WATER QUALITY Matters!

4-H WATER PROJECT ◆ UNIT 3

Water Quality Matters!

4-H Water Project Unit 3

Note to Educators and 4-H Leaders

This project is most appropriate for youth ages 12–16. It addresses several portions of Pennsylvania's Academic Standards for Environment and Ecology: 4.1.7 and 4.1.10.

Disclaimer

The specific pollution sources mentioned, although geographically appropriate, are entirely fictional and in no way represent pollution discharges from actual sources on the Schuylkill River or elsewhere. "Trout Run" is a fictional name, but the stream's characteristics are typical of those of many streams in that area.

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Penn State College of Agricultural Sciences research, extension, and resident education programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

This publication is available from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802. For information telephone 814-865-6713.

This publication is available in alternative media on request.

Produced by Information and Communication Technologies in the College of Agricultural Sciences

CAT D0680A 5M7/04ps4600

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Introduction

Jason and Leah are cousins. They are both 15 years old, and they live in Pennsylvania. Jason loves to fish on the Schuylkill River near his home in Philadelphia. For his science fair project, he decided to find out more about the water quality of the river. He told Leah about the project, and she decided to examine the water quality of the stream near her house. Leah lives near Trout Run in Westmoreland County, east of Pittsburgh. Jason and Leah agreed to compare their findings when they were finished.

Jason lives with his parents in a brick townhouse. Along the river where he fishes, there are several working and abandoned factory buildings. Unfortunately, people often dump garbage down the banks near these buildings. Upstream, one of the city's wastewater treatment plants discharges treated wastewater into the river. Upstream of that, an electric power–generating plant discharges water used to cool its equipment.

Leah lives with her family in an old farmhouse a few miles from a town. They and many of their neighbors have large, tree-covered lawns. Although Trout Run passes near Leah's house, it flows mainly through forestland. Acidic precipitation falls in this area of Pennsylvania as rain, snow, and mist.

Can you identify several potential pollution sources in the water by Leah and Jason's houses? Where would you think the quality of the water would be better—by Jason's house in the city or by Leah's house in the country? The answers might surprise you. The water quality in these two places is different, but one may not really have better water than the other.

You have probably heard the term "water quality" before, but can you define it? That's the topic of this book. You'll learn about water quality and how it is measured and regulated. You'll learn that the various rivers, creeks, and streams in Pennsylvania have

The Schuylkill River

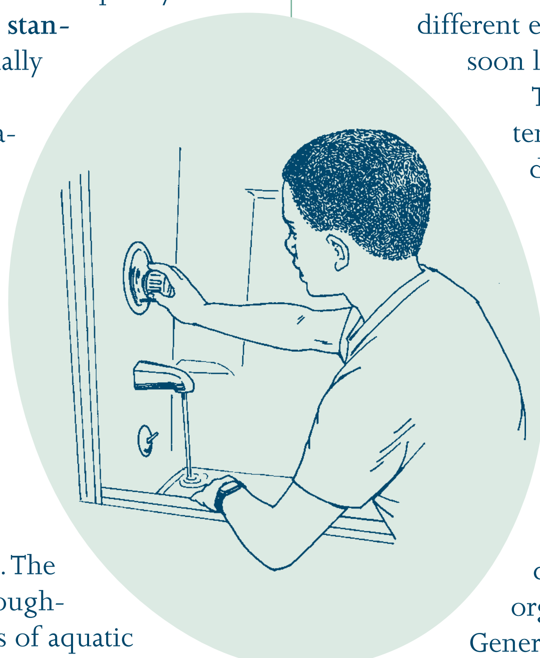
Trout Run

different water quality standards. You'll see how these differ for the Schuylkill River and Trout Run. You'll try your hand at some simple water quality tests. Then you'll learn about the major water quality problems in Pennsylvania. You'll wrap up this book with an activity that allows you to use aquatic insects to determine the health of a stream or body of water.

CHAPTER 1

What Is Water Quality?

Water quality refers to the condition, or degree of cleanliness, of water. For example, when you take a bath, you start with clean, hot water. When you're finished, the water is dirty and cool. The quality of the bath water changed in two important ways. We use criteria (plural form of criterion) to evaluate water quality. In the case of the bath water, we used the criteria temperature and clarity to describe the quality of the bath water. **Water quality standards** are used to set limits (usually numerical) for **water quality criteria.** For bath water, temperatures above about 100°F would make the water uncomfortably hot. Therefore, a standard of 100°F or lower could be applied for the temperature criterion of bath water.



If the electric power–generating plant upstream of Jason's house discharges water hotter than the standard for the Schuylkill River, a violation of water quality regulations results. The temperature standard varies throughout the year to protect the needs of aquatic organisms, but it is always much lower than 100°F.

The U.S. Environmental Protection Agency (EPA) sets recommended standards for each water quality criterion. However, states can use different standards as long as they are stricter than federal standards. Turbidity (clarity), the concentration of dissolved oxygen, the concentration and kinds of bacteria present, and pH (level of acidity) are just a few examples of other water quality criteria for which standards are set.

So what influences water quality? And how does all this stuff get into water? Water contains hundreds of different dissolved substances. Many of these are the result of natural processes. These processes include the weathering of rock, the erosion of soil, the decay of dead organisms, and the movement of salt spray from the ocean inland. People also contribute substances to water. We drive our cars, mine coal and other minerals, and generate electric power. With almost everything people do, we contribute substances to water. These various substances have different effects on water quality, as you'll soon learn.

The next section introduces the temperature criterion more fully and describes its effects on aquatic organisms and human health. This is just one of many water quality criteria.

Examining a Water Quality Criterion

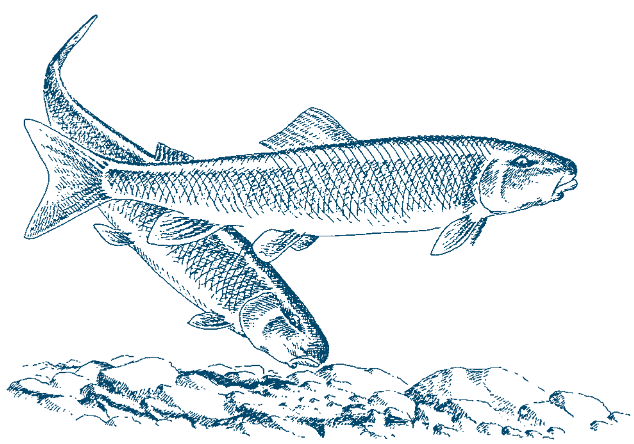
Temperature (abbreviated as T)—Water temperature and its yearly variability is a criterion that directly affects what kinds of organisms can live in a waterway. Generally, colder water temperatures (although not below freezing) allow a greater variety of creatures to live in the water. The temperature of a waterway can rise from the addition of water heated by industrial or power-generating operations or simply by flowing through sunny areas. Very warm water is not healthy for many fish and other kinds of aquatic life. Warm water contains less dissolved oxygen, which aquatic organisms need to live. The breeding cycles of some fish can be disturbed by changes in water temperature. Streams that have moderate temperatures year-round are usually better for fish.

How Water Is Used

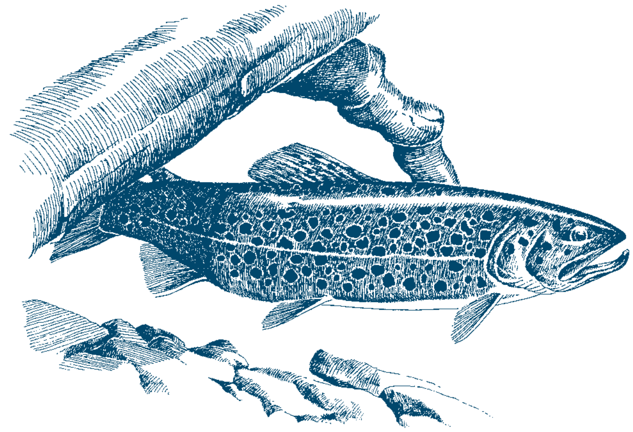
Water is used in a variety of different ways. What are some ways that you used water today? You probably got out of bed this morning, went to the bathroom, and flushed the toilet. This is a use of water. You probably brushed your teeth. This is another water use. Water is also used in many different ways outside the home. A lot of water is used to grow the food we eat and the fibers that become the clothes we wear. Virtually everything we use is made by using water in some way.

The quality of water necessary for different uses is almost as varied as the uses themselves. For instance, water that is of good enough quality for swimming is not necessarily suitable to drink or for cleaning fruits and vegetables. The intended use of water determines which criteria and standards are used to regulate water quality.

The Pennsylvania Department of Environmental Protection (DEP) has designated each stream and body of water in the state as providing various uses. These uses fall under the general classes of fish and aquatic life; water supply (for people, industry, farming, and wildlife); recreation; and aesthetics (the natural beauty of water). Most streams in the state are designated for some level of these uses. Many streams have different designated uses along their various sections.



