TOPIC 5

Getting Away from It All?

How far do you think you would have to travel to "get away from it all" to a place remote from the noise, crowding, and debris associated with our growing human population? The answer is, surprisingly far.

Every organism that exists, or has existed, exploits the environment to the best of its ability. Regardless of the type of organism, materials and energy are taken from the environment, and waste products are deposited. Usually wastes are used by other organisms as resources, so overall the environment remains relatively balanced over time. However, this is the case only if the rate at which wastes are removed is equal to or greater than the rate at which those wastes are produced.

Like other organisms, humans exploit their environment and then produce wastes in proportion to that exploitation. In the past when the human population was much smaller, this was not a problem — the environment could handle the amount of waste we produced. In the early 1800s there were about 1 billion humans on Earth, but this doubled by 1930. It doubled again by 1975 and reached the 6 billion mark by late 1999. How much of the world's resources does it take to support 6 billion humans? How much waste do 6 billion humans generate? How is it possible to measure this?

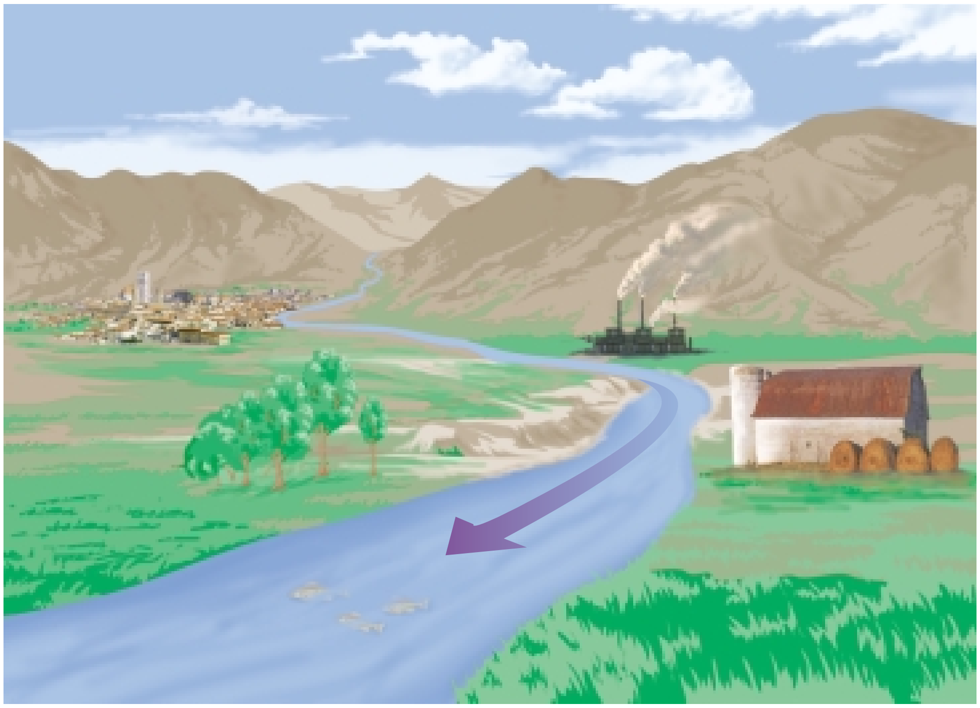


Figure 3.21 Where would pollutants most likely enter this river? What kind of pollutants do you think they would be?

Environmental Monitoring

All wastes entering the environment are potentially harmful, but some more so than others. Wastes that can be broken down into simple non-polluting compounds by naturally occurring chemical reactions, or bacterial action, are referred to as **non-persistent**. Fertilizers and sewage are examples of this type of pollutant. On the other hand, **persistent** pollutants accumulate in the environment, break down very slowly, or perhaps not at all. Pesticides, petroleum products, and heavy-metal wastes are examples. The damage caused by this type of pollutant can be irreversible.

Both persistent and non-persistent wastes are a concern if they become concentrated enough to harm living organisms. How can we detect the presence and determine the concentration of harmful substances in our environment? A detailed knowledge of chemistry helps us accomplish this. Most pollutants eventually find their way into water, either by being washed out of the atmosphere in rainfall and snow such as acid precipitation, or by direct seepage. By knowing the correct chemical tests for a pollutant, it is possible to determine the presence, or absence, of that pollutant within a water sample. In the next two investigations, you will test water samples for phosphates and nitrates (Investigation 3-H) and for carbon dioxide (Investigation 3-I).

