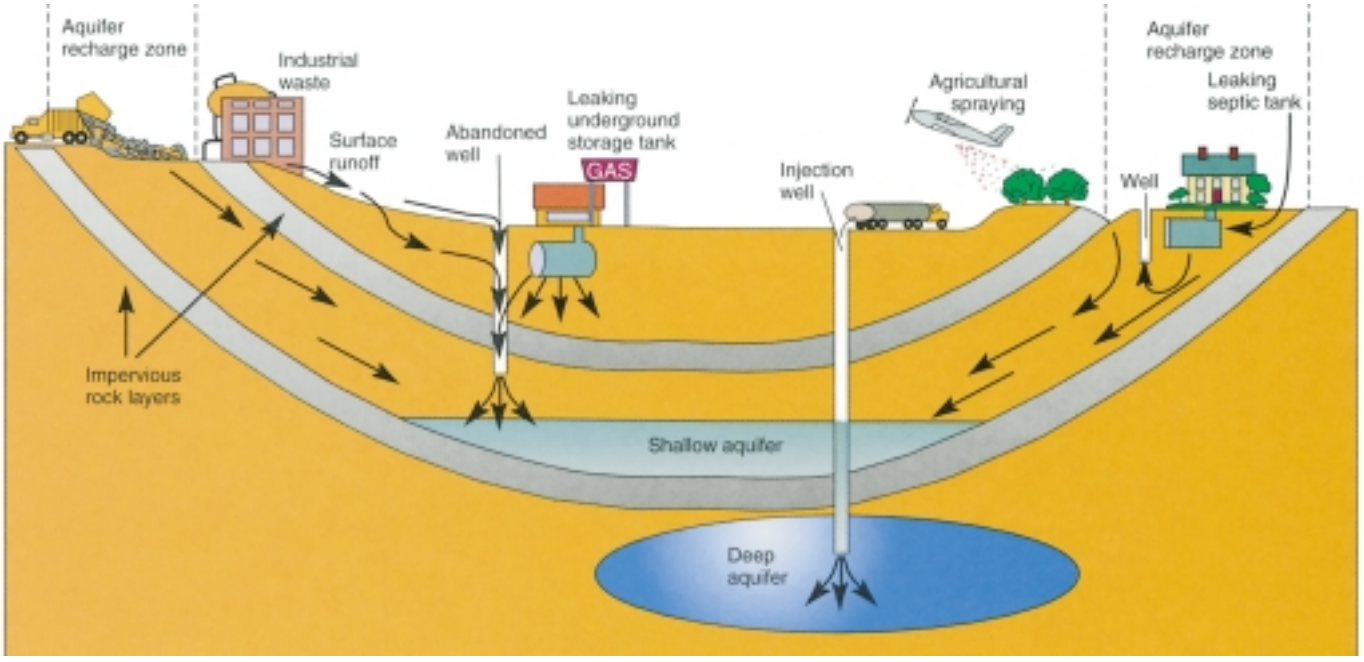


Figure 3.31 Possible sources of ground water pollution. Although much of what is shown in this illustration is now specifically prohibited in municipalities throughout Alberta, the result of these types of activities in the past require clean-up of some areas. What problems can you identify relative to the activities shown? Can you think of any practical ways to avoid the problems?

Pause & Reflect

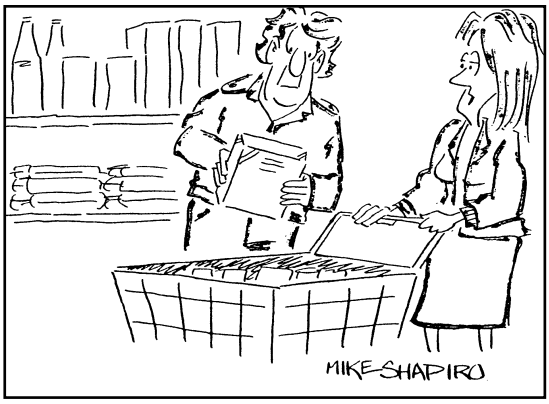
Demand for, and production of, automobiles soared in the 1950s and 1960s, resulting in great numbers of service stations to provide the fuel and oil to keep Canadians' vehicles on the road. Large underground storage tanks for petroleum products were installed at every site, but most of these tanks were made of steel and lacked any sort of corrosion protection. Within 15 years of installation, more than half the tanks were leaking significant amounts of petroleum contaminants into the soil. Consider that only one drop of oil can contaminate up to 25 L of water. How do companies clean up these sites? Do some research and write the answer in your Science Log.

Biodegradability and the Environment

Have you noticed that lately it seems as though everything is advertised as a "green" product? This designation was originally used to indicate that a product was biodegradable. **Biodegradable** substances are those organic compounds (natural or synthetic) that can be broken down by bacteria, fungi, and other simple organisms into carbon dioxide and water. With increasing public awareness of environmental hazards, it is more common now to find consumer products labelled "biodegradable" or "environmentally friendly." But can you take these claims at face value? While the label may proudly claim active ingredients are biodegradable, it doesn't tell you the other ingredients are not! A second problem is that while a compound may be biodegradable, it is not biodegradable under all conditions or in any reasonable period of time. Cultural anthropologists who have inspected old garbage dumps have recovered newspapers over 20 years old that are still readable! Landfills are often managed in a way that retards decay, because the production of gases resulting from decay is sometimes seen as a problem by the public. To avoid odours, the landfill may be kept dry. A lack of the proper mix of water, oxygen, and soil microbes prevent decomposition from occurring.

Bacteria and other microbes can decompose oil, but that same oil, when formed into a synthetic rubber tire, may never decompose. The organisms that would normally be responsible for decomposition cannot produce the chemical reactions or high temperatures necessary to break down the synthetic rubber. Even though oil and plastic contain almost exactly the same atoms, their different molecular structures result in different rates of decomposition. Table 3.6 illustrates the rate of biodegradation for some of the common substances found in household waste.

Finally, don't let labels fool you. A product may indeed be biodegradable and therefore a "green" product, but is it environmentally friendly? The decay products of many substances can actually be classified as hazardous wastes.



"It doesn't matter what it is. It's biodegradable."

