THE WATER SOURCEBOOK

GRADES

6-8

ZS-1803

WATER SOURCEBOOK

A Series of Classroom Activities for

Grades 6-8

Produced for

LEGACY, INC.

Partners in Environmental Education

in cooperation with

U.S. ENVIRONMENTAL PROTECTION AGENCY

Prepared by

UNIVERSITY OF SOUTH ALABAMA

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For information about obtaining a copy of the Water Sourcebook,

a. The Georgia Water Wise Council, 1033 Franklin Road, Suite 9-187, Marietta, GA 30067-8004 USA, 770/483-9474, 770/426-6901 (fax), or web page: www.griffin.peachnet.edu/waterwise/wwc.htm.

b. The Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994 USA, 800-666-0206 (phone), 703-684-2492 (fax), or web page: www.wef.org.

For information about the Water Sourcebook project, contact Legacy, Inc., P O Box 3813, Montgomery, AL 36109, (334) 270-5921.

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INTRODUCTION

The value of clean, safe water for individuals, communities, businesses, and industries can't be measured. Every living thing depends on water. The economy requires it. Water issues should be everyone's concern, but most people take water quality and availability for granted. After all, clean, safe water is available to most Americans every time they turn on the tap. Water issues do not become a concern until there is a crisis such as a drought or wastewater treatment plant failure. Educating citizens who must make critical water resource decisions in the midst of a crisis rarely results in positive change. Developing awareness, knowledge, and skills for sound water use decisions is very important for young people, for they will soon be making water resource management decisions. Properly equipping them to do so is essential to protect water resources.

WATER SOURCEBOOK PROGRAM

The Water Sourcebook educational program is directed specifically toward the in-school population. The program will consist of the development of supplemental activity guides targeting kindergarten through high school. Materials developed in the program are compatible with existing curriculum standards established by State Boards of Education throughout the United States and teach concepts included in those standards by using water quality information as the content.

The Water Sourcebooks include five chapters: Introduction to Water, Drinking and Wastewater Treatment, Surface Water Resources, Groundwater Resources, and Wetlands & Coastal.

DEVELOPMENT

The Water Sourcebooks are developed in three stages. First, classroom teachers are selected to write the activities with the assistance of education specialists. Teams of teachers are given the task of developing and writing the activities for each of the five instructional chapters. The second step involves testing the activities in the classroom and gathering technical reviews by water experts. From the evaluations provided by the testing teachers and technical reviewers, revisions are made. Finally, editing, and illustrations are completed, and the Water Sourcebook is published.

ACTIVITY DESIGN

All of the activities include "hands-on" components and are designed to blend with existing curricula in the areas of general sciences, language arts, math, social studies, art, and in some cases, reading or other areas. Each activity details (1) objectives, (2) subjects(s), (3) time, (4) materials, (5) background information, (6) advance preparation, (7) procedure (including setting the stage, activity, follow-up, and extension), and (8) resources. Fact sheets and a glossary section are included at the end of the guide to help equip teachers to deal with concepts and words used in the text that may be unfamiliar. A resource section contains a variety of relevant information related to water.

ORGANIZATION OF INDIVIDUAL ACTIVITIES

Each activity is organized in the same way, detailing objectives, materials needed, background information, and procedures. The following is a brief summary of what you should expect to find in each activity.

OBJECTIVES: Describes what the student should be able to do when the activity is completed.

SUBJECT: The general subject(s) to which the activity applies: Sciences, Mathematics, Social Studies, Language Arts, and so on.

TIME: The approximate number of minutes needed to complete the main exercise(s). More time may be needed for the follow-up and extension exercises. Some activities or follow-ups may require collecting data over several days/weeks, but will only need major time blocks at the beginning and end of the activity to explain, present information, and reach conclusions.

MATERIALS: List of materials needed to complete activity. Alternatives and optional materials are listed where appropriate. If the basic materials are not immediately available in your classroom, they can often be borrowed from other classes in the school or local college or university science departments, local government agencies, or area businesses.

BACKGROUND INFORMATION: Background information specific to the activity. This material is suggested as a basis for teacher lecture and/or student discussion when the activity is introduced. (More general background information can be found in the Fact Sheets located in the back of the guide.)

ADVANCE PREPARATION: Directions for the teacher/student to prepare materials in advance.

PROCEDURE: Complete directions to conduct the entire activity, including follow-up and extension ideas. Includes teacher sheets and student sheets.

Setting the Stage: Introduction of the main ideas of the activity to the students. This section may use student discussion questions/topics, sharing the pertinent background information, a demonstration or activity, or a combination of these.

Activity: Step-by-step instructions on how to do the activity.

Follow-Up: Suggestions for ending the activity, often with questions to demonstrate that students understand what they have done.

Extension(s): Suggestions for extending the activity into other subject areas and/or suggestions for other related activities. This part of the activity is optional. Some may be used as ongoing projects, while others may be used as additional classroom work for advanced students or for extra credit.

RESOURCE(S): Reference materials used either in developing the activity or to provide additional information and addresses for ordering materials used in the activity.

ACTIVITY PREPARATION
Once you have decided on the activity(ies) you will be doing, check the materials list. You will need to take into account the number of students or student teams in your class(es). Many materials are readily available, but some may need to be borrowed or purchased ahead of time.

Prepare copies of all the needed student handouts and/or transparencies or other materials for your use. Most activities contain ready-made masters for these. Teacher and student sheets can be easily removed from the binder and replaced after photocopying or producing a thermofax master for print duplication. Some activities also contain suggestions to make a transparency for use with an overhead projector. Transparencies may be made by a thermofax, a photocopier, or by tracing.

If you plan to have the students do part or all of the extension suggestions, you will want to add additional materials to your list. You may also need to locate other sources of information or telephone numbers to complete the extension. Many resource names and numbers can be found in the back of this book. Some extensions can be started simultaneously with the regular activity.

As you read through the activity, decide whether you will do optional suggestions. Check the suggested time for completion of the activity and add any time needed to do any extension activities. The time needed may vary from class to class. These activities have all been field tested in middle school classrooms. However, you might want to do a trial run of the activity yourself to evaluate the time needed and areas where minor problems might occur. It is also a good idea to mark points in the text where natural breaks can be taken to divide the activity into class periods.

The Fact Sheets included in the back of the guide and the background material included in each activity should provide the information necessary for your preparation. Further reading may be found in the list of resources at the conclusion of each activity. If these resources are not readily available, lists of additional resources are provided at the back of this Sourcebook.

PAGINATION

Each chapter is page-numbered separately and is designated with an appropriate chapter number. For example, the "Introduction" chapter begins with page 1-1, the "Drinking Water and Wastewater Treatment" chapter begins with 2- 1, and so on.

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Mathematics	X		X							X	X	X	
Biology		X	X	X			X		X				
Botany		X	X										
Chemistry				X					X	X			
Earth Science							X	X					
Ecology						X	X			X	X		
Geology								X					
Health			X										
Microbiology													
Physical Science									X				
Language Arts		X											
Social Studies		X				X							
Geography													
Art													
Drama													

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Mathematics				X						X			
Biology						X		X			X		
Botany									X				
Chemistry	X	X	X	X			X		X			X	
Earth Science													
Ecology					X	X	X			X		X	
Geology				X									
Health	X			X		X	X	X	X	X			
Microbiology										X			
Physical Science													
Language Arts	X												
Social Studies		X											
Geography													
Art							X	X			X	X	
Drama													

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Mathematics		X	X	X		X				X	X	X	
Biology	X			X			X						
Botany						X						X	
Chemistry		X				X		X	X			X	
Earth Science									X				
Ecology	X	X								X	X	X	
Geology			X					X					
Health													
Microbiology			X		X								
Physical Science						X							
Language Arts						X							
Social Studies										X			
Geography													
Art				X		X							
Drama													

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Mathematics				X		X		X					
Biology												X	
Botany													
Chemistry	X		X						X	X			
Earth Science													
Ecology		X											
Geology		X	X		X	X	X	X			X		
Health										X	X	X	
Microbiology													
Physical Science													
Language Arts								X					
Social Studies													
Geography													
Art					X			X					
Drama	X												

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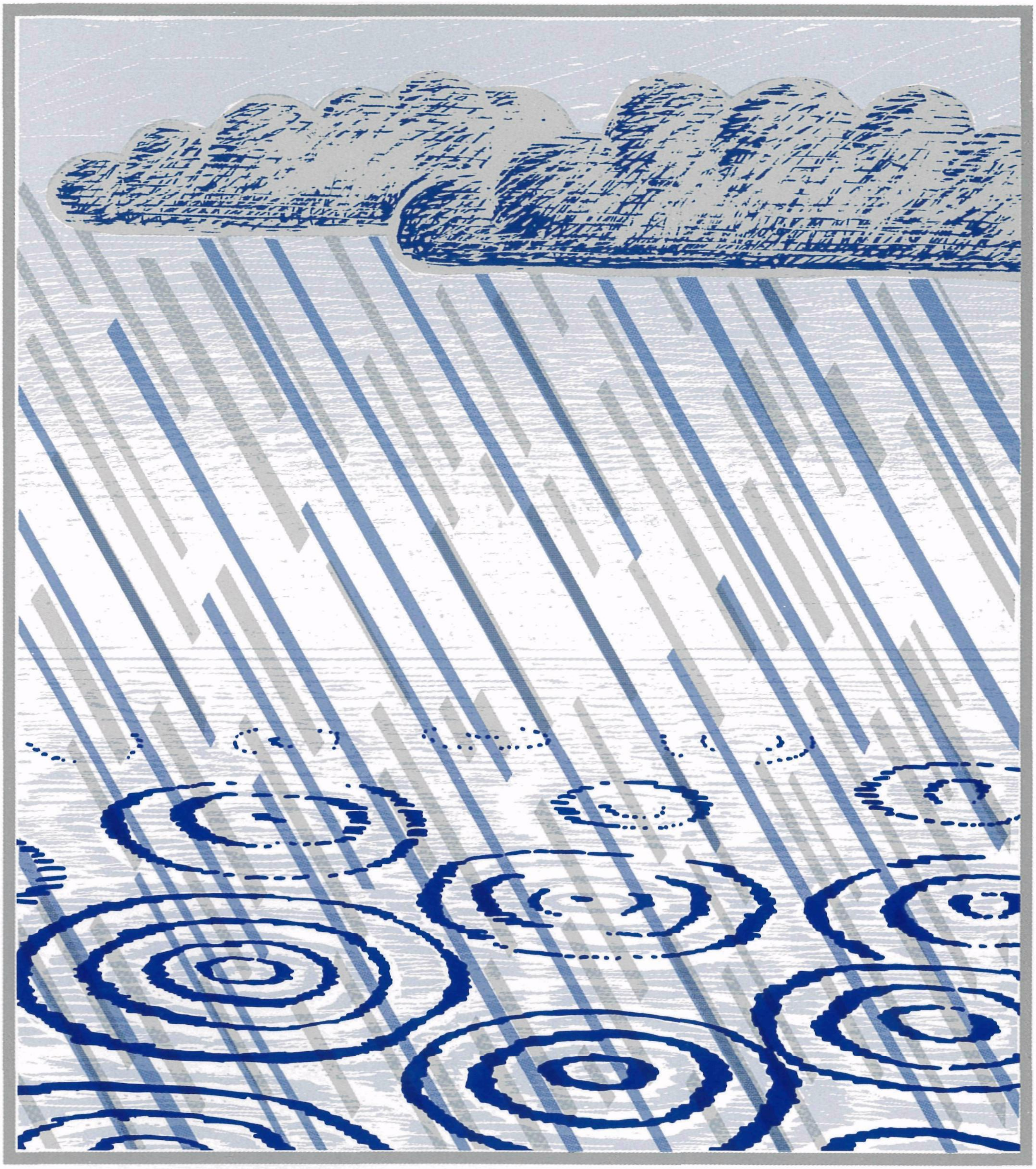
Mathematics	X	X						X	X				
Biology			X	X	X								
Botany				X					X				
Chemistry	X	X				X	X					X	
Earth Science									X	X			
Ecology			X	X		X					X		
Geology													
Health	X												
Microbiology													
Physical Science										X			
Language Arts									X			X	
Social Studies	X	X											
Geography							X	X					
Art						X		X		X		X	
Drama		X									X		



THE WATER SOURCEBOOK

INTRODUCTION TO WATER

TRANSPIRATION IN PLANTS

6 - 8

SUBJECTS:
Biology, Botany, Math

TIME:
3 consecutive class periods

MATERIALS:
potted plants
clear plastic bags
balances with gram weights
marker
sheet of graph paper
student sheet
teacher sheet

OBJECTIVES

The student will do the following:

1. Define the hydrologic cycle.
2. Define transpiration.
3. Name the three parts of the hydrologic cycle.
4. Record the amount of moisture given off by several green plants.

BACKGROUND INFORMATION

The hydrologic cycle begins with the evaporation of water from the oceans. The resulting water vapor is transported by moving air masses. Eventually this water vapor may form into clouds that could lead to precipitation.

What happens to all of the rain that falls on the United States in an average day? About 3 percent of this water will seep underground. About 31 percent will run off into rivers, streams, and lakes. About 66 percent of the water returns to the atmosphere through evaporation and transpiration.

Plants take water from the soil through their roots. They release water vapor to the atmosphere through thousands of small holes (called stomata) on the backs of their leaves in a process called transpiration. A big oak tree gives off about 150,000 liters of water a year. While water from streams and lakes evaporates, plants emit water vapor into the air through transpiration at a much higher rate. But the most significant recyclers of water are the Earth's oceans, which absorb solar energy and evaporate (just like water in a glass will). Evaporated water from the ocean becomes water vapor moving along the surface of the ocean. The air above the ocean also warms and rises, starting a convection cell and carrying water vapor with it. As warm air gets higher, it cools. The cooling water vapor turns back into liquid. The change from water vapor to liquid is called condensation.

Terms

condensation: the act or process of reducing a gas or vapor to a liquid or solid state.

evaporation: the act or process of converting or changing into a vapor with the application of heat.

humidity: the degree of wetness especially of the atmosphere.

hydrologic (water) cycle: the cycle of the Earth's water supply from the atmosphere to the Earth and back which includes precipitation, transpiration, evaporation, runoff, infiltration, and storage in water bodies and groundwater.

moisture: a small amount of liquid that causes wetness.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow.

transpiration: direct transfer of water from the leaves of living plants or the skins of animals into the atmosphere.

ADVANCE PREPARATION

A. Obtain enough green potted plants so that each group of students has two.

PROCEDURE

I. Setting the stage

A. Show a plant to the students.

B. Ask the students the following questions:

1. How do plants get water?

2. What happens to the water after it gets into the plant?

3. How does the water leave the plant?

4. Where does the water go after it leaves the plant?

5. Do plants contribute to the hydrologic cycle?

6. How do plants contribute to the hydrologic cycle?

7. Discuss the hydrologic cycle and how it works.

II. Activity

A. Divide the students into groups.

B. Give each group two potted plants, a plastic bag with a tie, and a balance.

C. Have the groups do the following:

1. Cover one of their plants with a plastic bag.

2. Tie the bag so that it is air tight.

3. Place the plants on opposite sides of the balance.

4. Make sure the plants are balanced by adding weight (gram) to one side if necessary.

5. Mark one side of the balance A and the other side B.

D. For the next three days, ask the students to observe any differences in the weight of the plants.

E. Students can determine the weight lost through transpiration by recording the number of grams it takes to balance the plants. Record this amount each day and plot it on the graph.

F. Have the students answer the questions below:

1. What do you see on the inside of the plastic bag?

2. Which side of the balance has gone up? Down?

3. Do you think all plants give off the same amount of water?

4. Where is the water that was lost in the plant that was not covered?

5. How does humidity affect water loss?

6. What season of the year will the plants give off the most water? The least water?

7. In what biomes would plants lose the most water? The least?

III. Follow-Up

A. Have the students relate transpiration to the hydrologic cycle and draw pictures showing transpiration as part of the hydrologic cycle.

IV. Extension

A. Have the students conduct the same investigation with various plants such as geraniums and cactuses.

B. Research the climatic conditions and types of plants in various biomes.

RESOURCE

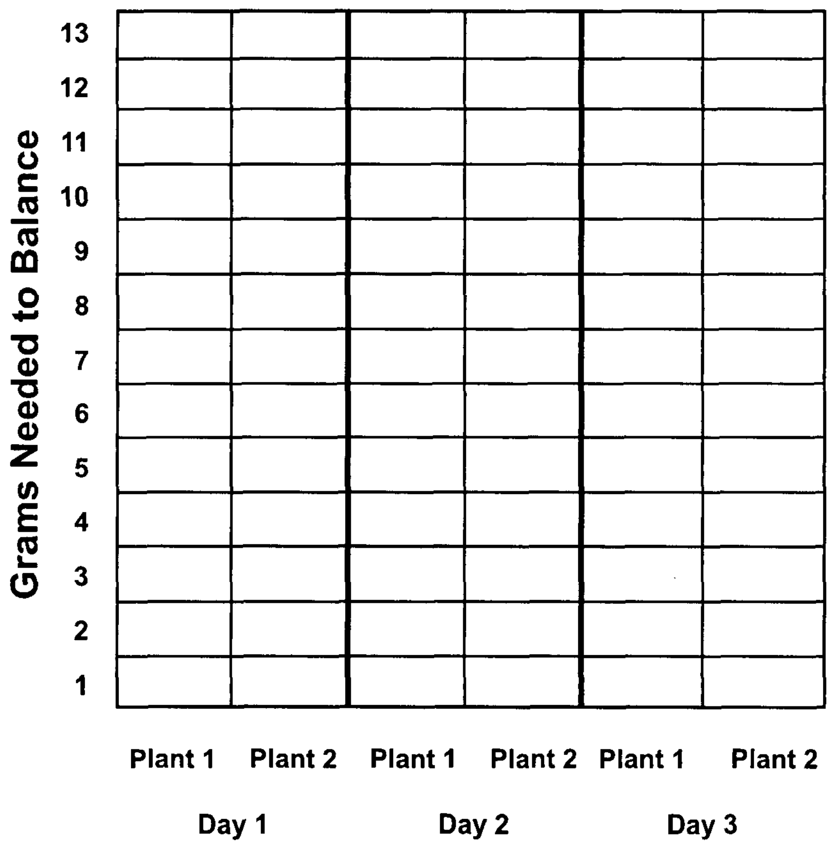
The Water Cycle: http://njnie.dl.stevens-tech.edu/curriculum/recycle.html

STUDENT SHEET — TRANSPIRATION IN PLANTS

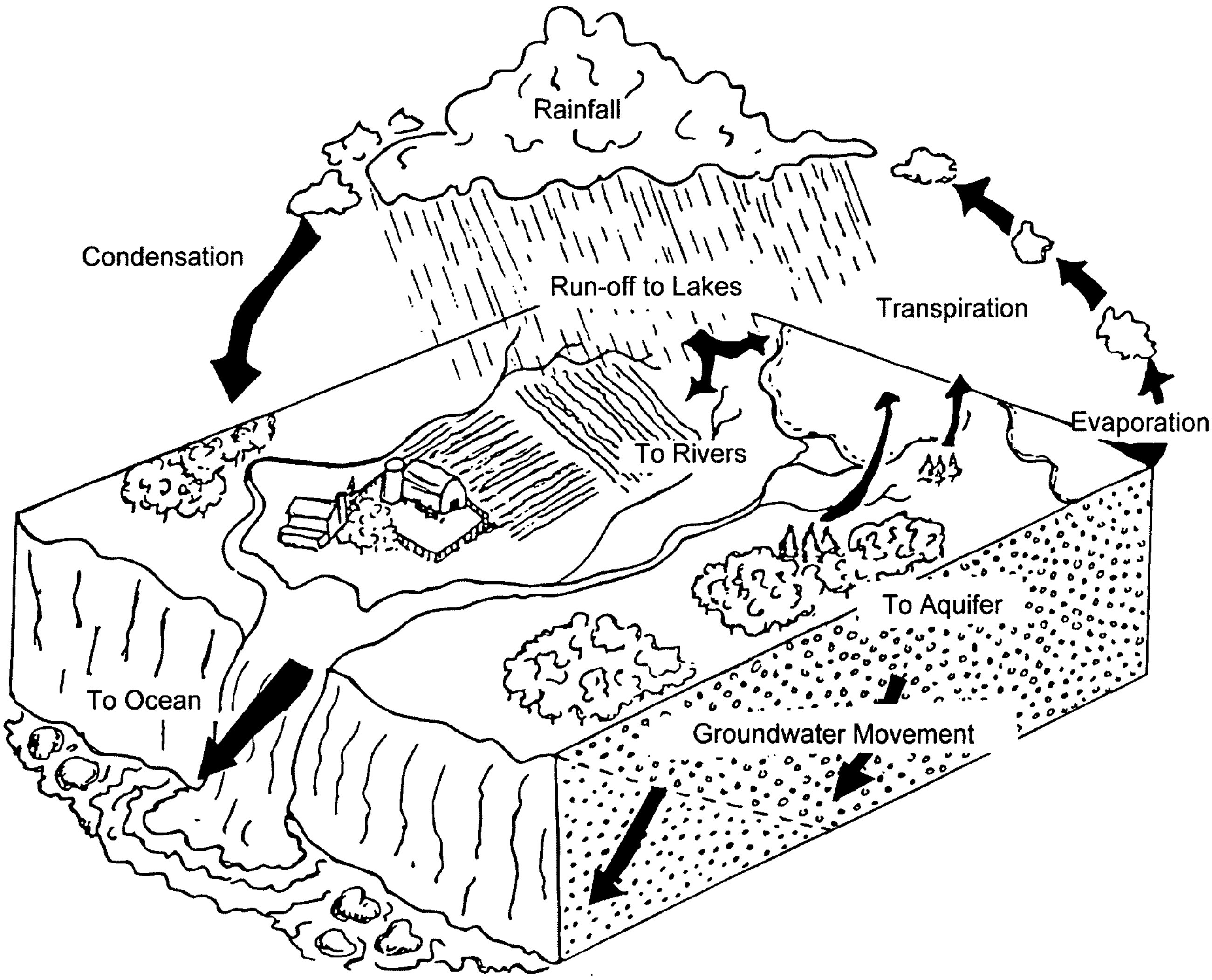
6 - 8

Directions: Determine the weight lost through transpiration by recording the number of grams it takes to balance the plants. Record this amount each day and plot it on the graph below.

	Day One	Day Two	Day Three
Plant #1 (enclosed in plastic)			
Plant #2 (without plastic covering)			



Hydrologic Cycle



DESIGN AND CONSTRUCT A TERRARIUM

6 - 8

SUBJECTS:
Biology, Botany, Language Arts

TIME:
50 minutes

MATERIALS:
2 L plastic soft drink bottle
5 cups potting soil
small plants that grow well in moist environments
5 cups of water
scissors
plastic wrap
masking tape
student sheet

OBJECTIVES

The student will do the following:

1. Design and construct a terrarium.
2. Explain the processes of the water cycle.
3. Describe how a closed system works.

BACKGROUND INFORMATION

The distribution of evaporation and precipitation over the ocean (its hydrologic cycle) is one of the least understood elements of the climate system. However, it is now considered one of the most important, especially for ocean circulation changes on decadal to millennial time-scales. The ocean covers approximately 75 percent of the Earth's surface and contains nearly all (more than 97 percent) of its free water. Thus, it plays a dominant role in the global water cycle. The atmosphere only holds a few cubic centimeters of liquid water, or 0.001 percent of the total. However, most discussions of the water cycle focus on the rather small component associated with terrestrial processes. This is understandable, since the water cycle is so vital to agriculture and all of human activity. Yet, current estimates indicate that 86 percent of global evaporation and 78 percent of global precipitation occur over the oceans. Since the oceans are the source of most rain water, it is important for us to work toward a better understanding of the ocean hydrologic cycle. Small changes in ocean evaporation and precipitation patterns may have dramatic consequences for the much smaller terrestrial water cycle. For example, if less than one percent of the rain falling on the Atlantic Ocean were to be concentrated in the central United States, it would double the discharge of the Mississippi River.

Groundwater is an integral part of the water cycle. The cycle starts with precipitation falling on the surface. Runoff from precipitation goes directly into lakes and streams. Some of the water that seeps into the ground is used by plants for transpiration. The remaining water, called recharge water, drains down through the soil to the saturated zone, where water fills all the spaces between soil particles and rocks.

The top of the saturated zone is the water table, which is usually the level where water stands in a well, if the local geology is not complicated. Water continues to move within the saturated zone from areas where the water table is higher toward areas where the water table is lower. When groundwater comes to a lake, stream, or ocean, it discharges from the ground and becomes surface water. This water then evaporates into the atmosphere, condenses, and becomes precipitation, thus completing the water cycle.

Terms

closed system: a system that functions without any materials or processes beyond those it contains and/or produces itself.

terrarium: a box, usually made of glass, that is used for keeping and observing small animals or plants.

ADVANCE PREPARATION

A. Have students complete the terrarium planning sheet.

PROCEDURE

I. Setting the stage

A. Discuss with students what a closed system is and how it works. (Example: an automobile engine)

B. Ask students the following questions:

1. What is a terrarium?

2. Where are they found?

3. Can anyone design a terrarium?

4. Are they expensive to make?

II. Activity

A. The teacher or the students should cut the top off the 2-liter bottle using scissors.

B. Have the students cover the bottom of the bottle with soil.

C. Have the students plant the small plants and water them.

D. Finally, have the students cover the terrarium with a piece of plastic wrap and seal it.

E. Ask the students to observe the terrarium carefully, noting the path of the water through the water cycle.

III. Follow-Up

A. Ask students to compare the way water moves in the terrarium to the steps of the water cycle.

B. Have the students compare their terrariums with those of other students in the class.

C. Students are to make daily observations of their terrariums and record their findings.

D. Ask students to explain what the terrarium observations say about water in our environment. (Answer: Water is never created or destroyed but is continually obtained, used, and recycled by nature—and by humans.)

IV. Extensions

A. Have students predict what would happen to the plants in three months, six months, or even a year.

B. Make a terrarium on a larger scale using a 5-gallon bottled water bottle.

C. Visit a greenhouse.

RESOURCES

Groundwater in the Water Cycle: http://hammock.ifas.ufl.edu/txt/fairs/16848

Fundamentals of the Ocean Water Cycle: http://earth.agu.org/revgeophys/schmit01/node1.html

Daily Observation of a Hydrologic Cycle in a Terrarium

	Observation
Day 1	
Day 2	
Day 3	
Day 4	
Day 5	
Day 6	
Day 7	
Day 8	
Day 9	
Day 10	

Extended Predictions of Hydrologic Cycle in a Terrarium

	Observation
One month	
Two months	
Three months	

Use the space below to summarize your findings:

AQUATIC FOODS

6 - 8

SUBJECTS:
Biology, Health, Social Studies

TIME:
50 minutes

MATERIALS:
pencil
paper
magazines
newspaper
poster
glue
food labels
student sheet

OBJECTIVES

The student will do the following:

1. Identify foods derived from aquatic sources.

2. Describe how the aquatic environment is important to our food sources.

BACKGROUND INFORMATION

Aquaculture is a form of agriculture which involves the propagation, cultivation, and marketing of aquatic plants and animals in a more-or-less controlled environment. Fish farming was first practiced as long ago as 2000 B.C. in China, but United States aquaculture started in the late 19th century. The Bible refers to fish ponds and sluices, and ornamental fish ponds appear in paintings from ancient Egypt. European aquaculture began sometime in the Middle Ages and transformed the art of Asian aquaculture into a science that studied spawning, pathology, and food webs.