White sucker



Brown trout

The water quality criteria that are applied to each stream depend on the one use that requires the cleanest or highest quality water. This use is referred to as the "critical use" of that stream. By protecting this use, all uses requiring lower water quality are also protected. The strictest critical use for most streams is usually either fish and aquatic life or water supply. "Cold-water fishery" (CWF) is a use designation that refers to the water quality requirements necessary for trout and related fish to survive. A waterway that is designated for both a cold-water fishery and a drinking water supply would follow the criteria and standards for cold-water fishery because some of the standards are stricter than those for a drinking water system. (Water supplies in the United States are always treated to ensure safety before drinking.) Fish that depend on cold water are important to Pennsylvania's economy. The state earned about $50 million from fishing-related activities in 1996. A large part of this total comes from trout fishing.

For the temperature standard, the year is divided into 19 periods with different maximum permitted temperatures for each period. For CWF, these temperatures range between 38 and 66°F. Also, the temperature may not change more than 2°F in one hour. The temperature standard is meant to protect the cold-water fish in the stream. This standard can present a challenge for some factories and wastewater treatment plants that discharge warm or even hot water. Many times, factories will not be permitted to locate on CWF streams because they cannot meet the temperature standard. Cold-water fishery streams stay cool in the summer because they are fed by **ground-water**, which is much cooler than surface water.

Trout Run near Leah's house is designated as a cold-water fishery. As the name suggests, brook trout live in this stream. A cold-water fishery is the critical use applied to this stream. The presence of trout generally means that water quality is quite good.

The Schuylkill River near Jason's house is designated as a warm-water fishery (WWF). Fish such as bass, suckers, and sunfish live best there. These fish tolerate somewhat lower quality water than cold-water fish. The temperature standard for WWF ranges from 40° to 87°F throughout the year. Again, the standard says that stream temperature may not change more than 2°F in one hour. Streams that are warm-water fisheries get much warmer in summer than do cold-water fishery streams.

Checking the temperature of Trout Run's water

So how did the DEP decide which waterways should be assigned which uses? The use assignments were based on the uses at the time the regulations were put in place. For example, a stream that supported cold-water fish and a potable (drinkable) water supply when the uses were decided would probably have been assigned those two uses. A waterway that was quite polluted might have been designated for a use requiring lower water quality, such as navigation by barges and other types of boats.

What Is Water Pollution?

Water is considered "polluted" when the concentration of one or more substances makes the water unsuitable for its intended or "beneficial" use. For example, a stream designated as a public water supply would be considered polluted if a tanker truck accidentally spilled gasoline into it, directly or indirectly. Because gasoline is poisonous to humans and other animals, the spill would prohibit the stream from being used as a water supply.

What happens when a waterway does not meet its water quality criteria standards? If the DEP can prove that this failure is because of a specific source of pollution **(point-source pollution)**, the person or company responsible can be fined. Individual people can even be imprisoned for violating water pollution laws. Some streams often or always fail to meet their assigned water quality standards. Often, no single specific pollution source can be determined, and the pollution comes from many sources **(nonpoint-source pollution)**. Work is constantly underway to improve the water quality of these streams.

Complete Inquiry Time Activity 1 to learn more about the kinds of substances that pollute water and how they affect aquatic life.

INQUIRY TIME ACTIVITY 1

Contamination Central

Learning Objective

Learn that chemicals, salts, and detergents can pollute water.

Materials Needed

3 medium (about 2 cups each) clear jars with lids, water, measuring cup, tablespoon, 1 tablespoon each of liquid detergent, salt, and vinegar

Procedure

Label one jar "detergent," one jar "salt," and one jar "vinegar." These are the "pollutants" for this activity. Put about 1 cup of water into each jar. Add 1 tablespoon of pollutant to each jar, as labeled. Screw the lid onto each jar and shake each well. Set each jar down, remove the lid, and answer the Reflections.

Reflections

1. Describe how the water and the pollutants have mixed.

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2. What "real-life" pollutants produce effects similar to each of the test pollutants?

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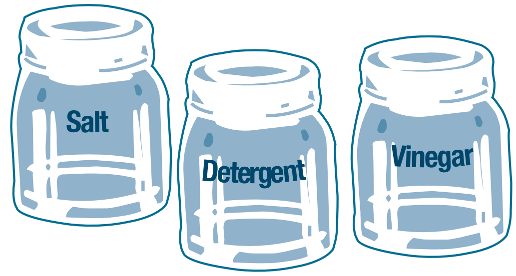

3. How might each real-life pollutant affect aquatic creatures?

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4. Do any of the jars have an odor? Is odor a pollutant? Would you drink water that smelled this way?

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5. Is detergent a pollutant? Is the water draining from your clothes or dishwasher polluted?

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6. Taste the water in the salt jar. Does it taste salty? Would you like to drink this water if you were thirsty? Where does salt pollution come from?

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Adapted with permission from "Stream Study and Water Quality Assessment Curriculum," University of New Hampshire Cooperative Extension, 1991.

INQUIRY TIME ACTIVITY 2

My Water Source and Land Use List

Learning Objectives

Find out where your drinking water comes from. Identify land uses in your watershed and possible pollutants based on these land uses. *(See next page for examples.)*

Materials Needed

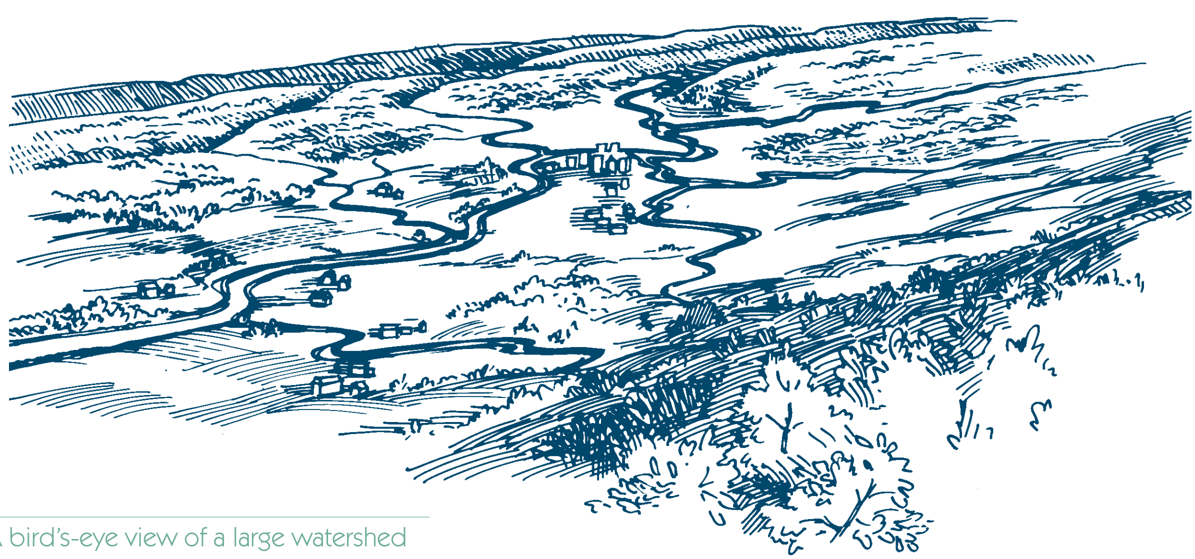
Pen or pencil, paper, phone, phone book, transportation (optional)

Procedure

Do you know where your drinking water comes from before it reaches the faucet? If you don't, find out. If you have a private well or spring, ask your parent or an adult in your household what he or she knows about it. If your city or town supplies the water, call the town hall or the local water department. Check the blue pages of the phone book for the number. Find out the name of the source, whether it is groundwater or surface water, and where the source is located.

Next, an optional activity is to have a trusted adult take you to the water source. Notice the **watershed** of your drinking water source. The land area through which water moves or drains to reach a waterway or water source is called a watershed. Think of the watershed as the bowl of land into which all the **precipitation** that will end up in your water source falls. Your water source lies at the bottom of the bowl. Some bowls (watersheds) are very small and some are quite large.

If your water comes from a large river, the watershed is very large. It might take several days to drive it from end to end. If your water comes from a small mountain stream, you might be able to stand in one place and see the whole watershed. The Schuylkill River is a much larger waterway than Trout Run, so the land area of Jason's watershed is larger than Leah's.



A bird's-eye view of a large watershed

Look around and see if you can tell where some of the edges of your watershed might be. If you see a hill or mountain, water that hits the side of the hill or mountain facing you would fall in your watershed. Depending on the lay of the land, water that hits the other side of the hill or mountain might not be falling in your watershed.

Regardless of whether you were able to travel to your water source, try to make a list of the ways land is used in your watershed or around your drinking water source. Uses might include farms, golf courses, athletic fields, factories, parking lots, houses, and lawns. What else?