Table 3.6

Rate of Biodegradation of Household Waste

Material	Time to biodegrade
cotton fabric	1–5 months
paper	2–5 months
orange peels	6 months
wool fabric	1–5 years
cigarette butts	1–12 years
milk cartons	5 years
plastic shopping bags	10–20 years
leather	25–40 years
nylon fabric	30–40 years
tin cans	50–100 years
aluminum cans	80–100 years
plastic 6-pack holder rings	450+ years

Career CONNECT

Dr. Roger Saint-Fort

Not many people think wading through garbage is an exciting way to make a living, but Dr. Roger Saint-Fort thinks so. As an environmental chemist and a Mount Royal College professor, he researches many aspects of the environment, from biological treatment of waste water and biofiltration to organic and inorganic contaminants in soil and ground water systems. In his classes he teaches students about:

- waste management (how to best manage garbage with the least harm to the environment)
- ground water contamination (chemicals in ground water systems)
- environmental instrumentation (the tools of the trade, including atomic absorption spectrometer, gas chromatographs, and infrared); these machines help chemists separate and analyze samples
- soil remediation (how to remedy contaminated soils)

Roger conducts research projects for various industries in the college laboratory. One of Roger's research projects involves analyzing garbage at Calgary landfills. He and his students filled huge drums with landfill material and let it settle for five years. Then they looked at what had biodecomposed as well as the leachate, the liquid produced by decomposing garbage. After five years, items such as pop cans, pizza boxes, and newspapers were virtually unchanged.

Roger says that some of the biggest challenges in this field are the misconceptions. People think that plastics are worse for the environment than are kitchen wastes. But kitchen waste decomposes and creates harmful gases and leachate — a more serious problem than plastics, which do not decompose. With the growing population causing more strain on waste management, Roger predicts the landfill will be full in about 30 years. To prevent this, he feels there needs to be a large-scale composting effort in cities and a sustainable effort to minimize waste rather than just reactions to the issue when it's too late.

There are many different research areas of environmental chemistry. Find out more about an area that interests you by doing research at the library or on the Internet. These areas could include: soil or ground water remediation; soil contamination, and screening for toxins in contaminated soil.

Word CONNECT

The word "degrade" comes from the Latin word *gradus*, meaning "step." The prefix *de-* is used to indicate removal or separation. "Degrade" is used in a chemical sense to signify the reduction of a chemical to a simpler molecular structure. The word itself is the Middle English version of the Old French verb *dégrader*, which in turn was taken from the ecclesiastical Latin verb *degradare*, used by clerics and monks to signify lower quality or character. Look up the meaning of "degrade" in a dictionary. In your notebook, explain how this meaning relates to the origins of the word.

*"They didn't tell **me** what to do with it. I thought they told **you** what to do with it."*

Hazardous Wastes

A **hazardous** waste is any discarded material that contains substances that are known to be poisonous, toxic, corrosive, flammable, or explosive. This certainly sounds serious, and it is! You would be surprised at the number of potential hazardous wastes to be found in your own home. The average Canadian household contains about 12–40 L of hazardous waste. You can easily recognize hazardous products because they are required to indicate their hazardous nature with a clear, highly visible signal word. The words DANGER and POISON are meant to indicate that the substance marked is highly toxic, corrosive, flammable, or explosive. WARNING and CAUTION are used to indicate a moderate or slight toxicity respectively. In addition, the substance must have all appropriate WHMIS symbols clearly displayed. Table 3.7 is not an exhaustive list of household hazardous substances, but you will probably recognize many of these in your own home.

Skill FOCUS

To review the WHMIS symbols, turn to Skill Focus 1.

Table 3.7

Hazardous Household Substances

Kitchen area	Bathroom area	Garage/storeroom
sink cleaners	tub and tile cleaners	paints, thinners, and glues
drain cleaners	disinfectant sprays	lawn and garden herbicides
floor wax/cleaner	nail polish and removers	ant traps or powders
oven cleaners	prescription medicines	degreasers
silver polish	hair dyes and cosmetics	antifreeze and gasoline
furniture polish	toilet cleaner	motor oil and brake fluid

You may notice that many of the hazardous substances in your home are used for cleaning purposes. The property these substances share is that they are all solvents. A **solvent** is any substance that can be used to dissolve another substance. Water, you may remember, is the most common solvent. Household products such as paint thinners, spot removers, turpentine, and nail polish remover are almost 100 percent solvent. Furniture oils, glues, paints, and shoe polish contain fewer solvents, but they do contain solvents. Many of these solvents are classified as organic because they are based on hydrocarbon compounds. It is important to note that ALL organic solvents are hazardous. Almost all organic solvents are poisonous if swallowed or inhaled in a large enough amount, and will cause rashes after repeated exposure. High concentrations of most solvents will result in dizziness, nausea, fatigue, and loss of co-ordination. Long-term exposure to many solvents can result in brain damage.

INQUIRY

INVESTIGATION 3-K

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

A Survey of Household Hazardous Wastes

Household hazardous wastes can be toxic to humans, and can burn, catch fire, or explode. The solvents in them evaporate quickly and are especially dangerous because often they are difficult to detect, having no colour or long-lasting smell. You might breathe in their vapours without realizing it. To reduce risk, always label them well (preferably in their original containers) and store in a secure, dry location. Seal all lids and caps and ensure that they are childproof. Keep these products away from heat and open flames. Some common toxic organic solvents in hazardous household products are:

- aromatic hydrocarbons (toluene, xylene)
- isopropyl alcohol or methyl alcohol
- chlorinated hydrocarbons (ethylene dichloride, methylene chloride, perchloroethylene, trichloroethylene, trichloroethane)
- naphthas
- petroleum solvents (kerosene, gasoline, mineral spirits)
- turpentine and acetone

Finally, although latex paints are water-based, they are not without toxic risk. Some latex paints contain a mercury-based fungicide as a preservative. As a heavy metal, mercury is toxic.

Skill FOCUS

For tips on using the Internet and making graphs, turn to Skill Focus 9 and 10.

Part 1

Question

How many and which types of hazardous wastes are found in the average household?

Safety Precautions

- Take care when inspecting products that you identify in your search. Remember these are HAZARDOUS products. Do not spill the contents during your inspection and avoid any container that is leaking. Wash your hands thoroughly if any of the products touches your skin, and after you finish your survey.