The history of aquaculture in the United States can be traced back to the mid-to-late 19th century when pioneers began to supply brood fish, fingerlings, and lessons in fish husbandry to would-be aquaculturists. Until the early 1960s, commercial fish culture in the United States was mainly restricted to rainbow trout, bait fish, and a few warm water species, such as buffaloes, bass, and crappies. The most widely recognized types of aquaculture in the United States are the catfish industry and crayfish farms in the South and the trout farms in Michigan and the West. Both of these industries involve the culturing of a single fish species for food. Another familiar type of aquaculture is the production of bait minnows and crayfish for use by recreational fishermen. There are several categories of production of aquaculture products: 1) food organisms, 2) bait industry, 3) aquaria trade-ornamental and feeder fish, 4) fee fishing, 5) pond and lake stocking, and 6) biological supply houses.

The production of food organisms is the most common form of aquaculture practiced in the United States. Of the approximately 60 species that have the potential to be grown as food fish, technical support and markets limit these to a select few. The most common food fish and shellfish in the United States are catfish, trout, salmon, carp, crayfish, freshwater shrimp, striped bass and its hybrids, and tilapia.

<u>Terms</u>

aquaculture: the science, art, and business of cultivating marine or freshwater food fish or shellfish, such as oysters, clams, salmon, and trout, under controlled conditions.

mariculture: the cultivation of marine organisms in their natural habitats, usually for commercial purposes.

ADVANCE PREPARATION

A. Gather newspapers and magazines.

B. Obtain labels from certain foods.

C. If students want to, they can bring in food.

PROCEDURE

I. Setting the stage

A. Discuss aquaculture and mariculture. (Example: Seaweed, also known as algin or algar, is used as a thickener in ice cream and is also used as a suspension agent in chocolate milk.)

II. Activity

A. Using newspapers and magazines, clip out all foods derived from aquatic environments.

B. Allow students to draw and label the foods from aquatic sources they brought in.

C. Construct a mural or a bulletin board of pictures and advertisements to show aquatic foods and their sources.

III. Follow-Up

A. Ask the following questions using the mural or bulletin board:

1. Where do certain foods come from?

2. How are they obtained?

3. Where and how are they processed?

4. How are they used?

IV. Extensions

A. Research aquaculture and mariculture in the U. S. and other countries.

B. Classify the aquatic food products according to the kinds of aquatic habitats in which they are found: saltwater (ocean, estuary, marsh) and freshwater (lake, pond, river, stream).

C. What environmental requirements must be met for successful aquaculture? How are they met in real-world applications?

D. Keep a list of foods eaten for a week. Classify each as aquatic or not aquatic.

RESOURCES

Western Regional Environmental Education Council 1987, Project Aquatic Wild, P.O. Box 18060, Boulder, CO 80308-8060. (303) 444-2390.

A Basic Overview of Aquaculture: http://info.utas.edu.au/docs/aquaculture/Pages/Swann.html#400

6 - 8

Directions: List in the correct column the foods you eat in a week.

	Aquatic	Non-Aquatic
List of Foods Eaten		

ON YOUR MARK, GET SET, EVAPORATE

6 - 8

SUBJECTS:
Chemistry, Math

TIME:
50 minutes

MATERIALS:
chalkboard
chalk
sponge
pail of water
salt
clock with second hand
student sheet

OBJECTIVES

The student will do the following:

1. Explain the hydrologic cycle.

2. Explain the terms evaporation, condensation, and precipitation.

BACKGROUND INFORMATION

Evaporation is the main way water on land is transferred to the atmosphere. It is the process whereby liquid moisture is turned into gaseous moisture. Energy is supplied from the sun or atmosphere. This energy causes the water molecules to vibrate faster which causes them to move further apart. As temperatures increase, molecules at the water surface detach and move into the atmosphere. Saturation of the lower atmosphere occurs, dependent upon atmospheric conditions. Cold, humid air undergoing little movement will quickly saturate, but warm, dry air undergoing turbulent mixing as a result of wind will saturate slowly leading to higher evaporation rates.

Factors influencing evaporation:

Meteorological Factors
1. Radiation: This can come directly from the sun or indirectly from the surrounding atmosphere. This causes an increase in the temperature of the air and water.
2. Wind: Evaporation is higher in areas that are open and subject to air movement than in sheltered areas with little movement of the air. Air movement and turbulence is desirable to mix up air and cause saturated lower layers to mix with drier upper air.

Physical Factors
1. Salinity: An increase in salinity leads to a proportional decrease in evaporation rates.
2. Surface Area: As the surface area of the water body increases, the total evaporation increases.

Terms

condensation: the act or process of reducing a gas or vapor to a liquid or solid state.

evaporation: the act of converting or changing into a vapor with the application of heat.

hydrologic (water) cycle: the cycle of the Earth's water supply from the atmosphere to the Earth and back which includes precipitation, transpiration, evaporation, runoff, infiltration, and storage in water bodies and groundwater.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow.

ADVANCE PREPARATION

A. Assemble all of the materials you will need for this activity.

PROCEDURE

I. Setting the stage

A. Fill a glass full of water.

B. Set it on a table close to a heat source.

C. Show the students the glass of water.

1. Ask the students what they think will happen to the water over a period of time.

2. Ask them to explain the process of evaporation.

3. Ask the students what they think will happen to a glass of oil, coca cola, and syrup over time.

II. Activity

A. Distribute the student sheets. Divide the class in half and get two volunteers to come to the chalkboard. Two other volunteers will watch a clock.

B. Have the volunteers draw a circle about two feet in diameter on each half of the blackboard. Provide the two volunteers with a wet sponge.

C. Ask the volunteers to stand in front of the circles. When you say "go," the volunteers will then wet the circle with a sponge.

D. The students who are seated will observe the spot and alert the clock person when their spot is completely dry. The volunteers with the clocks have to immediately stop the clocks when their spot dries.

E. The race is run 2 out of 3 times. The best 2 out of 3 wins.

III. Follow-Up

A. Ask the students the following questions:

1. What happened to the water that the volunteers wiped on the board?

2. Where did the water go?

3. Do you think various substances diluted in water would affect the rate of evaporation?

4. Think of ways to make the water evaporate faster. (Shining a hot light on the circle, using a fan, etc.)

5. What are natural occurrences or results of evaporation? (Answer: lowering of lake levels during warm, dry periods.)

6. What happens within streams and lakes with evaporation relative to pollutants? (Answer: pollutants concentrate.)

IV. Extensions

A. Use saltwater instead of freshwater to conduct the above race.

B. Use alcohol.

RESOURCES

Siepak, Karen L. Water. Carson-Dellosa Publishing Company, Inc., Greenboro, NC, 1994.

Hackett, Jay & others. Science, Merrill Publishing Co., Columbus, OH, 1989.

Evaporation: http://giswww.king.ac.uk/aquaweb/main/evaporat/evapo1.html

Directions: Complete the following chart.

Time it takes for the water to evaporate:

	Race #1	Race #2	Race #3
Volunteer #1			
Volunteer #2			

Time it takes for the alcohol to evaporate:

	Race #1	Race #2	Race #3
Volunteer #1			
Volunteer #2			

SUMMARY:

Explain the results in the space below:

ENVIRONMENTAL VEHICLE PLATE MESSAGES

6 - 8

SUBJECT:
General

TIME:
30 minutes

MATERIALS:
"license plates" made up with shortened environmental terms and phrases
activity sheet
poster board
pens/markers
student sheets

OBJECTIVES

The student will do the following:

1. Decode hidden messages on imaginary vehicle plates.
2. Create plate twisters dealing with water topics.

BACKGROUND INFORMATION

This activity is appropriate for any unit on water. This activity uses any terms that relate to water, such as river, hydrologic cycle, precipitation, runoff, watershed, reservoir, etc., and relates them to the growing popularity of environmental license plates and personalized messages unique to each owner. See the Glossary or other activities for more ideas.

<u>Terms</u>

watershed: land area from which water drains to a particular water body.

hydrologic (water) cycle: the cycle of the Earth's water supply from the atmosphere to the Earth and back which includes precipitation, transpiration, evaporation, runoff, infiltration, and storage in water bodies and groundwater.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow.

reservoir: a body of water collected and stored in a natural or artificial lake.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

hydroelectric: that generation of electricity which converts the energy of running water into electric power.

conservation: act of using the resources only when needed for the purpose of protecting from waste or loss of resources.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

ADVANCE PREPARATION

A. Discuss the topic of water and the many ideas it encompasses.

B. Have the license plates already made up. These may be done on a poster board or placed on a worksheet. At the end of this exercise is a sample worksheet that you may administer to your students.

PROCEDURE

I. Setting the stage

A. Show the students a sample license plate and ask if they can decipher the hidden message.

B. Explain to the students that they will be playing a game to see how many hidden messages they can correctly reveal on the license plates.

C. This activity can be done individually or with a partner. Remind them that it will be a timed activity. The first to decode the hidden messages correctly will be the winner. You may want to have a prize for the winner.

II. Activity

A. Individual work

1. Pass out the activity sheet to all students and begin timing. Have students decode the messages and define the term or explain the process.Call time and have students count the number they got correct.

2. Have students create their own messages based on water terms. They can trade with other students or groups and decode each other's messages.

B. Group work

1. Hold up the first plate to the first pair of partners. The students will try to decipher the message within 30 seconds. If they get the plate correct, they receive a point. If they miss the answer, Team 2 gets a chance, and so on through the other teams.

2. The game ends depending upon the teacher's discretion and time.

C. Key to plates:
1. Groundwater
2. Hydrologic cycle
3. Water vapor
4. Point source pollution
5. Condense
6. Evaporate
7. Conserve
8. Water bird
9. Molecule
10. Conserve water
11. Watershed

III. Follow-Up

A. Have the students make up their own plate messages. They may want to play a round of the game with their license plate ideas.

B. Make a bulletin board of all the plate messages to be shared with other classes.

IV. Extensions

A. Students may write the words and phrases in complete sentences.

B. Have the students compile all of their plate messages and make a booklet.

C. Over a specified time period, have students collect plate messages they observe on the roads during their daily routines.

D. Have the students write to their local license commissioner for a list of creative license plates.

RESOURCES

State Agencies (Revenue, Licensing, Finance Departments).

Directions: Please decode the following vehicle license plate plates.

1) G Water ______________________

2) Hydro C ______________________

3) Water V ______________________

4) P S Poll ______________________

5) C dense ______________________

6) va p rate ______________________

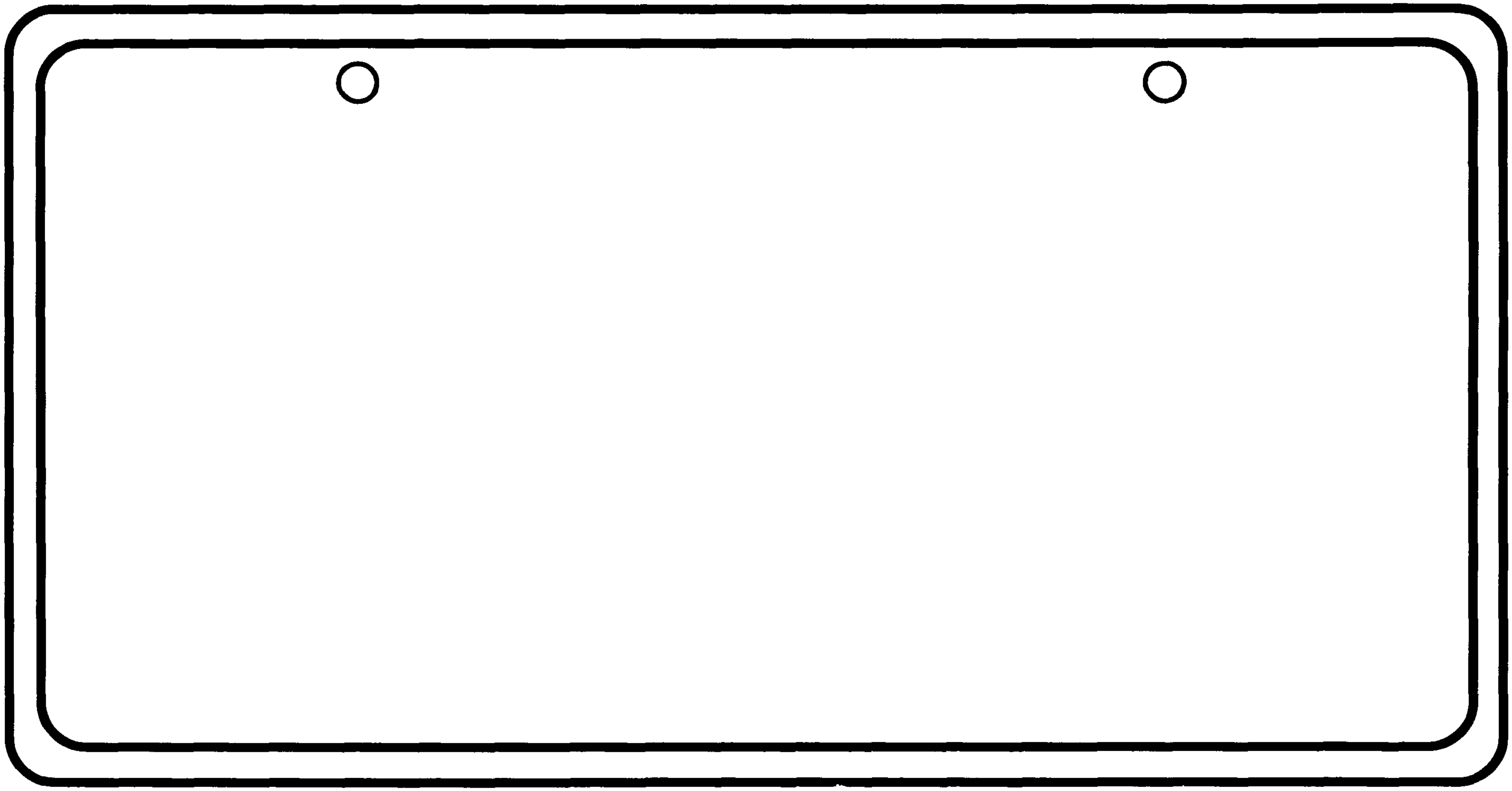
7) C serve ______________________

8) Wa Bird ______________________

9) Mo cule ______________________

10) Con H2O ______________________

11) Water S ______________________



NUTRIENTS AND WATER QUALITY

6 - 8

SUBJECTS:
Biology, Ecology

TIME:
Takes place over the course of about one month. Set up approximately two weeks ahead of experiment.

MATERIALS:
5 clear 1-qt or larger containers (plastic soda bottles or canning jars)
water with algae from a freshwater pond or purchased from a supply house
plant food
aged tap water (allow to sit about 48 hours)
light source (direct sunlight or strong artificial light)
pollutants: cooking oil (colored red), detergent (not green), vinegar
camera and film (optional)
student sheet

OBJECTIVES

The student will do the following:

1. List changes in water conditions caused by various pollutants, such as household chemicals, that often end up in aquatic environments.
2. Describe potential effects on animals and plants caused by these pollutants.
3. Classify sources of pollution.

BACKGROUND INFORMATION

Two nutrients that are essential for the growth and metabolism of plants and animals are *nitrogen* (N), and *phosphorus* (P). Plant growth depends on the amount of phosphorus available. Phosphorus is present in low concentrations in numerous bodies of water, so it is a growth-limiting factor. Since nitrogen is found in several forms, it is frequently more available than phosphorus. Nitrogen is used by plants to make plant proteins, which animals convert into their own proteins when they eat the plants.

Even though nutrients are needed, too much nutrient material in the water can cause pollution. Algae use up phosphorus quickly. When there is excess phosphorus, a vast growth of algae called an algal bloom can occur. The water may then look like pea soup. The algae rob the water of oxygen needed to sustain life. Some forms of nitrogen can cause similar problems in water.

There are several ways that excess nutrients get into the water. Both nitrogen and phosphorus are part of living plants and animals and become part of organic matter when the plants and animals die and decompose. Nutrients come from human, animal (including pet), and industrial wastes. Other sources of nutrients are human activities that disturb the land and its vegetation, such as road and building construction, farming, and draining of wetlands for development. Normally, nutrients are held in the soil and stored in the wetlands. When soil erodes and washes away, it carries the nutrients along until it ends up in the water. If wetlands are drained for development, they can no longer filter nutrients from runoff.

<u>Terms</u>

nutrient: an element or compound, such as nitrogen, phosphorus, and potassium, that is necessary for plant growth.

algal bloom: a heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from farm fertilizers and detergents; phosphates or algal blooms also occur naturally under certain conditions.

point source pollution: pollution that can be traced to a single point source, such as a pipe or culvert (Example: industrial and wastewater treatment plant discharges).

nonpoint source pollution (NPS): pollution that cannot be traced to a single point, because it comes from many individual places or a widespread area (Example: urban and agricultural runoff).

ADVANCE PREPARATION

A. Set up jars at least two weeks before the experiment begins. Explain to the class that they are setting up model water environments for an experiment to be done later. Plants in a wetland or other aquatic system need nutrients to grow. Nutrients are found in all natural systems. Fill the jars with aged tap water. Add one teaspoon of plant food to each jar and stir well.

B. To improve the quality of the model, use pond water or try adding a bit of soil from a pond or aquarium gravel along with the water. Place the jars in a window where they will get good indirect light or light provided by an incandescent or fluorescent light source. The jars should not be placed in a cold location.

C. Explain to the students that they will be using the model aquatic environments to test the effects of certain pollutants that come from home. Students should decide on household products to use—products that they feel are used frequently, are often dumped down the drain, and thus end up in waterways. Students should bring samples of these materials from home.

PROCEDURE

I. Setting the stage

A. Begin with a classification exercise explaining that students are to organize what they already know about pollution. Some water pollution comes from specific sources such as drains, pipes, effluent from industry—outfalls. This is called point source pollution. Other kinds of pollution come from many widespread sources and are called non-point source pollution. Write these terms on the chalkboard making two columns. Have students suggest things that pollute the water and place them in categories in the chart.

B. Explain that students will conduct pollutant tests with the models set up two weeks ago.

II. Activity

A. Take out the jars, which by now should have algae growing in them. Have the class decide on three safe pollutants to test—use more plant food for the fourth jar, use the fifth jar as a control. When the class has decided what to test, add the materials to the four jars. Add a reasonable amount: two tablespoons of a strong detergent; enough oil to just cover the surface; 1/4–1/2 cup of vinegar; one or two teaspoons of plant food. Ask students to explain how each pollutant could get into the environment in real life.

B. Leave the jars in the light as before. Have the students write their predictions as to what will happen in each container. Photograph the jars (with labels and dates showing) two or three times each week for several weeks.

III. Follow-Up

A. Results will depend on the type of pollutant used.

   1. Some pollutants, such as the plant food, favor plant growth and will cause an algal population explosion. This is not healthy since it disrupts the balance of organisms. When the algae die and decompose, oxygen is used up. Ask students to name some plants and animals that would be affected by this situation. Oysters and clams would suffocate because they are unable to move to another location to get more oxygen. A thick mat of algae will block out sunlight needed by other plants.

   2. Other pollutants, such as acids, would cause the water to be clear since everything in the water would be killed.

3. The sample with the oil spill may surprise students. If the algae have enough sunlight, they may produce enough oxygen to keep things alive below the oxygen-impervious oil layer. Ask students to consider the effects of a larger spill—ducks and other birds would become coated with oil and not be able to fly, fish gills would be clogged, etc. Ask the students for their conclusions.

B. Human activities which result in water pollution can affect the water environment in ways that are disastrous for natural communities. Some nutrients are necessary for an aquatic habitat, but having too many is harmful. Have the students explain how.

IV. Extensions

A. Ask students whether or not they can devise a method to reverse the pollution in their models. (Example: Add baking soda to the acid model to neutralize the acid, which is similar to adding limestone rocks to lakes or streams to lessen the effects of acid rain. Example: Mop up the oil spill with sawdust, cotton, etc. Could students skim off the oil from their model and let oxygen through again?)

B. Discuss ways to keep pollutants from reaching the water and ways to reduce the amounts that do get through.

RESOURCES

"What's In the Water?" Living In Water, pp. 55-57.

WOW!: The Wonders of Wetlands, pp. 80, 87-89.

Directions: Record your observations of changes in water conditions caused by pollutants.

	3 days	6 days	9 days	12 days	15 days	18 days	21 days
Jar #1 (1 tsp. plant food added — pollutant added is motor oil)							
Jar #2 (1 tsp. plant food added — pollutant added is strong detergent)							
Jar #3 (1 tsp. plant food added — pollutant added is vinegar)							
Jar #4 (1 tsp. plant food added — pollutant is 2 more tsp. plant food)							
Jar #5 (1 tsp. plant food added — no pollutant added. This is the control.)							

WATER RESOURCE PROBLEMS: TOO LITTLE WATER

6 - 8

SUBJECTS:
Earth Science, Ecology, Social Studies

TIME:
50 minutes

MATERIALS:
soil
gravel
sand
pebbles
bedding plants
shallow pan
water
student sheets

OBJECTIVES

Students will do the following:

1. Make a model of a drought.
2. Explain why water is our most abundant resource.

BACKGROUND INFORMATION

Human activities are causing environmental changes that can directly affect global conditions and global politics. During the late 19th and 20th centuries, modern civilization began to degrade the quality and viability of global ecosystems through air and water pollution, changes in atmospheric trace-gas levels, and massive development projects that directly affect ecological balances. Such degradation alters the quality and quantity of resources such as freshwater, genetic reserves, and agricultural soils. These impacts, in turn, can affect political and security relationships, as demonstrated by recent events in Somalia and northern Africa, friction over acid rain, water pollution, and shared rivers throughout the world, and growing global concern about climatic changes and depletion of stratospheric ozone. Future international tensions and conflict may thus come to depend as much on environmental and resource pressures as on the geopolitical inclinations of nations.

Terms

desalination: the purification of salt or brackish water by removing the dissolved salts.

drought: a lack of rain or water; a long period of dry weather.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

water conservation: practices that reduce water use.

ADVANCE PREPARATION

A. Prepare separate containers of soil, gravel, small stones, pebbles, and sand.

B. Gather all materials for groups of four.

C. Select a nice warm place (plenty of sunshine) around the building (undisturbed) to leave the activity materials for 4 to 5 days.

D. Review the general steps of conducting scientific investigations with students. Later they will write up their investigations using these steps.

1. Define the problem
2. Formulate the hypothesis

3. Collect information or data.

4. Test the hypothesis.

5. Analyze the results.

6. Formulate a tentative conclusion. Stress that conclusions are tentative based on the procedures that were followed in this specific investigation. Results may turn out differently if the investigation was done at another time in another place. To get more accurate results, scientists repeat investigations several times and get an average.

PROCEDURE

I. Setting the stage

A. Have students bring in plants, or ask nearby nursery to donate bedding plants.

B. Work near running water.

II. Activity

A. Have the students do the following:

1. Place equal amounts of sand, soil, gravel, and pebbles in a shallow baking pan. Start with the largest size material and put it on the botton. This should be the gravel unless the pebbles are larger. Make this the first layer. Then add the next largest material ending with the soil as the top layer.

2. Add small stones to the pan.

3. Add plant life to the pan and sprinkle with water.

4. Set pan aside for 4 or 5 days.

5. Make observations daily and record them on the data chart.

III. Follow-Up

A. Have students write up the activity following the steps of scientific investigation.

B. Have students do research on droughts.

C. Research different water requirements of various plants.

D. Assign research papers on each of the topics in the background information.

IV. Extensions

A. Repeat the investigation using different plants. Use plants with a wide range of adapatability such as succulents and broad - leafed plants.

B. Call a plant nursery and find out about their watering practices. When do they water? How long do they water? Which plants need the most water? Which plants need the least amount of water?

C. Repeat the investigation with the same kinds of plants but leave one in the pot or pan and plant the other in the ground. What differences are there in how often the plant needs to be watered?

RESOURCE

Arms, Karen, Environmental Science, Holt, Rinehart and Winston, Orlando, FL, 1996.

Directions: Observe your plants each day and record your observations.

DAY	OBSERVATIONS
1	
2	
3	
4	
5	

WATER RESOURCE PROBLEMS: TOO MUCH WATER

6 - 8

SUBJECTS:
Earth Science, Ecology, Geology

TIME:
50 minutes

MATERIALS:
soil
gravel
small stones
pebbles
bedding plants
shallow pan
water
beaker (baby food jars for water)
student sheet
teacher sheet

OBJECTIVES

The student will do the following:

1. Explain what happens to various areas that are flooded.
2. Measure the amount of water required to saturate and supersaturate a soil sample.

BACKGROUND INFORMATION

Some countries have enough annual precipitation, but they get most of it at one time of the year. More than 2,000 cities world wide are located completely or partially on flood plains suffering floods on an average of once every two to three years. (This is a statistical average. Major floods may occur three times within a month, annually for five consecutive years, or not for several hundred years.)

Flooding is disastrous. It has become more severe over the years. It causes billions of dollars in property damages. People die by drowning and snakebite. Some are left homeless. Hundreds of thousands contract diseases such as cholera and typhoid fever from contaminated water and food supplies.

Floods occur when a watershed receives so much water that its waterways cannot drain it off properly. A watershed is an area of land (usually quite large) over which water drains into a river or stream. A small river will drain several thousand or hundreds of thousands of acres of land. Within any one watershed, excess rain will cause increased water levels downstream. What occurs at any point along a river can affect not only that point but also the entire watershed.

To minimize the effects of a flood, engineers build levees to constrict the overflow of rivers. As more communities build levees, the water in a river is forced to flow at a higher rate because it cannot spread out. As the water flows at a higher rate, it alternatively erodes and deposits sediment and alters the riverbed. The situation worsens as the water rushes downstream. The water level can only continue to rise, eventually spilling over the levees. During prolonged periods of flooding, many levees give way because they are under pressure from the swollen river and are being undercut by water seepage.

Floods in undeveloped areas are not as damaging as the floods in developed areas. First of all, many natural areas have thousands of acres of wetlands which act as giant sponges to soak up excess water. Second, many rivers overflow into the floodplain—a low, flat area on either side of the river. If a river is allowed to spread out onto its floodplain, the flow downstream is slowed. A river's floodplain can accommodate huge amounts of water which are diverted from the main channel and held back. Allowed to flood in this way, the river creates less damage downstream. If humans do not interfere with it, a stream or river produces its own flood control system

Floods are the most frequent and most lethal natural disasters. Ninety-seven percent of the Earth's water is in the oceans; only 0.014% is in lakes, rivers, soil, and the atmosphere. Floods occur when a larger than normal amount of water moves through an area without adequate natural or human-made barriers, or the soil capacity to accommodate the water. This large amount of water may result when previously controlled large bodies of water escape their boundaries or may result from rainfall, melted snow or ice, sea surges, and accidental damming. A high tide combined with an atmospheric depression can cause the seas to flood low lying areas. The majority of floods, called flash floods, happen unpredictably after a big rain. A cubic foot of water weighs 62 pounds. Sand and clay mixed with the water increases force. Most damage results from the impact of moving water and the objects carried by it. In 1969, the National Weather Service began predicting flash floods. Potential flooding is predicted using automatic rainfall gauges, radar, and human observation. Stilling wells, which measure small changes in river height, are also used.

Terms

flooding: an overflowing of water, especially over land not usually submerged.

floodplain: a low, flat area on either side of a river that can accommodate large amounts of water during a flood, lessening flood damage further downstream.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow.

saturation: the state of being infused with so much of a substance (Example: water) that no more can be absorbed, dissolved, or retained.

supersaturation: the state of being infused with more of a substance (Example: water) than is normally possible under given conditions of temperature and pressure.