Cool Tools

Bee Probes

Honeybee colonies have been used for centuries to provide honey and pollinate flowers, fruit trees, and other crops. But now, scientists have found a new use for the busy insect. Honeybee colonies are used globally to indicate the presence of hazardous materials in the environment. Millions of established colonies provide constant monitoring. Because honeybees can live under many different environmental conditions, small colonies can be introduced almost anywhere hazardous substances are suspected.

Scientists at the University of Montana have designed electronic beehives (right) that provide useful information about the environment. Electronic hives record the behaviour of every bee, including how often it flies, the pollen it gathers, and how the bees control the environment in the hives. Pollutants brought into the hives by the bees are detected using electronic instruments attached to the hives.

1. Bees leave the hives and pick up water, nectar, pollen, and airborne water particles.
2. When bees return to the hives, they fan their wings to control the air temperature in the hives.
3. Pollutants in the environment that were picked up by the bees are released into the air of the hives as the bees fan their wings.
4. Pollutants released by the bees are measured using chemical probes attached to the hives.
5. The chemical data are analyzed to determine which pollutants were brought into the hives from the local environment.

Thinking Critically

1. Why are bees useful animals for detecting pollution?
2. What are common causes of pollution in your area?
3. Research how a miner's canary was used to warn about hazardous substances. How is this similar to how honeybee colonies are being used?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Would you like to know more about the use of bees as a tool for detecting environmental hazards? Go to the web site above, and click on Web Links to find out where to go next. In your notebook, write how you think other environmentally sensitive organisms could be used to protect the environment.

INQUIRY

INVESTIGATION 3-H

SKILLCHECK

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

Measuring the Amount of Phosphates and Nitrates in a Water Supply

You may recall from Topic 1 that phosphorus promotes plant growth. The most likely source of phosphorus is in the form of phosphate, which occurs naturally in most soil and water in amounts under 0.5 ppm. Nitrogen is most often available in the form of nitrates, and clean water naturally contains from 0.1 to 0.3 ppm. Excessive amounts of nitrates in water is usually a sign of decomposition of organic matter. Tiny plants called algae may form a dense growth or "algal bloom." This is often the result of excess phosphates and nitrates that enter water sources from sewage and agricultural run-off. In time the algae dies, and decomposition of the algae leads to low oxygen levels. This may lead to death or injury to aquatic animals. The strong smell of decay is often an indication that this process is occurring.

CONTINUED ▶

Question

How can you determine the presence of phosphates and nitrates in a sample of water?

Prediction

Make a prediction about which of the water samples contain phosphates or nitrates.

Safety Precautions

- Dilute ammonium hydroxide solution is corrosive. Clean up any spills on the lab bench or floor immediately and inform your teacher. If you spill on your skin, wash the area immediately with lots of cool water.

Apparatus

test tubes
medicine droppers
test tube rack
water test kit (LaMotte™)
graduated cylinder

Materials

4 water samples (distilled water; water containing fertilizer; water containing dishwashing detergent; water from a local pond, lake, or stream)
dilute ammonium hydroxide solution
magnesium sulfate solution

Part 1

Testing for Phosphates

Procedure

1. Label four clean, dry test tubes to correspond with the four water samples.

2. Place about 10 mL of each water sample into its corresponding test tube.
3. Using the medicine dropper, carefully add 20 drops of the dilute ammonium hydroxide solution to each of the test tubes.
4. Carefully add 2 mL of magnesium sulfate solution to each test tube and let stand in the test tube rack undisturbed for 3–5 min.
5. The formation of a precipitate (magnesium phosphate) indicates the presence of phosphate within that water sample.

Skill FOCUS

For tips on measuring the volume of liquids, turn to Skill Focus 5.

Part 2

Testing for Nitrates

Procedure

Carefully study the instructions and procedures that come with your water test kit. The following steps are used with the LaMotte™ kit.

1. Pour distilled water into the test tube that is supplied with your kit until it reaches the 2.5 mL mark.
2. To the water sample add the mixed acid reagent to bring the volume to the 5 mL mark.
3. Cap the test tube and invert it three or four times. Let the test tube stand undisturbed for 2 min.
4. Using the measuring spoon supplied with the test kit, add one level spoonful of the nitrate-reducing reagent to the test tube.
5. Cap the test tube and invert it continuously for 1 min. Let the test tube stand undisturbed for 10 min.