Apparatus

felt pens or coloured pencils

Materials

poster paper

Procedure

1. Search your home for products likely to be hazardous. You may wish to enlist the help of a responsible adult. In general you will look for, but should not limit yourself to, the following:

adhesives	drain openers	batteries
automobile oil and gas products	fungicides and wood preservatives	paint stripper and thinners
grease and rust solvents	oven cleaners	wood and metal cleaners
pesticides	lighter fluids	paints
nail polish and nail polish removers	flea collars and shampoos	wood and metal polishers
bleach	spot removers	antifreeze
ammonia	laundry detergents	aerosol cans

CONTINUED ▶

2. For each hazardous product you find, note the major hazard indicated on the label and count the number of cans or bottles found. **Record** your findings in a clearly labelled data table or chart. Use the following categories as headings:
   (a) paints and solvents
   (b) pesticides
   (c) household cleaners
   (d) automobile products
   (e) other
3. Ensure the product is safely stored before you search for the next one.

Analyze

1. Which of the five categories contained the most household hazardous products found in your home?
2. Construct a bar graph illustrating your totals in each of the areas (a) to (e) as compared to the class average.
3. Would you expect every student in the class to have obtained similar results to yours? Explain your answer.
4. Based on your survey, what hazard category did most containers fall under — Dangerous, Poisonous, Flammable, Explosive, or Toxic?

Conclude and Apply

5. How safely stored were the hazardous products you identified? What are the consequences of incorrect storage of those products?

Part 2

Question

What are the hazards involved in use and storage of paints and adhesives?

Procedure

1. Carefully study the label on one of the paints or adhesives that you found during your survey of your household hazardous wastes. Is the solvent used in that product listed by name? If it is, **record** the name. If the solvent is not listed, **record** the name of the product, the name and address of the manufacturer, and any contact information supplied (e-mail address, web site, telephone number).
2. If the solvent is not listed on the label, contact the manufacturer and request an MSDS sheet for that product. This will allow you to proceed to step 3.
3. After determining the name of the solvent in the chosen product, search the Internet for any information about that solvent. You should be able to describe:
   - what the solvent is
   - what happens to the solvent when it enters the environment
   - likely methods of exposure
   - how that solvent can affect your health
   - how you might medically determine whether you have been exposed or not

   If possible, also try to obtain the LD50 information relating to that solvent. The Agency for Toxic Substances and Disease Registry (ATSDR) is a good place to start.
4. Prepare a one-page poster that summarizes the information you obtained in step 3.

Analyze

1. Why is exposure to paint (oil-based or water-based) likely to cause health problems?
2. Why should you avoid contact with solvent-based adhesives?
3. How easy was it for you to obtain information relative to the actual risks and actual toxic effects of the solvent that you investigated? Are there any reasons to explain the ease or difficulty of your task?

Waste Management — Back to the 4 Rs

Garbage is any material for which we no longer have a use — old paper, plastic, food scraps, tin cans, glass bottles, used motor oil, motors — you name it! Fortunately, we no longer consider surplus pesticides or cleaning products to be garbage but hazardous wastes. However, whether garbage or hazardous waste, we still have the problem of disposing of it.

The environmental movement involves four principles — the 4 R's: Reduce, Reuse, Recycle, and Recover. Reduce is the preferred option of the four, because it has the most potential to change things. If goods are not manufactured in the first place, then not only will they not be present to be discarded but there will be a saving of the materials and energy needed to make those goods. Lower costs are a direct result. Reuse and recycle are a good second option. One person's "trash" is, from another viewpoint, someone else's untapped resource. Paper waste forms one quarter of the mass of municipal garbage and almost all of it can be recycled. Glass and metals account for a total of about 8 percent, and plastics about 6 percent of the wastes we generate. Of course not all of the glass, metals, or plastics can be recycled, but at least some of it can be. Yard wastes (about 20 percent) and food wastes (about 9 percent) are usually biodegradable, thus reducing the quantity of waste even more. So why do we need landfills?

Figure 3.32 Old tires don't decay and are almost indestructible. The high temperatures needed to break them down may result in toxic emissions, so dumping in landfills has been the traditional solution.

Math CONNECT

The average Canadian generates an average of 2 kg of unwanted materials per day. The population of Canada is about 30 500 000. Find out the current population of your province. Then calculate the amount of unwanted materials generated per day in your province and in Canada. If 1 kg of trash takes up 0.004 m^3 of space, how tall would a column of the trash produced by your province be, if the column's base had an area of 1 m^2? (The Calgary Tower is 190 m tall. How would the pile of trash compare?)

Although recycling does incur costs for transporting, handling, sorting, cleaning, and storing, it nonetheless has many advantages. For example, the production of recycled paper requires 58 percent less water and generates 74 percent less air pollution than when paper is made from trees.

Recycling one single aluminum can saves enough energy to run a television set for 3 h. The energy needed to make one brand-new can from aluminum ore is enough to recycle 20 aluminum cans. Recycling conserves resources, but recycling is a voluntary activity. How might municipalities encourage more people to recycle?

DidYouKnow?

Edmonton's Waste Management Centre enables the city to divert 70 percent of its residential wastes away from landfill. The facility is one of the largest of its kind in North America and complements coexisting recycling programs by separating recyclable materials from compostable materials. Organic wastes — including paper and cardboard that are not able to be recycled — are mixed with sewage sludge from the city's waste water-treatment plant. Slow mixing occurs over one to three days in giant drums, 74 m long and 4.9 m in diameter. After mixing, the material is screened to remove non-biodegradable materials and then sent to aeration bays for optimum composting. State-of-the-art odour-control systems capture, cool, scrub, and biofilter the air from the entire facility before venting to the outside environment.