ADVANCE PREPARATION

A. Prepare container with sand, gravel, pebbles, and small stones.

B. Gather enough materials for groups of four.

C. Work near running water.

PROCEDURE

I. Setting the stage

A. Discuss with students the key terms.

B. Explain that floods are disastrous.

C. Have students suggest ways to prevent or reduce flood damage.

II. Activities

A. Divide the students into groups of four.

B. Give each group the following: sand, soil, gravel, small stones, pebbles, bedding plants, shallow pan, and a beaker with water.

C. Have students do the following:

1. Place equal amount of sand, gravel, small stones, pebbles, and soil in the shallow dish.

2. Arrange the plants throughout the soil mixture.

3. Saturate the soil mixture with water. Make and record observations.

4. Supersaturate the soil mixture, make observations, and record.

III. Follow-Up

A. Have students write up the activity, utilizing the steps of the scientific method.

B. Have students list reasons why flooding is disastrous.

C. Have students list various flood management/control methods.

IV. Extension

A. Research areas in the US and worldwide that have experienced devastating floods. Find out how many people died and what the estimated amont of damage was in dollars. Indicate the flooded areas on a map.

RESOURCES

American Water & Energy Savers, Inc.: http://www.americanwater.com/49ways.htm

Miller, Tyler, Living in the Environment, Wadsworth Publishing Co., Belmont, CA, 1990.

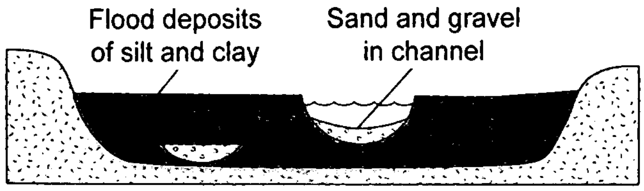
Monorama Talaiver, author: Floods: http://ms.mathscience.k12.va.us/lessons/weather/flood.html

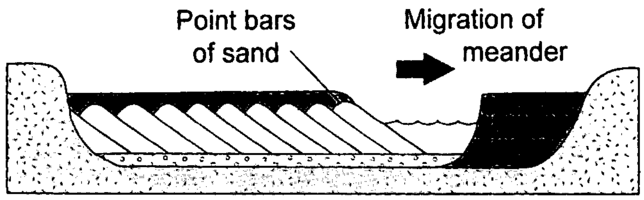
Newton's Apple: Floods: http://132.230.36.11/schule/earthquake/floods.html

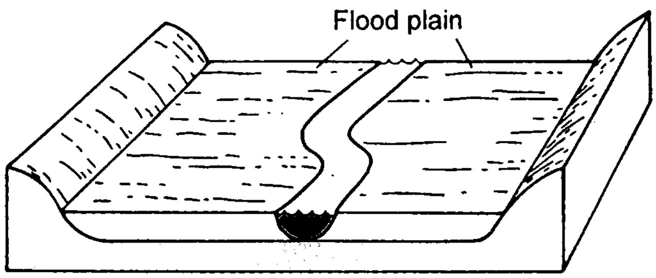
Pacific Institute: Water and Sustainability: http://www.igc.apc.org/pacinst/progs.html#

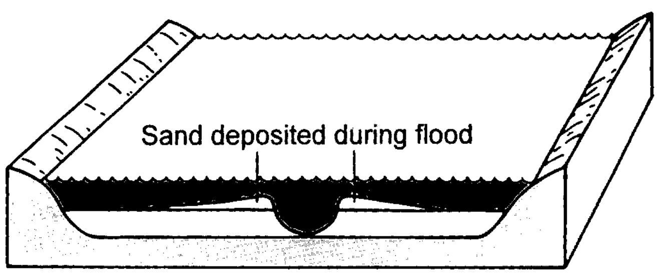
U.S. Army Corps of Engineers District Offices

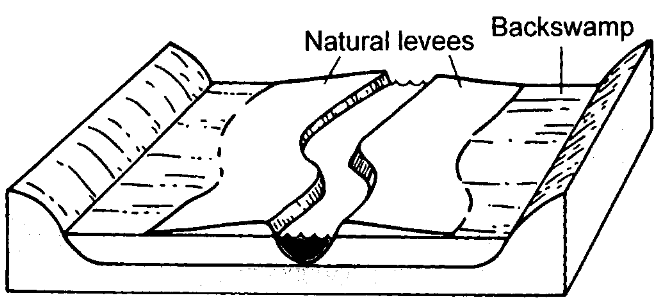
DAY ONE	**Soil Type:**	**Observations:**
	Saturated	
	Supersaturated	
DAY TWO	**Soil Type:**	**Observations:**
	Saturated	
	Supersaturated	
DAY THREE	**Soil Type:**	**Observations:**
	Saturated	
	Supersaturated	
DAY FOUR	**Soil Type:**	**Observations:**
	Saturated	
	Supersaturated	
DAY FIVE	**Soil Type:**	**Observations:**
	Saturated	
	Supersaturated	


Flood deposits of silt and clay
Sand and gravel in channel


Point bars of sand
Migration of meander


Flood plain


Sand deposited during flood


Natural levees
Backswamp

WATER CAREER FAIR

6 - 8

SUBJECT:
Biology, Chemistry, Physical Science

TIME:
3 class periods

MATERIALS:
student sheet

OBJECTIVES

The student will do the following:

1. Identify different water-related careers that work specifically with water.

2. Design a career fair exhibit to showcase careers related to water.

BACKGROUND INFORMATION

If someone asked you to name the different careers that are related to water, you might immediately think of a marine biologist or someone in the Navy or Coast Guard. Perhaps you might even think of one who works with different sea animals that are held in captivity. However, these are only a few water-related careers. Some examples of workers in water-related jobs are weather forecasters, landscape architects, and nursery workers. Consider the oil rig worker that helps build and maintain off-shore oil rigs. What about the operators for wastewater treatment plants whose duties include testing water samples and maintaining equipment? Consider also those who work daily to assure that toxic waste does not reach our drinking water supply, or the meter reader who determines how much water we use. There's also the meteorologist, climatologist, or aqueduct builder. The list is endless. Our lives are maintained and surrounded by water. A water-related career is probably one of the most important careers one could choose.

Terms

hydraulic: operated, moved, or brought about by means of water.

ADVANCE PREPARATION

A. Gather materials needed for students to build an exhibit on their selected careers.

PROCEDURE

I. Setting the stage

A. Discuss different water-related careers and how each one relates to students personally. Use as many visuals as possible, including pictures, videos, speakers, etc.

1. Ask students to name different types of water-related careers.

2. Ask students if they know someone who works in this area.

II. Activity

A. Have students research the topic of "water-related careers." Guide students as to how to do this. For example, have them look up marine biologist in an encyclopedia or dictionary, or have students interview an individual in a water-related career.

1. Students should generate their own questions for the interview, asking at least ten questions. Some sample question areas are listed below:

a. Educational background or training

b. Salary range

c. Daily responsibilities and duties

d. Amount of travel involved

e. Location of most work opportunities

B. Have students create a poster or backboard that provides information about the career.

III. Follow-Up

A. Have students design exhibits and hold a water-career fair using the library where other students can view their projects.

IV. Extensions

A. Take a field trip to a water or wastewater treatment plant or another type of water facility.

B. Have speakers come in.

C. Consider businesses that might allow students interested in certain careers to "shadow" someone working there for one day. This would enable the students to see the daily responsibilities of that particular career.

RESOURCES

Biological Science. Green, 1994.

Earth Science. Holt, 1994.

WATER-RELATED CAREERS

- Agricultural Engineer
- Aquarium Director
- Archaeologist
- Aquatic Entomologist
- Biologist
- Biosolids Specialist
- Boat Builder
- Boater
- Botanist
- Bottled Water Company Employee
- Builder
- Chemist
- Chemical Engineer
- Civil Engineer
- Coast Guard
- College/University Professor
- Commercial Fisherman
- Computer Scientist
- Desalination Plant Director
- Diver
- Docks Master
- Ecologist
- Environmental Attorney
- Environmental Chemist
- Environmental Engineer
- Environmental Scientist
- Farmer
- Fire Fighter
- Fisheries Biologist
- Forester
- Geographer
- Geologist
- Groundwater Contractor
- Health Dept./Environmental Inspector
- Hydraulic Engineer
- Hydrologist
- Ice Skater
- Landscape Artist
- Landscape Architect
- Limnologist
- Malacologist
- Marina Owner/Operator or Employee
- Marine Salvage Engineer
- Marine Geophysicist
- Marine Geologist
- Marine Conservationist
- Marine Explorer
- Marine Technician
- Merchant Marine
- Meteorologist
- Motor Sailboater
- Navy
- Oceanographer
- Olympic/Professional Swimmer
- Photographer
- Physical Scientist
- Plant Physiologist
- Plumber
- Potter
- Professional Tournament Fisherman
- Professional Skier (Water or Snow)
- Rafting Guide
- Ranger
- Recreation Instructor
- Science Teacher
- Scuba Diver
- Ship Builder
- Seaman
- Snow Hydrologist
- Soil Scientist
- Structural Engineer
- Submariner
- Sunken Treasure Hunter
- Tugboat Biologist
- Underwater Photographer
- Wastewater Treatment Engineer
- Water Meter Reader
- Water Level Controller
- Water Resources Engineer
- Water Quality Control Officer
- Well Driller
- Yachtsman
- Zoologist

WATER EVAPORATION

6 - 8

SUBJECTS:
Chemistry, Math

TIME:
50 minutes

MATERIALS:
pan balance
cellulose sponges
scissors
plastic sandwich bag
spotlight
hot water
cold water
electric fan
petri dishes
student sheets

OBJECTIVES

The student will do the following:

1. Determine the different factors that affect evaporation rate.
2. Brainstorm to come up with ideas to solve a problem.
3. Employ the scientific method while designing and conducting an experiment.

BACKGROUND INFORMATION

Water Evaporation
See "Transpiration in Plants" activity for information on water evaporation.

Humidity is the water vapor or moisture content always present in the air. Humidity can be defined in two ways:

1. Absolute humidity is the weight of water vapor per unit volume of air, pounds per cubic foot or grams per cubic centimeter.
2. Relative humidity (RH) is the ratio of the actual partial vapor pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature. Relative humidity is the commonly accepted measurement of the moisture content in the air.

In simpler terms, relative humidity may be considered as the amount of water vapor in the air compared to the amount the air can hold at a given temperature. Warm air can hold more moisture than cold air. For example, 10,000 cubic feet of 10 degrees F air can hold 5,820 grains of moisture representing a relative humidity of 75 percent. If this air is heated to 70 degrees F, it will still contain the same 5,820 grains of moisture. When it is at 70 degrees F, 10,000 cubic feet of air can potentially hold 80,550 grains of moisture; however, the 5,820 grains it actually holds gives it a relative humidity of about 7 percent.

When humidity is low (less than 40 percent RH), air seeks to draw moisture from any available source. Dry air can make one feel "cold" in a warm room. Moisture evaporates readily from the skin and leaves a feeling of chilliness even with the temperature at 75 degrees F or higher.

When humidity is high (>60 percent), the humid air tends to make people feel that their environment is warmer than it really is. An area at 72 degrees F and 60 percent or greater RH feels warmer than an area at 72 degrees F and 40 percent RH; this is because the evaporative cooling of the body through perspiration is reduced by the high RH of the surrounding air.

Terms

evaporation: the act or process of converting or changing into a vapor with the application of heat.

molecules: the smallest portions of a substance having the properties of the substance.

saturated air: air that contains as much moisture as it is possible to hold under existing conditions.

humidity: the degree of wetness, especially of the atmosphere.

condensation: the act or process of reducing a gas or vapor to a liquid or solid state.

cloud: a visible mass of tiny bits of water or ice hanging in the air usually high above the Earth.

ADVANCE PREPARATION

A. Students must plan for a control on the factor they are going to test. Remember—the control is to be treated exactly like the variable. Use only one factor to test the variable.

B. Students should write down and be prepared to discuss all steps in the scientific method except stating the problem. (The problem was presented to them.)

PROCEDURE

I. Activity

A. Use one of the factors listed in the student sheet and the materials given to design and carry out an experiment to prove or disprove your prediction for the stated problem. The factors are wind, humidity, water, temperature, or surface area.

   1. Record the steps of your experiment.

   2. Record the results of your experiment. Remember to weigh all sponges before and after use.

B. Compare your results with other groups who are testing the same factor.

C. All groups share the results with the entire class using the charts.

D. Answer the following questions.

   1. Which factor had the fastest evaporation rate? Why? The slowest rate? Why?

   2. How would the above factors influence the different oceans of the world?

   3. Explain how winter, spring, summer, and fall affect the evaporation rate.

III. Extensions

A. Have students construct an iceberg. Fill a balloon with tap water and freeze overnight. The next day peel the rubber off and place the iceberg in a clear container filled 1/2 full of water. Answer the following questions:

   1. How much of the iceberg is above the water? Below the water?

   2. Why are icebergs very dangerous to ships?

B. Write reports on famous shipwrecks.

C. Watch the movie, *The Poseidon Adventure*.

D. Do the Word Search (attached).

RESOURCES

Oceans in Motion, MacMillan / McGraw-Hill, 1995.

Humidity: Friend or Foe, by Enviros: The Healthy Building Newsletter.

Directions: Design and conduct an experiment.

Selected Factor (circle one)	Prediction		
Sun's Energy Wind Humidity Water Temperature			
	Surface Area-Sponge	Weight Before	Weight After

List and number the steps you will follow in your experiment.

1.

2.

3.

4.

5.

6.

INFLUENCE ON EVAPORATION RATE

Sun's Energy	Wind	Humidity	Water Temperature	Surface Area

Explain the results of your experiment.

Directions: Answer the following after conducting your experiment.

1. Which factor had the greatest evaporation rate? Why?

2. Which factor has the slowest evaporation rate? Why?

3. How would the above factors influence the different oceans of the world?

4. Explain how winter, spring, summer, and fall affect evaporation rate?

WORD SEARCH

C	E	G	M	K	B	L	D	M	O	H	R	R
O	R	T	O	U	J	C	L	O	U	D	I	K
N	E	K	L	Z	W	B	C	M	D	Y	A	E
D	R	A	E	I	R	Z	I	I	B	Z	D	T
E	E	K	C	G	E	D	L	R	O	E	B	A
N	H	M	U	P	F	O	M	K	T	M	K	R
S	P	I	L	E	S	P	Z	A	E	O	E	O
A	S	O	E	C	U	L	R	E	A	T	E	P
T	O	U	L	E	S	U	K	R	Z	A	E	A
I	M	O	L	M	T	J	A	C	E	G	O	V
O	T	S	F	A	L	C	M	J	A	F	R	E
N	A	B	S	J	M	O	I	S	T	U	R	E
Z	E	M	G	F	A	V	A	P	O	R	F	M

WORD SEARCH ANSWER KEY

C	E	G	M	K	B	L	D	M	O	H	R	R
O	R	T	O	U	J	C	L	O	U	D	I	K
N	E	K	L	Z	W	B	C	M	D	Y	A	E
D	R	A	E	I	R	Z	I	I	B	Z	D	T
E	E	K	C	G	E	D	L	R	O	E	B	A
N	H	M	U	P	F	O	M	K	T	M	K	R
S	P	I	L	E	S	P	Z	A	E	O	E	O
A	S	O	E	C	U	L	R	E	A	T	E	P
T	O	U	L	E	S	U	K	R	Z	A	E	A
I	M	O	L	M	T	J	A	C	E	G	O	V
O	T	S	F	A	L	C	M	J	A	F	R	E
N	A	B	S	J	M	O	I	S	T	U	R	E
Z	E	M	G	F	A	V	A	P	O	R	F	M

HOME WATER USE

6 - 8

SUBJECTS:
Ecology, Math

TIME:
20 minutes

MATERIALS:
plastic ruler
bath tub with shower
student sheet

OBJECTIVES

The student will do the following:

1. Calculate the volume of water used in the home.

2. Identify methods of conserving water in the home.

BACKGROUND INFORMATION

Which requires less water, a bath or a shower? Did you know 30 percent of your indoor water is used in flushing the toilet? The average toilet uses five to seven gallons per flush. An average household can save about $100 a year and help conserve thousands of gallons of water by installing water-efficient toilets. These "improved" toilets rely on an efficient bowl design and increased flushing velocity—instead of extra water—to remove wastes.

Which uses more water—washing dishes by hand or in a dishwasher? The average dishwasher uses about 10 gallons of water per load, while washing the same number of dishes by hand takes about 16 gallons (though you'll use less water if you use the sink or a dishpan for washing and rinsing). Newer, efficient dishwashers use as little as five gallons per cycle, which means they also consume less energy to heat the water.

Showers and baths account for one-third of most families' water use. The typical shower head allows a water flow of eight to 10 gallons per minute. Installing a flow restrictor or low-flow shower head will reduce this flow by one-half, and most people can't tell the difference. A faucet that drips once per second wastes 2,300 gallons of water a year. Most household leaks are easily fixed by replacing worn parts, like the washer.

Terms

natural resource: something (as a mineral, forest, or kind of animal) that is found in nature and is valuable to humans.

freshwater: water containing an insignificant amount of salts, such as in inland rivers and lakes.

renewable resource: a resource or substance, such as a forest, that can be replenished through natural or artificial means.

conserve: to save a natural resource, such as water, through intelligent management and use.

ADVANCE PREPARATION

A. Discuss with students the importance of conserving water.

B. Make sure each student has a plastic ruler.

PROCEDURE

I. Setting the stage

A. Ask students to estimate how many gallons of water they use daily.

B. Ask students to estimate how many gallons of water they use when taking a bath or shower.

II. Activities

A. Have students measure the amount of water they use when taking a bath by following these steps:

1. Run the bath.
2. Before getting into the tub, measure the depth of the water with a plastic ruler.
3. Record the depth of the water on the Student sheet.

B. Have students measure the amount of water they use when taking a shower by following these steps:

1. Close the bathtub drain.
2. Take a shower using your usual amount of time.
3. Before draining the bathtub, measure the depth of the water with a plastic ruler. (Do not stand in the tub when measuring.)
4. Record the depth of the water on the Student sheet.

III. Follow-Up

A. Have the students answer the following questions on Student Sheet 1.

1. Which requires more water, a bath or a shower?
2. Should the procedure have included a specific length of time for the shower?
3. Why is it important that the depth of the water in the tub be measured without a person in the tub?

B. Have the students review Home Water Use - Ways to Save Water: Student Sheet 2. Ask students to check each one they already use in their home to save water. Have them circle the ones they will plan to use in the future.

C. Have students answer the questions on the Home Water Student Sheet 3. Have them answer questionsl individually first. Then put them into small groups and have them compare answers.

IV. Extensions

A. Ask the students to imagine their city is experiencing a severe water shortage. Have them list ways in which they, as citizens, can conserve water during the crisis.

B. Ask students to keep track of how many baths and showers are taken in their home each day for a week. Calculate how much water is used in the house for baths and showers.

C. Have students go to a hardware store or call one and find out about shower flow restricters. How do they work? How much water do they save? Calculate how much water could be saved in their house if one was installed in each shower.

D. Call the city or county water department. Find out where the city water comes from and how much it costs per 1,000 gallons.

RESOURCE

Earth Science. Prentice Hall, Englewood Cliffs, NJ, 1991.

STUDENT SHEET 1 *HOME WATER USE*

6 - 8

Directions: Measure the length and width of the bathtub or shower. Then measure the depth of the water used for a bath and for a shower. Record these measurements below:

Bath:

Shower:

To determine how much water is used in one bath or shower, use the formula for volume, V = length x width x height. Use your measurements from above.

Bath:

Shower:

Using the chart below, figure the amount of water used in one day, one week, one month, and one year, by multiplying the volume of water used in one bath or shower by the number of baths and showers taken during each of those times.

	1 Day	1 Week	1 Month	1 Year
Bath Tub				
Shower				

Now, answer the following questions:

1. Which requires more water, a bath or a shower?

2. Should the procedure have included a specific length of time for the shower?

3. Why is it important that the depth of the water in the tub be measured without a person in the tub?

Ways to Save Water

1. Never put water down the drain when there may be another use for it, such as watering a plant or garden or cleaning.
2. Verify that your home is leak-free because many homes have hidden water leaks. Read your water meter before and after a two-hour period when no water is being used. If the meter does not read exactly the same, there is a leak.
3. Repair dripping faucets by replacing washers. If a faucet is dripping at the rate of one drop per second, 2,700 gallons per year can be wasted, which adds to the cost of water and sewer utilities and places strain on septic systems.
4. Check for toilet tank leaks by adding food coloring to the tank. If the toilet is leaking, color will appear within 30 minutes.
5. Avoid flushing the toilet unnecessarily. Dispose of tissues, insects, and other waste in the trash rather than the toilet.
6. Take shorter showers. Replace shower heads with ultra-low-flow versions.
7. Use the minimum amount of water needed for a bath by closing the drain first and filling the tub only 1/3 full.
8. Operate automatic dishwashers and clothes washers only when they are fully loaded, or properly set the water level for the size of load being washed.
9. When washing dishes by hand, fill one sink or basin with soapy water. Quickly rinse them under a slow-moving stream from the faucet.
10. Store drinking water in the refrigerator rather than letting the tap run every time cold water is needed.
11. Do not use running water to thaw meat or other frozen foods. Defrost food overnight in a refrigerator or by using the defrost setting on a microwave.
12. Kitchen sink disposals require lots of water to operate properly. Start a compost pile as an alternate method of disposing food waste instead of using a garbage disposal. Garbage disposals also can add 50% to the volume of solids in a septic tank which can lead to malfunctions and maintenance problems.
13. Insulate water pipes. Hot water is available faster, and this avoids wasting water while it heats up.
14. Don't over water the lawn. As a general rule, lawns only need watering of one inch every 5 to 7 days in the summer. A hearty rain eliminates the need for watering for as long as two weeks.
15. Water lawns during the early morning hours when temperatures and wind speed are the lowest. This reduces losses from evaporation.
16. Don't water the street, driveway, or sidewalk. Position sprinklers so that water lands on the lawn and shrubs — not the paved areas.
17. Raise the lawn mower blade to at least three inches. A lawn cut higher encourages grass roots to grow deeper, shades the root system, and holds soil moisture better than a closely clipped lawn.
18. Avoid over-fertilizing the lawn. The application of fertilizers increases the need for water.
19. Plant native and/or drought-tolerant grasses, ground covers, shrubs and trees. Once established, they do not need to be watered as frequently, and they usually will survive a dry period without any watering.
20. Do not hose down the driveway or sidewalk. Use a broom to clean leaves and other debris from these areas. Using a hose to clean a driveway can waste hundreds of gallons of water.
21. Consider using a commercial car wash that recycles water. At home, park the car on the grass when washing it.
22. Avoid the installation of ornamental water features (such as fountains) unless the water is recycled.
23. Consider a new water-saving pool filter for swimming pools. A single back-flushing with a traditional filter uses from 180 to 250 gallons or more of water.

Directions: Answer the following questions in complete sentences.

1. How many gallons of water can you expect per year if a faucet drips at the rate of one drop per second?

2. How can you verify that your home is leak free?

3. Please explain how you can check for toilet leaks.

4. Why should you avoid over-fertilizing your lawn?

5. Why should you use a commercial car wash instead of washing your car by hand?

6. Is it possible to have an ornamental water feature (such as a fountain) and not waste water? Please explain.

7. Please list two reasons you should not use a garbage disposal.

8. What time of day should you water your lawn?

9. How can insulating your water pipes help to conserve water?

10. How does raising the blade on your lawn mower help to conserve water?

WATER METER READER

6 - 8

SUBJECTS:
Ecology, Math

TIME:
2 class periods
7 days to read home meters

MATERIALS:
home water meter
old water bill
student sheets

OBJECTIVES

The student will do the following:

1. Determine how much water his or her family uses at home.

2. Observe, interpret data, infer, and use numbers to compare water usage to that of other students.

3. Construct a graph using collected data on water usage.

BACKGROUND INFORMATION

Water is a valuable resource. The average household uses 200 gallons of water per day. Water shortages are occurring in many parts of the world because of rising demand from growing populations, unequal distribution of useable freshwater, and pollution. We must all be conscious of the water we are using and learn ways to conserve water. By changing personal habits, such as running water while brushing teeth, people can save a lot of water.

Each household can monitor the amount of water it uses by reading its water meter. There are several types of water meters. The water company in your area should have directions on how to read a water meter. Families can use meter readings as a challenge to reduce water use. Read the meter, obtain an average water use, and strive as a family to reduce water use by 1-2 gallons per day or 10-20 gallons per week, etc.

As much as half of the water being used now for domestic purposes can be saved by practicing certain conservation techniques. Water can be saved in the bathroom by using low volume shower heads, taking shorter showers, stopping leaks, and by using low volume or waterless toilets. Toilet flushing is the largest domestic water use. Each person uses 13,000 gal (50,000 liters) of drinking quality water a year to flush toilets. Regulations in many areas now require water-saving toilets be used. An old toilet can conserve water by having a water-displacement device, such as a half-gallon milk jug filled with water or sand, placed in the storage tank. Special water conserving appliances such as dishwashers and washing machines are available now that reduce water consumption greatly.

Approximate volumes of home water usage are as follows:

Bath	100–150 L (30-40 gallons)
Shower	20 L (5 gallons) per minute
Washing clothes	75–100 L (20-30 gallons)
Flushing a toilet	10-15 L (3-4 gallons) or more
Dishwasher	50 L (15 gallons) per load
Cooking	30 L (8 gallons) per day
Watering a lawn	40 L (10 gallons) per minute

Different communities use several types of water meters. Meters have different numbers of dials. As water moves through the water pipes, the meter pointers rotate. To read a meter, find the dial that has the lowest denomination indicated. Record the last number that the pointer has passed. Continue this process. If the meter has more than one dial, the meter may be measured in gallons, cubic feet, or cubic meters.

<u>Terms</u>

cubic feet: the volume of a cube whose edges are a specified number of feet in length. (Example: 3 cubic feet would be a cube that is 3 feet long, 3 feet high, and 3 feet wide.)

cubic meters: the volume of a cube whose edges are a specified number of meters in length. (Example: 3 cubic meters would be a cube that is 3 meters long, 3 meters high, and 3 meters wide.)

gallon: a unit of liquid capacity equal to four quarts (about 3.8 liters).

unit: a fixed quantity (as of length, time, or value) used as a standard of measurement; a single thing, person, or group forming part of a whole.

ADVANCE PREPARATION

A. Have students draw a picture of their water meter and bring it to class.

B. Have students bring to class a water bill from their households..

PROCEDURE

I. Setting the stage

A. Discuss the different types of meters using the pictures the students bring to class. Discuss the bills that the family receives each month.

B. Show students how to calculate how much water is used in a home using the Meter Reader Student Sheet.

C. Fill in Day 1 together as a class so students know how to use the sheet.

II. Activity

A. Have the students read their home water meters at the same time of the day for 7 days (one week).

B. Have the students subtract the previous day's reading to find the amount of water used each day.

C. Ask the students to record how water is used in their homes each day (bath, shower, clothes washing, dishwasher).

D. Using graph paper, have student plot data daily. Label the vertical axis with the units used by your meter.

III. Follow-Up

A. Have the students answer the following questions:

1. What day did your family use more water? Why?

2. What was the total amount of water used by your family during the week?

3. What is the average amount of water used by each person in your family?

4. Estimate a monthly and yearly average of water usage in your home.

5. Would the family's water usage vary during the year? Why?

6. How can your family conserve water?

IV. Extensions

A. Have students find out the source of their water supply and trace it until it reaches their homes. Who determines if the supply is pure? How often is the water tested, and how is the wastewater treated?