6. Swirl the test tube gently before removing the cap and inserting the test tube into the nitrate-N comparator with the axial reader.

7. Compare the test tube containing the water sample with the colour standard that it matches. Read the number off the nitrate-N comparator and **record** the reading.

8. Convert the reading to parts per million (ppm) of nitrate by multiplying by 4.4 and **record** your answer.

9. Repeat steps 1–8, replacing the distilled water with each of the other three samples in turn.

10. When you have completed the investigation, remove your gloves and wash your hands with soap and water.

Analyze

1. Which of the water samples contained phosphates? Do the results of your testing match what you would expect to find for each sample?

2. Which of the water samples contained nitrates? Do the results of your testing match what you would expect to find for each sample?

3. What was the purpose in testing the distilled water? The water containing fertilizer?

Conclude and Apply

4. Do you consider the water sample from the local pond, lake, or stream to be polluted? Explain your reasoning.

DidYouKnow?

Water-quality technicians frequently use dyes to track the movement of wastes in sewage systems to locate cracks in pipes that are in need of repair. With large-volume systems, or those with many outlets, the dyes are often hard to spot, so caffeine was suggested as a substitute. Caffeine has no natural occurrence in the environment other than from human waste. It is almost completely unchanged as it passes through the body and is easy to detect. However, a study in Seattle, Washington, found that two-thirds of test sites in Puget Sound were already polluted with caffeine. Apparently, this pollution was caused by motorists and coffee-stand operators dumping cold coffee into sewer systems, which then mixed into the general environment. Unfortunately, this meant that the traditional dye method had to remain in use.

DidYouKnow?

Most laundry and dishwasher detergents contain water softeners (usually sodium carbonate), which help soaps remain effective even in hard water. Hard water contains calcium, magnesium, and/or iron salts. These salts react with the soapsuds to form curds and reduce the cleaning power of the soap. By adding sodium carbonate, the calcium, magnesium, or iron binds to the carbonate instead of the soap suds.

INQUIRY

INVESTIGATION 3-I

SKILLCHECK

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

Testing Water Quality

One method of determining the quality of a water sample is to figure out the amount of oxygen and carbon dioxide gas dissolved in the water. Polluted water often has low oxygen content. It may also have a high carbon dioxide content, since a by-product of bacterial respiration is carbon dioxide. Clean water usually has high oxygen content. Other factors also affect the oxygen content of water. For instance, turbulent water has more water mixed into it than still water does, and temperature affects how much dissolved oxygen the water can hold. When analyzing a water sample for dissolved oxygen content, you should consider when and where the sample was taken.

Question

How do temperature and turbulence affect the oxygen content in water?

Hypothesis

Form a hypothesis about the effect of temperature and turbulence on the oxygen content in water.

Safety Precautions

- Dilute sodium hydroxide solution is corrosive. Clean up any spills on the lab bench or floor immediately and inform your teacher. If you spill any on your skin, wash the area immediately with lots of cool water.

Apparatus

3 Erlenmeyer flasks
1 medicine dropper
hot plate
beaker tongs or oven mitts
400 mL beaker
water test kit (Hach™)

Materials

Part 1	Part 2
water samples (100 mL of tap water, 100 mL of aquarium or pond water, 2 sealed flasks containing 100 mL of boiled and cooled tap water)	water samples (100 mL of tap water, 100 mL of water from an aquarium or pond)
	phenolphthalein solution
	0.4% sodium hydroxide solution

Part 1

Dissolved Oxygen

Procedure

Carefully study the instructions and procedures that come with your water test kit. The following steps are used with the Hach kit.

1. Add tap water to the Dissolved Oxygen bottle (round bottle with glass stopper) supplied with your kit by allowing the water to overflow the bottle. To avoid trapping air bubbles in the bottle, tilt the bottle slightly and insert the stopper quickly to force out air bubbles. If bubbles become trapped in the bottle in step 2, discard the sample before repeating the test.

2. Add the contents of Hach powder pillows #1 (manganous sulfate) and #2 (alkaline iodide azide) to the BOD bottle. Insert the stopper supplied for the bottle (making sure that there is no air trapped inside) and shake vigorously to completely mix the solution. A small amount of powder may remain at the bottom of the bottle. This will not affect the test results.