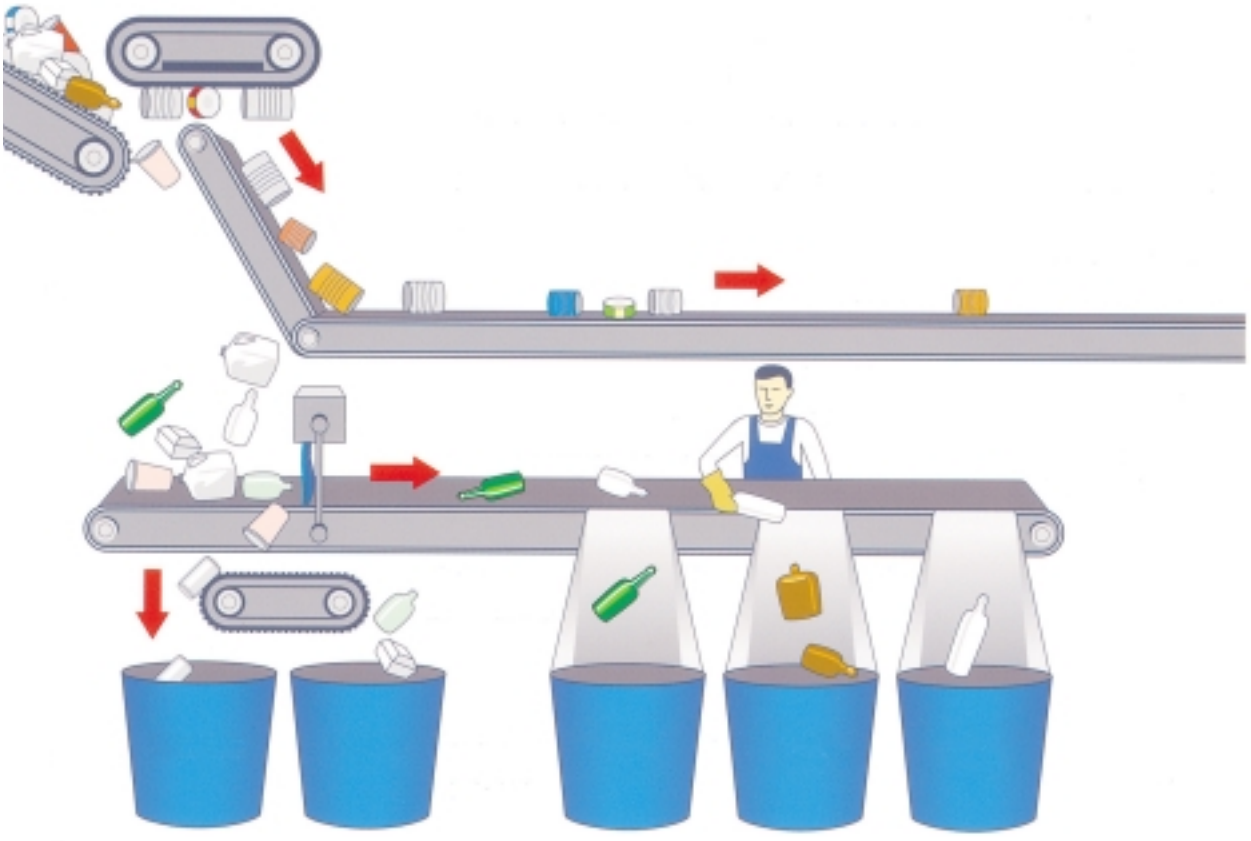


Figure 3.33 Recyclable materials first go to a material recovery facility, where they are sorted mechanically and manually. Glass is separated by colour — amber, green, or colourless. Plastics are sorted by type.

Landfill Construction and Design

Despite the best efforts of even the most aggressive recycling campaign, a considerable amount of material needs to be dumped in a landfill. In the absence of efficient recycling, the garbage that reaches a landfill is almost 60 percent organic. The increased noise, traffic, and mess associated with daily operation of a typical landfill are some of the concerns that lead to a N.I.M.B.Y. response. A sanitary landfill is one short-term solution. As you can see in Figure 3.34, much of the garbage in a **sanitary landfill** is covered each day to avoid windblown litter and attracting scavengers. Most modern sanitary landfills incorporate a clay liner (and some add a plastic liner) that prevents fluids from filtering down into ground water supplies. **Leachate**, the liquid that results as wastes decompose and rainwater filters down through the landfill, is collected and sent to waste water-treatment centres. The anaerobic conditions created by burying organic waste results in the production of methane and carbon dioxide. Methane will filter up to the surface and cause safety problems due to the risk of explosion. At many landfills, methane is piped to the surface and burned or "flared off" in a controlled manner.

Figure 3.34 In a sanitary landfill, trash and garbage are crushed and covered each day to prevent accumulation of vermin and spread of disease. A waterproof lining is now required to prevent leaching of chemicals into ground water.

STRETCH Your Mind

Disposable diapers account for almost 2 percent of the total volume of our landfills. This may sound like a lot of diapers, and it is, but then you need to consider that most parents change anywhere from 5000 to 10 000 diapers per child. Critics of the use of disposable diapers point out that such diapers are made from mostly synthetic materials, require vast amounts of energy to produce, and are really not very biodegradable, so they will last almost forever in a landfill. Industry representatives are quick to point out that growing the cotton for cloth diapers uses vast amounts of pesticides and chemical fertilizers, and the washing of cloth diapers requires large amounts of energy, disinfectants, detergents, and water. So which method, cloth or disposable, would you use as an ecologically conscious parent? It's your choice.

DidYouKnow?

At Edmonton's Waste Management Centre, the production of methane gas by decomposing garbage in the Clover Bar landfill is fully exploited. Over 100 wells have been sunk deep into the landfill. The methane gas is withdrawn, purified, and shipped by pipeline to the nearby Clover Bar Generating Station, where it is burned to create electricity. At maximum capacity this process provides enough gas to meet the electricity requirements of 3600 houses, and the City receives royalties of between $30 000 and $75 000 per year, depending on how much is captured.

The City of Edmonton uses methane gas from its landfill to produce electricity for residental use.

Secure Landfills

Hazardous and toxic wastes represent a different sort of challenge. They must be disposed of in specific ways. **Secure landfills** use the same clay liner system as other landfills, but it is overlaid with a layer of gravel, a grid of perforated drain pipes to collect any seepage, and a final thick plastic liner backed by soft padding. Sand cushions the plastic liner from the drums of waste, which are stacked into the landfill. Thick layers and walls of soil separate the drums if seepage occurs. When full, the landfill is capped by clay, plastic, and soil. Wells are drilled outside the site to monitor any possible leakage from the site.