Once you have identified a number of the land uses, make a list of materials that might be associated with those land uses that you would not want in your drinking water. For example, these might include fertilizer from lawns or runoff water from parking lots.

Land Uses **Possible Pollutants**

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Reflections

Can you think of some ways that you or your family could reduce the use of some of the pollutants you named above? List these below. Try to think of one way for each household-related pollutant. Put some of your ideas into practice and encourage your friends and family to do the same!

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Looking Ahead...

Now we'll go on to learn about how our water is kept safe through water quality standards. If you have forgotten the difference between water quality criteria and standards, look back to the beginning of this chapter or in the glossary. These two terms are difficult to keep straight.

There are three basic types of water quality criteria: physical, chemical, and biological. Water temperature and turbidity (clarity or clearness) are examples of physical criteria. The pH of water is an example of a chemical criterion. Measures of bacteria are biological criteria. The next three sections explore each basic type of criterion in greater depth.

CHAPTER 2

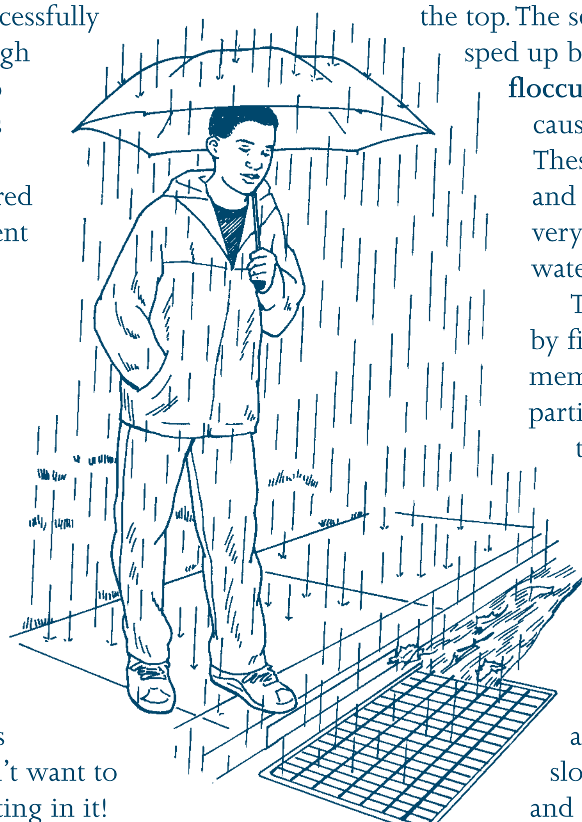
Physical Criteria

You already learned about how temperature, a physical criterion, affects stream life. Physical criteria include those that are major properties of water. Turbidity is another example of a physical criterion. Any reduction in the clarity or clearness of water is called turbidity. Soil particles, bits of leaves, and other materials suspended in water cause turbidity. These are blown by wind into water or wash into waterways during rainstorms or with melting snow. Fish may not lay eggs successfully in water with high turbidity. High turbidity can also be harmful to other aquatic organisms such as insects.

Turbidity is officially measured by scientists using a measurement unit called a nephelometric turbidity unit (NTU). A special electronic device called a nephelometer measures the amount of light that comes through a sample and converts that to NTUs.

High turbidity can also make killing disease-causing bacteria in the water difficult. Turbidity in drinking water should not exceed 1.0 NTU (the drinking water *standard*). Water with less than 1.0 NTU is perfectly clear. Most people don't want to drink water that has things floating in it!

The turbidity in the Schuylkill River near Jason's house is greater than that in Trout Run. Much of the watershed of the Schuylkill is paved over with roads, parking lots, and buildings. This means that when it rains, water rushes over the ground instead of soaking in or **infiltrating** the soil. Rushing water can carry dirt and debris from all these paved surfaces directly into waterways. The watershed of Trout Run is mostly forested. The soft unpaved ground soaks up most of the rain and snow that falls on it, so water rarely flows overland directly into the stream. But even here, heavy rain will cause some turbidity.



How do we remove or treat turbidity? Turbidity is caused by solid particles suspended in water. Given enough time, most particles will settle out. That's why turbidity can be treated by allowing water to stand still in a pool and then siphoning the clear water off the top. The settling of solid particles can be sped up by adding chemicals called **flocculants** to the water. Flocculants cause particles to join together. These larger particles are heavier and settle out faster. Flocculants are very important in treating drinking water.

Turbidity can also be removed by filtering water through a **porous** membrane or bed of sand. All particles larger than the pores in the filter or sand bed get stuck there. Sand filters are often used to remove turbidity from drinking water.

We can also reduce turbidity before it gets into a waterway by planting grass, trees, and other plants along the waterway's banks. This slows the flow of surface water and filters out soil particles before they cause turbidity in the waterway.

Strips of vegetation planted or left along waterways are called **buffer strips** because they protect or buffer the water from the effects of pollutants that cause turbidity.

Inquiry Time Activity 3 will allow you to see turbidity and practice filtration for yourself.

INQUIRY TIME ACTIVITY 3

Settling Sediment and Stream Bank Vegetation

PART 1

Learning Objective

Learn how soil settles out of water.

Materials Needed

2 medium (about 2 cups) clear jars with lids, tablespoon, 2 tablespoons of soil, measuring cup, about 2 cups of water, flashlight, sheet of white paper

Procedure

Pour 1 cup of water into each jar. Add 2 tablespoons of soil to one jar. Put the lid of the jar on and shake well. Set the jar down and watch what happens. Next, shine a flashlight through the jar with soil. Can you see the light coming through the other side of the jar? Do the same for the clear jar without soil. Watch the soil settle slowly to the bottom of the jar.

Reflections

1. Describe how the water looked after you shook the jar of water and soil.

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2. Describe the brightness of the light passing through the two jars. Shine the light through the jar onto a piece of white paper to estimate the percentage of light that is absorbed or blocked by the suspended soil.

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3. How might the reduction in light caused by soil in the water affect aquatic life in a stream or other waterway?

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4. Would you drink water with soil suspended in it?

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5. How long will it take for the water to become completely clear again in the soil jar? This may take longer than you think! Let the jar sit and see how long.

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6. What did you observe about how the soil settled out of the water? Did small or large particles settle out first?

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PART 2

Learning Objective

Observe soil in natural waters and practice water filtration.

Materials Needed

2 medium-sized clear jars with lids, white paper coffee filter, magnifying glass, funnel, clock or watch with a seconds hand or digital counter

Procedure

Collect water from a stream after a rainstorm. Do this *only* with proper permission. Collect your sample from a safe place on the bank where there is no danger of falling into the water. Do not stand in the stream. Put the lid on the jar and shake it. Notice whether the water is clear or cloudy. Place the coffee filter inside the funnel and then slowly pour the water through the funnel into a clean jar. Look at the sediment and other material collected on the filter. A magnifying glass may aid in this observation. This is visible evidence of sediment suspended in stream water, even when you can't see the sediment. Is the filtered water clear? This demonstrates turbidity removed by filtration.

PART 3

Learning Objective

See how vegetation slows soil erosion and protects against sedimentation (the transport of soil into water).

Materials Needed

2 shoe boxes or other boxes at least as large, 2 plastic trash bags large enough to line the boxes, watering can or an empty container with holes about the size of a pencil tip poked in the bottom, 2 medium-sized clear jars, 2 blocks of wood or bricks about the same thickness (books will also work, but they might get wet), 1 piece of sod cut to fit in one box, loose soil from near where the sod was dug, a small table, measuring cup, straw or grass clippings

Procedure

1. Cut a V-shaped notch in one end of each box so that the point of the V reaches just to the bottom of the box. Line each box with a plastic bag that extends over the sides of the box and over the V.

2. Place the sod, grass-side up, in one box. Place the soil in the other box in a gently packed down layer about as thick as the sod. The soil should have no grass or other vegetation growing in it.

3. Set the boxes on the table and place a block of wood or other object under the uncut end of each box so that they are tilted slightly down toward the end of the box with the notch. Place each box so that the end with the notch is slightly over the edge of the table. Place a jar under each notch to catch water (see illustration).

4. Fill the watering can with 3 cups of water. Pour water near the back of one box (farthest from the V). Time how long it takes for this water to reach the jar. Now repeat the process with the next box and jar. Pour again from the same height and at approximately the same rate. Watch what happens to the water in each box and the appearance of the water collected in the jars.

Reflections

1. Use the measuring cup to determine how much water came out of each box. How much water came out of the bare soil versus the soil with grass?