3. If oxygen is present in the sample, a brownish-orange precipitate will form.

4. Let the bottle stand undisturbed until the precipitate settles halfway to the bottom of the bottle. The top half of the sample should appear clear. Shake vigorously and again let the bottle stand undisturbed until the precipitate settles halfway to the bottom.

5. Add the contents of powder pillow #3 (sulfamic acid) to the sample and shake. The precipitate will dissolve and the water will turn yellow.

6. Carefully pour the yellow DO sample to completely fill the measuring tube that is supplied with your kit and add this to the square mixing bottle supplied with your kit. Measure and pour a second full measuring tube of the same sample into the mixing bottle.
7. Add one drop of sodium thiosulfate titrant to the square mixing bottle and swirl the bottle to mix the titrant into the sample.
8. While swirling, continue to add titrant *one drop at a time* to sample until the sample just barely becomes clear and stays clear after swirling. *Count the number of drops needed to change the sample from yellow to clear.* **Record** the number of drops of titrant needed to turn the sample clear.
9. Repeat steps 1–8 using the aquarium or pond water in place of the tap water.
10. Unseal one of the flasks of boiled, cooled water. Measure the amount of dissolved oxygen by repeating steps 1–9 with this water in place of the tap water.
11. Unseal the other flask of boiled, cooled water. Pour the contents of the flask into a beaker. Aerate the water by pouring the water back and forth between the beaker and the flask for 1 min. Return the water to the flask and measure the amount of dissolved oxygen in the sample by repeating steps 1–9 using this water in place of the tap water.

Part 2

Dissolved Carbon Dioxide

Procedure

1. Place the 100 mL sample of tap water into an Erlenmeyer flask.
2. With a dropper, add *five drops of phenolphthalein solution* to the sample. Mix by gently swirling the flask. *If* a light pink colour *forms and stays*, *no* carbon dioxide is present. **Record** this result. *If* a light pink colour *forms and then quickly disappears*, carbon dioxide gas is present. Continue with the procedure.
3. With a clean dropper, add *sodium hydroxide solution one drop at a time* to the sample, until the sample just barely becomes light pink and remains pink after swirling. *Count the number of drops needed to change the sample pink.* **Record** the number of drops of sodium hydroxide needed to turn the water sample pink.
4. Repeat steps 2 and 3 with 100 mL of aquarium or pond water.
5. When you have completed the investigation, remove your gloves and wash your hands with soap and water.

Analyze

1. Find the amount of dissolved oxygen in each sample of water used in Part 1 in parts per million (ppm). Each drop of titrant equals 0.5 mg/L (0.5 ppm) of dissolved oxygen, so divide the number of drops of titrant needed to produce a clear solution by 2. Carry your divisions to one decimal place.
2. Find the amount of dissolved carbon dioxide in each sample of water used in Part 2 in parts per million (ppm). To do this, multiply the number of drops of sodium hydroxide needed to produce a pink solution by 5.

Conclude and Apply

3. How does the temperature of water affect its ability to contain dissolved oxygen?
4. How does turbulence affect water's ability to contain dissolved oxygen?
5. Based on your measurements of dissolved oxygen and carbon dioxide, would you consider the aquarium or pond water to be polluted? Explain your reasoning.

Biological Indicators of Water Quality

Most types of pollution lower the ability of an environment to support life. For aquatic systems, pollution often decreases the amount of dissolved oxygen in the water. In effect, pollutants decrease the number and variety of organisms that are present in the affected area. This decrease in biological diversity has been well documented for aquatic systems and is a useful indicator of the quality of any source of water.

Although there are no defined standards for diversity, there are a few organisms that are typical to both "clean" and "polluted" waters. These organisms are generally referred to as **biological indicators**. For example, some species of fish, such as trout and perch, are found only in clean, well-oxygenated bodies of water. In contrast, carp and catfish are two fish species that can tolerate higher levels of pollution.