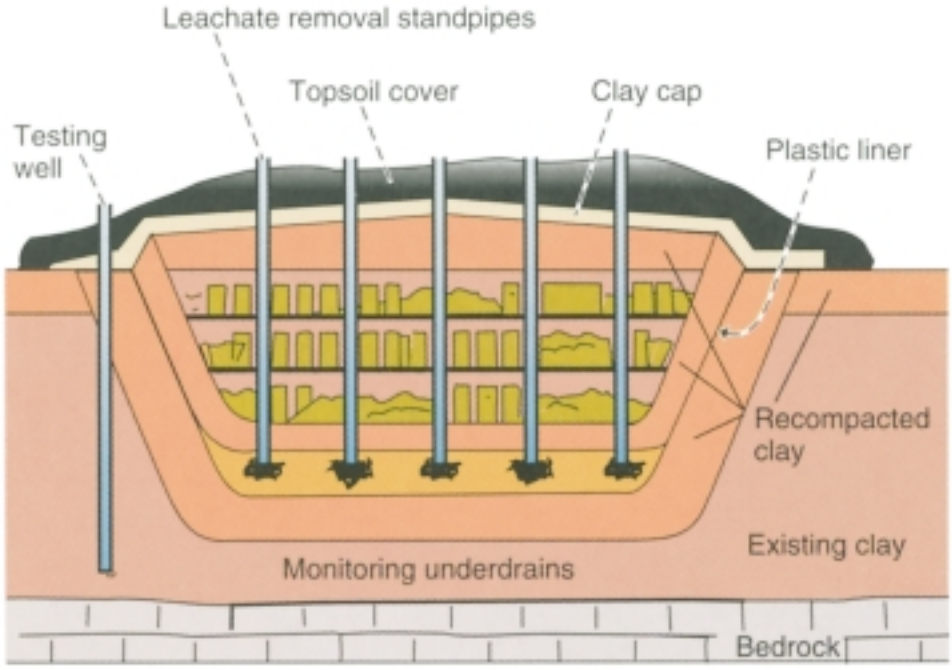


Figure 3.35 A secure landfill for toxic waste. Contents are enclosed by a thick plastic liner and two or more layers of impervious compacted clay. A gravel bed between the clay layers collects any leachate, which can then be pumped out and treated. Testing wells sample for escaping contaminants.

DidYouKnow?

At the Swan Hills Treatment Centre, hazardous and toxic wastes are destroyed by incinerators that operate at 1200°C. The oxide gases and particles produced by these extreme temperatures are passed through a scrubbing system, and the residue is stabilized. Inorganic solid wastes that aren't reduced by incineration methods are treated chemically and physically to form stable compounds. Liquid inorganic wastes are chemically reduced and neutralized, then filtered to remove solids that form. Those solids are stabilized to an inert compound. All solids formed in treatment are deposited in a secure landfill, and any liquids are treated, then injected into a stable rock formation almost 2 km below the surface.

Find Out ACTIVITY

Garbage In, Garbage Out?

When garbage is put into landfills, it is covered under other trash and soil and isn't exposed to sunlight and other things that help decomposition. When examined by a researcher, one landfill was found to contain grass clippings that were still green and bread that had not moulded.

In this activity, you will make a model of a sanitary landfill and compare and contrast the decomposition of different materials in a landfill.

Safety Precautions

- Be especially careful not to expose your skin or eyes to garbage items.

Materials

scissors
2 2L plastic bottles
soil
thermometer
plastic wrap
graph paper
rubber band
trash (including fruit and vegetable scraps, a plastic item, a metal item, a foam cup, and notebook paper or newsprint)

Procedure

Performing and Recording

1. Cut off the tops of two 2 L bottles.
2. Add soil to each bottle until it is half filled.
3. On graph paper, trace the outline of all the garbage items that you will place into each bottle. Label each outline and keep them.
4. Place the items, one at a time, in each bottle. Completely cover each item with soil.
5. Add water to your landfill until the soil is slightly moist. Place a thermometer in each bottle and seal the bottle with the plastic wrap and a rubber band. Store one bottle in a cold place and put the other on a shelf.
6. Check the temperature of your landfill on the shelf each day for two weeks. Record the temperatures in a data table that you design.
7. After two weeks, remove all of the items from the soil in both bottles. Trace the outlines of each on a new sheet of graph paper. Compare the sizes of the items with their original sizes.
8. Be sure to dispose of each item properly as instructed by your teacher. When you have completed the investigation, remove your gloves and wash your hands thoroughly.

What Did You Find Out?

Analyzing and Interpreting

1. Most decomposition in a landfill is due to the activity of micro-organisms. The organisms can live only under certain temperature and moisture conditions.

   Explain how the decomposition rates would have differed if the soil had been completely dry.
2. Compare your results with the results from the bottle that was stored at a cold temperature. Explain the differences you observe.
3. Why do some items decompose more rapidly than others?
4. What problems are created in landfills by plastics?

Figure 3.36 Mustard plants

Bioremediation — Mother Nature to the Rescue

You have already seen how water hyacinths can help remove pollutants at waste water treatment centres. Plants tend to take in pollutants through their roots and either concentrate and store those pollutants, or in many cases change those pollutants to less noxious forms. Mustard, fescue grass, and the familiar poplar tree are examples of plants that reduce hazardous substances to less harmful forms. Mustard and fescue grass (shown in Figures 3.36 and 3.37) are currently being used to remove selenium metals from contaminated soils left by irrigation. This method of using living organisms to fix a problem is referred to as **bioremediation**, and is a cheap and effective alternative to other methods of waste treatment.

The discovery of bacterial species that can attack and break down some of the more persistent and toxic wastes is yet another method of bioremediation. Normally these bacteria have very limited range, a result of the extreme conditions where they live. Some exist only at high temperatures and/or pressures. Some are able to survive only in extremely acidic or anaerobic conditions. Container tanks called **bioreactors** house these bacteria in appropriate conditions where contaminated ground water is pumped in and the bacteria are encouraged to go to work. Who knows? In a few years we may be able to eliminate the need for landfills completely.

Figure 3.37 Fescue grass

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To find information about the Environmental Protection Agency's Citizen's Guide to Phytoremediation. Go to the web site above, and click on Web Links to find out where to go next. In your notebook, write a paragraph or two presenting your opinion on this issue.