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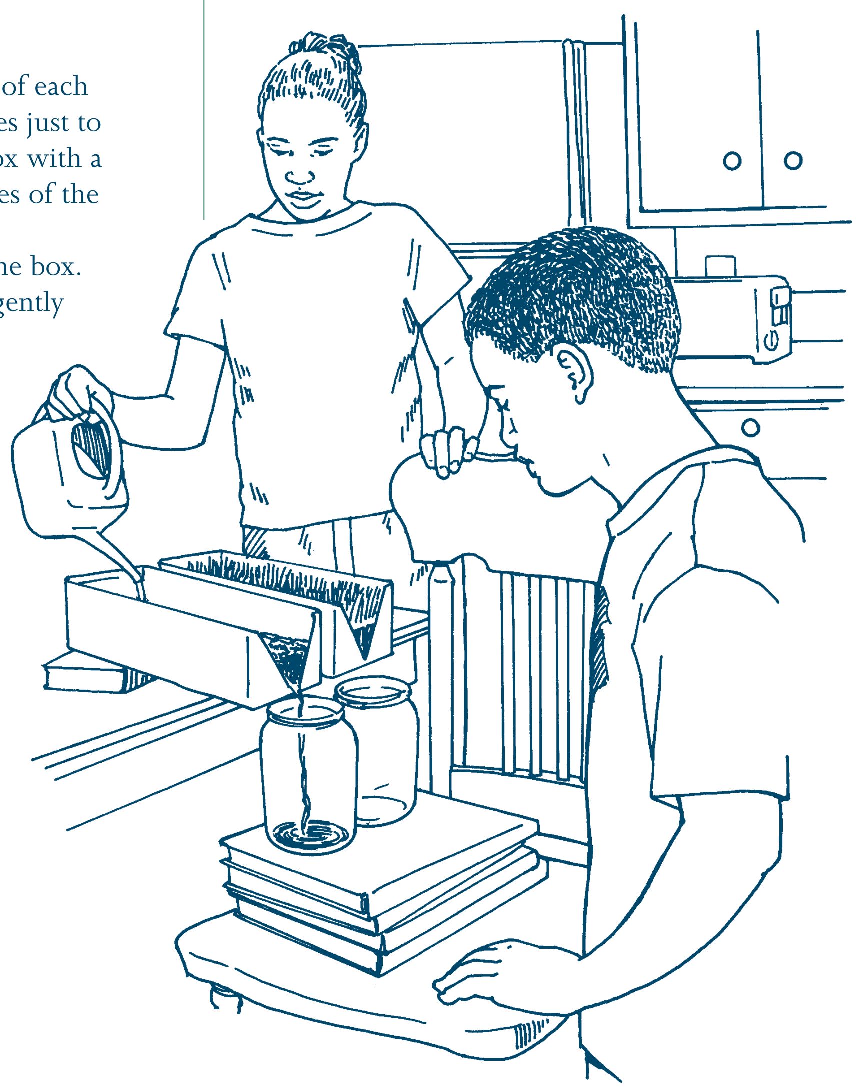


2. Did the water exit each box at the same rate? Which was faster? Can you explain why?

3. Compare the water in each jar. Which is clearer? Why?

4. In which box was less soil lost to the forces of water?

5. What materials might you use to reduce the erosion of the bare soil? Think about construction sites you have seen. What kinds of materials are used to control soil movement? Empty any water in the catch jar for the grassy soil box. Place that jar to catch water coming out of the bare soil box. Try placing straw, leaves, or grass clippings on the bare soil and repeating the experiment to see if the water coming out of the bare soil box with the added materials is clearer. Record your observations here:

6. Write a short paragraph about how the results of your experiments relate to scraping soil bare to build roads and buildings. If you were a fish, would you rather live in a stream where the watershed was covered with grass and other vegetation or where the soil was bare? Why?

Adapted with permission from "Stream Study and Water Quality Assessment Curriculum," University of New Hampshire Cooperative Extension, 1991.

CHAPTER 3

Chemical Criteria

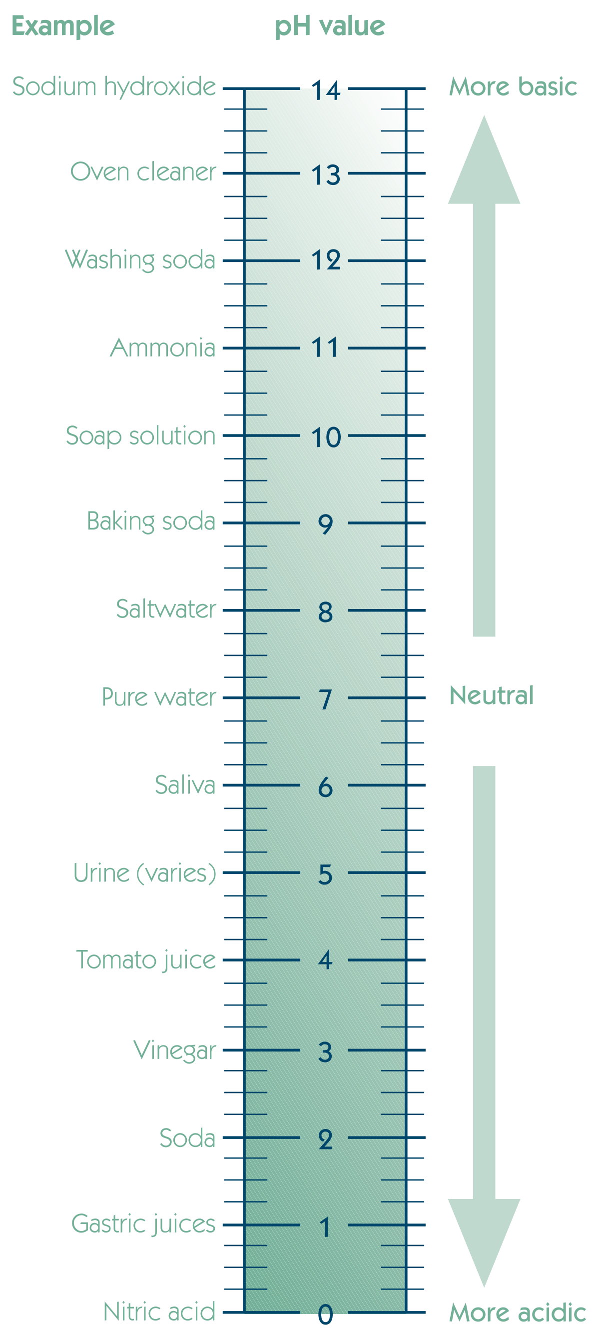
Chemical criteria deal with the actual makeup of stream water, including all the things that are in water besides good old H_2O. **pH** is an example of a chemical water quality criterion; it is a measure of how acidic or basic a substance is. pH is measured on a scale of 0 to 14. A pH of less than 7 indicates acidity. A substance with a pH of 6 is 10 times more acidic than a substance with a pH of 7. A pH greater than 7 is basic. A substance with a pH of 8 is 10 times more basic than a substance with a pH of 7. A pH 7 is considered neutral—neither acidic nor basic.

Water that is acidic can have several negative effects. It could contain high amounts of metals that make the water taste metallic. Acidic water flowing through lead drinking water pipes will dissolve lead into the water, potentially causing a lead poisoning hazard. Certain metals, such as aluminum, become soluble in acidic water and can be harmful to fish. Dissolved aluminum can kill fish by damaging their gills and decreasing the level of sodium in their blood. Fish eggs and young fish are also very susceptible to acidity and toxic metals.

How can we change the pH of water? Acidity can be reduced by adding a basic substance such as baking soda or crushed limestone. Acidity can be increased by adding an acid.

Leah and Jason measured the pH of their waterways. Jason found that the pH of the Schuylkill River near his house was 7.6. This is within the pH standard for warm-water fisheries. The standard states that the pH of cold- and warm-water fisheries should be between 6 and 9. Leah measured the pH of Trout Run to be 6.2. The moderate acidity of the stream probably stems in part from the very acidic rain and snowfall the area receives. Scientists have measured rainfall pH as low as 3.5 in that area. There would probably be more trout if the stream's pH was closer to neutral. Inquiry Time Activity 4 will teach you how to measure pH using various common substances. Then you'll explore the pH of the stream nearest you.

The pH Scale



INQUIRY TIME ACTIVITY 4

pH Exploration

PART 1

Learning Objectives

Learn to measure the pH of common substances. Understand which common substances are acidic and which are basic.

Materials Needed

Swimming pool water test kit or litmus paper (see the resource list at the end of this booklet for information about where to buy these); 6 small cups; about 1 tablespoon each of some or all of the following: lemon juice, orange juice, vinegar, tap water, milk, baking soda (dissolve a clump about the size of a pea in 1 tbsp tap water). If a pH meter is easily available and you are working with someone who knows how to use it, you could use that instead for these tests. (If you use a pH meter, you'll need enough of each of the liquids to fill a cup about 3 inches deep. You might want to try some measurements with the pH meter and litmus paper or the pool test kit to see how they compare.)

Procedure

Measure 1 tbsp of each of the substances named above into a separate cup. Test the pH of each substance with the pool test kit, litmus paper, or pH meter, following the directions with the test materials. Record your results in the table below.

Substance	pH
lemon juice	
vinegar	
orange juice	
tap water	
milk	
baking soda solution	

You could also try testing the pH of tap water from several nearby towns and several sources of bottled water.