B. Have students visit home improvement shops to calculate the cost of water conserving products as well as to determine where to obtain them.

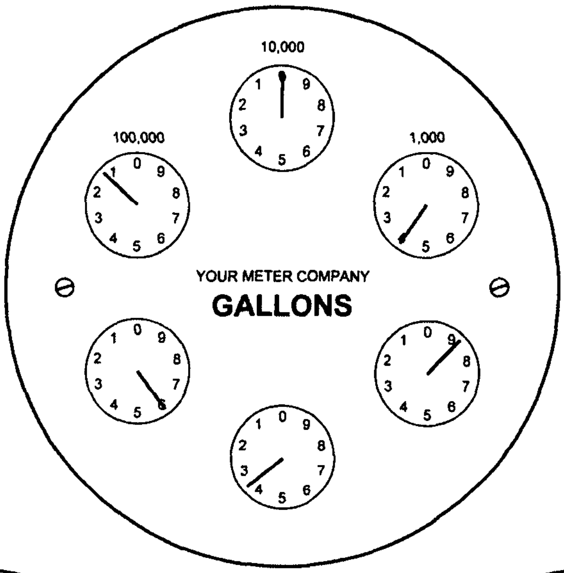
C. Take a field trip to a water treatment plant.

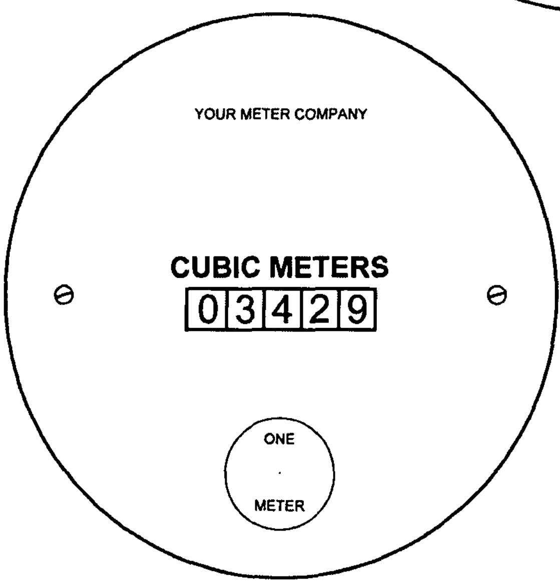
RESOURCES

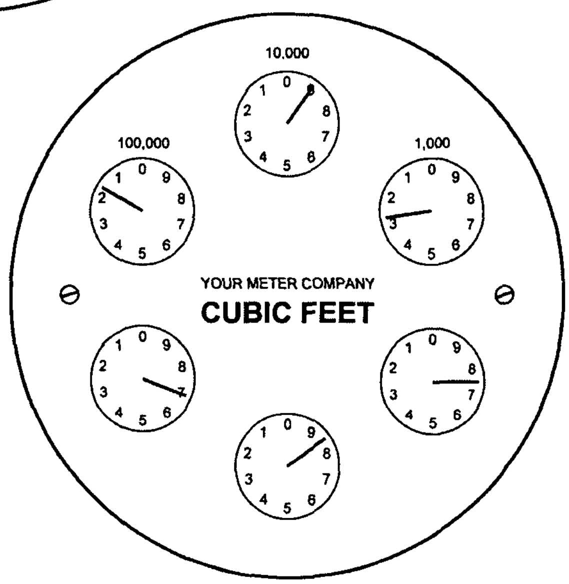
Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Home Water Usage

Your water meter probably looks like one of these. The first meter is read clockwise and measures water in gallons. The second meter measures water in cubic feet and is read in the same manner. (To convert cubic feet to gallons you must multiply the number on the meter by 7.5.) The third meter is read like a digital clock. Meters 1 and 2 have six dials, which are read clockwise. Begin with the "100,000" dial and read each dial to the "1" dial. Remember that when the dial is between two numbers, you read the smaller number. Read and record the number shown on each meter.



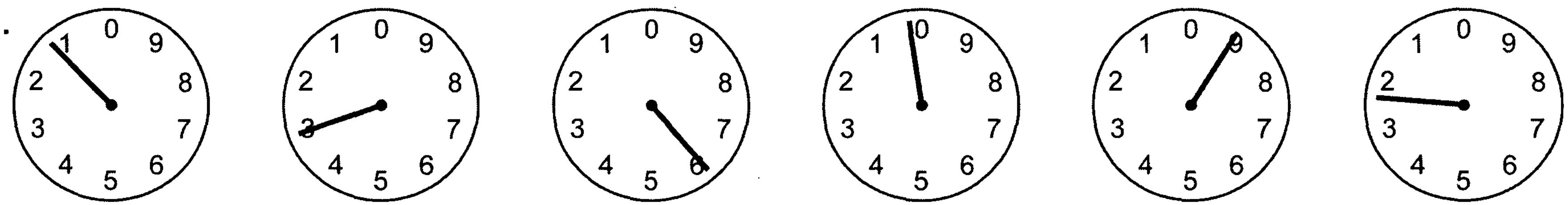




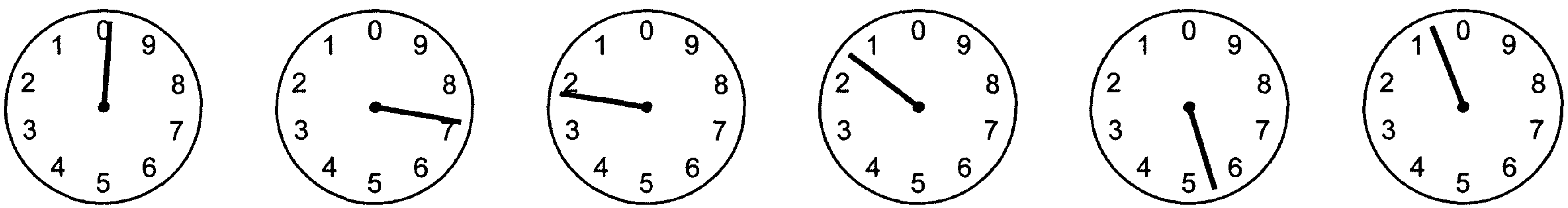
Home Water Usage

Directions: Reda the dials from left to right. When the dial is between two numbers, read the smaller number. Write the numbers in the blanks below the dials.

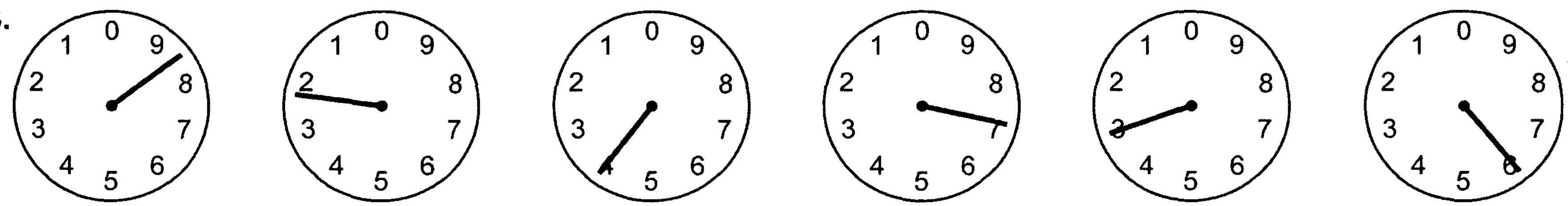
1.



2.



3.



Directions: List how water is used in your home. Indicate how many times each occurred and how much water was used. Compute a total for each day and for the entire seven days.

Day 1 — Date ________________

shower (25 gal)	x ______	showers	= __________	gallons
bath (35 gal)	x ______	baths	= __________	gallons
dishwasher (15 gal)	x ______	loads	= __________	gallons
laundry (20 gal)	x ______	loads	= __________	gallons
toilet (4 gal)	x ______	flushes	= __________	gallons
teeth (1 gal water runs)	x ______	brushings	= __________	gallons
meals (8 gal per day)			= 8	gallons
		Total Gallons	__________	

Day 2 — Date ________________

shower (25 gal)	x ______	showers	= __________	gallons
bath (35 gal)	x ______	baths	= __________	gallons
dishwasher (15 gal)	x ______	loads	= __________	gallons
laundry (20 gal)	x ______	loads	= __________	gallons
toilet (4 gal)	x ______	flushes	= __________	gallons
teeth (1 gal water runs)	x ______	brushings	= __________	gallons
meals (8 gal per day)			= 8	gallons
		Total Gallons	__________	

Day 3 — Date ________________

shower (25 gal)	x ______	showers	= __________	gallons
bath (35 gal)	x ______	baths	= __________	gallons
dishwasher (15 gal)	x ______	loads	= __________	gallons
laundry (20 gal)	x ______	loads	= __________	gallons
toilet (4 gal)	x ______	flushes	= __________	gallons
teeth (1 gal water runs)	x ______	brushings	= __________	gallons
meals (8 gal per day)			= 8	gallons
		Total Gallons	__________	

Day 4 — Date ________________

shower (25 gal)	x ______	showers	= __________	gallons
bath (35 gal)	x ______	baths	= __________	gallons
dishwasher (15 gal)	x ______	loads	= __________	gallons
laundry (20 gal)	x ______	loads	= __________	gallons
toilet (4 gal)	x ______	flushes	= __________	gallons
teeth (1 gal water runs)	x ______	brushings	= __________	gallons
meals (8 gal per day)			= 8	gallons
		Total Gallons	__________	

Day 5 — Date ________________

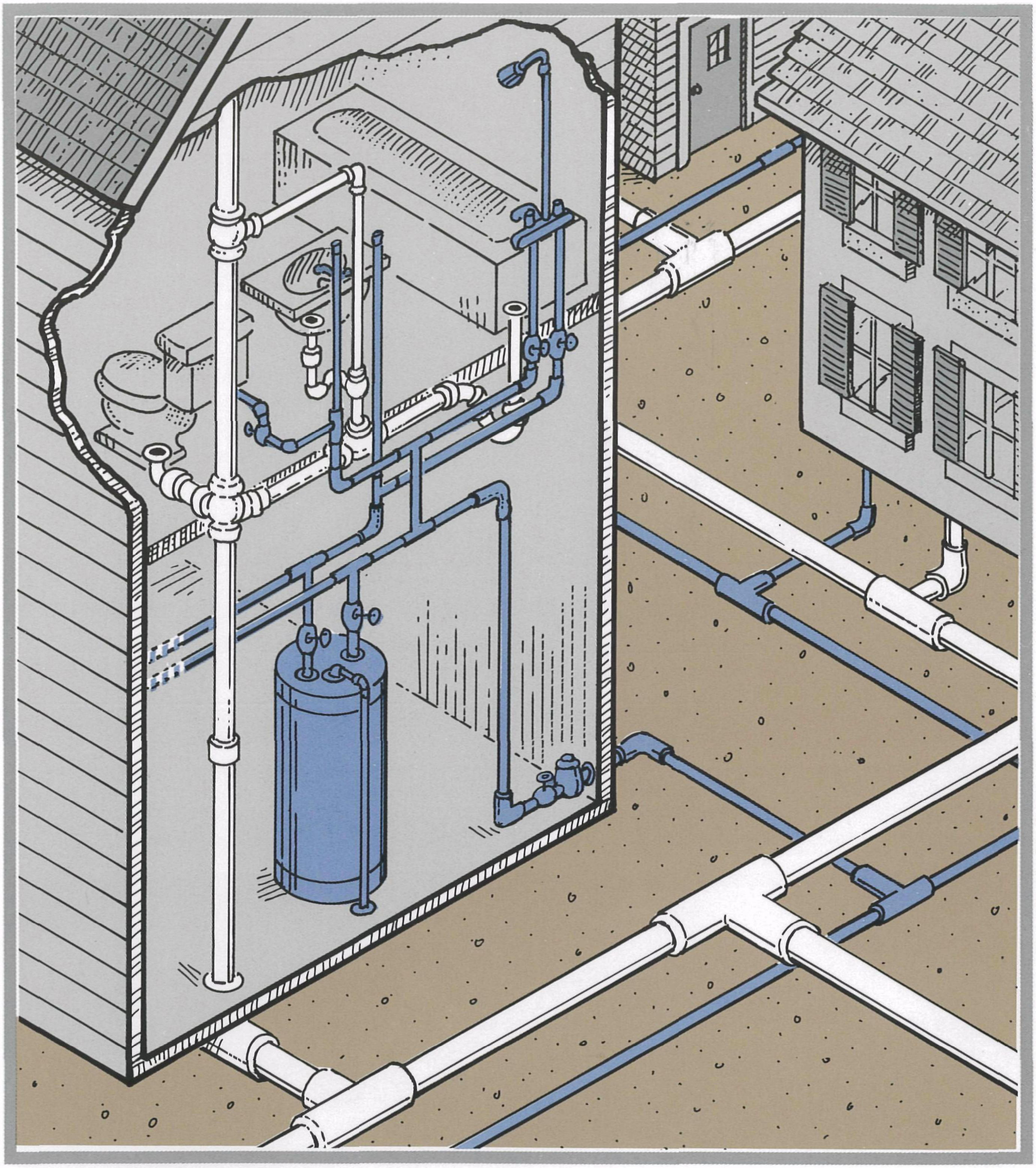
shower (25 gal)	x ______	showers	= __________	gallons
bath (35 gal)	x ______	baths	= __________	gallons
dishwasher (15 gal)	x ______	loads	= __________	gallons
laundry (20 gal)	x ______	loads	= __________	gallons
toilet (4 gal)	x ______	flushes	= __________	gallons
teeth (1 gal water runs)	x ______	brushings	= __________	gallons
meals (8 gal per day)			= 8	gallons
		Total Gallons	__________	

Day 6 — Date ________________

shower (25 gal)	x ______	showers	=	__________	gallons
bath (35 gal)	x ______	baths	=	__________	gallons
dishwasher (15 gal)	x ______	loads	=	__________	gallons
laundry (20 gal)	x ______	loads	=	__________	gallons
toilet (4 gal)	x ______	flushes	=	__________	gallons
teeth (1 gal water runs)	x ______	brushings	=	__________	gallons
meals (8 gal per day)			=	8	gallons
		Total Gallons		__________	

Day 7 — Date ________________

shower (25 gal)	x ______	showers	=	__________	gallons
bath (35 gal)	x ______	baths	=	__________	gallons
dishwasher (15 gal)	x ______	loads	=	__________	gallons
laundry (20 gal)	x ______	loads	=	__________	gallons
toilet (4 gal)	x ______	flushes	=	__________	gallons
teeth (1 gal water runs)	x ______	brushings	=	__________	gallons
meals (8 gal per day)			=	8	gallons
		Total Gallons		__________	



THE WATER SOURCEBOOK

DRINKING AND WASTEWATER TREATMENT

CONTAMINANT SCAVENGER HUNT

6-8

SUBJECTS:
Chemistry, Language Arts

TIME:
2 class periods

MATERIALS:
writing supplies
student sheets

OBJECTIVE

The student will do the following:

1. Identify substances and activities within a household that contribute to water pollution.
2. Identify safe cleaning alternatives for commercial cleaning products.

BACKGROUND INFORMATION

Pollutants that come from homes often originate in the kitchen, bathroom, or garage. Some chemicals such as oil, paint thinner, and pesticides often find their way down the drain and into the water system. Household cleansers, such as drain cleaner, oven cleaner, and tarnish remover have caustic chemicals that lower water quality. These products have chemical ingredients that may not be removed during water treatment. A partial solution would be to avoid putting these chemicals directly into water in the first place. Hazardous household wastes can be taken to approved disposal sites.

Fortunately, there are non-toxic alternatives that can be used instead of some household cleansers. Items such as baking soda and vinegar can be used in different combinations to clean different areas of the home. Baking soda can be used in place of a room deodorizer. Boiling water, vinegar, and baking soda can be used with a plunger to take the place of a toxic drain cleaner. Vinegar wiped with newspaper can be used as a window cleaner. Scouring powder can be replaced by baking soda and vinegar. Salt, baking soda, and a piece of aluminum foil in warm water can take the place of a tarnish remover.

Terms

alternative: a chance to choose between two or more possibilities; one of the two or more possible choices.

caution: a warning against danger.

disposal: a disposing of or getting rid of something, as in the disposal of waste material.

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials.

ADVANCE PREPARATION

A. Prepare two copies of the "Contaminant Survey" sheet and one copy of the "Alternative Cleaning Products" sheet for each student.

B. Make an overhead of the "House Cutaway."

PROCEDURE

I. Setting the stage

A. Divide class into teams. Have at least two products per team on hand. Have each student fill out one contaminant survey sheet using the two team products. Have the students work in teams to find the information.

B. Assign a different area of the house to each team: kitchen, garage, garden/yard, bathroom, basement, and laundry room.

C. Displaying the overhead of the house, brainstorm with the class a list of possible products used in each location.

II. Activities

A. Have each team fill in the remaining contaminant survey sheet with the products brainstormed for their area of the house.

B. Have students collect data from their own homes. Explain that some products will not have an entry in each category.

C. Have the students meet in their teams and combine their lists into a master list for their area.

D. Have the students use the "Safe Alternatives to Toxic Home Cleaners" handout to fill in the "Alternative Cleaning Products" sheet for the cleaning products they found.

III. Follow-Up

A. Review data with students:

1. What products did they find?
2. How do we use these products?
3. How do these products affect water? (This may be on the label under the caution statement.)

IV. Extensions

A. Have the students keep track of how many times they use alternative cleaning products.

B. Let the students share this project with their families at home. Encourage them to show their families their home surveys and the list of alternative products that could be used.

C. Have the students watch television advertisements and check the products advertised for environmental or physical safety.

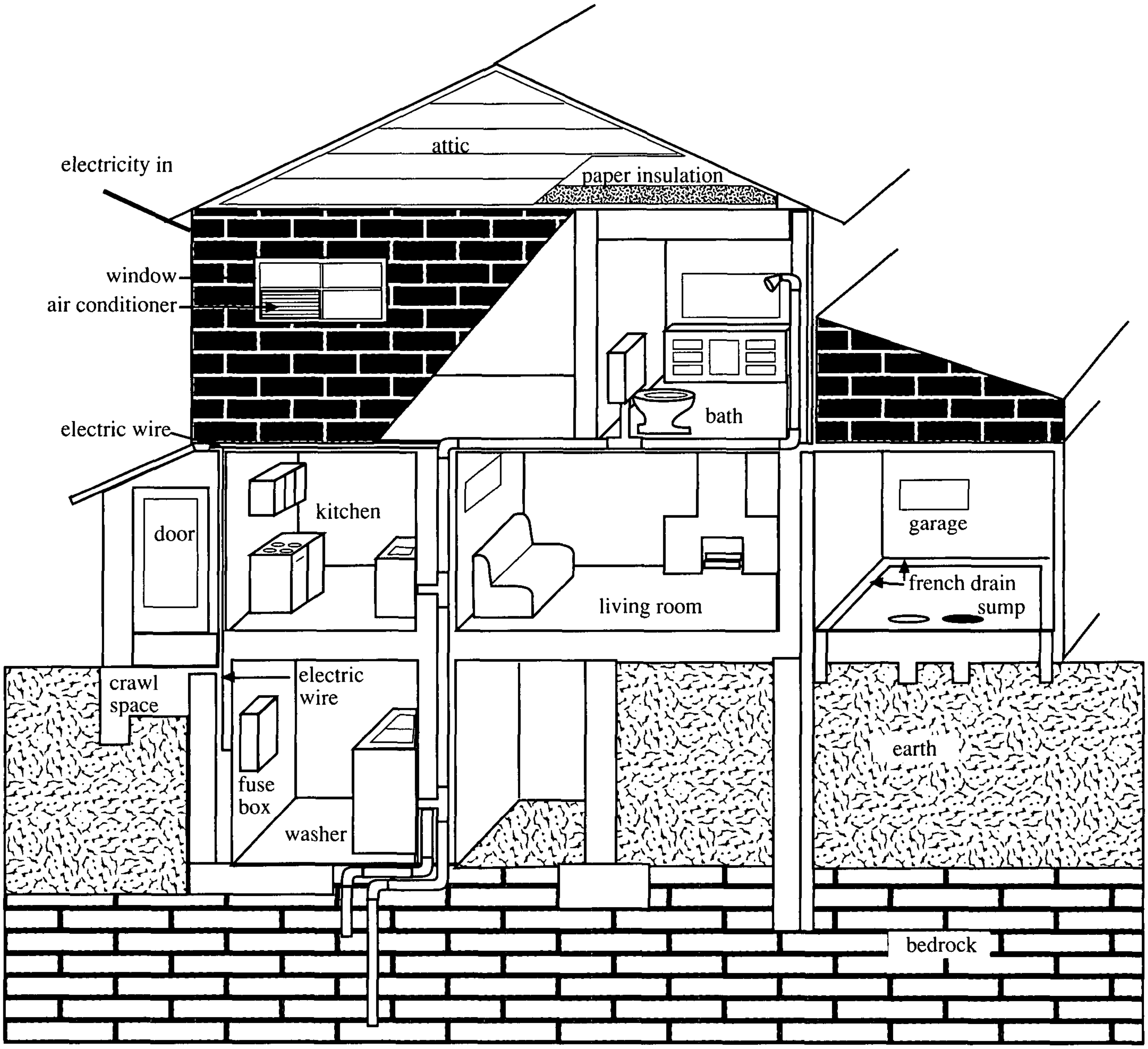
D. Have the students make their own handbooks to take home and refer to as needed.

RESOURCES

Gralla, Preston, How the Environment Works, Ziff-Davis Press, Emeryville, California, 1994.

Household Hazardous Waste Wheel. Available from Legacy, Inc. 800 - 240 - 5115.

Project Wet: Curriculum and Activity Guide, Watercourse and Western Regional Environmental Education Council, 1995. Obtain from Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057 (Fax: 406-994-1919; e-mail: rwwet@msu.oscs.montana.edu).



Directions: Use a colored marker to trace all the possible routes by which radon may enter this home.

Product Name	Four Main Ingredients	Container Plastic Glass Paper	Caution Statement	First Aid	Disposal Procedure

PRODUCT	SAFE ALTERNATIVE INGREDIENTS

SAFE ALTERNATIVES TO TOXIC HOME CLEANERS

The average home in America today has between 10-15 gallons of toxic products. The following is a list of safe alternatives to some of these toxic chemicals used in the home. Please be aware that, although these "home brews" may be friendlier for the environment, this does not mean they are safe for human consumption (even common materials such as vinegar can be harmful if consumed in large quantities). So treat these mixtures with care and keep them out of children's reach.

DRAIN CLEANER

Dissolve 1 lb. washing soda in 3 gallons of water and pour down the drain. Grind lemon rinds and 1/4 cup borax in garbage disposal and rinse with hot water.
Pour 1/2 cup baking soda into drain and follow with 1/2 cup vinegar or lemon juice (beware of a strong reaction from these two chemicals). Let the mixture sit for 15 minutes before rinsing with hot water.

BEST BET: avoid dumping grease down the drain; instead, pour into soup can, freeze it, and throw it out on garbage day.

APPLIANCE CLEANER

Combine 1 tsp borax, 2 tbsp vinegar, 1/4 tsp liquid soap and 2 cups of very hot water in a spray bottle. Shake gently until everything dissolves; spray the mixture onto appliances and wipe with a rag.

OVEN CLEANER

Sprinkle oven generously with water, sprinkle with baking soda, sprinkle again with water. Let sit overnight and wipe up. If desired, wipe entire oven with liquid soap and rinse thoroughly.
Mix 2 tbsp liquid soap, 2 tsp borax and warm water.

CREAMY SOFT SCRUBBER

Combine 1/2 cup baking soda in a bowl with vegetable-oil-based liquid soap, stirring into a creamy paste. Scoop onto a sponge and wash desired surface. Rinse thoroughly. If a disinfectant is desired, add borax; for heavy washing jobs, add washing soda.

WINDOW CLEANER
Shake up 1 tsp liquid soap, 3 tbsp vinegar and 2 cups water in a spray bottle. Use as you normally would.

LINOLEUM FLOOR CLEANER

Blend 1/2 cup liquid soap, 1/2 cup lemon juice, and 2 gallons warm water. Wash floors as usual.

STAIN REMOVERS

COFFEE STAINS – rub moist salt on the item
RUST STAINS on clothes – lemon, juice, salt, and sunlight
SCORCH MARKS on clothes – use grated onions
INK SPOTS on clothes – cold water, 1 tbsp cream of tartar and 1 tbsp lemon juice
OIL STAINS on clothes – rub white chalk on stain before laundering
PERSPIRATION STAINS on clothes – white vinegar and water
GENERAL SPOTS on clothes – club soda or lemon juice or salt

BATHROOM CLEANERS

MILDEW REMOVER – use equal parts vinegar and salt
TOILET BOWL CLEANER – paste of borax and lemon juice, or just borax, left in toilet overnight and wiped out in the morning
TUB AND TILE CLEANER – combine 1/2 cup baking soda, 1 cup white vinegar, and warm water

POLISHES FOR AROUND THE HOUSE

for CHROME – apple cider vinegar
for SILVER – mix 1 qt. warm water, 1 tbsp baking soda, 1 tbsp salt, and a piece of aluminum foil
for COPPER – lemon juice and salt
for STAINLESS STEEL – mineral oil
for BRASS – worchestershire sauce or vinegar and water

SHOE POLISH

banana peel

INSECT PROBLEMS AT HOME

Ants – red chili powder at point of entry into house
Moths – cedar chips
Fleas on pets – gradually add brewers yeast to pet's diet
Nematodes in garden – plant marigolds

LIQUID FABRIC SOFTENER

baking soda or borax in the rinse water

RUG & UPHOLSTRY CLEANER

club soda

DECAL REMOVER (ON GLASS)

soak with white vinegar

RUSTY BOLT / NUT REMOVER

carbonated beverage / vinegar

CAUTION

Be judicious using any of these mixtures. Test on a small, hidden area when cleaning clothes, carpets, etc. As indicated earlier, these mixtures can be harmful if ingested or used carelessly.

The easiest and safest way to manage household hazardous waste is not to make it in the first place. Choose less toxic products and products whose processing results in less toxic waste.

INSECT PROBLEMS AT HOME Cont'd

Flies – well-watered pot of basil
Roaches – chopped bay leaves and cucumber skins
Insects on outdoor plants – soapy water on leaves, then rinse; or boil elderberry leaves in water and add a touch of liquid soap to make a spray

DESALINATION / FRESHWATER

6-8

SUBJECTS:
Chemistry, Social Studies

TIME:
2 class periods

MATERIALS:
goggles
washers
scissors
towel
glycerin
glass tubing bent at right angles
shallow pan
ice
water
pan balance
table salt
two 500 mL beakers
1000 mL flask
1-hole rubber stopper
rubber tubing
hot plate cardboard
teacher sheet

OBJECTIVES

The student will do the following:

1. Produce freshwater from saltwater by the process of desalination.
2. Discuss the substances found in ocean water (composition).
3. Discuss why some substances in seawater do not remain in solution for long periods of time.

BACKGROUND INFORMATION

Oceans are physical combinations of different substances. These substances are in the oceans because they were dissolved, given off by volcanoes, or were weathered off. Seawater is a well-mixed solution of dissolved salts in water. Sodium and chloride combine to form common salt. Sodium and chloride ions together account for 86 percent of the salt ions present in seawater. Sulfate, magnesium, calcium and potassium ions together make up the next 13 percent of salt ions present. Other elements such as iodine are present in trace concentrations and are measured at less that one part per million.