TOPIC 6 Review

1. Why is it that although we are no longer producing chlorofluorocarbons (CFCs), the ozone layer is still being destroyed?
2. What are the main steps in sewage treatment? Describe the purpose of each step and the overall purpose of sewage treatment.
3. What is the difference between ground water and surface water?
4. What makes a waste a hazardous waste? List five hazardous wastes around your home and describe how you would dispose of them.
5. **Apply** There are 15 fewer trees cut down for every 1200 kg of paper recycled. For a large city, 150 000 kg of paper are recycled every month. How many trees are saved every year due to recycling?

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

pollutant
pollution
toxicity
acute toxicity
chronic toxicity
LD50
non-persistent wastes
persistent wastes
biological indicator
macroinvertebrate
point source
non-point source
ground water
aquifer
biodegradable
hazardous
solvent
sanitary landfill
leachate
secure landfill
bioremediation
bioreactor

Reviewing Key Terms

1. Explain the term "pollution." (4)

2. Explain the phrase "the danger is in the dose." (4)

3. Why is the toxicity of a substance expressed as an LD50 measurement? (4)

4. What makes the macroinvertebrates such a good biological indicator species? (5)

5. Why is it worse to have a point source discharge into ground water than it is to have it discharge into surface water? (5)

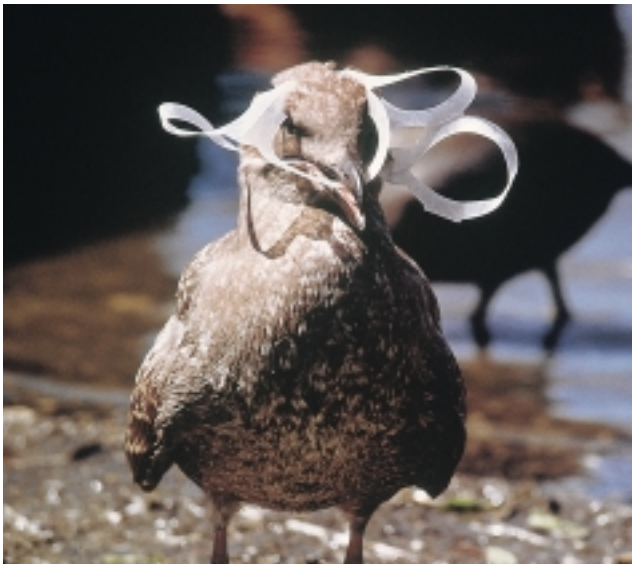
6. Why do most glues come with warnings about avoiding skin contact and the importance of keeping the lid on the container when not being used? (6)

Understanding Key Concepts

7. Explain how heated water that is discharged by a power plant can be a pollutant. (4)

8. Describe how excess agricultural run-off in the spring leads to a decrease in the number of stonefly and dragonfly larvae downstream of where the run-off enters the water. (5)

9. The young western gull in the picture is unable to remove the plastic six-pack holder tangled around its head. Recycling reduces litter and may have prevented this unfortunate occurrence. Describe three other reasons why recycling is beneficial to the environment. (6)



10. Describe the differences between a sanitary and a secure landfill. What is it about a landfill that makes it "sanitary"? (6)

11. You may be surprised to find that fluorescent light bulbs are classified as hazardous wastes. Investigate and explain why this is so. (6)

12. Many small coastal towns and cities extend sewage pipes out into the ocean and release untreated sewage directly into the seawater. What two mechanisms might be acting to reduce or prevent this from being a severe case of pollution? (6)

UNIT 3

Ask an Expert

After graduating from the Chemical Technology Program at NAIT, Heather Sumner put her interest in science and the environment to work. She started in a laboratory as a chemical technologist analyzing samples. She then moved to the field as an environmental consultant at Green Plan Ltd. in Edmonton, where Heather has worked on many projects and offered her nine years' experience to businesses and the government to help make Alberta a cleaner place to live and work.

Q **How did you turn your love of science into a career as an environmental consultant?**

A I started working in an environmental laboratory and became familiar with that aspect of environmental chemistry — working with soil and water samples from various monitoring programs. Then I decided to do something different. I worked for an environmental sampling equipment supplier for about a year and that is where I was introduced to environmental consulting.

Q **Has your experience in both the laboratory and the field been beneficial to you?**

A Yes, definitely. Working for both sides has been helpful because now that I am submitting samples to the lab, I understand what the technologists require in order to get the best results.

Q **What does an environmental consultant do?**

A We prepare different types of assessments and reports for clients, depending on what they need. Basically, it starts with us looking at the historical background and use of a property. Then we determine if there is a need to collect any soil or water samples from it. If we find that there is some contamination, the next step is to find out how much and where it ends. Lastly, we determine how to do remediation and clean-up.

Q **How do you collect samples?**

A To collect soil samples, I use hand augers or core samplers. We may hire a licensed driller if there is going to be lots of test holes. Also, past a depth of a metre or two, we have to get the heavy-duty equipment to drill down that far. For water samples, we have a licensed drilling contractor install ground water-monitoring wells, and then we use bailers to collect samples.

Q **Is your job finished once you collect the samples?**

A No. Once I collect the samples and get the results back, I generally prepare a report for my client, detailing the work I've done, the methods I used, the lab results, and an interpretation of the results.

Q **Is the report shared with a government body?**

A Reports have to be submitted to Alberta Environment so that they are aware of the issue on the property. They keep records about the property and can take steps to ensure that any contamination is cleaned up.

Q **For what are the samples analyzed?**

A There are many things. Samples can be tested for heavy metals, hydrocarbons such as gasoline and diesel fuels, or salt contamination. It runs the gamut, but those are what I have been exposed to since I've been consulting.

Q **What do you enjoy most about your job?**

A I do a lot of work outdoors. I am lucky because I have a balance between indoor and outdoor work. If I am not in the field, I am in the office writing reports. It is fascinating. You can have a manual or training, but that doesn't always work in the field. There are always different situations that you have to adapt to.

EXPLORING **Further**

Supercritical, Super-Useful

Once environmental chemists like Heather Sumner have identified contamination in soil, environmental companies use a form of carbon dioxide to clean it. The carbon dioxide is brought up to a certain pressure and temperature. In that state it becomes a supercritical fluid. It behaves a little like a liquid and a little like a gas.