Reflections

1. How much variability in pH do you see?

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2. Which substances are acidic and which are basic?

PART 2

Learning Objective

Determine the pH of the stream nearest you and how it varies from its source to its mouth, or at other points along the stream.

Materials Needed

Detailed map of your area showing streams (a topographic map or the *Pennsylvania Gazetteer* works well); water test kit, litmus paper, or portable pH meter; several small cups.

Procedure

Note public access points for the stream you want to study. Do not trespass on private property. In the company of a trusted adult, collect a water sample from the stream from free-flowing water, if possible, rather than stagnant water. Be careful to stay away from dangerously high water levels. Take the pH measurement. Repeat on 2 or 3 other sections of the stream, using a new, clean cup. You could also measure the pH of several streams nearby to see how they compare.

Reflections

1. Describe your observations. How does the pH of your study stream compare with that of some of the common substances you measured earlier?

2. Does the pH fall within the pH standard for warm- and cold-water fisheries (6–9)?

3. Based on pH alone, do you think this stream provides good habitat for fish?

CHAPTER 4

Biological Criteria

Biological water quality criteria deal with the presence of living organisms in water. Many kinds of bacteria and other tiny organisms live in water. These organisms are so small that they can only be seen with a microscope. Most are completely harmless to other aquatic organisms and humans, but there are some that can cause very serious diseases, or even death, in people who drink water that contains them. Checking a water sample for all of the many different kinds of tiny, or microscopic, organisms is difficult. That's why scientists often rely on testing for a certain kind of bacteria, called fecal coliform.

Fecal coliform bacteria come in many shapes and can indicate that other disease-causing organisms are present. Magnified 23,000 times.

The concentration of fecal coliform bacteria in water is a biological water quality standard. If there are fecal coliform bacteria in water, the water is contaminated by human and/or animal fecal (waste) material. The presence of a high concentration of fecal coliform also indicates that other disease-causing organisms are likely to be present.

Most microorganisms are not harmful to fish, but there are some that can kill or sicken fish. Diseased fish are found more often in water of poor quality, including water with high fecal coliform concentrations.

Sources of bacterial contamination include runoff from lawns where pets are exercised, home septic systems that are not working properly, and fecal material from wild and domestic animals. You learned in chapter 2 that water flowing over forest- and farmland and lawns can often infiltrate into the soil. The soil may remove some bacterial contamination because bacteria will stick to soil particles. Water flowing over paved surfaces such as roads and parking lots does not infiltrate the soil. Therefore, this water may contain more bacteria.

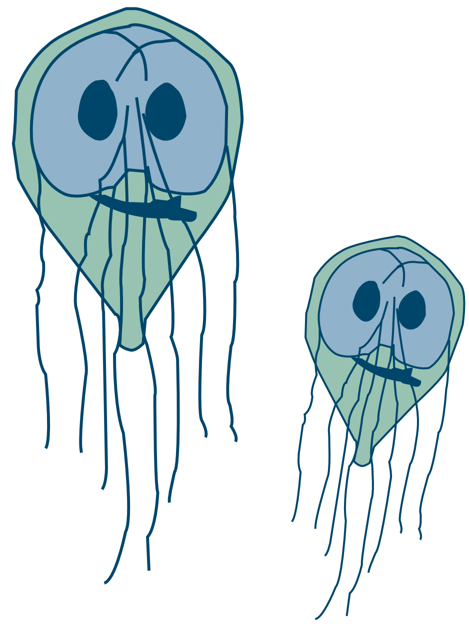
All surface and shallow groundwater in Pennsylvania is assumed to have fecal coliform bacteria. You should never drink this water until it's been treated.

Where do you suppose the concentration of fecal coliform will be higher—in the Schuylkill River in Philadelphia or in Trout Run in rural Westmoreland County? Why? You might be tempted to say the Schuylkill, but the answer is not necessarily clear cut. The Schuylkill watershed certainly contains more paved surfaces, so water on its way to the river has less chance to be purified by passing through soil. But there are probably many homes in rural Westmoreland County that have septic systems instead of municipal sewers. If these septic systems are not working properly, pollution by fecal coliform bacteria may result. There may also be areas where livestock have direct access to Trout Run. Manure from farm animals is another prime cause of bacterial contamination of waterways. When livestock have access to stream banks, manure can be washed right into streams. So although we may think of "city water" as dirty and "rural water" as clean, you can see that that is not necessarily so.

Water used for swimming is called the "water contact" use designation. The bacteria standard for water contact use requires that the average concentration of bacteria in five water samples collected over a 30-day period can be no more than 200 fecal coliforms per 100 milliliters (ml) of water. The standard also specifies that no more than 10 percent of the samples taken during a 30-day period may contain more than 400 fecal coliforms per 100 mL of water. The water contact use standard allows a greater concentration of fecal coliforms during spring, fall, and winter, when people are not in contact with the water. Obviously, water that is only clean enough for swimming is not generally clean enough for drinking.

Another biological indicator of water quality is the diversity and kinds of aquatic macroinvertebrates (animals without a backbone that are large enough to be easily seen with the naked eye) in a waterway. Insects, clams, worms, crayfish, and snails that live in water are collectively called aquatic macroinvertebrates. There is a greater variety and number of aquatic macroinvertebrates in relatively clean water than in dirty water.

In Inquiry Time Activity 5, you'll collect and examine some of these organisms for yourself. You'll learn how to make a general assessment of the health of a stream or body of water based on the kinds of aquatic macroinvertebrates you find.



Strange as they appear, these giardia microorganisms are the cause of gastrointestinal illness in people. They indicate fecal water contamination. Magnified 5,000 times.

INQUIRY TIME ACTIVITY 5

Aquatic Macroinvertebrates as Indicators of Water Quality

Learning Objectives

Learn how to sample a waterway for aquatic macroinvertebrates. Observe different kinds of aquatic macroinvertebrates. Learn how aquatic macroinvertebrates can be used as general indicators of water quality.

Materials Needed

Boots or waders; walking stick for balance; rubber gloves; whistle to summon help in an emergency; large bucket; large shallow pan; a pair of tweezers; small paint brushes; magnifying glass

Procedure

Approach the stream you have been studying at a public access point or where you have the landowner's permission. Work with at least one other person, one of whom should be a trusted adult. For safety, do not attempt to sample large streams or rivers and sample only when water levels are low. Use one or more of the following methods to locate aquatic macroinvertebrates in a stream. The best method for gathering organisms from your study stream will depend on the characteristics of the stream bottom. Read through each method and choose the best one(s) for your stream. You will return the organisms you find to the stream when you're done, so keep them in water and handle them gently.

Rock-rubbing method. *Use this method in streams with rocky bottoms.* Randomly choose several rocks from across the stream bed from an area of the stream where water flows in a rapid-like or wavy fashion. Try to choose rocks that are always underwater during normal stream flow conditions. Each rock should be about 4–6 inches in diameter and should be easy to move. Place the rocks in a bucket filled with stream water.

Holding one of the rocks over the shallow pan half-filled with stream water, gently brush the rock with a soft brush or your hands. Try to dislodge any particles stuck to the rock's surface. Scrape off clumps of gravel or leaves stuck to the rock. These clumps may be caddisfly houses. Repeat for each rock. Examine the water in the bucket for living material that has fallen off the rocks. Transfer anything you find to the pan.

Stick-picking method. *Use this method in streams without "rapids" or a rocky bottom.* Collect several sticks (approximately 1 inch in diameter and relatively short) that are underwater in the stream and place then in a bucket filled with stream water. Select partially decomposed sticks that have soft wood and a lot of crevices and are found in the flowing water, not buried in the bottom.

Fill the shallow pan halfway with water from the stream and remove one of the sticks from the bucket. Examine the stick, making sure you hold it over the pan so no organisms are lost. Pick the loose bark from the stick to find aquatic macroinvertebrates. After examining the sticks, it might be helpful to break up the woody material and examine it carefully. Using tweezers or a paint brush, carefully remove anything that resembles a living organism and place it in the pan. Repeat for all sticks. Also examine the bucket contents for living material that has fallen off the sticks. Transfer anything you find to the pan.

Rules for Aquatic Invertebrate Collectors

You do not need a permit to sample for aquatic organisms in Pennsylvania as long as the state's rules are followed. These are:

1. You may have no more than 50 organisms in your possession at one time.
2. If you use a net to catch insects, it may be no larger than 4 feet by 4 feet.
3. Anyone old enough to require a fishing license must have one during sampling, as well as a second form of identification.