A process called desalination is used to remove salt from the ocean. Distillation is one of the most common methods of desalination. At desalination plants ocean water is heated so water vapor will form. This vapor is then collected and cooled. The end product from this procedure is fresh water. The ocean, therefore, stores freshwater. Desalination is a very expensive process but very much welcomed in areas with limited or no supply of freshwater.

Areas such as Kuwait, Saudi Arabia, Morocco, and the state of Florida have a limited supply of freshwater and an abundant supply of seawater. Some areas, such as Oman and Bahrain, have no access to freshwater. Lack of freshwater is a limiting factor for population and industrial growth. Technology is now being used to convert seawater into freshwater for use in areas with limited or no access to freshwater.

Terms

desalination: the purification of salt or brackish water by removing the dissolved salts.

glycerin: a sweet, thick liquid found in various oils and fats and can be used to moisten or dissolve something.

halite: a white or colorless mineral, sodium chloride or rock salt.

mineral: a naturally occurring substance (as diamond or quartz) that results from processes other than those of plants and animals; a naturally occurring substance (as ore, petroleum, natural gas, or water) obtained usually from the ground for human use.

mixture: two or more substances mixed together in such a way that each remains unchanged (sand and sugar form a mixture).

salinity: an indication of the amount of salt dissolved in water.

ADVANCE PREPARATION

A. Have all equipment ready prior to lab day. Be sure to cut and bend glass tubing so it fits into the holes in the stopper. All glassware needs to be clean.

PROCEDURE

I. Setting the stage

A. Stress that the students should be careful when putting the glass into the stopper and rubber tubing into the glass tubing.

II. Activity

A. Have the students perform or watch as you demonstrate the following:

1. Dissolve 18 g of table salt in a beaker filled with 500 mL of water.
2. Put the solution into the flask. Place the flask on the hot plate. Do not turn the hot plate on.
3. Connect the stopper, glass tubing, and rubber tubing (see diagram). Use the glycerin on the ends of the glass tubing. Using protective gloves or holding the tubing with a towel, gently slide the glass into the stopper and rubber tubing.
4. Put the stopper into the flask. Make sure the glass tubing is above the solution.
5. Make a small hole in the cardboard. Slide the free end of the rubber tubing through the hole. Do not let the tubing touch the hot plate.
6. Put the cardboard over a beaker and weigh it down with four washers. This will hold it in place.
7. Place the beaker in the shallow pan that is filled with ice.
8. Turn on the hot plate, bringing the solution to a boil. Write down what occurs to the solution in the flask and the beaker.
9. This process will be continued until almost all of the solution is boiled away.
10. Turn off the hot plate and let the beaker cool.

III. Follow-Up

A. Ask the students the following questions, or have them answer the questions in groups.

1. What occurred to the solution in the flask?
2. What occurred inside the beaker?
3. Taste the H_2O inside the beaker. Does the water taste salty?
4. Is anything in the flask? If your answer is yes, identify.
5. Do you still have the same amount of water that you started with? Explain.
6. Look at the sides of the flask and write down what you see.
7. Write a paragraph and explain how desalination produces fresh water.

IV. Extensions

A. Debate the idea of obtaining gold from the oceans.

B. Provide water samples and have students use a test kit to analyze the water. Kits can be obtained from a biological supply catalog.

C. Obtain water from the ocean or Gulf (if available). Place an open container of seawater in the sun, allowing the sun to help the water evaporate more quickly, leaving a salt residue behind. (This can also be used to introduce the activity.)

D. Have students do research on the Nansen bottle or salinometer, then make a model of one of these instruments.

E. Have students research the Gulf War in Kuwait and the surrounding area and discuss what happened to the environment when Hussain blew up the oil wells and the desalination plant.

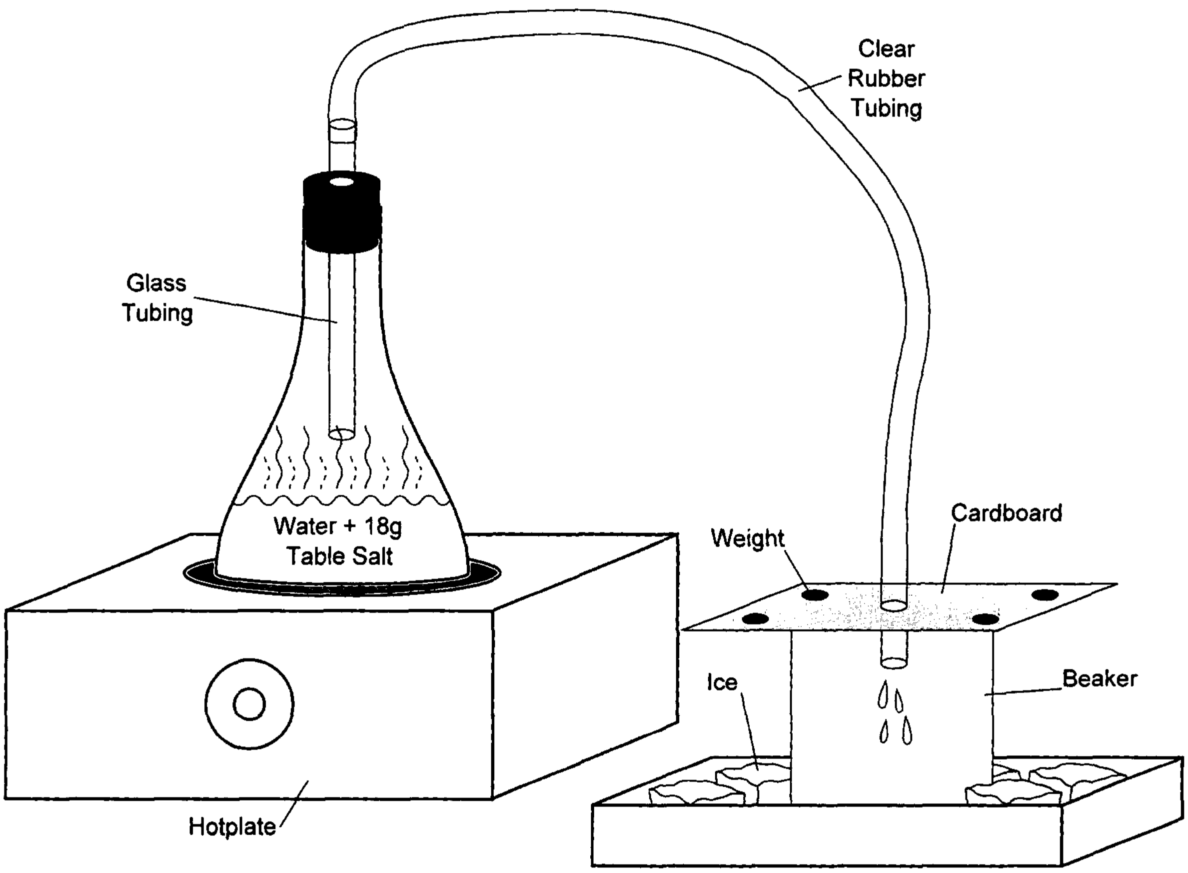
F. Have students calculate the cost of building a desalination plant.

G. Have students research and report on other methods of desalination (e.g., reverse osmosis, ultrafilteration or others) and list the advantages/disadvantages of all methods.

RESOURCES

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Duxbury, Alison B. and Alyn C. Duxbury, Fundamentals of Oceanography, Wm. C. Brown Publishers, Dubuque, Iowa, 1996.


Clear
Rubber
Tubing
Glass
Tubing
Water + 18g
Table Salt
Weight
Cardboard
Ice
Beaker
Hotplate

HOW SOFT OR HARD IS YOUR WATER?

6-8

SUBJECTS:
Chemistry, Geology, Math,

TIME:
50 minutes

MATERIALS:
borax or washing soda
different samples of water
distilled water
second timer
test tubes with stoppers or small bottles with corks or caps
medicine dropper
soap
marking pencil
student sheets

OBJECTIVES

The student will do the following:

1. Test samples of water to determine how a chemical water softener (borax, washing soda) affects water's ability to form suds.

BACKGROUND INFORMATION

Water that contains large amounts of dissolved calcium or magnesium is considered to be "hard." The chemical weathering of rocks containing calcite, dolomite, or ferromagnesium minerals leaching into groundwater supplies or streams is often the source of hard water for home use. Hard water causes several problems in homes.

A reaction occurs when hard water comes in contact with detergents. During this process the calcium ions precipitate the fatty acids from the soap. A form of scum or gelatinous, gray curd forms. The curd forms as calcium ions are removed from the water. This process continues until all of the calcium ions are bound up in the curd. The soap will not lather until all of the calcium ions are bound in the curd. For this reason, households that have hard water must use larger amounts of detergent.

Hard water causes other household problems by precipitating a scaly deposit inside tea kettles, hot water tanks, and hot water pipes. This scaly deposit consists of carbonate salts that, over time, can build up enough to clog an entire hot water piping system in a home. The entire hot water piping system must then be replaced.

"Soft" water carries ions that do not react with the soap and therefore allows lathering. Water softeners are available for home use that replace calcium ions with sodium ions. The sodium ions do not affect lathering or cause scaly deposits to build up. Soft water containing large amounts of sodium may be harmful, however, for persons with salt-free or low-sodium diets. Soft water tends to be significantly more aggressive than hard water and can leach metals from pipes (primarily lead and copper). Some water suppliers add zinc ortho phosphates to the water to reduce its softness and balance its pH to near 7.0.

ADVANCE PREPARATION

A. Make a soap solution by dissolving a walnut-sized piece of soap in 1/2 liter (about 1 pint) of water.

B. Collect samples of water from different places, such as a stream, a river, a lake, a well, a spring, and a faucet. You may also use various brands of bottled water from different locations in the US,

PROCEDURE

I. Setting the stage

A. Place half of each sample in a separate bottle so that each bottle is half full. Place distilled water into one pair of bottles. Label each sample.

II. Activity

A. Have the students follow these steps:

1. Using a medicine dropper, add ten drops of the soap solution to one of the distilled water samples.

2. After closing the bottle, shake for several seconds and lay the bottle on its side. Observe the suds in the bottle.

3. If, at the end of one minute, no suds remain, continue to add the soap solution one drop at a time until some suds remain at the end of one minute.

4. Record on the student sheet the total number of drops of soap solution needed for the water sample to contain suds.

B. Repeat steps 1 - 4 for each of the different samples of water collected. Record the data on the student sheet.

C. Repeat steps 2, 3, and 4 with the other set of samples. Treat each water sample by dissolving a few crystals of either washing soda or borax in each sample before adding the soap solution. This should make the water sample softer but do not announce this to the students, let them figure it out.

III. Follow-Up

A. Have the students answer the following questions:

1. Using the data you recorded in the table under "No Water Softener," which water sample was the softest? Which was the hardest?

2. List all of the samples in order of hardness, beginning with the softest.

3. Why is the method used in this activity a way of determining the relative hardness of water rather than the actual hardness of water?

4. How were the results different when the samples were treated with a water softener?

5. What conclusions can you draw from the results observed when the chemical water softener was added to the samples?

IV. Extension

A. Have the students graph the results of the treatments. (See a sample graph on the student sheet.)

B. Have the students test their water at home.

RESOURCES

McGeary, David and Charles C. Plummer, <u>Physical Geology: Earth Revealed, 2nd Edition</u>, Wm. C. Brown Publishers, Dubuque, Iowa, 1994.

<u>Project Wet: Curriculum and Activity Guide</u>, Watercourse and Western Regional Environmental Education Council, 1995. Obtain from Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana

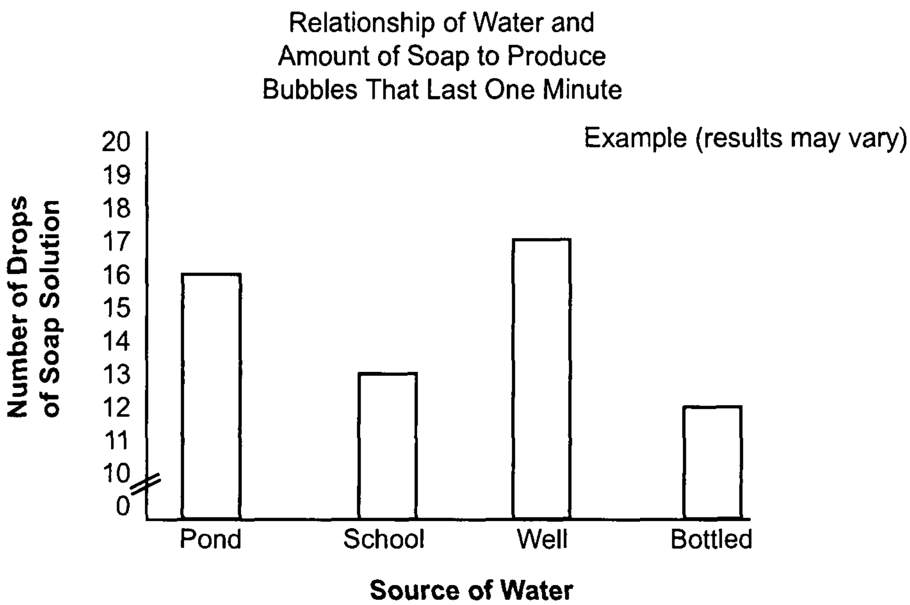
Directions:
1. Fill each test tube or jar half full with sample water and cap it.
2. Label each sample.
3. Using a medicine dropper, add ten drops of the soap solution to the first sample (distilled water).
4. Shake the sample for five seconds, lay it on its side, and observe the suds.
5. Time for one minute. If no suds remain, add more soap one drop at a time until suds remain for one minute.
6. Record the number of drops added to each sample on the table below.
7. Repeat steps 1 – 6 with the same samples. Treat each by dissolving a few crystals of washing soda or borax in each sample before adding the soap solution.

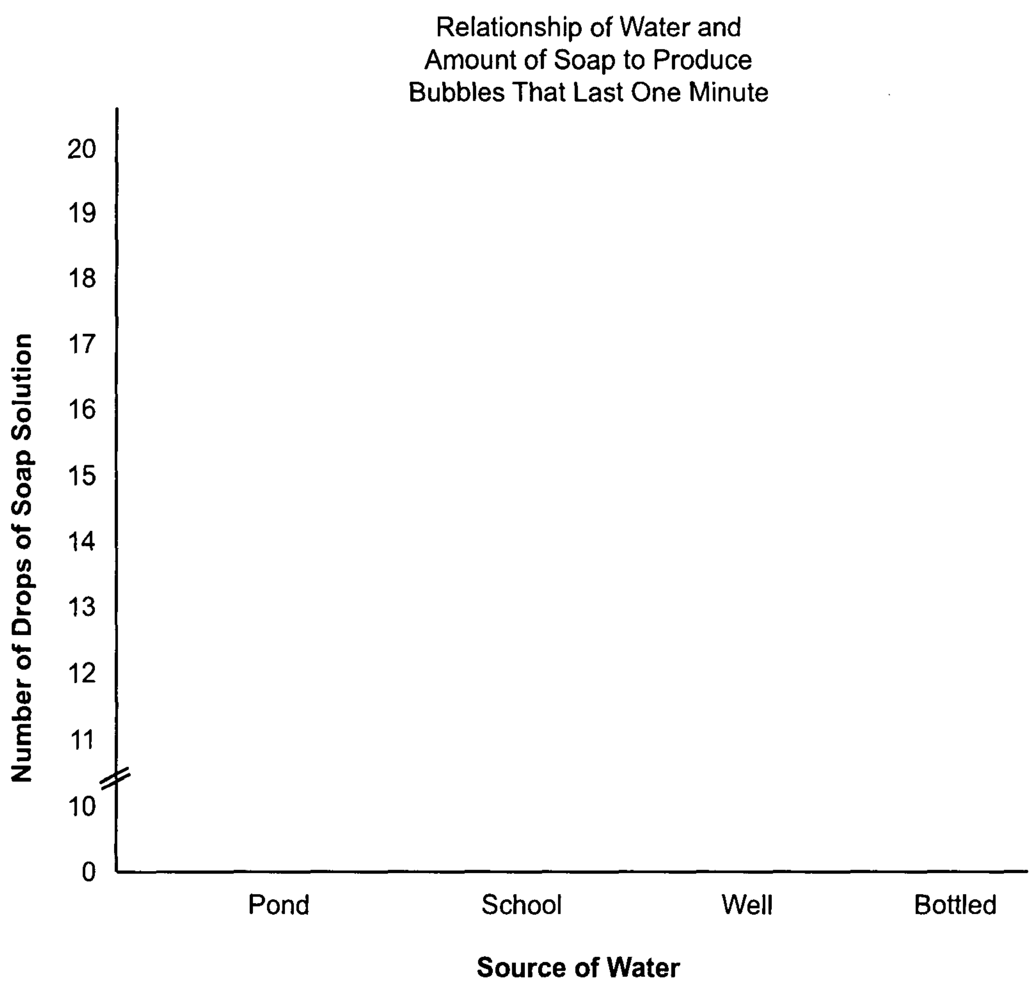
UNTREATED SAMPLES

Sample Type	# Drops of Soap Added	Description of Sample
1. Distilled		
2. Faucet		
3.		
4.		
5.		
6.		

TREATED SAMPLES

Sample Type	# Drops of Soap Added	Description of Sample
1. Distilled		
2. Faucet		
3.		
4.		
5.		
6.		


Relationship of Water and
Amount of Soap to Produce
Bubbles That Last One Minute
Example (results may vary)
Number of Drops of Soap Solution
20
19
18
17
16
15
14
13
12
11
10
0
Pond
School
Well
Bottled
Source of Water


Relationship of Water and
Amount of Soap to Produce
Bubbles That Last One Minute
Number of Drops of Soap Solution
20
19
18
17
16
15
14
13
12
11
10
0
Pond
School
Well
Bottled
Source of Water

HOW TO TREAT POLLUTED WATER

6-8

OBJECTIVES

The student will do the following:

1. Demonstrate a method of treating polluted water.

BACKGROUND INFORMATION

Water pollution has increased greatly over the years as the population has grown and development has occurred. Water treatment has also grown. Water is cleaned in nature as it passes through sand and gravel. Drinking water or wastewater treatment plants use metal grating and screens that filter out large debris. Most point sources are treated; nonpoint sources have continued to grow, however. Raw sewage must now be treated before it is allowed to enter our rivers, lakes, and ocean. All water from streams and lakes must be treated or purified again before it can be used as drinking water. The procedures used for treating water in this experiment are similar to the procedures used in water treatment plants.

Polluted water is usually treated in three steps. The first step is pretreatment. The second step is the primary treatment of settling and skimming. Layers of sand and gravel are used for filtration. During this process, solids get trapped in the sand and gravel while the water flows through. The third step is the secondary treatment of aeration and settling. Aeration is the process of stirring or bubbling air through the liquid. Adding oxygen to the water promotes the growth of helpful aerobic bacteria and other microorganisms that can decompose organic material. This process is called *biological degradation*. Wastewater treatment plants have large aeration tanks and clarifiers that do this procedure. Finally, chlorine is added to the water or other disinfection procedures are used to kill any remaining harmful bacteria.

SUBJECTS:
Chemistry, Earth Science, Health

TIME:
15 minutes preparation
2 days time for biological degradation
1 day aeration time
50 minutes investigation

MATERIALS:
sand
fine gravel
medium gravel
funnel
filter paper
ring stand and ring
aerator or stirrer
goggles for each student
chlorine bleach
large jar
4 large test tubes
test tube rack
two 400 mL beakers
green food coloring
dirt
organic matter
detergent
glass-marking pencil
student sheet

Terms

aeration: to expose to circulating air.

chlorine: a chemical element, symbol Cl, atomic number 17, atomic weight 35.453; used as a disinfectant in drinking and wastewater treatment processes.

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in water; used in both wastewater and drinking water treatment.

organic material: material derived from organic, or living, things; relating to or containing carbon compounds.

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

sewage contamination: the introduction of untreated sewage into a water body.

ultraviolet light: similar to light produced by the sun. Ultraviolet light is produced by special lamps. As organisms are exposed to this light, they are damaged or killed.

ADVANCE PREPARATION

A. Gather all materials before lab session.

B. Do steps 1 and 2 of the activity as a demonstration or have groups of students complete them. Depending on the maturity and skill level of the students, this may be best done as a teacher demonstration.

C. Run off copies of the data table.

PROCEDURE

I. Setting the stage

A. Discuss background information with students.

II. Activity

A. Have the students perform the following procedure:

1. Fill a large glass jar 3/4 full of water. Add some dirty ground-up organic matter such as grass clippings or orange peels, a small amount of detergent, and a few drops of green food coloring.

2. Cap the jar, shake it well, and let the mixture stand in the sun for two days.

B. After the polluted sample has ripened for two days, have the students do the following:

1. Shake the mixture and pour a sample into one of the test tubes. Label this test tube "Before treatment, Sample # 1"

2. Use an aerator from an aquarium to bubble air through the sample in the jar. Allow several hours for aeration; leave the aerator attached overnight. If you do not have an aerator, use a mechanical stirrer or mixer and also leave on overnight.

C. The next day, when aeration is complete, have the students:

1. Pour another sample into a second test tube labeled "Aerated, Sample # 2."

2. During treatment, fold a piece of filter paper in half twice. Hold three sides and pull out the remaining side to form a cone. Wet the paper with tap water and then insert the cone in a funnel. Mount the funnel on a support.

3. Place a layer of medium gravel, then fine gravel, and finally white sand in the funnel. (A filtration plant does not use filter paper, but the sand trap is several meters deep. The paper replaces several layers of sand.)

4. Pour the remaining aerated liquid through the filter into the beakers. This takes a while and spills easily. Do not allow the liquid to spill over the filter paper. You may have to filter the same liquid several times before you obtain good results.

5. Pour a sample of the filtered water into a third test tube labeled "Filtered, Sample # 3".

6. With goggles on, pour another sample of the filtered water into a fourth test tube labeled "Chlorinated, Sample # 4." Add two to three drops of chlorine bleach to the test tube. Mix well until the water is clear.

7. Carefully observe all four test tubes. Write a detailed description of each liquid in the data table on the student sheet. Include the odor of each sample. **Do not taste!**

III. Follow-Up

A. Have students fill in the data table.

B. Ask students the following questions:

1. What changes in the composition of the liquid did you observe after aeration?

2. Did aeration remove any of the odor?

3. What was removed by the sand filter?

4. Did the addition of chlorine cause the water to become clearer?

5. Did the chlorine remove the green color?

6. Did the chlorine have an odor? Was it worse than the wastewater?

IV. Extensions

A. This can also be set up in an aquarium using several layers of sand and gravel. Pour water through as a solution to filter. It is impressive to note how much it takes to filter the color out of the water.

B. Visit a local wastewater treatment plant (always accompanied by an operator or manager).

C. Invite a guest speaker from a wastewater treatment plant to speak with the class about treatment processes, experiences, costs, and benefits to the community and environment.

RESOURCES

Biological Science: An Ecological Approach, 7th edition, BSCS Innovative Science Education, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1992.

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Directions: Fill in the following information for each sample.

Describe Step 1 (Making Solution):
Describe Step 2 (Aeration):
Describe Step 3 (Filtration):
Describe Step 4 (Chlorination):

RECORD OBSERVATIONS OF SAMPLES 1, 2, 3, 4

Sample 1
Sample 2
Sample 3
Sample 4

LEAKY FAUCET

6-8

SUBJECT:
Ecology

TIME:
50 minutes

MATERIALS:
plastic cups
graduated cylinders
water
nail
stop watch or watch with second hand
student sheets

OBJECTIVES

The student will do the following:

1. List how water resources can be managed to meet human needs.
2. Describe how conservation is essential to water resource management.
3. Explain how much water can be wasted by a leaky faucet.

BACKGROUND INFORMATION

Water is a major limiting factor of the environment. Without water life cannot exist. Increasing pressure on water resources and widespread, long-lasting water shortages in many areas exist for three reasons. The first reason is that increases in human populations are putting great demands on natural freshwater sources. The second reason is that there is an unequal distribution of usable freshwater. The final reason is that existing water supplies are becoming more and more polluted, more used, and less available.

Water is not usable in all forms and is not evenly distributed. Only 3 percent of the world's water supply is drinkable. Only .5 percent is reachable. Through careful management and conservation, available water supplies will be able to meet the demands of our increasing population. Practicing conservation is extremely important to everyone. Scientists estimate that 30 - 50 percent of the water supply used in the United States is wasted. Leaky pipes and faucets waste up to 30% of the nation's water. Industries can practice conservation by cleaning and reusing the water needed to make products. Plastic sheets that line irrigation canals can prevent much water from seeping into the ground.

As much as half of the water now being used for domestic purposes can be saved by practicing certain conservation techniques. Water can be saved in the bathroom by using low-volume shower heads, taking shorter showers, stopping leaks, and by using low-volume or waterless toilets. Toilet flushing is the largest domestic water use. Each person uses 50,000 liters (13,000 gallons) of drinking quality water each year to flush toilets. Special water-conserving dishwashers, washing machines, and other appliances that greatly reduce water consumption are available today.

It is estimated that half of all the water used for agriculture is lost. Better farming techniques, such as minimum tillage, use of mulches, and trickle irrigation, can reduce water losses dramatically. Almost half of all water used in electric power plants and other industrial facilities is for cooling. Dry cooling systems may be a useful alternative. Water used for cooling may also be reused for something else.

Term

conservation: planned management of natural resources (such as water) to prevent waste, destruction, or neglect.

ADVANCE PREPARATION

A. Gather materials.

B. Make sure the cups hold enough water to drip for one minute based on the size of the nail hole. The hole should simulate the approximate size of the drip that would come from a leaky faucet.

PROCEDURE

I. Setting the stage

A. If graduated cylinders are not available, make your own by using a larger cup marked off in specific measurements for the graduated cylinder. Be sure the top cup, the "drip cup," does not slip inside the larger. If it does, use toothpicks placed close to the top to hold the "drip cup" in place.

B. Provide a foam or plastic cup and a nail for each group. You may want to demonstrate to the students how to punch a hole into the bottom of the cup.

C. Explain to the students they will be doing three trials to get an average volume.

II. Activity

A. Fill the cups with water.

B. Set the cup on top of the graduated cylinder.

C. Start timing.

D. Collect water drops in the cylinders for one minute.

E. Measure the water volume collected from each cup.

F. Record the data on the student sheet.

G. Repeat three times.

III. Follow-Up

A. Ask the students the following questions:

   1. How does this activity relate to water that is wasted in a leaky kitchen faucet?

   2. If you cannot stop the leak right away, what could you do with the water?

B. Have the students compute the volume of water that would be "wasted" from each cup after one hour, one day, one week, one month, and one year.

C. Have the students complete the "Conserve Water at Home" student sheet.

IV. Extensions

A. Observe water use around the house and list ways to conserve.

B. Have students work in teams (cooperative learning) to create posters of ways to conserve water.

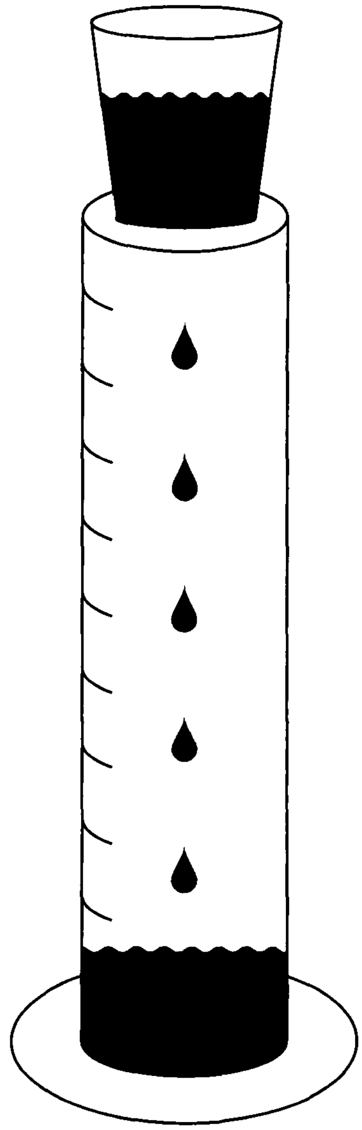
C. Have the students make up their own cartoon strip, which can be shown to the whole school by placing it on a bulletin board.