Use your local library to find out more about supercritical fluids and the research that is being carried out with them around the world. As a starting point, go to

www.mcgraw.ca/links/sciencefocus9

An *Issue* to Analyze

A SIMULATION

Not in My Backyard

Think About It

Ammonia (NH_3) is a colourless, pungent gas at room temperature. One of its compounds, ammonium nitrate is used to make fertilizers and explosives.

Commercially, ammonia is produced by reacting nitrogen with hydrogen at high temperatures and pressures. The hydrogen for this reaction is purchased from industries that use hydrocarbons. Thus ammonia plants are near petrochemical plants.

Suppose that you live in a small, rural community that has grown up around a petrochemical plant. The president of a new chemical company wants to build a chemical plant nearby. This plant will process ammonia to produce fertilizer and precursors for explosives. The president assures the Town Council that the plant will not manufacture the explosives. The company will purchase land near the edge of town, very close to a marsh that is a nesting area for wetland birds such as cormorants, ducks, bitterns, and red-winged blackbirds.

The company expects to employ up to 150 local residents, mostly for manufacturing jobs. There will also be openings for engineers and chemists. Local farmers expect to benefit from reduced fertilizer costs. Some townspeople, however, are concerned about the consequences for the environment and human health, especially the effects of fumes, gaseous emissions, and potential spills.

The plant will be equipped with pollution-control technologies. As well, every effort will be made to minimize spills and leaks. The proposal includes an action plan, explaining what to do if a spill or leak does occur. This action plan will be delivered to every home.

A town-hall meeting is scheduled for next week so people can ask questions and voice their concerns at this meeting.

Plan and Act

1. The following people have submitted requests to make formal presentations at the meeting:
   - an area farmer
   - a member of an environmental advocacy group
   - a chemist who lives in the community
   - a town resident who has a respiratory illness
2. The following company representatives will also speak at the meeting:
   - the president of the company
   - the architect who will design the plant
   - a chemical engineer
3. As a class, discuss the information presented in Think About It. Clearly identify the issue faced by the community.
4. Your teacher will give your group the role of one of the people making presentations at the meeting. As a group, discuss the point of view you are likely to hold in your role. Think about the kind of information you will be expected to supply to others and how you will obtain that information. How could you persuade others to your point of view? If in your role you are in favour of the plant, what alternatives might you present that will lessen the risks people anticipate or increase the benefits? If in your role you are against the plant, what alternatives could you present?
5. As a class, your task is to assess the alternatives that are presented at the meeting and to ensure that the consequences of each alternative have been explained clearly so that you can assess the risks and benefits of the new chemical company. You will then recommend to the mayor (your teacher or another person) whether the application for the new company should be accepted or rejected.
6. When the Town Council has made its decision, go back to your group and evaluate the decision on the basis of all that you have learned. If it is a good decision, you may decide to vote for the plant as a community. If you feel that there were some faulty steps in the above process, you may wish to repeat it.

How Can Science Help?

With your group, write down some of the ways that science could help you examine and assess this issue thoroughly, find and evaluate alternatives, and come to a decision. You might want to monitor the area now for environmental and human health and obtain the plant's forecasts for how this is expected to change and how any harm can be mitigated. You will need to decide what data you require and the most efficient way to collect and record it. You might want to set up a comparison study with another community with a similar plant to find out if spills and leaks have occurred and what kinds of remediation were undertaken, with what level of success. Be as thorough as you can in preparing this part of the task. The better informed you are and the more concrete information you can provide, the better equipped you will be to discuss the issue and to develop alternatives that will help to resolve the issue.

Analyze

1. Compare the presentations on the basis of their scientific soundness, logic, and passion.
2. In what ways did your understanding of science and technology help you in this project?

UNIT

3 Review

Unit at a Glance

- Nutrients are compounds or elements that are essential for production of the organic matter that makes up living organisms.
- Organic nutrients are carbon-based compounds such as carbohydrates, proteins, lipids, and vitamins, which are produced by green plants and modified by animals.
- Inorganic nutrients — the minerals — are divided into macrominerals and trace elements, depending on how much is needed for normal health.
- Minerals are essential components of enzymes and vitamins, the molecules that help regulate the chemical reactions in living organisms.
- Artificial fertilizers greatly increase the amount and types of plant crops that can be grown for human consumption, but also require large amounts of fresh water.
- Agriculture influences the environment by effectively decreasing biodiversity.
- The use of chemical poisons and toxins to control pests is widespread and although they are effective in reducing disease-causing organisms, they should be carefully controlled and regulated.
- Fossil fuel combustion results in the emission of nitrogen, sulfur, and carbon oxides that react with moisture in the atmosphere to form acid compounds.

- Acid precipitation results in the leaching of minerals from soils, and damage to living organisms.
- Acid-base neutralization reactions between minerals, such as limestone (calcium carbonate) and acidified waters in lakes and streams, can lead to more neutral pH water.
- The amount or dose of a pollutant that will cause harm is established by observing the effects of the pollutant on living organisms.
- Toxicity is usually expressed in parts per million (ppm) or parts per billion (ppb).
- Since different organisms respond to toxic chemicals in different ways, toxicity is commonly measured by the LD50 — the dose needed to kill 50 percent of the population that it is applied to.
- The monitoring of the levels of pollutants in any ecosystem requires knowledge of how to detect those pollutants or their effects, either by chemical testing or direct observation of biological organisms.
- Biological indicators are organisms whose presence or absence gives clues as to the amount of pollution affecting any ecosystem.
- The dispersal of atmospheric pollutants is affected by global wind patterns. Pollutants may be carried great distances before their effects are felt.
- Biodegradable wastes are those wastes that can be broken down by the action of living organisms. The rate of biodegradability is determined by the chemical structure of the waste material.
- Bioremediation is the use of living organisms, such as plants and bacteria, to control or remove the presence of pollutants from the general environment.

Understanding Key Concepts

1. The elements calcium, phosphorus, and magnesium are all essential to human health. What common role do these elements have in the human body?