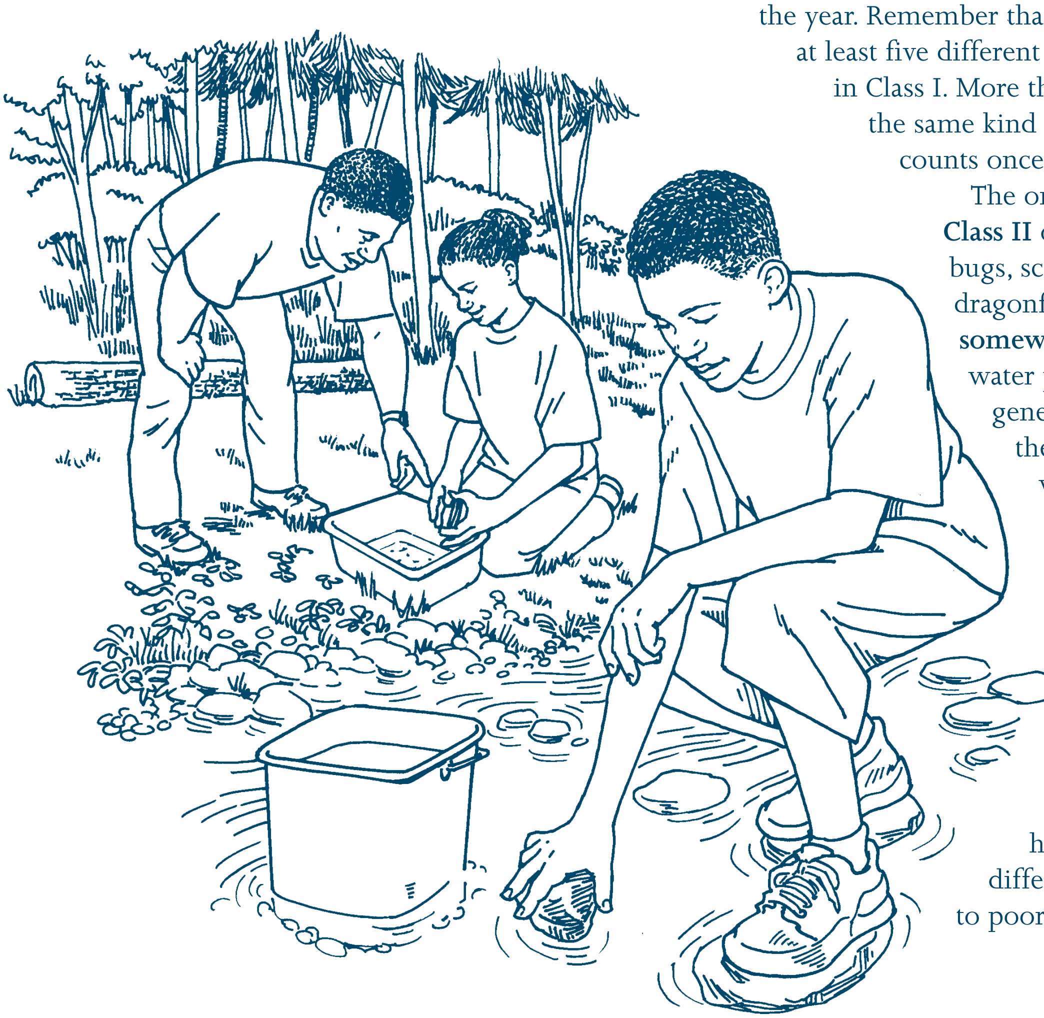
Leaf pack-sorting method. *This method can be used in streams with or without a rock bottom.*

Remove several handfuls of submerged leaves from the stream and place them in a bucket. Remove each leaf one at a time and look closely on both sides for aquatic organisms. Hold the leaf over the shallow pan of stream water. Using tweezers or a paint brush, carefully remove anything that resembles a living organism and place it in the pan. Also examine the water in the bucket to see if anything has fallen off the leaves. Transfer anything you find to the pan.

Assessment

You are not expected to become an expert in identifying aquatic macroinvertebrates in one or two collecting sessions. Therefore, we have simplified the determination of stream health by looking for just a few kinds of aquatic macroinvertebrates that serve as biological water quality indicators. Use the pictures on pages 24–26 to determine what kinds of organisms you've collected. You don't need to precisely identify every organism you find, but the pictures will give you a good idea of what you're looking at. Note the kinds and classes of organisms you find on the "Notes" page in the back of this book. Use a magnifying glass to observe the organisms so you can clearly see the legs, gills, and tails.

The organisms shown in **Class I** on page 24 (mayflies, stoneflies, caddisflies, and others) are **sensitive** to water pollution. They will not occur in polluted water. Therefore, if you find five or more *different kinds* of these organisms in your sample, that stretch of the stream can be classified as high-quality water. It probably meets most or all of the water quality standards for its designated critical use throughout the year. Remember that you're looking for at least five different kinds of organisms in Class I. More than one individual of the same kind of organism only counts once.



The organisms shown in **Class II** on page 25 (sow bugs, scuds, damselflies, dragonflies, and others) are **somewhat sensitive** to water pollution. You will generally find a few of them in high-quality water and a lot of them in slightly polluted water. If your stream sample contains ten or more different kinds of organisms in Class I or II, it is high quality; if it has less than ten different kinds, it has fair to poor water quality. It probably fails to meet some of the water quality standards for its critical use at some times during the year.

The organisms shown in Class III on page 26 (aquatic worms, crane flies, water striders, and others) are **tolerant** of water pollution. You will find them in all kinds of water, from the cleanest to the dirtiest. However, if your stream sample is dominated by organisms in this category, the water quality is poor. The water in this stretch of stream probably fails to meet many of the water quality standards for its critical use at many times during the year. Of course, if you find very few or no bugs, the water may be severely polluted.

When finished, be sure to return all the organisms and the water to the stream.

If you found this activity particularly interesting, you might want to find out whether there is a local citizens' group that performs periodic monitoring of area waterways. See the resources list at the end of the book for more information. These groups are always eager for volunteers.

Reflections

1. Record the number and diversity of aquatic macroinvertebrates you found. Based on this, how would you rate your study stream's water quality?

2. Think back to Inquiry Time Activity 2 in which you identified some of the land uses in the watershed of your drinking water supply. Based on what you learned in that activity, does the water quality classification made using aquatic macroinvertebrates as indicators suggest that some land uses are impacting your study stream?

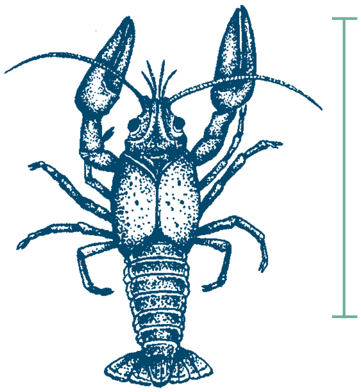
Aquatic invertebrate sampling procedures adapted from:

Sharpe, W. E., W. G. Kimmel, and A. R. Buda. *Biotic Index Card*. Center for Watershed Stewardship, The Pennsylvania State University, University Park, PA. Available at www.sfr.cas.psu.edu/water/.

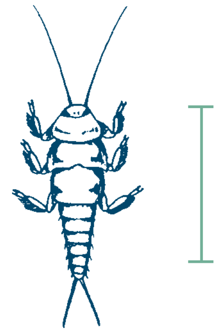
U.S. Environmental Protection Agency Office of Water. 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA 841-B-97-003. www.epa.gov/owow/monitoring/volunteer/stream/

Some Class I Organisms (Pollution Sensitive)

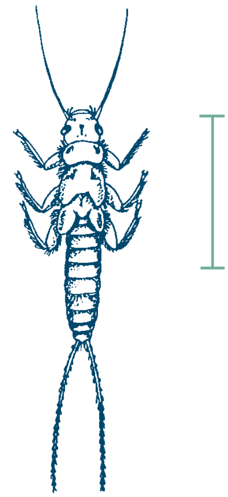
Sizes of illustrations not proportional. Bar lines indicate relative size.