RESOURCES

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Project Wet: Curriculum and Activity Guide, Watercourse and Western Regional Environmental Education Council, 1995. Obtain from Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057 (Fax: 406-994-1919; e-mail: rwwet@msu.oscs.montana.edu).

Experiment set-up



Directions:

1. Place the plastic cup on top of the graduated cylinder. Make sure someone holds it the whole time.
2. As soon as the water is poured in the cup, start timing for one minute.
3. At the end of one minute, move the cup off the cylinder. Put your finger over the hole.
4. Record your results.
5. Do three trials.

Trial # 1 – volume of water = ____________

Trial # 2 – volume of water = ____________

Trial # 3 – volume of water = ____________

Total volume ____________

Average volume (divide total by 3) in one minute = ____________

6. Answer the following questions based on your trials:

a. How does this activity relate to water that is wasted by a leaky faucet?

b. If you cannot stop the leak right away, what could you do with the water?

c. Compute the volume of water wasted in the following time periods:

one hour ______

one day ______

one week ______

one month ______

two months ______

one year ______

Use the vertical letters below to write a sentence about conserving water. An example is provided for you.

C ____________________

O ____________________

N ____________________

S ____________________

E ____________________

R ____________________

V ____________________

E ____________________

W ____________________

A ____________________

T ____________________

E ____________________

R ____________________

A ____________________

T AKE SHORTER SHOWERS

H ____________________

O ____________________

M ____________________

E ____________________

LET'S GIVE WATER A TREATMENT

6-8

SUBJECTS:
Art, Biology, Ecology, Health

TIME:
50 minutes

MATERIALS:
pond water
rain water
dirty water (mix dirt and water)
four clear plastic cups labeled A, B, C, and D
small can with holes in bottom
paper towel
sand
microscopes
bottle with eye dropper filled with bleach
slides
goggles for each student
student sheet

OBJECTIVES

The student will do the following:

1. Define potable water.
2. Learn why water is treated for drinking purposes.

BACKGROUND

Sources of water pollution include the home, leaking septic systems, industry, cities, agriculture, logging operations, and mines. Pollutants from these sources eventually get into both surface and groundwater. Water for drinking is taken from both surface and groundwater.

Infectious agents such as bacteria, viruses, and parasites can come from untreated or improperly treated human wastes, farm animal wastes, and food processing factories with inadequate waste treatment facilities. Water runoff from these areas carries pathogens to nearby waterways and water sources. Drinking water must therefore be disinfected during the treatment process to kill these pathogens. Chlorine is the most commonly used water disinfectant. A form of liquid chlorine ($NaOCl$ or $CaOCl_2$) is one of the compounds in bleach.

Hazardous wastes such as household cleansers and paint thinners are often poured down the drain or onto the ground. These household items contain harmful chemicals that cannot always be removed during water treatment, so they should be used as infrequently as possible. Household wastes should be disposed of carefully. Reading the label is often a good way to determine how and where to use and dispose of household chemicals. Heavy rains in cities wash dirt, wastes, and pollutants from city streets into storm drains. Industries and mining operations produce harmful chemicals and sometimes radioactive materials.

The Environmental Protection (EPA) Agency is a federal agency that seeks to protect water quality. For years many people assumed that groundwater could not become polluted. It was thought that water was cleansed as it passed through the soil. Soil can filter water to some extent; however, it cannot remove certain chemicals. In 1988, a survey by the EPA showed that 45 percent of public water systems that were served by groundwater sources were contaminated with industrial solvents, agricultural fertilizers, pesticides, or other synthetic chemicals.

In 1972, Congress passed the Clean Water Act. This important legislation appropriated funds for reducing water pollution. Much of the money has been spent on improving municipal sewage treatment plants.

Terms

landfill: a large, outdoor area for waste disposal; landfills where waste is exposed to the atmosphere (open dumps) are now illegal; in "sanitary" landfills, waste is layered and covered with soil.

pollutant: an impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that may be harmful to or affect the health, survival, or activities of humans or other living organisms.

potable: fit or suitable for drinking, as in potable water.

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration, and is stored in streams, lakes, wetlands, reservoirs, and oceans.

ADVANCE PREPARATION

A. Assemble all materials. Check pond water to make sure it has life in it.

B. Use a designated, clean working area.

C. Label glasses A, B, and C.

D. Make copies of the data table.

E. If you do not have enough goggles for all students, do the activity as a teacher demonstration.

PROCEDURE

I. Setting the stage

A. Discuss proper use of microscope.

B. Discuss why water needs to be clean and what health problems can occur if it contains harmful organisms or pollutants.

II. Activity

A. Pour some pond water (A), rain water (B), and "dirty" water (water that has been mixed with soil and shaken) (C) into clear plastic cups. Label each.

B. Have the students observe a drop of pond water under the microscope and draw what they see.

C. Have the students observe a drop of rain water under the microscope and draw what they see.

D. Have the students observe a drop of dirty water under the microscope and draw what they see.

E. Pour dirty water into a can with a paper towel and sand and set the can over a clear cup labeled D.

F. Allow this to stand for 30 minutes.

G. Add several drops of bleach to cup A and have students observe what happens to the organisms after bleach is added. Compare cup A to cups B and C. Even water that appears to be clear must be disinfected with chemicals to make sure it is safe to drink.

H. Treat the water in cups B and C by putting several drops of bleach in each.

I. Stir cup A and compare it with the treated water in cups B and C. Allow the students to look at a sample of each again with a microscope.

J. Have the students observe a sample of the water in cup D under the microscope.

III. Follow-Up

A. Have the students answer the following questions:

1. What did you observe?

2. What is the difference between the water in cups A, B, and C?

3. Is this filtered water clean enough to drink?
4. Is there any use for this water?
5. What do you see in the microscope?
6. What happens to the microorganisms when bleach contacts them?
7. What is potable water?

IV. Extensions

A. Visit a wastewater treatment plant.

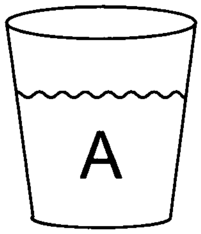
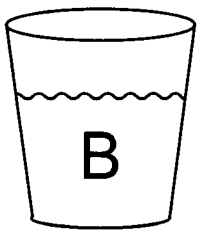
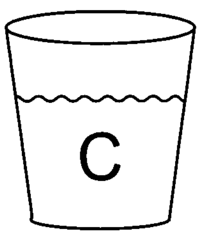
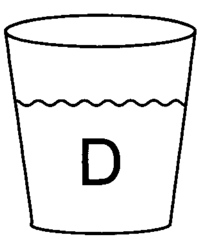
B. Bring in a speaker from an industry such as a paper company that handles treating wastewater.

RESOURCES

Department of 4H and other youth programs, "4H Water Wise Guys," Cooperative Extension Service, April 1992.

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Gralla, Preston, How the Environment Works, Ziff-Davis Press, Emeryville, California, 1994.

Water	1st Observation	2nd Observation
 Pond		
 Rain		
 Dirty		
 Filtered Dirty		

1. What did you observe in Sample A after you added the bleach?

2. Do you think Sample D is clean enough to drink? Why or why not?

PURIFYING WATER

6-8

SUBJECTS:
Art, Chemistry, Health

TIME:
2 class periods

MATERIALS:
stereomicroscope
petri dish
samples of pond water
laundry bleach
small beaker
medicine dropper
student sheets

OBJECTIVES

The student will do the following:

1. Discuss ways of conserving resources.

2. State what the acronym "EPA" stands for and explain the agency's function.

3. Discuss ways water pollution can be controlled.

4. Describe how laundry bleach can be used to purify water.

BACKGROUND INFORMATION

Water pollution affects our water ecosystems. Freshwater is a renewable resource, but it can become so contaminated by pollution that it is no longer safe for consumption. Water can become polluted by fertilizers, pesticides, and other wastes that have run off land into surface water or leached into groundwater. Poor land use rapidly increases sediment erosion, and pollutants can quickly reach surface water.

In large, rapidly flowing rivers, contaminants are diluted quickly to low concentrations and the aquatic oxygen supply and the waste decomposition is quickly renewed. Sewage is one common water pollutant. When the amount of sewage is large in comparison to the water volume, an overabundance of phytoplankton is produced. The organisms that decompose the phytoplankton use up the available oxygen, so aerobic organisms in the area die. As the water flows downstream, the sewage is diluted and further decomposed, and the oxygen supply increases.

Huge amounts of sediment and surface runoff end up in rivers daily. Runoff from factory waste can include poisonous chemicals such as lead, mercury, alkalis, and chromium, which kill the organisms that decompose organic wastes. Hydroelectric plants discharge hot water into rivers, which changes the light, temperature, and atmospheric gases of the aquatic environment, rendering it intolerable for many organisms. Perpetually warm water may change the type of species living in the area. Humans depending on this water can also have their health affected by these pollutants.

Terms

chlorine: a chemical element, symbol Cl, atomic number 17, atomic weight 35.453; used as a disinfectant in drinking and wastewater treatment processes.

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

ADVANCE PREPARATION

A. Set up lab stations with required materials.

B. Collect water samples from a pond, making sure the water contains microscopic organisms.

PROCEDURE

I. Setting the stage

A. Discuss the activity objectives using the background information.

B. Explain to the students they will be doing three treatments to get an average.

II. Activities

A. Place the petri dish on the microscope's stage.

B. Pour the pond water into the petri dish.

C. Have the students observe the movement of the microorganisms.

D. Have the students draw on the student sheet what they see through the microscope and describe the movement of the microorganisms.

E. Add one drop of bleach. Have the students observe and describe what happened to the microorganisms.

F. Continue adding one drop of bleach at a time. Continue this until all movement has stopped.

G. Repeat steps B – F three times, filling in the information on the student sheet.

III. Follow-Up

A. Ask students the following questions after they have completed the student sheet:

   1. What do you conclude from your three treatments?

   2. What other methods could be used to purify water?

B. Have the students use the steps in the scientific method to write up the lab activity (problem, procedure, data, conclusion).

IV. Extensions

A. Call a water treatment facility and ask what is done to purify the drinking water. Find out what is added, when, and how much.

B. Take a field trip to a water treatment facility.

C. Write a letter to your regional Environmental Protection Agency office (there are 10), state environmental agencies, or local organizations concerned with water protection. Request information on topics such as water quality, water testing, and water regulations. (See Resources chapter for addresses.)

RESOURCES

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Gralla, Preston, How the Environment Works, Ziff-Davis Press, Emeryville, California, 1994.

BSCS Innovative Science Education, Biological Science: An Ecological Perspective, Teacher's Edition, Kendall Hunt Publishing Co., Dubuque, Iowa, 1992.

Trial #
Drawing

no bleach

Approximate # of microorganisms moving _______

Describe what you observed.

1 drop

Approximate # of microorganisms moving _______

Describe what you observed.

2 drops

Approximate # of microorganisms moving _______

Describe what you observed.

3 drops

Approximate # of microorganisms moving _______

Describe what you observed.

Supply the following information based on your three treatments.

Directions: Count the approximate number of microorganisms that were moving during each of the treatments.

	Treatment #1	Treatment #2	Treatment #3	Total 1, 2, 3	Average (divide total by 3)
no bleach (no treatment)					
1 drop					
2 drops					
3 drops					

Answer the following questions based on your investigation:

1. What is the effect of adding bleach to pond water?

2. How does the amount of bleach affect the microorganisms?

3. What other methods could be used to purify water?

WATER TREATMENT PLANTS

6-8

SUBJECTS:
Biology, Botany, Health

TIME:
Teacher set-up one day ahead, then 30 minutes for demonstration and discussion.

MATERIALS:
celery stalks
2 beakers (jars may be used)
food coloring
water
knife
teacher sheet
student sheet

OBJECTIVES

The student will do the following:

1. Describe how plants remove pollutants from water.
2. Discuss the limitation of plants' ability to remove pollutants from water when overburdened with pollutants from the land.

BACKGROUND INFORMATION

Many people fail to realize that plants are essential to the health of our water supply. Wetlands and their plants are an increasingly popular alternative for filtering wastewater from homes, factories, schools, and businesses. Plants growing in a wetland filter pollutants out of runoff, rainwater, and wastewater before it enters bodies of water.

The tangle of leaves, stems, and roots in a densely vegetated wetland trap trash and particles of sediment. These remain in the wetland, while the cleaner water moves away. As water moves through a wetland, plants also take up toxic pollutants and nutrients. Nutrients are used by the plant for metabolism and growth while other substances are stored in the tissues of the plant.

In a natural system, plants are fairly efficient at keeping the system in balance even when there is a naturally occurring flow from upstream. However, when human activities in the water and on land add nutrients, sediment, and toxic pollutants, plants cannot clean everything. We must be careful that our activities will not send pollutants into the water. We also must maintain and even add to the wetlands that help keep out those pollutants that we miss or cannot control.

Many pollutants run off of the land from construction sites, highways, streets, and the communities in which we live. Sometimes ponds or ditches are built to filter runoff from these sites. These ponds are ditches, which are often planted with wetland plants to aid in the filtering. Rain and runoff also rest a bit here before moving on. This means that many of the pollutants, especially soil particles, settle to the bottom while the cleaner water drains off from the top. These ponds or ditches are called storm water management ponds.

Natural and constructed wetlands are now being used for sewage treatment in some areas. One city in California transformed a 160 acre garbage dump into a series of ponds and marshes. The sewage is first pumped into the holding ponds where it undergoes the settling process. Bacteria and fungi digest the organic solids that have settled out. Effluent from the holding ponds then passes through the marshes where water is filtered and cleansed by aquatic plants.

Terms

nutrient: an element (or compound thereof), such as nitrogen, phosphorus, and potassium, that is necessary for plant growth.

pollutant: an impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that may be harmful to or affect the health, survival, or activities of humans or other living organisms.

storm water runoff: surface water runoff that flows into storm sewers.

ADVANCE PREPARATION

A. The activity may be done in groups or as a demonstration. Prepare the demonstration one day before the lesson. Repeat these steps in front of the class to show how the demonstration was prepared.

B. Place one set up of celery in the refrigerator to note whether any differences are noted in the chilled plant.

PROCEDURE

I. Setting the stage

A. Prepare a solution in a beaker by adding several drops of food coloring to water. Explain that the food coloring represents pollution by a toxic substance (a pesticide, for example). Students may come up with other examples.

B. Ask students to imagine water flowing through a wetland that has many plants. Tell students that the stalks of celery are similar to plants growing in a wetland, such as sedges, cattails, and grasses.

II. Activity

A. Cut off the bottom half inch of the celery stalks and place them in the water overnight. Over time the colored water will travel by capillary action up the stalk. This will be a visible demonstration of how plants can absorb pollutants with the water they "drink."

B. The colored water may or may not be visible on the outside of the stalk. Cut off one-inch pieces of the celery and hand them to the students to study closely. They will see colored dots on the cross section, which are water-filled channels in the celery.

III. Follow-Up

A. Ask the following questions or have students answer them in groups:

1. How do wetland plants help to purify water? (They purify water by taking up pollutants from it.)

2. Why is the water remaining in the beaker still polluted? (Plants can only do so much. As new, hopefully clean, water flows into the system, the pollutants will be somewhat diluted and the water a bit less polluted. If the water continues to flow on to other parts of the wetland, other plants will continue to remove pollutants. Wetland soil also helps to filter out some pollutants.)

3. Where does the water go after uptake into the plant? (It is transpired out through the stomata in the plants' leaves and usually evaporates.)

4. What happens to the pollutants? (Some are used in the plants' metabolic processes, some are transformed into less harmful substances, while others are stored in the plants' tissues and could be re-released into the environment if the plants die.)

5. Why can't we simply dump all of our waste into wetlands? (Wetlands can only do so much, so many pollutants still end up in the water. Too many pollutants will harm or destroy a wetland. The best solution is to reduce the pollution.)

IV. Extensions

A. Have the students check their neighborhoods and other places undergoing construction to observe the areas after a rainstorm.

B. Have the students write a plan for how they would control pollutants if they owned a large plant nursery.

C. If the neighborhood has a storm water management pond, ask the students to observe it. Many are located near large shopping centers and parking lots. Ask the students to observe the pond on a dry day and on a day after a heavy rain.

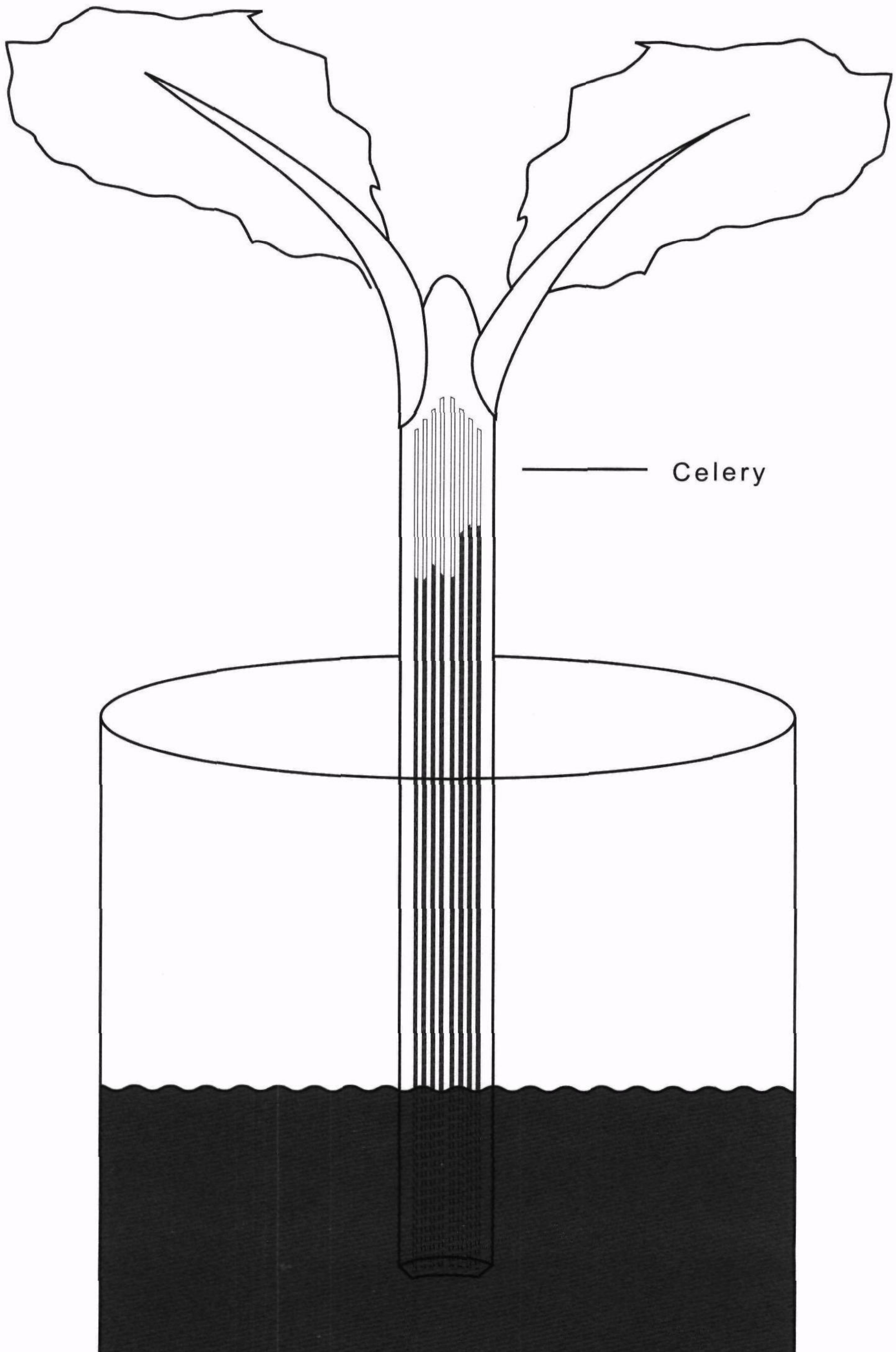
RESOURCES

"Treatment Plants," Discover Wetlands.

WOW!: The Wonder of Wetlands.

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Dennison, Mark S. and James F. Berry, Wetlands: Guide to Science, Law, and Technology, Noyes Publications, Park Ridge, New Jersey, 1993.


Celery

1. How do wetlands help to purify water?

2. Why is the water remaining in the beaker still polluted?

3. Where does the water go after uptake into the plant?

4. What happens to the pollutants?

5. Why can't we simply dump all of our waste into wetlands?

PURIFICATION OF WATER

6-8

SUBJECTS:
Ecology, Chemistry, Health

TIME:
50 - 90 minutes

MATERIALS:
photographs or posters of water and wastewater treatment plants
list of steps involved in water and wastewater treatment plants
local map
student sheets

OBJECTIVES

The student will do the following:

1. Identify the reasons for purifying water for communities.
2. Describe the water treatment processes that occur at a water filtration and treatment plant.
3. Describe the wastewater treatment processes that occur at a municipal wastewater treatment facility.
4. Compare the municipal system's water purification system to the ways water is purified in nature.
5. Discuss the advantages and disadvantages of chlorinated water.

BACKGROUND INFORMATION

Rivers and lakes are sources of water for municipal areas. Water samples collected from these water sources often look cloudy. Samples can look clear and still contain invisible sources of pollution. Rivers and lakes must be monitored for contamination and other sources of pollution.

Water that enters the municipal water supply has to be cleaned before it can be used and must also be cleaned after it is used. Thus, the water is both precleaned and post-cleaned. Precleaning takes place at a water treatment plant, and post-cleaning takes place at a wastewater treatment plant.

In some areas of the country, raw or insufficiently treated wastewater threatens the purity of the water resources. Poorly treated wastewater may contain harmful levels of bacteria and chemicals that can jeopardize human life.

Municipal water systems are responsible for cleaning the water before it is used. The water treatment system includes standardized steps for the treatment of the water before it is allowed to enter the homes of individual citizens.

The following steps are included in a water treatment filtration system:

1. Screening removes large objects from the water.
2. Pre-chlorination adds chlorine to kill disease causing organisms.
3. Flocculation adds alum and lime to remove suspended particles by trapping them in a jelly-like suspension formed from the added particles.
4. Settling allows trapped particles and solids to settle to the bottom.
5. Sand filtration allows sand to act as a natural filter, removing nearly all suspended material.
6. Post-chlorination adjusts the chlorine to maintain long-term action to kill disease-causing organisms.
7. Other treatments, such as fluoridation, pH adjustment, and further aeration, can be optional steps.

The following steps are included in a wastewater treatment system:

1. Preliminary Treatment: Screening is when large objects are removed; smaller objects are ground into even smaller pieces, and sand and dirt are allowed to settle out.

2. Primary Treatment: Primary settling happens when floating grease and scum are skimmed and heavier organic solids settle out.

3. Secondary Treatment: Aeration tanks add air and allow bacteria to digest organic substances. Sometimes rock or plastic media filters are used to grow bacteria that consume organisms in the wastewater.

4. Final settling is when bacteria settle out of the wastewater and are removed to a solids treatment process for stabilization. The stabilized solids, called biosolids, are then suitable for disposal on cropland, in landfills, or for other beneficial uses, such as compost.

5. Disinfection or chlorination means that additional chlorine is added to kill disease-causing organisms. Chlorine can be harmful to humans in large amounts. Chlorine can react with water and produce harmful substances such as chloroform which is carcinogenic. Other popular means of disinfection include ultaviolet irradiation that uses ultraviolet rays to kill harmful bacteria.

6. Optional treatments include controlling water pH by using carbon dioxide to form carbonic acid. Carbonic acid can neutralize alkaline compounds. Heavy metal ions and phosphate ions can also be removed by precipitation.

7. Advanced treatment processes also remove toxins such as ammonia.

Terms

carcinogen: cancer-causing agent.

chlorination: water disinfection by chlorine gas or hypochlorite.

flocculation: the process of forming aggregated or compound masses of particles, such as a cloud or a precipitate.

purification: the process of making pure, free from anything that debases, pollutes, or contaminates.

settling: the process of a substance, such as heavy organic solids or sediment, sinking.

sewage contamination: the introduction of untreated sewage into a water body.

wastewater: water that has been used for domestic or industrial purposes.

ADVANCE PREPARATION

A. Research the water treatment and wastewater treatment plants in your area.

B. Display diagrams of water and wastewater treatment plants on bulletin boards.

C. Make duplicate copies of the steps in water and wastewater treatment.

PROCEDURE

I. Setting the stage

A. Locate the water treatment and wastewater treatment plants in your area on a local map.

B. Discuss the water supply that provides the water for the water treatment plants.

C. Compare the number of students in the class who use water from a water treatment plant with the number who have private wells.

II. Activities

A. List the steps involved in purification of a municipal water supply and explain what happens at each step.

B. Ask the students to draw and label the activities involved in each of the steps.

C. Have the students speculate regarding what might happen if a step was not included.

D. List the steps involved in the treatment of wastewater at a wastewater treatment plant.

E. Ask the students to draw and label the activities involved in each of the steps.

F. Have the students speculate regarding what might happen if a step was not included.

G. Have the students research the amount of chlorine added to the water at each treatment facility. Discuss as a class the possible effects of over-chlorinating.

H. Discuss alternative methods of disinfection.

I. Have the students compare their drawings and descriptions to the wall diagrams.

III. Follow-Up

A. Ask students to research the optional steps used by water treatment facilities in local and surrounding communities. Discuss which optional steps can be detrimental to people or to the environment.

B. Discuss the possible hazards of using well water rather than water from a water treatment facility.

IV. Extensions

A. Take a field trip to the local water treatment and wastewater treatment plants.

B. Secure a speaker from a local, state or federal environmental agency, the local utility company, or an environmental consulting firm to discuss each person's responsibility in protecting our surface waters.

C. Develop a clean water monitoring group to collect data from local rivers and streams.

RESOURCE

American Chemical Society, ChemCom: Chemistry in the Community, Kendall Hunt Publishing Company, Dubuque, Iowa, 1993.

The following steps are included in a water treatment filtration system:

1. Screening — removal of large objects from the water.

2. Pre-chlorination — addition of chlorine to kill disease-causing organisms

3. Flocculation — addition of alum and lime to remove suspended particles by trapping them in a jelly-like suspension formed from the added particles

4. Settling — trapped particles and solids are allowed to settle to the bottom

5. Sand filtration — sand acts as a natural filter, removes nearly all suspended material

6. Post-chlorination — adjustment of the chlorine to maintain long-term action to kill disease-causing organisms

7. Other treatments — fluoridation, pH adjustment, and further aeration can be optional steps

The following steps are included in a wastewater treatment system:

Step 1 – Preliminary Treatment:

1. Screening — large objects are removed; smaller objects are ground into even smaller pieces, and sand and dirt are allowed to settle out.

Step 2 – Primary Treatment:

2. Primary settling — floating grease and scum are skimmed and solids settle out.

Step 3 – Secondary Treatment:

3. Aeration — *aeration tanks add air and allow bacteria to digest organic substances.*

4. Final settling — sludge continues to settle out, and it is aerated, chlorinated, and dried for incineration or for dumping in landfills.