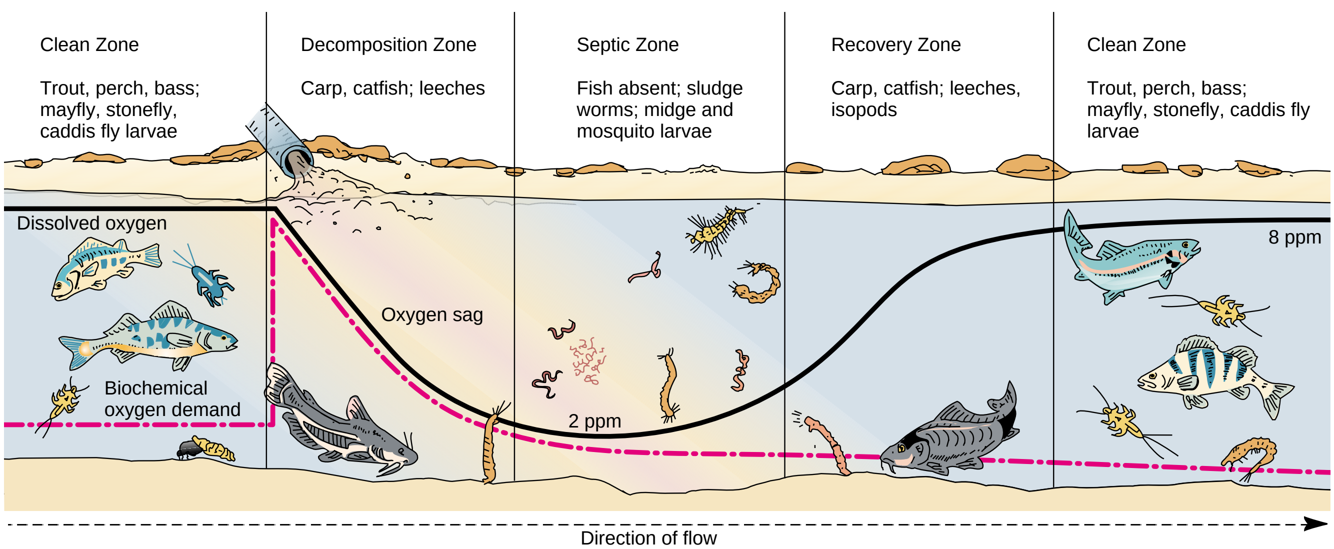


Figure 3.22 Oxygen sag downstream of an organic source. A great deal of time and distance may be required for the stream and its inhabitants to recover.

The most useful organisms for a biological indicator of water quality are the **macroinvertebrates** — organisms visible to the unaided eye and lacking a backbone. The macroinvertebrates in the lakes, rivers, and creeks around you are crustaceans (e.g., crayfish), molluscs (e.g., clams and mussels), gastropods (e.g., snails), oligochaetes (e.g., worms), and insects. Since the larval forms of insects are the most numerous of the macroinvertebrates that are usually found, they are generally the focus of most stream surveys. A survey of the number and type of macroinvertebrates found in a body of water can provide a general indication of whether pollutants are present or not. Table 3.5 shows some examples. However, it is important to remember that organisms that are representative of poor water quality may be found in any type of water, whereas organisms representative of good water quality are found only in water of good quality!

Table 3.5

Water Quality Indicators

Good Quality (8–10 ppm of oxygen)	Moderate Quality (4–8 ppm of oxygen)	Poor Quality (0–4 ppm of oxygen)
stonefly nymph	dragonfly nymph	midge larvae
mayfly nymph	damselfly nymph	blackfly larvae
caddisfly larvae	cranefly larvae	pouch snail
water penny beetle	clams and mussels	leech
riffle beetle	sowbug	aquatic worm
gilled snail	crayfish	planorbid snail

Figure 3.23 Scientific research in protected areas, such as Riding Mountain National Park, helps us monitor the health of our ecosystems.

Pause& Reflect

Lichens are rootless organisms that are a combination of a fungus and a green alga or photo-synthetic bacteria. One of the hardiest organisms found on Earth, they are relatively unaffected by extremes in temperature. They can survive long periods of drought, and grow almost anywhere, because they absorb all of their nutrients directly from the atmosphere. But lichens cannot tolerate poor air quality!

Because different varieties of lichens are more sensitive to certain pollutants than others, an early warning system for air pollution has been devised using them. The presence or absence of specific lichen varieties alerts scientists to the presence of pollutants in an area long before other organisms are affected.

Find out which other plants can be used as acid-base indicators and list them in your Science Log.

DECISION-MAKING

INVESTIGATION 3-J

SKILLCHECK

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

Assessing Water Quality with Macroinvertebrates

Think About It

According to WHO's Global Water Supply and Sanitation Assessment for the year 2000, nearly 1.1 billion people lack access to improved sources of water. What affects the quality of water sources in your area and what issues are involved? In this investigation you will use a technique that provides a scientific basis for assessing water quality.