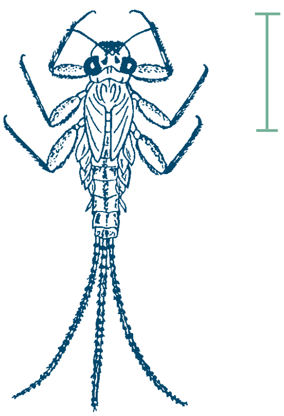
Crayfish*



Stonefly nymph

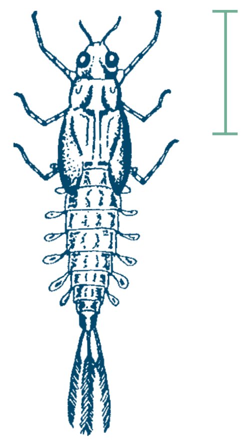


Stonefly nymph



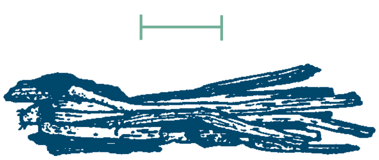
Mayfly nymph

Pill or fingernail clam*

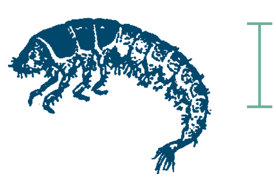


Mayfly nymph

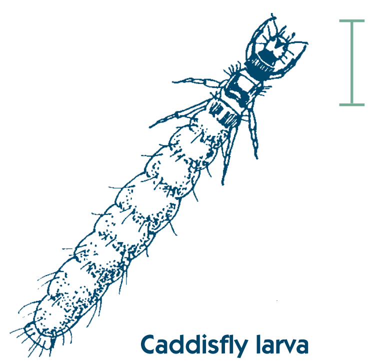
Caddisfly
larva case



Caddisfly larva*



Caddisfly larva*

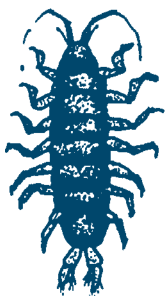


Caddisfly larva

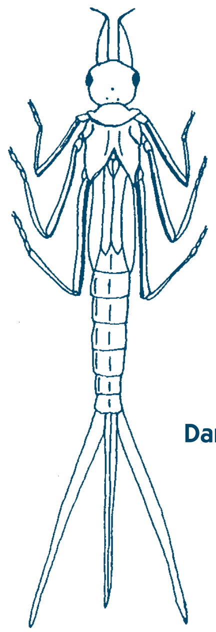
Illustration Credits, pages 24–26:
Illustrations whose captions are marked with an asterisk (*) are provided by the University of Wisconsin–Extension in cooperation with the Wisconsin Department of Natural Resources (except for the snail on the far left, page 26). They are based on a key developed by Riveredge Nature Center, Newburg, WI. All other illustrations are by Patti Estheimer and are provided courtesy of the Pennsylvania Department of Conservation and Natural Resources, Bureau of State Parks.

Some Class II Organisms (Moderately Pollution Tolerant)

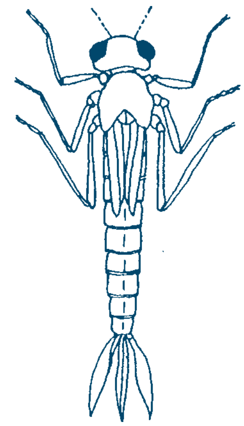
Sizes of illustrations not proportional. Bar lines indicate relative size.



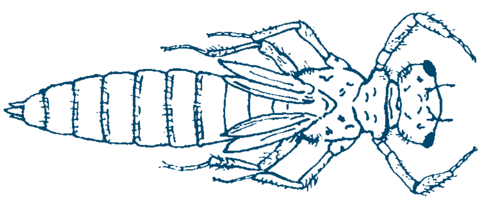
Aquatic sowbug or isopod*



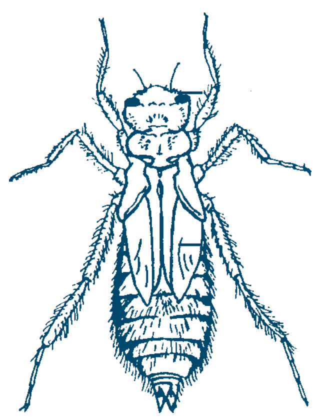
Damselfly nymph



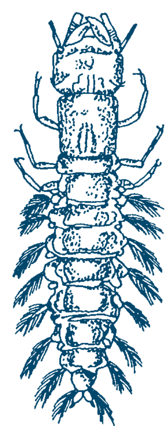
Damselfly nymph



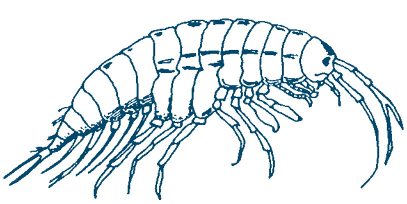
Dragonfly nymph



Dragonfly nymph



Hellgrammite

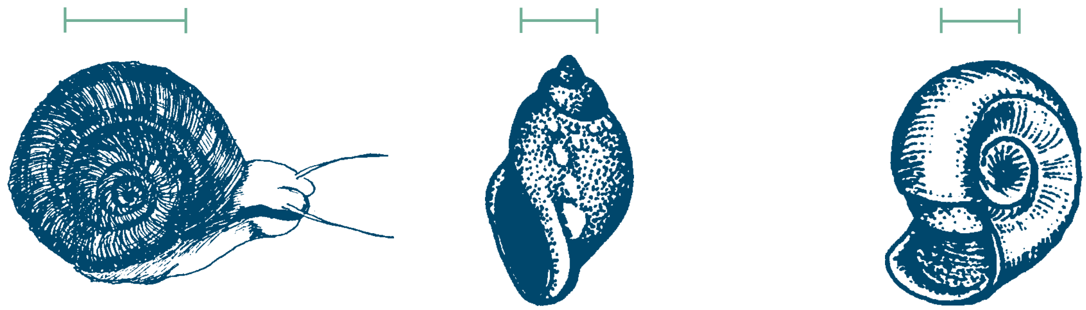


Scud

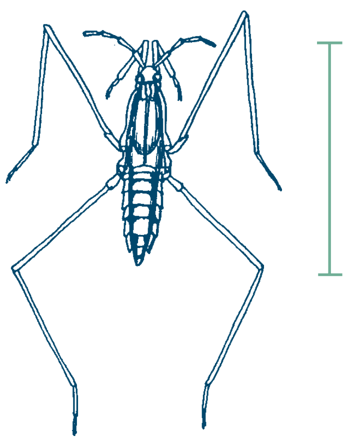
Water penny*

Some Class III Organisms (Pollution Tolerant)

Sizes of illustrations not proportional. Bar lines indicate relative size.

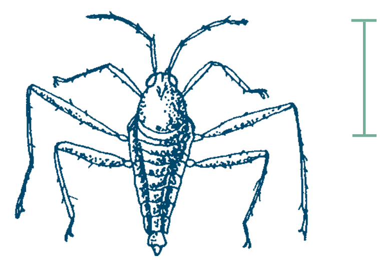


Snails*

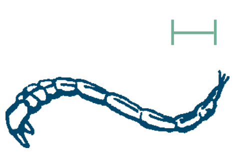


Waterstrider

Water boatman



Waterstrider



Midge larva*

Midge pupa*

Blackfly larva*

Flatworm or planaria*

Cranefly larva*

CONCLUSION

Water Quality Matters

After learning so much about water quality through their investigations, Leah and Jason volunteered with local citizens' water-quality monitoring groups on the Schuylkill River and on Trout Run. During their yearly summer visits on the Schuylkill, they saw firsthand the kinds of aquatic insects that indicate fair water quality. They saw a lot of sow bugs, scuds, damselflies, and midge flies, some water pennies, and one mayfly. In Trout Run, they saw a greater diversity of macroinvertebrates, including some from Class I. They found a few mayflies and stoneflies, two crayfish, and many water pennies, sow bugs, scuds, damselflies, and midge flies. The collection of aquatic organisms gathered from Trout Run indicates that its water is of good quality.

Jason and Leah both found it so interesting to search for the various organisms and learn about water quality that they vowed to continue working with volunteer stream-monitoring groups in their areas. They also decided to work with other volunteers to clean up stream banks and watersheds near their homes.

Learning about water quality is an important thing for everyone to do. Just as Jason and Leah took the time to understand water quality criteria, standards, and water uses for the waterways near their homes, we all can do the same for the waterways we know and love. Improving the water quality of a stream or other waterway requires that people get involved. Will you play a part in improving the environment where you live? This effort starts with knowing more and understanding the facts about water quality. Water quality matters to everyone and everything!

Appendixes

Answers to Reflection Questions

INQUIRY TIME ACTIVITY 1

Contamination Central

1. The liquid detergent will make the water cloudy and bubbly. Most of the salt will dissolve in the water with mixing. Vinegar will not be visible in the water.

2. Laundry detergent—discharge from washing machines or car washes

Salt—from road salting in winter

Vinegar—acidic mine drainage, acid rain, acid stone drainage

3. Many detergents contain phosphates, which trigger excessive growth of algae. When the algae die, the decomposition consumes oxygen. This can kill fish and other aquatic creatures. Algae may also become so thick that very little light penetrates to the plants that are growing underwater. These can be an important food source for fish and if they die, fish may also die.

Salt usually contains sodium, which is a problem for people with high blood pressure. It also makes water taste bad.

Acids can increase the concentration of aluminum and iron in water. These metals can build up on fishes' gills and impede their breathing.

4. Both the vinegar and detergent jars have an odor. Odor is a pollutant. Water should be free of all odors. Water that has an odor is considered polluted and may or may not be harmful to drink. The cause of the odor must be discovered in order to determine whether the water is safe to drink. The vinegar water would be safe to drink because vinegar is a food, but it sure wouldn't taste good to most people.

5. Any odor associated with detergent would make the water unsafe. Drinking it might make you sick to your stomach.

6. The water in the salt jar will taste salty, which is unpleasant to most people. Salt pollution comes from road salt applied in the winter to melt snow and ice.