2. What is a nutrient?

3. What are the four major classes of organic nutrients? Specify their roles in nutrition.

4. What connection do plants have to the mineral content in our bodies?

5. How do bacteria in the soil help provide nutrients for plants?

6. What are the three main elemental ingredients found in a bag of fertilizer? What are the roles of those ingredients in plant growth?

7. List two potential problems associated with a move to high-yield agricultural methods that rely on fertilizer use and high-yield crop varieties.

8. What are the three main types of pesticides in use? In general, how are they different?

9. Explain why DDT was such an important discovery in the quest to improve human health.

10. Describe why the use of DDT was eventually banned on a global scale.

11. What is the difference between a poison and a toxin? Is it realistic to use the term "toxic" to describe both poisons and toxins?

12. Describe at least two advantages and two disadvantages of using pesticides in agriculture.

13. What are the health benefits of organic farming? What are the disadvantages?

14. What alternatives might there be to the use of pesticides?

15. Which acids are the main cause of acid precipitation? Write their names and formulas. What is the main source of each of these acids?

16. What is the meaning of the symbol pH? How does the acidity of a liquid with a pH of 3.4 compare to one with a pH of 4.4?

17. What are two consequences of acid precipitation falling to the ground in a forest?

18. Why is acid precipitation so dangerous to plants and animals living in water?

19. Which regions of Canada are most affected by acid precipitation? Give two reasons why regions may be affected differently.

20. Why do all new model cars require a catalytic converter attached to the exhaust system? Describe how a catalytic converter operates.

21. Describe the difference between pollution and a pollutant. Is it possible to use the two terms interchangeably?

22. How does the number of exposures before symptoms occur relate to whether a chemical is defined as having acute or chronic toxicity?

23. Why is an LD50 the preferred method for reporting the toxicity of any particular chemical?

24. Using thalidomide as an example, explain the concept of acceptable risk.

25. What is it about a pollutant that makes it non-persistent?

26. Explain why water testing is a focus for many environmental scientists when they are trying to assess the presence of chemical pollutants.

27. Why is the presence of phosphates and nitrates in a water sample a good indicator of a polluted body of water?

28. Why is measuring the level of dissolved oxygen in a pond a good indicator of the state of "cleanliness" of the water in that pond?

29. Describe the effect of a reduction of dissolved oxygen in a water source on the community of organisms living in that water.

30. Why is the presence of macroinvertebrate species a focus for testing the quality of water? List two macroinvertebrate species that are indicative of clean water and two that are indicative of poor water quality.

31. How can lichens provide an early warning system for air pollution?

32. List three non-point sources of pollutants and suggest methods for reducing the emissions from those sources.

33. Why do atmospheric pollutants concentrate at higher latitudes?

34. Identify the location and mechanism by which CFCs cause damage to the environment. What is the significance of this damage to humans?

35. Which common activities are most likely to contribute to surface water pollution? What can you as an individual do to help prevent the presence of those pollutants?

36. Name and describe the three phases of waste water treatment.

37. Define the terms "ground water" and "aquifer." How are these terms connected?

38. List three sources of ground water contamination.

Developing Skills

39. Solanine, a toxin found in green potatoes, has an LD50 of 6.0 ppm. What amount of this toxin would need to be consumed to produce a 50 percent chance of being lethal for a 60 kg person?

40. The data shown below represents the effect of pesticides to control disease-causing pest species. The number of resistant species was obtained by direct measurement and the number of insecticides in use is the closest estimate possible given the wide range of applications and geographic locations.

Year	Number of resistant species	Number of insecticides in use
1938	7	–
1948	14	40
1954	25	60
1957	76	76
1960	137	100
1963	157	115
1965	185	122
1967	224	140
1975	364	182
1978	392	184
1980	432	185

(a) Make a graph of the data, with years on the horizontal (x-axis) and number on the vertical (y-axis). Use one coloured line to show the number of resistant species, and another coloured line for the number of insecticides in use at that time.

(b) What is the relationship between years and the number of resistant species? Between year and number of insecticides in use?

(c) What do you think is the reason for the difference in the two lines?

(d) A number of authorities have used the data given to justify a ban on the use of chemical insecticides and a switch to more organic methods, such as the use of Bt pesticides (*Bacillus thuringiensis*). In your opinion, is the use of a genetically engineered bacteria a better option than the use of chemical pesticides? Give reasons for your answer.

Problem Solving/Applying

41. Many people believe that zinc lozenges can help relieve symptoms of the common cold (about 13 mg every 2 h). The recommended daily allowance for zinc is 12–25 mg, and some experts warn that as little as 150 mg of zinc can cause copper deficiency. Explain how using zinc lozenges in the dose recommended by some people might lead to symptoms of anemia (low red blood cell count).

42. Your lawn is looking a little unhealthy, so you decide to apply a chemical fertilizer to "perk it up." You find a bag in your garage that is labeled 7-7-15. Is this an appropriate fertilizer for your lawn? Why?

43. In a train derailment, a significant amount of sulfuric acid leaked into a nearby lake, despite efforts to contain the spill. Environmental scientists who investigated the effect of the sulfuric acid on the lake itself found that the pH of the lake was near normal despite the large volume of acid added to the lake. How could this be?

Critical Thinking

44. PCBs (polychlorinated biphenyls) are stable chlorinated hydrocarbon compounds used between 1929 and 1979 primarily as insulators in electrical transformers. PCBs are fat soluble and do not biodegrade. Disposal of old electrical equipment into landfills creates the risk of introducing PCBs to the environment. A proposal is made to build a high-temperature incineration plant near your community to treat PCB wastes from across the province and from other provinces. Give reasons for and against the construction and operation of such a plant.

45. Technologies are available to reduce or eliminate acidic emissions caused by human activities. Why is acid precipitation still a serious problem? Why might it increase in the future?

46. Marathon runners who consume large quantities of water during a race run the risk of experiencing a condition called "water intoxication" in which they suffer seizures with symptoms resembling those of epilepsy. Your friend uses this as proof that any chemical is hazardous in excess amounts, but also claims that logically this means that any chemical is also safe if it is in a small enough dose. What is the error in this statement? Explain.

Pause & Reflect

Look back at the Focussing Questions on page 176 and check your original answers to these questions. How would you answer those questions now that you have investigated the Topics in this Unit?