How Can Science Help?

By 2015, the United Nations Millennium Declaration pledges "to reduce by one-half the proportion of people without sustainable access to adequate quantities of affordable and safe water." Efforts by WHO, UNICEF, and other international organizations have contributed to global awareness of the problem and the establishment of international programs. Between the years 1990 and 2000, these programs increased access to improved sources of water from 79 to 82 percent of the world's population. Since the early 1990s, organizations worldwide have been participating in monitoring programs for water supplies. These monitoring programs provide the reliable and consistent statistics needed for informed policy making.

Safety Precautions

- Conduct this investigation only under the supervision of your teacher.
- Be careful when handling living organisms.
- Be sure to wash your hands when you are finished the investigation.

Apparatus

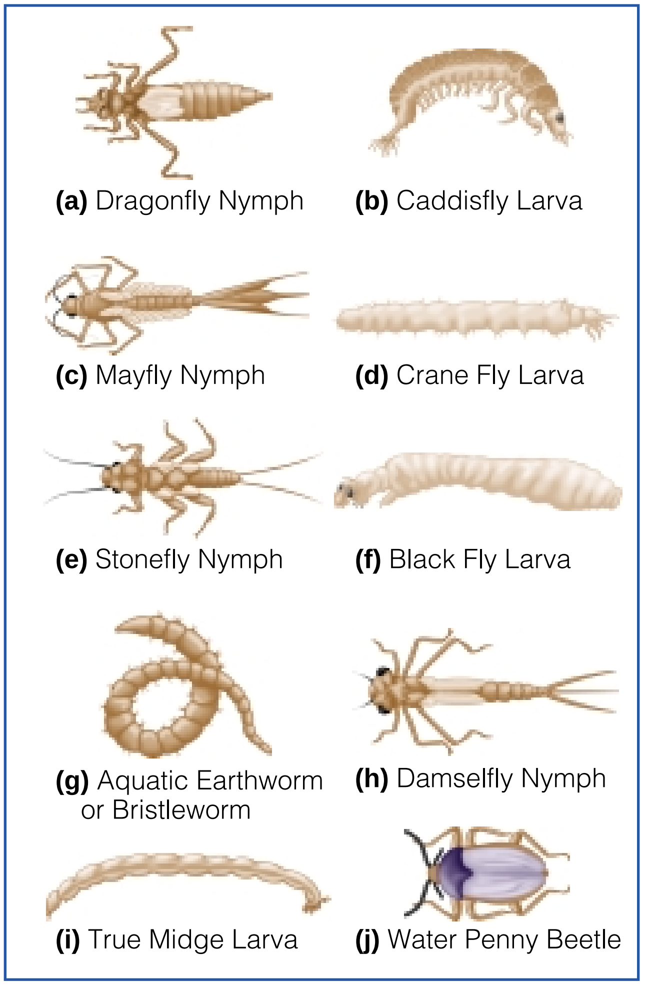
1.2 m^3 nylon screen or mesh net with a metal rim
turkey baster or plastic forceps
pan or paper plate
hand lens
thermometer
pH paper or universal indicator
portable water test kit (optional)
illustrated classification keys to the macroinvertibrates (*A Guide to the study of Fresh-Water Biology* by Needham and Needham is a good reference)

Procedure

1. Collect a sample of organisms from the river or stream bottom by placing the nylon screen or mesh net against the bottom and kicking against the bottom upstream of the net for at least 1 min. You should overturn and scrape any rocks that are present. Be sure that your net is placed to intercept all of the floating debris stirred up by the kicking.

Note: If you are testing a pond or lake where there is no current, use the net with a metal rim to scoop material from the bottom mud, especially around the base of any weedy areas.

2. You should examine the larger bits of wood that are disturbed by your kicking, since some of the organisms you are attempting to collect may be stuck to the underside of the wood.
3. Wash away the mud and dirt by shaking the screen or net while holding it partly under the surface of the water.
4. Using the turkey baster or plastic forceps, transfer any organisms collected to the pan or paper plate and group them by shape.
5. Using a classification key and a hand lens to examine each organism, identify as many of the organisms as you can. The following illustrations may help in your identifications.



6 As you identify an organism, **record** this fact in a data table such as the one shown. Check the box next to the name of the organism.