5. Disinfection/chlorination — additional chlorine is added to kill disease-causing organisms. Other disinfection processes include ultraviolet irradiation.

6. Optional treatments — water pH can be controlled by using carbon dioxide to form carbonic acid. Carbonic acid can neutralize alkaline compounds. Heavy metal ions and phosphate ions can also be removed by precipitation.

BACTERIA IN WATER

6-8

SUBJECTS:
Art, Health, Math, Microbiology

TIME:
50 minutes

MATERIALS:
water samples from various sources
bacterial plates
collecting bottles
petri dishes with prepared media
pipette or medicine dropper
gloves
biology text
safety goggles
teacher sheet showing types of bacteria
student sheets

OBJECTIVES

The student will do the following:

1. Inoculate petri dishes with water samples.
2. Observe and record the growth of bacterial colonies.

BACKGROUND INFORMATION

Seventy-one percent of the Earth is covered by water. Only three percent of this water is considered to be freshwater. Freshwater is water that contains less than 0.5 parts per thousand dissolved salts. Ninety-nine percent of the freshwater is either locked up in ice or snow or buried in groundwater aquifers. Lakes, rivers, and other surface freshwater bodies make up only about 0.01 percent of all the water in the world.

Freshwater is a major limiting factor for both biological systems and human societies. Growing world human populations are continuing to place great demands on freshwater supplies. Water shortages are resulting from rising demand, unequal distribution of usable freshwater, and increasing pollution of existing water supplies.

The presence of coliform bacteria in water is a sign that the water has been contaminated. Water quality control personnel monitor water for the presence of coliform bacteria. Coliform bacteria live in the colon or intestine humans and other animals.

ADVANCE PREPARATION

A. This activity will be used in conjunction with a unit on pollution of the environment. Students should have reviewed the basic types of bacteria as indicators of pollution and possible sources of contamination by domestic or agricultural sewage.

B. Because this unit follows microscope use and microorganisms, the students should be familiar with lab techniques. This activity will allow students to directly observe standard lab procedures in determining the pollution level of an area's water bodies.

PROCEDURE

I. Setting the stage

A. Assign groups of four to six students.

B. Distribute three water samples to each group.

C. Prepare the petri dishes by labeling them with the group number and date. **Note: Safety goggles should be worn during this lab.**

II. Activity

A. Students will use a pipette or medicine dropper to inoculate each dish with water from a different source.

B. Have the students tape the dishes (to avoid leakage or exposure) and put them in a cool, dark place.

C. Ask the students to observe the cultures and identify and count the colonies daily for one week. Have them compile and graph the data so comparisons with other groups can be made. Reference books and lab manuals should be available to help with identification.

D. After one week, the teacher should destroy the cultures by pouring household bleach into each dish and then incinerating it. Instruct the students regarding the reasons for careful handling.

III. Follow-Up

A. Evaluate each group's lab techniques during the setting up and observations of the cultures.

B. Evaluate the graphs and data collected during the activity.

C. Students will write answers to the following questions:

1. Explain which culture demonstrated the most types of colonies.

2. Discuss the possible health hazards associated with bacterial pollution.

3. Describe the appearance of bacteria, either from your culture plates or from reference books.

IV. Extensions

A. Identify possible sources of bacterial contamination.

B. Conduct other water parameter tests to determine if pH, nitrates, and phosphates have any correlation to the colony counts.

C. Take a field trip to local water and/or sewage treatment plants.

D. Invite a water quality expert to speak to the class.

RESOURCES

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Project Wet: Curriculum and Activity Guide, Western Regional Environmental Education Council, 1995. Available Through Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057 (Fax: 406-994-1919; e-mail: rwwet@msu.oscs.montana.edu).

Directions: Number each petri dish and inoculate with a different water sample. Record your observations each day for a week, and then graph your results.

Dish # 1 Water Source ____

Day 1

Day 2

Day 3

Day 4

Day 5

Directions: Number each petri dish and inoculate with a different water sample. Record your observations each day for a week, and then graph your results.

Dish # 2 Water Source ____

Day 1

Day 2

Day 3

Day 4

Day 5

Directions: Number each petri dish and inoculate with a different water sample. Record your observations each day for a week, and then graph your results.

Dish # 3 Water Source ______________________________________

Day 1

Day 2

Day 3

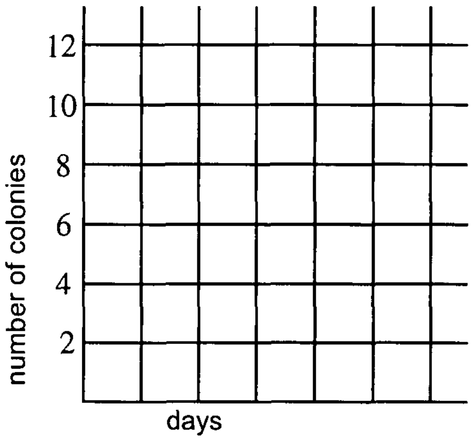
Day 4

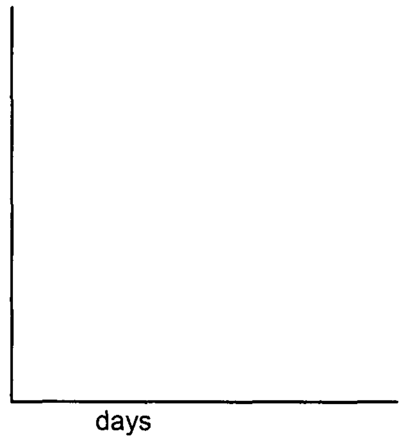
Day 5

Graph your results. Make sure you title your graph and label the x (horizontal) and y (vertical) axes. The first is done.

Number of colonies in ________________ water.

#1





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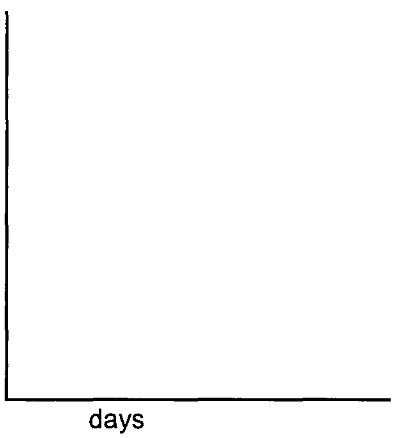

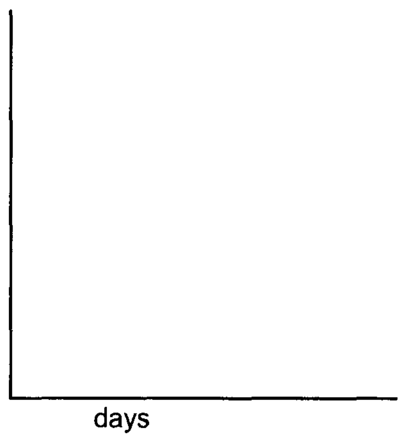

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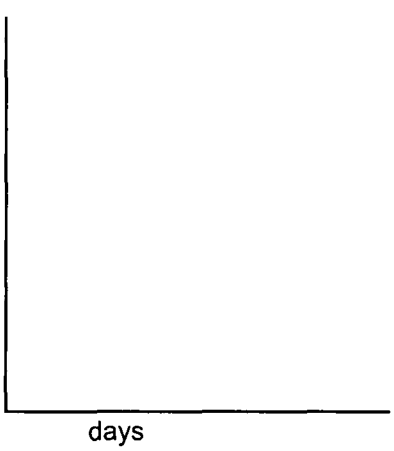

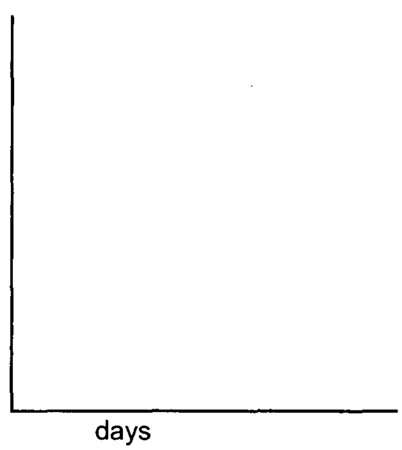

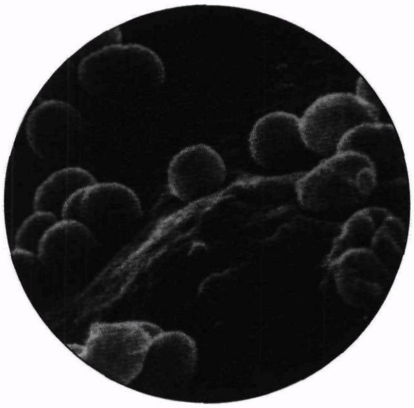

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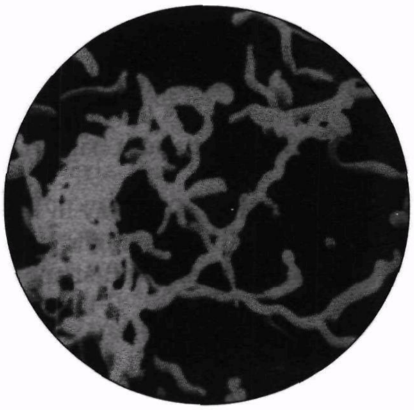


SPIRILLA

ROD

INDICATING INSECTS

6-8

SUBJECTS:
Biology, Ecology

TIME:
2 class periods

MATERIALS:
swiftly moving stream
fine netting (2 feet X 10 feet)
jars (one per student)
insect field guides
white sheet
student sheets

OBJECTIVES

The student will do the following:

1. Compile a table of the different kinds and quantities of insects found in a shallow stream.

2. Create a classification system for the insects found.

3. Appraise the quality of the water based on the insects found.

BACKGROUND INFORMATION

Healthy streams contain entire communities of plants, animals, and other organisms which interact with one another and their environment. Producers such as cyanobacteria, diatoms, and water mosses grow on the stones at the edge or on the bottom of the brook. These producers provide food and shelter to aquatic insects. The insects in turn provide food for the small fish inhabiting the brook.

Any physical, biological, or chemical change in water quality that adversely affects living organisms is considered to be pollution. Water pollution affects all the living things of a stream. Some organisms are resistant to certain types of pollutants. Others, however, are less resistant and are vulnerable to the adverse effects of water pollution.

Water quality researchers often sample insect populations to monitor changes in stream conditions. The insects are monitored over time to assess the cumulative effects of environmental stressors such as pollutants. Environmental degradation resulting from pollution will likely decrease the diversity of insects found by eliminating those that are less tolerant to unfavorable conditions. Insects such as the mayfly, stonefly, and caddis fly larvae are sensitive or intolerant to changes in stream conditions brought about by pollutants. Some of these are able to leave for more favorable habitats. Some, however, are either killed by the pollutants or are no longer able to reproduce. Other organisms such as dragonflies, damselflies, and nymphs are called facultative organisms. These organisms prefer good stream quality but can survive polluted conditions.

ADVANCE PREPARATION

A. Have students bring in an empty, average-sized jar.

B. Locate a swiftly moving stream that is at least 3-4 inches deep, but not deeper than approximately 12 inches.

C. Obtain a fine netting that will not allow small insects to pass through.

D. Obtain several insect field guides.

PROCEDURE

I. Setting the stage

A. Explain the relationships between insects and water quality.

B. Discuss the best locations in a stream to collect the insects.

C. Make sure students know how to classify.

II. Activity

A. Select a stream to be tested and bring all the required materials.

B. Locate an area of the stream that has a swiftly moving current. Have the students observe and record the kinds of insects found on the surface of the water.

C. Stretch the netting across the stream perpendicular to the current. Secure the bottom of the net along the bottom of the stream with larger rocks and pebbles. Hold the top of the net above the surface of the water.

D. Have a few students stand about 10-15 feet upstream and disturb the water by shuffling their feet on the bottom, being sure to kick up both large and small rocks.

E. After this disturbed water has passed the point of the netting, have the students quickly pick the bottom of the netting up out of the water without letting the top part of the netting drop into the water.

F. Place the netting on a white sheet on the banks of the stream so that the insects can be observed. Have the students record the kinds and quantities of insects present in a data table.

G. The students should now compare the types of insects found on the surface of the water to the types collected.

H. After separating and observing the insects, place the insects in jars for further observations.

III. Follow-Up

A. Have the students create a classification system of the insects found. Then have them use an insect guide to identify the type of insects found and check the accuracy of their classification system.

B. Use field guides to identify the relationship between the kinds of insects and the indication their presence has on water quality. Write a brief paper on the water quality of the stream tested.

C. Have the students prepare several graphs of the types and quantity of insects found in the stream.

IV. Extensions

A. Have the students identify the various larvae found and the insects into which they will develop.

B. Research the physical characteristics of the insects found at the surface of the water and the adaptations they have made to live there.

C. Invite a limnologist to class to talk about the relationship between insects and water quality.

RESOURCES

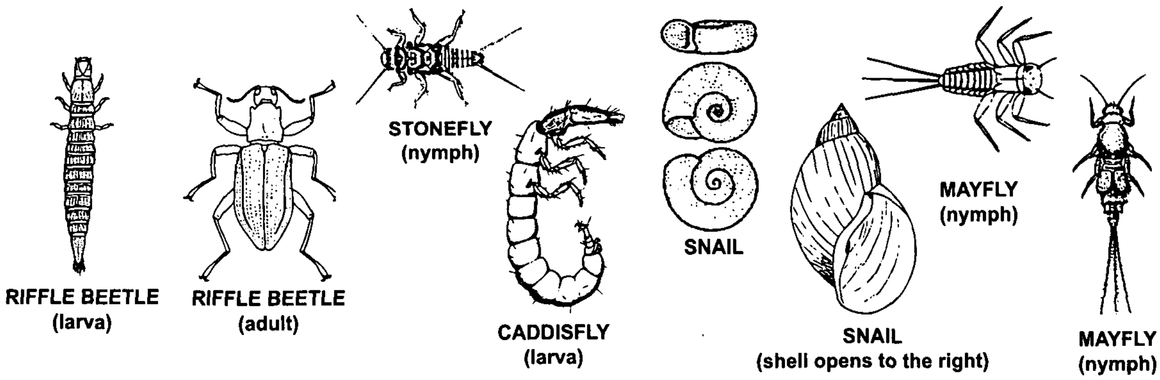
Biological Science: An Ecological Approach, Kendall/Hunt Publishing Company, Dubuque, Iowa,1992.

Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

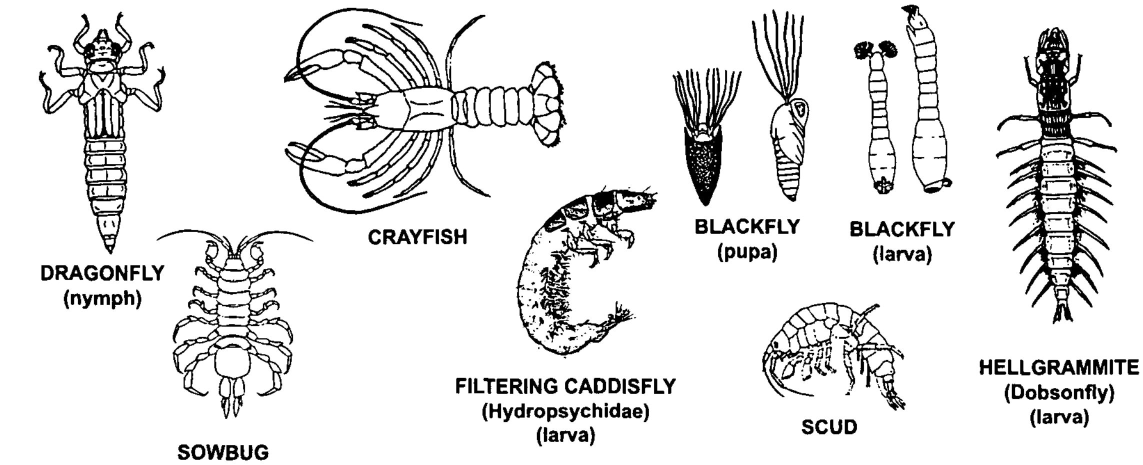
Project Wet: Curriculum and Activity Guide, Watercourse and Western Regional Environmental Education Council, 1995.

MACROINVERTEBRATE GROUPS
Beginner's Protocol PICTURE KEY

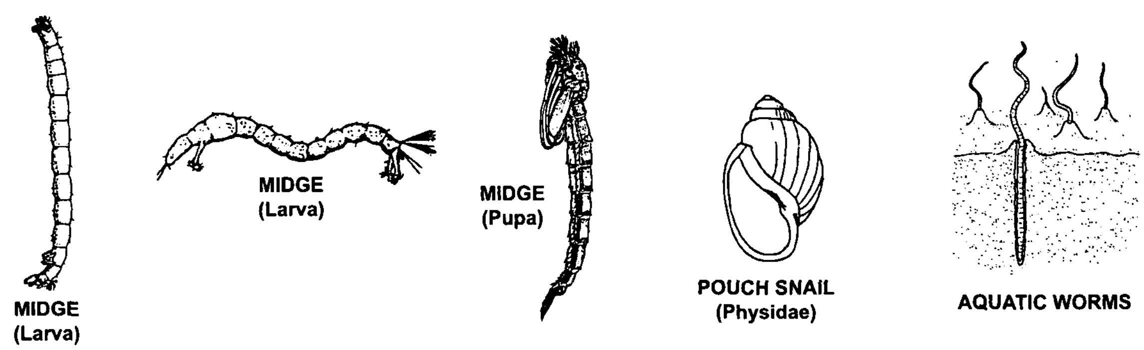
GROUP 1 *These organisms are generally pollution intolerant. Their dominance generally signifies* ***Excellent-Good Water Quality.***



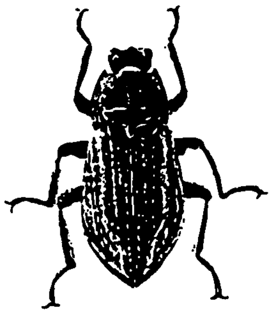
GROUP 2 *These organisms exist in a* ***Wide Range*** *of water quality conditions.*



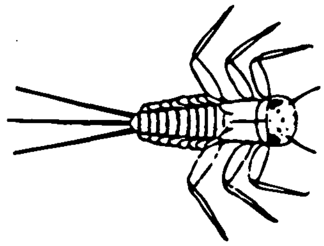
GROUP 3 *These organisms are generally tolerant of pollution. Their dominance generally signifies* ***Fair-Poor Water Quality.***



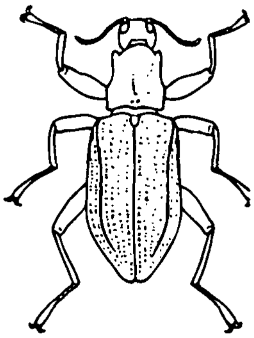
GROUP 1
"Bugs"



RIFFLE BEETLE (adult)

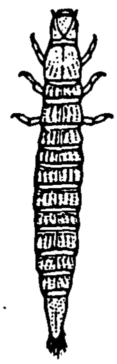


MAYFLY (nymph)

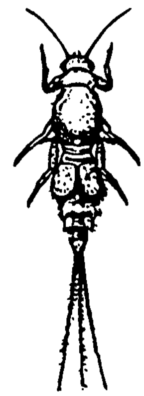


RIFFLE BEETLE (adult)

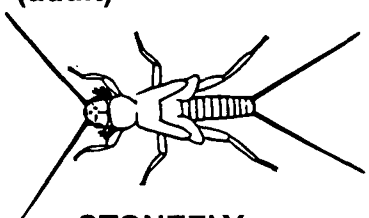
MAYFLY (nymph)



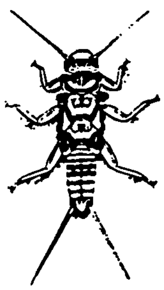
RIFFLE BEETLE (larva)



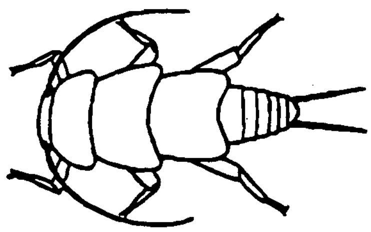
MAYFLY (nymph)



STONEFLY (nymph)

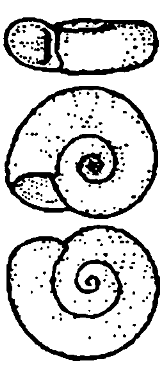


STONEFLY (nymph)



STONEFLY (nypmth)

CADDISFLY (larva)

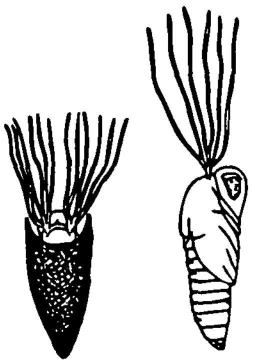


SNAIL

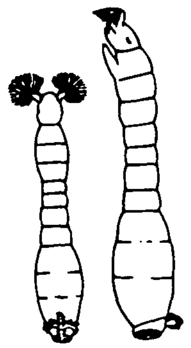
SNAIL (shell opens to the right)

CADDISFLY (larva)

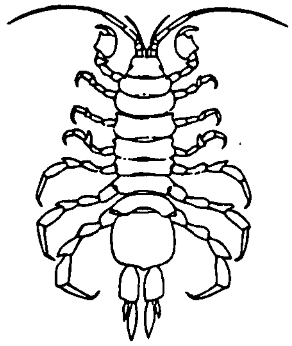
GROUP 2
"Bugs"



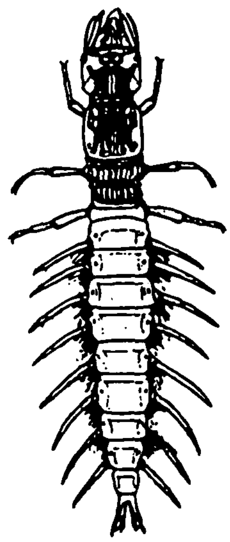
BLACKFLY (pupa)



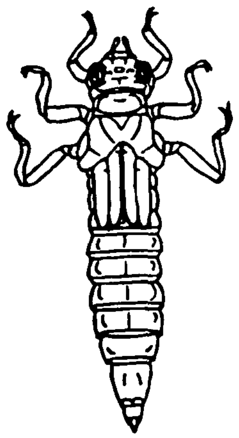
BLACKFLY (larva)



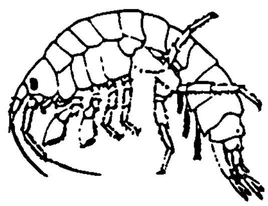
SOWBUG



HELLGRAMMITE (Dobsonfly) (larva)



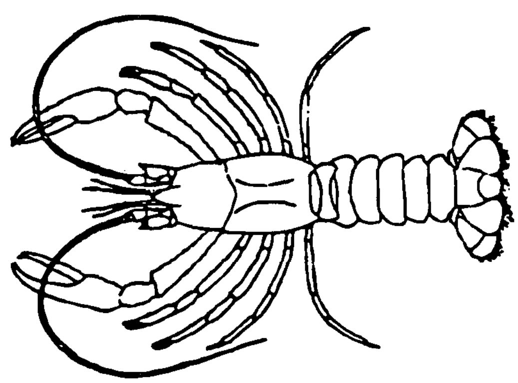
DRAGONFLY (nymph)



SCUD

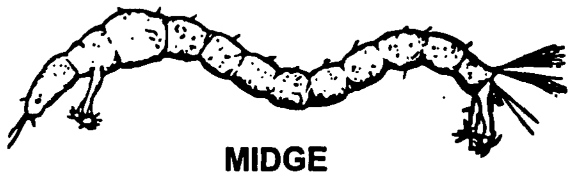
SNIPE FLY (larva)

FILTERING CADDISFLY (Hydropsychidae) (larva)

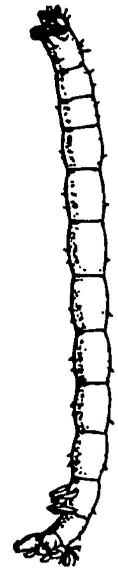


CRAYFISH

GROUP 3
"Bugs"

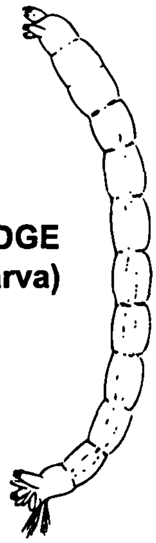


MIDGE
(Larva)

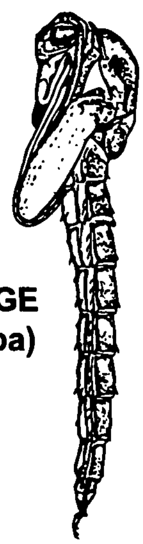


MIDGE
(Larva)

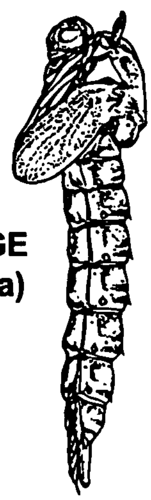
MIDGE
(Pupa)



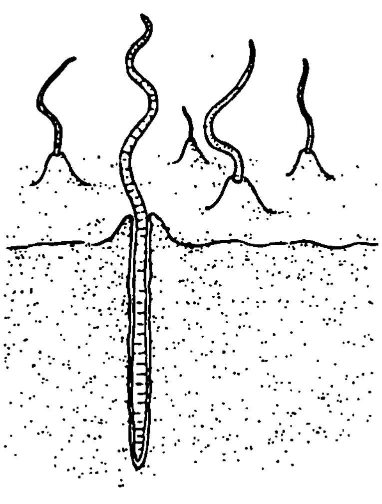
MIDGE
(Larva)



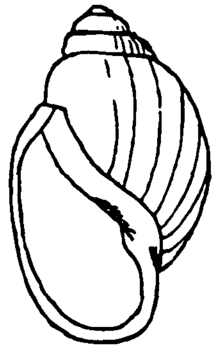
MIDGE
(Pupa)



MIDGE
(Pupa)



AQUATIC WORMS



SNAIL
(shell opens to the left)

WATER POLLUTION SOLUTIONS

6-8

SUBJECTS:
Art, Chemistry, Language Arts

TIME:
50 minutes

MATERIALS:
scissors
index cards
glue
paper
old magazines
camera and film (optional)
copier (optional)

OBJECTIVES

The student will do the following:

1. Define water pollution.
2. List ways water is polluted.
3. List different kinds of chemicals that can cause water pollution.
4. List ways water pollution can be prevented.
5. Develop various activities to help promote clean water awareness.

BACKGROUND INFORMATION

Water pollution has been attributed to three main causes: human population growth, industrialization, and natural resources development. About one quarter of America's water supply is measurably polluted. Many developing countries have essentially no unpolluted water.

The best solution to water pollution is prevention. If we want to have healthy water, we must create less pollution. Farmers, municipal authorities, industrialists, governments, and the general public must all clean up their activities to reduce pollution.

Individuals can do many things to help clean up our water supply. A good place to start is the home. The main source of water pollutants that come from homes originate in the kitchen, bathroom, or garage. Some chemicals, such as oil, paint thinner, and pesticides, often find their way down the drain and into our water systems. Household cleansers such as drain cleaner, oven cleaner, and tarnish remover have caustic chemicals that lower water quality. These products have chemical ingredients that may not be removed during water treatment. A partial solution would be to avoid putting these chemicals directly into water in the first place. Hazardous household wastes can be taken to approved disposal sites.