INQUIRY TIME ACTIVITY 2

My Water Source and Land Use List

Some possible land uses and their *potential* pollutants:

- Farming—sediment, pesticides/herbicides, fertilizers, bacteria
- Houses—malfunctioning septic systems, motor oil, pet waste, paints, household cleaners, pesticides, herbicides, fertilizers, detergents
- Parking lot/road—oil and grease, sediment
- Industrial—toxic chemicals, oil, solvents
- Commercial—toxic chemicals, oil, solvents, cleaners

INQUIRY TIME ACTIVITY 3

Settling Sediment and Stream Bank Vegetation

Part 1

1. The soil becomes suspended throughout the water and the water turns brown or black with soil.

2. Nearly 100 percent of the light from the flashlight will be transmitted through the jar of just water. The percentage of light transmitted through the water and soil depends on the characteristics of the soil used. There may be virtually no light transmitted through the soil and water mixture.

3. If a waterway is clogged with sediment, aquatic plants may not receive as much light as they need to live. Some fish, insects, and other creatures depend on these plants for food.

4. Most people expect their drinking water to be crystal clear.

5. Times will vary due to soil texture (particle size). Soils with fine particles (such as clay and silt) will take longer than soils with larger particles (silt, sand).

6. The upper section of water clears first. Large particles of soil settle to the bottom first because they weigh more.

Part 3

1. Your answer will depend on how much water you poured on the boxes.
2. Water will pass through the soil box faster. Some water will soak into the soil and some will flow over the top of the soil, but it will all soak into the sod.
3. Water from the sod box is clearer because it infiltrates the soil. Some water flows across the surface of the soil in the soil box and picks up soil particles.
4. Less soil was lost to the forces of water in the sod box.

INQUIRY TIME ACTIVITY 4

pH of Common Substances

Part 1

Substance	pH
lemon juice	2.4
vinegar	3.0
orange juice	3.5
tap water	~7
milk	6.5
baking soda solution	8.3

Part 2

1. Some fish are more tolerant than others of low-pH water. However, very few can survive at pH less than about 4.5. This is because the acidity changes the flow of elements into and out of a fish's blood and makes the blood more acidic.

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MacKenzie, K. and F. Mitchell. 1997. *Stream Study and Water Quality Assessment Guide*. New Hampshire Fish and Game Department and University of New Hampshire Cooperative Extension Service.

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Pennsylvania Code, Chapter 93, Water Quality Standards. www.pacode.com/secure/data/025/chapter93/chap93toc.html

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Swistock, B. R., W. E. Sharpe, and J. A. Clark. 2000. *Water Tests: What Do the Numbers Mean?* Penn State Cooperative Extension. University Park, PA. pubs.cas.psu.edu/FreePubs/uh136.html

U.S. Environmental Protection Agency Office of Water. 1998. *Water Quality Criteria and Standards Plan—Priorities for the Future, Interim Final Report*. EPA 822-R-98-003. pp. 5–6.

U.S. Environmental Protection Agency Office of Water. 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA 841-B-97-003. www.epa.gov/owow/monitoring/volunteer/stream/

Resources

Volunteer Water Quality Monitoring Information

DEP's Citizen Volunteer Monitoring Program contains databases for collecting and using information from thousands of citizen volunteer monitors around the Commonwealth; list of monitoring sites: www.dep.state.pa.us/dep/deputate/watermgt/WC/subjects/cvmp.htm.

U.S. Environmental Protection Agency Office of Water. 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA 841-B-97-003. www.epa.gov/owow/monitoring/volunteer/stream/

Pennsylvania Water Quality Data and Information

DEP's Water Quality Assessments and Standards Page
Links to the full water quality report; existing use classifications;
www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/wqstandards.htm

DEP's Bureau of Watershed Management
www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm

DEP's Pennsylvania Gazetteer of Streams
www.dep.state.pa.us/eps/default.asp?P=fldr200149d1642109%5Cfldr200149d3334147

U.S. EPA's Surf Your Watershed Site
Contains links to all kinds of information about watersheds all over the country—citizen groups, water quality data, watershed restoration projects, etc.
cfpub.epa.gov/surf/locate/index.cfm

USGS Water Resources of Pennsylvania
pa.water.usgs.gov/

Pennsylvania Association for Rivers and Watersheds
Contains directory of and links to watershed associations; searchable by association name or by watershed name; great list of links related to Pennsylvania water quality
www.pawatersheds.org

Water Test Kits and Lab Supplies

Acorn Naturalists
155 El Camino Real
Tustin, CA 92780
Phone: 800-422-8886
Fax: 800-452-2802
www.acornnaturalists.com
water test kits

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215-3398
Phone: 800-334-5551
Fax: 800-222-7112
www.carolina.com
water test kits, litmus paper

Fisher Science Education
3970 Johns Creek Court
Suite 500
Suwanee, GA 30024
Phone: 800-766-7000
www.fisheredu.com
litmus paper

Labwarehouse.com
P.O. Box 1030
Skokie, IL 60076
Phone: 847-647-0011
www.labwarehouse.com
litmus paper

LaMotte
P.O. Box 329
Chestertown, MD 21620
Phone: 800-344-3100
water sampling kits, field and lab water testing equipment, educational materials

VWR Sargent Welch
Phone: 800-27-4368
www.sargentwelch.com

Watercenter.com
3213 West Wheeler St. #224
Seattle, WA 98199
Phone: 206-284-1350
www.watercenter.com
pool water test kits, water test kits

Also check the phone book for a local aquarium (pet) store or pool dealer to find water test kits. Some pharmacies can also supply litmus paper for checking pH.

4-H Project Completion

Project completion requirements may vary by county. However, all five Inquiry Time Activities should be completed, and a poster illustrating a lesson learned from one of the activities is recommended.

Glossary

Aquifer: underground sediment, sand, or rock deposits that hold significant quantities of water

Acidic precipitation: rain, snow, and fog that is more acidic than pure water because of interactions with atmospheric pollutants

Buffer strips: strips of vegetation planted or left along waterways to protect the water from the effects of pollutants

Flocculant: material that causes the solid particles in water to join together, making them heavier and faster to settle out

Groundwater: water that has moved down through the soil and is held in porous rock and in cracks in nonporous rock

Infiltrate: to pass into; in this case referring to water slowly seeping into soil

Nonpoint-source pollution: water pollution that enters a body of water through diffuse sources, rather than through a pipe or distinct source (example: pollution from lawn fertilizer)

Potable: fit to drink, drinkable

Point-source pollution: water pollution that enters a body of water from a distinct source, such as pipe

Porous: having many tiny pores or holes

Precipitation: all forms of water that fall from the sky—rain, snow, and sleet

Water quality criteria: those conditions or parameters such as pH, temperature, and turbidity to which standards (numeric concentrations or levels) are applied to assess quality

Water quality standards: numeric concentrations, levels, or conditions of water quality criteria for which governments monitor; laws or regulations that states adopt to maintain and improve water quality and to protect people's health and that of aquatic creatures

Watershed: the land area through which water moves or drains to reach a waterway or body of water

NOTES

4-H Activities Report

This report will help you keep a better record of your club activities. Fill it in as you complete each activity or assignment. Refer to this record when you are entering county, state, and national programs. Ask your local leader to explain these programs to you.

My 4-H Activities Report for the 20 ______________Club Year

Projects taken____

____

____

____

Offices held____

Club____

County____

"Show-and-tells" given to

Family____________________________________

Friends____________________________________

Local club____________________________________

County____________________________________

Regional____________________________________

State____________________________________

News articles____________________________________

Radio____________________________________

TV____________________________________

Things done to improve my health ____________________________

____

____

Community service or citizenship work done

By myself____________________________________

With club____________________________________

Number of meetings my club(s) held this year________________

Number I attended____

Number of new members I encouraged to join 4-H______________

Number of boys and girls I helped with projects________________

In what way?____

____

____

Check those attended and tell how you helped

__________ 3- or 4-day camp

__________ 1-day camp

__________ Club or county tours

__________ Club picnic

__________ Countywide picnic

__________ 4-H Sunday

__________ County fair

__________ Achievement programs

__________ Roundup

__________ Teen Leader Retreat

__________ State 4-H Capital Days

__________ Camp Leadership Training

__________ Penn State 4-H Achievement Days

__________ Pennsylvania Farm Show

__________ National 4-H Week

__________ State Ambassador Conference

__________ Judging training

Others:

____

____

____

PENNSTATE

1 8 5 5

College of Agricultural Sciences
Cooperative Extension

Name ____________________

Address ____________________

____

Name of club or group ____________________

Leader's or teacher's name ____________________

4-H Club Motto

"To make the best better"

4-H Club Pledge

I pledge
my head to clearer thinking,
my heart to greater loyalty,
my hands to larger service, and
my health to better living, for
my club,
my community,
my country, and
my world.

4-H Club Colors

Green and White

18 U.S.C. 707