7 Return the organisms to the water as close as possible to the site from which they were obtained.

8 As a group, collect some or all of the following information.
- a photograph or sketch of the collection site
- the appearance of the water
- the pH of the water
- the temperature of the water
- evidence of human activity near the water (structures, artifacts)
- water quality measurements using a water test kit (dissolved oxygen, nitrates, phosphates)

9 Wash your hands before eating or drinking.

* Sensitive	Moderately sensitive	Tolerant
☐ stonefly nymph	☐ dragonfly nymph	☐ midge larvae
☐ mayfly nymph	☐ damselfly nymph	☐ blackfly larvae
☐ caddisfly larvae	☐ cranefly larvae	☐ pouch snail
☐ water penny beetle	☐ clams and mussels	☐ leech
☐ riffle beetle	☐ sowbug	☐ aquatic worm
☐ gilled snail	☐ crayfish	☐ planorbid snail
	Index value **(B)** Boxes checked × 2 = ___	**Index value** **(C)** Boxes checked × 1 = ___
Total Index Value = ____ (A) + ____ (B) + ____ (C) = ____		
Water Quality Rating (by total index value) Excellent (>22) Good (17–22) Fair (11–16) Poor (<11)		

*Sensitive organisms require water of good or excellent quality.

Analyze

1. Using the measurements and results obtained in your survey, assess the quality of water at your sample site.
2. Identify any sources of material entering the body of water where you are sampling, and suggest how the material might affect the water quality.
3. If the source(s) in #2 are from human activity, identify an alternative course of action for each source, to diminish any negative effect on water quality.
4. You were asked to return the organisms to their original location. Why?

Figure 3.24 Sewer outfalls, industrial effluent pipes, acid draining out of abandoned mines, and other point sources of pollution are generally easy to recognize.

Point Versus Non-point Sources

Determining the presence of pollutants within a body of water is really only a first step. Ideally, we must be able to monitor the changes in the concentration of those pollutants and track them to their source. This is where it gets tricky! As shown in Figure 3.24, pollutants that enter the environment from specific locations — **point sources** such as drainpipes and smokestacks — are easy to monitor and control, but what about those pollutants that have had a chance to mix into the environment before they are detected? As shown in Figure 3.25, the emission of pollutants from **non-point sources** — such as feedlots, golf courses, construction sites, and fertilized fields — are often separated both in time and location from the source, since the pollutants become highly dispersed as they travel. This type of pollutant is much harder to control because the emissions do not occur regularly. Acid rain is a good example of just such a non-point source pollutant.

Environmental organizations, both governmental and private, agree that the cheapest and most effective way to reduce pollution is to reduce the emission of pollutants. Efforts since the early 1970s have led to new regulations and emphasis on the 4 Rs of the environmental movement — Reduce, Reuse, Recycle, and Recover — but as you will see in the next Topic, even this comes with its own set of problems!

Figure 3.25 Water pollution occurs with bank erosion and bacterial deposition. The effects of non-point sources like this one are difficult to determine since the pollutants are scattered or diffused.

TOPIC 5 Review

1. A student claims that it is unfair to judge the quality of a water sample based on just one result. Would you agree or disagree? Explain your answer.

2. What would be the effect of an increase in water temperature on the organisms that live within that water? Explain.

3. Explain how phosphates and nitrates create low-oxygen conditions within a body of water.

4. **Apply** A science class has completed a water-sampling project of the river that flows through town. At each of the marked sites, macroinvertebrates were identified and counted. The class noted that the population of bottom-dwelling insects showed marked changes relative to the location on the river from which the sample was taken.

	Number of each organism detected				
Site number	Aquatic worms	Midgefly larvae	Leeches	Dragonfly nymphs	Stonefly nymphs
A	23	17	32	155	264
B	257	125	0	0	0
C	224	117	29	0	0
D	210	98	40	37	0
E	67	78	43	81	13
F	36	24	35	94	97

(a) Based on the numbers and types of organisms detected at each site, would you consider site C to be of low-, medium-, or high-quality water? Why?

(b) Site E is found to have a high number of aquatic worms living there. Aquatic worms are known to be tolerant of low-oxygen conditions. Would you consider site E to be polluted? Explain your answer.

(c) The main difference between sites C and D is a small set of rapids between the two sites. Explain how these rapids influence the presence of dragonfly nymphs found at site D.

(d) The class decides that both the farm and the town's sewage outlet contribute to the lower quality of the water downstream of the town. What is the major difference between the two sources?