Individuals can also influence political leaders to pass laws that prohibit or decrease water pollution. Other ways to decrease water pollution include decreasing water runoff from surfaces in the neighborhood, disposing of hazardous materials properly, and using biological controls instead of toxic pesticides in the home and garden.

Terms

impurity: something that, when mixed into something else, makes that mixture unclean or lowers the quality.

pollutant: an impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that may be harmful to or affect the health, survival, or activities of humans or other living organisms.

water pollution: the act of making water impure or the state of water being impure.

ADVANCE PREPARATION

A. Gather all of the materials that you will need for the following activities.

PROCEDURE

I. Setting the stage

A. Show the students various pictures illustrating water pollution.

B. Ask the students to describe the situations in each picture.

C. Tell the students about the pictures and relate them to water pollution.

II. Activity

A. Divide the class into groups and ask them to choose one of the activities below to draw attention to water pollution solutions.

1. Pollution Solution Cartoon

   a. The students are responsible for writing a cartoon story depicting characters who are trying to save the Earth's water from pollution.

2. Pollution Solution Book Marks

   a. The students can make their own book marks. The pictures on the book marks describes a solution to pollution.

3. Pollution Solution Rap Song

   a. The students can make up a song that is based on a solution to water pollution.

4. Pollution Solution Flash Cards

   a. The students can cut out, copy, or draw some pictures from magazines that show water contamination problems. Better yet, they can take their own pictures.

   b. The pictures can be placed in chronological order: the students will arrange the pictures and explain how what is happening in one picture can cause what they see in other pictures.

5. Pollution Solution Video

   a. The students can write and film a short video on water pollution. It should be no more than 2-3 minutes and be modeled after a public-service announcement.

III. Follow-Up

A. The students can research local and regional areas that have had problems with water pollution. Examples are the Thames River in London, England; the Hudson River in New York; Chesapeake Bay in Maryland; the Everglades in Florida; the Mississippi River near New Orleans; and many others.

B. Students can research individual incidents of water pollution, such as Love Canal; the Exxon Valdez tanker spill; Times Beach, Missouri; the North Carolina hog waste problem; or other local events.

IV. Extensions

A. The class can invite a spokesperson from the EPA to come in and talk about current trends in preventing water pollution.

B. The class can conduct a survey of the area in which they live to determine the extent of water pollution and suggest ways to prevent further pollution.

RESOURCES

DeVito, Alfred and Krockover, Gerald, Creative Sciencing. Scott, Foresman and Co., Glenview, IL, 1991.

Marine Pollution: http://www.panda.org/research/facts/fct_marine.html

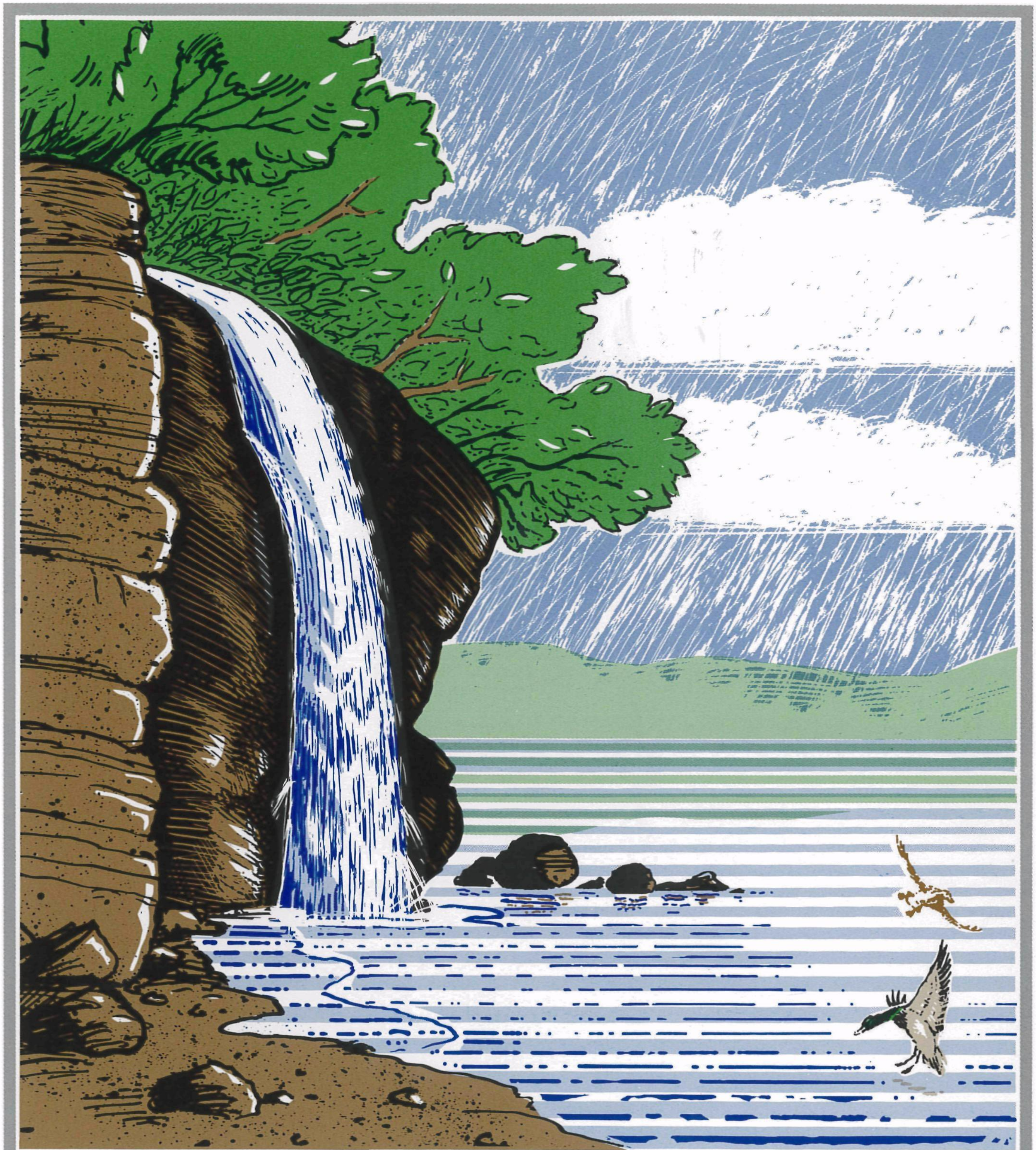
Maton, A., Ecology: Earth's Natural Resources. Prentice Hall Science, NJ, 1991.

Project Wet: Curriculum and Activity Guide, Watercourse and Western Regional Environmental Education Council, 1995. Available through Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057 (Fax: 406-994-1919; e-mail rwwet@msu.oscs.montana.edu).

Sund, Robert, Accent on Science. Charles E. Merrill Publishing Co., Columbus, OH, 1983.

Water Pollution: http://www.fcn.org/fcn/ecosystem/water_po.html

Water Education Federation brochure on Household Contaminants. Available through http://www.wef.org.



THE WATER SOURCEBOOK
SURFACE WATER

BIOASSESSMENT OF STREAMS

6-8

SUBJECTS:
Biology, Ecology

TIME:
field trip or walk to a stream, then 2 class periods

MATERIALS:
magnifying glasses—one per student, if possible
2 buckets per team
2 hand nets for scooping stream debris
one clipboard & pencil per team
rubber boots for 2 people
student sheets

OBJECTIVES

The student will do the following:

1. Work as a team to gather organisms from a stream to evaluate if the water quality is excellent, good, or fair to poor.

BACKGROUND INFORMATION

The quality of streams can be determined by analyzing macroinvertebrates present. Macroinvertebrates are those organisms lacking a backbone that are visible to the naked eye. In freshwater streams, they include insects, crustaceans (crayfish and others), mollusks (clams and mussels), gastropods (snails), oligochaetes (worms), and others. In most streams and rivers, the larval insects dominate the macroinvertebrate community. These organisms provide an excellent tool for stream quality assessment work because they are restricted to their immediate habitat and cannot escape changes in water quality.

The problems affecting streams can be grouped into three general categories:

1. Physical – stream alterations such as reduced flow or temperature extremes, including excessive sediment input from erosion or construction which unfavorably alters riffle characteristics. The result of physical impacts to a stream range from a general reduction in the numbers of all organisms to a reduction in the diversity of taxa.
2. Organic Pollution and Enrichment – the introduction of large quantities of human and livestock wastes, as well as agricultural fertilizers. Mild organic enrichment usually results in a reduction in diversity, leaving a marked increase in the types and numbers of macroinvertebrates that feed directly on organic materials. Because of the organic enrichment, excessive blooms of algae and other aquatic plants provide a plentiful food supply, favoring algae and detritus feeders.
3. Toxicity – this includes chemical pollutants such as chlorine, acids, metals, pesticides, oil, and so forth. It is very difficult to generalize the effects of toxic compounds upon macroinvertebrates, since a number of the organisms vary in their tolerance to chemical pollutants. Generally speaking, however, a toxicity problem is usually the only condition that will render a stream totally devoid of macroinvertebrates.

Terms

detritus: *loose fragments or grains that have been worn away from rock.*

macroinvertebrates: organisms that are visible to the naked eye and lack a backbone.

taxa: one of the hierarchical categories into which organisms are classified.

ADVANCE PREPARATION

A. Either schedule a field trip or walk your class to a nearby stream or do the same activity as a classroom simulation, with 3 "streams" that have paper cut-out animals to be found and analyzed.

B. Divide the room into teams of about 10 students each with a team recorder for each group who will need a pencil, clipboard, and "Stream Quality Assessment Form."

C. Run off copies of the “Stream Quality Assessment Form,” the “Macroinvertebrate Groups” form, and the “Bugs” sheets showing common stream macroinvertebrates.

D. Gather magnifying glasses for the class. The small ones tied around the neck like a necklace work very well.

E. Procure a couple of hand nets to gather stream debris. Procure 2 buckets per group.

F. Make sure those who will be in the stream wear rubber boots. Sometimes it is best for the teacher or a parent to get in the stream and do the actual gathering in the nets. Let the students go through the net contents and find the animals.

G. Contact an environmental scientist (if possible), for help in identifying the animals.

PROCEDURE

I. Setting the stage

A. Pour a glass of “mystery water” (made of sweetened tea) and tell the class this water was collected from a stream near a chemical plant. Ask if you have any volunteers to drink it. If there are no volunteers, drink the whole glass and brag about how delicious it tasted. Then pour a glass of “mystery water” (made of clear saltwater) and ask for a volunteer to taste it. Warn them that you are not sure where it came from and that they had better only take a sip. (One sip will not make anyone sick.)

B. Discuss the problem of determining water quality when the water has not been tested. Ask if the students can think of a way to determine water quality without a water testing kit.

II. Activity

A. Plan a trip to a nearby stream to bioassess the water quality. Each team should have an adult advisor, if possible, to help identify organisms. The “Macroinvertebrate Groups” form will help to identify organisms. Make sure one member of each team serves as a recorder with a clipboard, pencil, and “Stream Quality Assessment Form.” Use the bottom half of the form to tally each animal discovered by a team member.

B. Only one or two people need to get into the stream (in the shallow parts, wearing rubber boots) and use nets to scoop up mud, leaf, and other stream debris. This is emptied out into a bucket in the center of each team, whose members go through it looking for organisms. As they find organisms, they identify them as belonging to group 1, 2, or 3 and are tallied by the team recorder.

C. This process lasts about 45 minutes. The goal is to find 100 organisms for each team, but stream assessment can be accomplished with fewer specimens. The teams do not bring specimens back to the school, although it is interesting to bring back a water specimen to view under the microscope.

D. After returning to school, the class analyzes and compares all team data. If many specimens (over 22) are found from Group 1, the stream is of excellent quality, since these organisms are pollution-intolerant. If there are few or no specimens from Group 1 and 2, and mostly specimens from Group 3, one can assume the stream quality is poor, with only pollution-tolerant organisms able to survive.

III. Follow-Up and Extension

A. Many opportunities exist to teach children about environmental issues after this activity. A few possibilities include cleaning up a poor quality stream, trying to find out the source of pollution and getting it stopped, and assessing other streams.

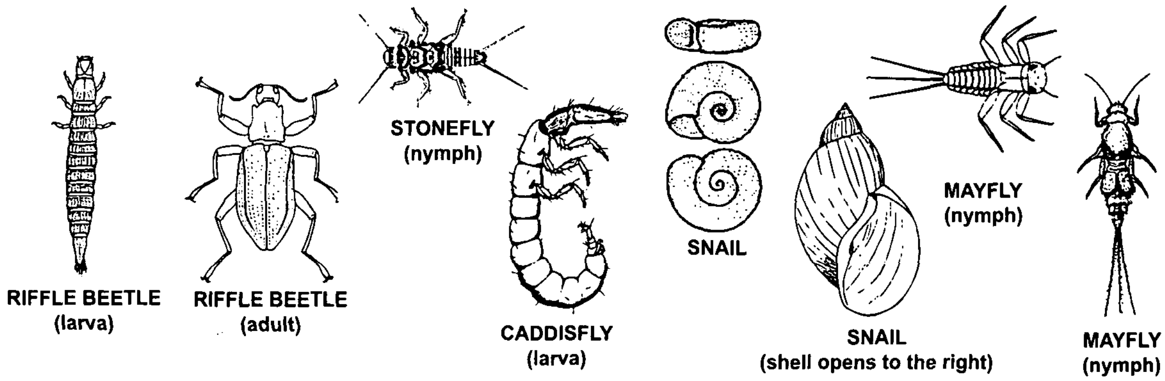
RESOURCES

Kentucky Water Watch. Biological Stream Assessment: http://www.state.ky.us/nrepc/water/introtxt.html

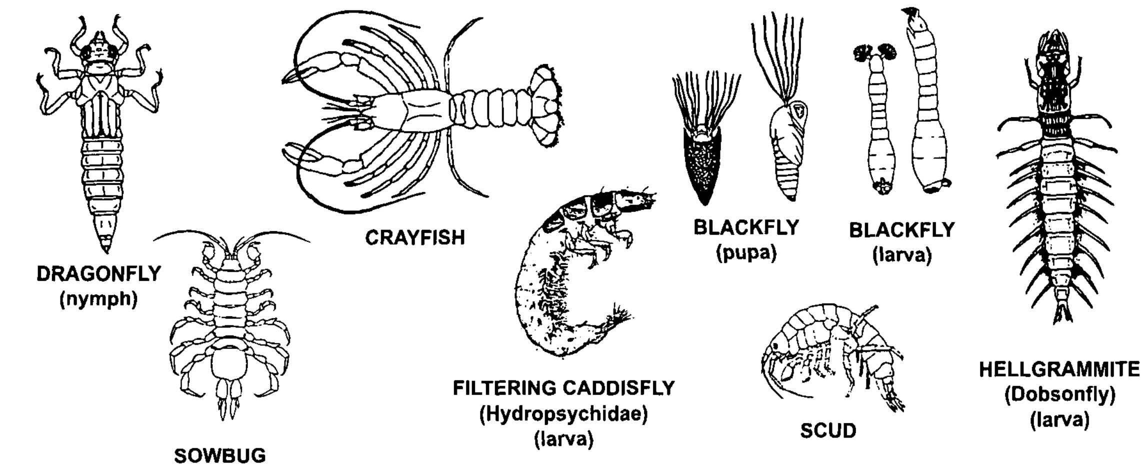
State Water Watch Organizations.

MACROINVERTEBRATE GROUPS
Beginner's Protocol PICTURE KEY

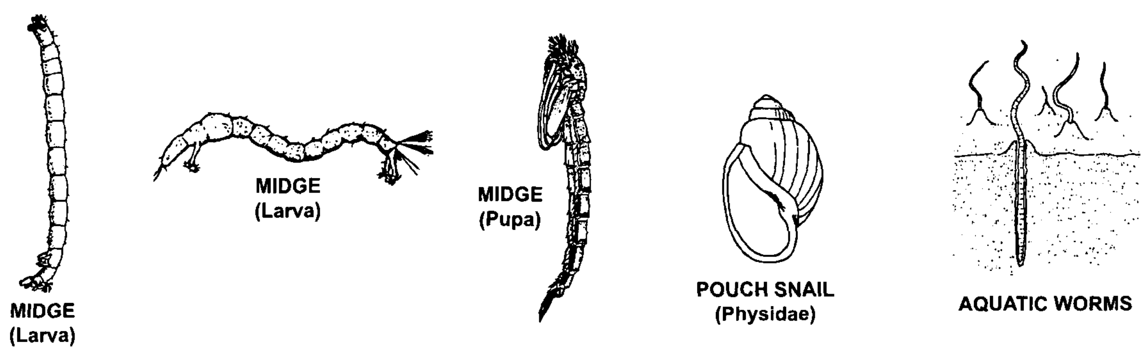
GROUP 1 *These organisms are generally pollution intolerant.*
Their dominance generally signifies ***Excellent-Good Water Quality.***



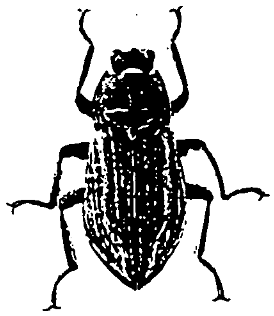
GROUP 2 *These organisms exist in a* ***Wide Range*** *of water quality conditions.*



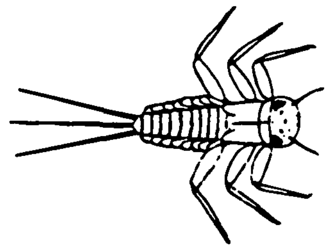
GROUP 3 *These organisms are generally tolerant of pollution.*
Their dominance generally signifies ***Fair-Poor Water Quality.***



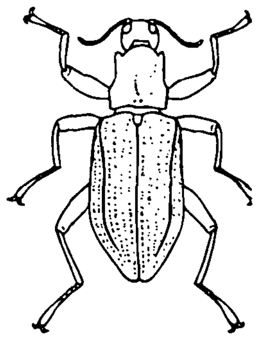
GROUP 1
"Bugs"



RIFFLE BEETLE
(adult)



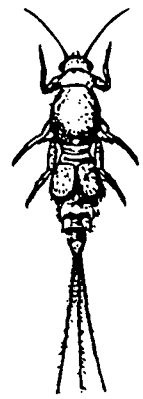
MAYFLY
(nymph)



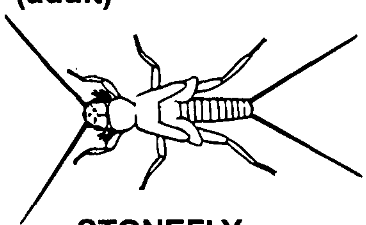
RIFFLE BEETLE
(adult)

MAYFLY
(nymph)

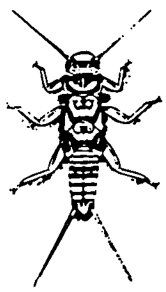
RIFFLE BEETLE
(larva)



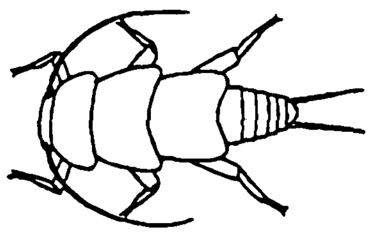
MAYFLY
(nymph)



STONEFLY
(nymph)

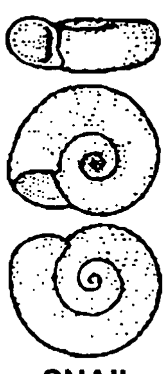


STONEFLY
(nymph)

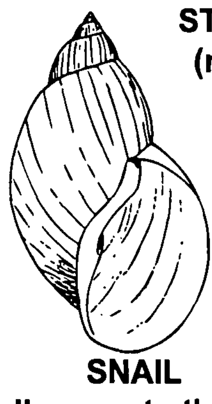


STONEFLY
(nypmth)

CADDISFLY
(larva)



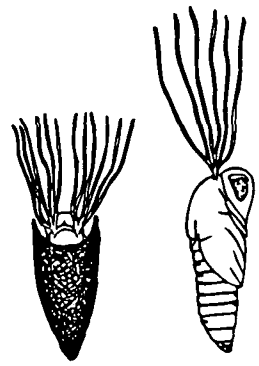
SNAIL



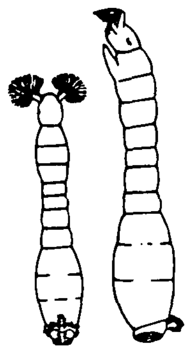
SNAIL
(shell opens to the right)

CADDISFLY
(larva)

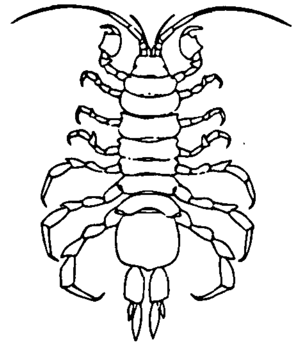
GROUP 2
"Bugs"



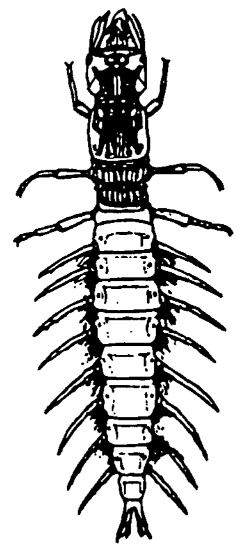
BLACKFLY
(pupa)



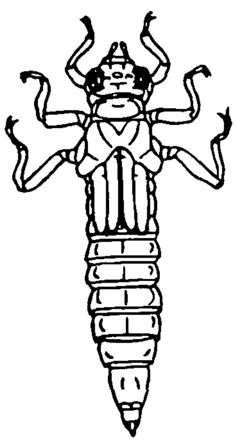
BLACKFLY
(larva)



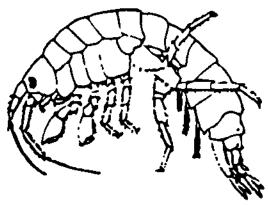
SOWBUG



HELLGRAMMITE
(Dobsonfly)
(larva)



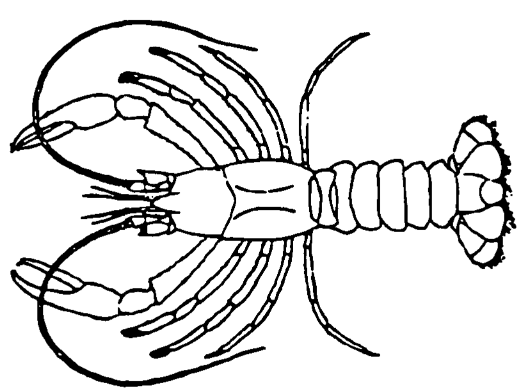
DRAGONFLY
(nymph)



SCUD

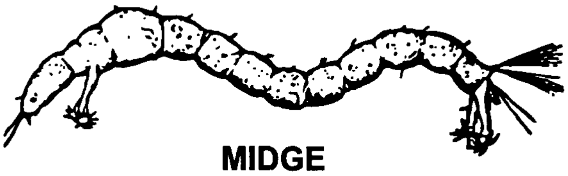
SNIPE FLY
(larva)

FILTERING CADDISFLY
(Hydropsychidae)
(larva)

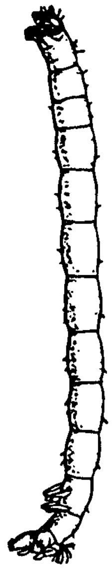


CRAYFISH

GROUP 3
"Bugs"

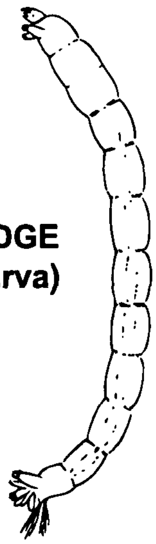


MIDGE (Larva)

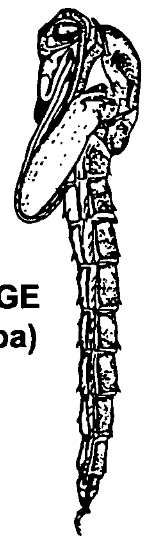


MIDGE (Pupa)

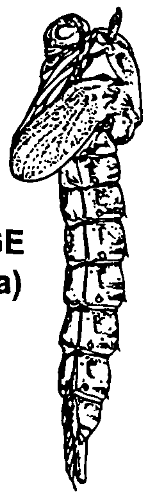
MIDGE (Larva)



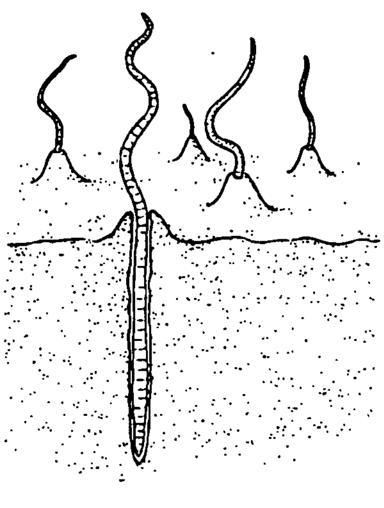
MIDGE (Larva)



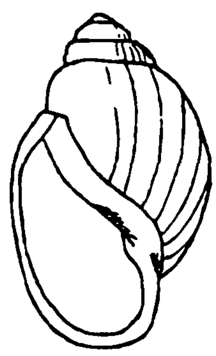
MIDGE (Pupa)



MIDGE (Pupa)



AQUATIC WORMS



SNAIL (shell opens to the left)

STREAM QUALITY ASSESSMENT FORM

Monitoring Group

Name: ____________________ Stream Name: _____________

Site Location: _________________ Date:__________ Time (military):_________

County: ______________________ Town/City:________________

• •

Organic Substrate Components: ____

Canopy Cover: open partly open partly shaded shaded

Streamside Vegetation type: ____

Turbidity: clear sightly turbid turbid opaque

Water Conditions (color, odor, bedgrowths, surface scum):______________________

• •

Chemical Assessment

Please convert ˚F to ˚C (˚C=[˚F–32] x 5/9) & feet to centimeters (cm=ft x 30.48)

Air temp ˚C:_________________ Water temp ˚C:__________

Water depth (cm):_____________ Secchi Depth (cm):_______

Alkalinity (mg/l):_____________ Hardness (mg/l):_________

Dissolved Oxygen (mg/l):______ pH (SU):_______________

Turbidity (JTU):______________

• •

Width of Riffle:______________

Bed Composition of Riffle (%):

Silt:________

Sand:_______

Gravel (1/4" -2"):__________

Cobbles (2"-10"):__________

Boulders (>10"):___________

CLEANING POINT SOURCE POLLUTION

6-8

SUBJECTS:
Chemistry, Ecology, Math

TIME:
50 minutes

MATERIALS:
clear plastic cups
medicine dropper
straw
spoon
motor oil
water
paper towels
student sheet

OBJECTIVES

The student will do the following:

1. Estimate the amount of pollution in a water sample.

2. Remove pollution from water using different methods.

3. Measure the pollution removed and calculate the percentage of pollution removed from each sample.

4. Analyze and discuss the most effective methods of cleaning pollution from water.

BACKGROUND INFORMATION

Point source pollution is pollution that is discharged from a single source, such as an oil tanker, water treatment plant, or a factory. Point source pollution is easily identified and can be traced to its source. It is often difficult to enforce cleanup of point source pollution, even when the source is identified. Point source pollution can also come from septic-tank systems, storage facilities for polluted waste, petroleum products stored underground, and runoff from landowners.

Organic chemicals are products composed of hydrocarbons originally found in ancient plants. A petroleum product, such as oil, can be accidentally released into the environment when collisions of tankers occur, when ships run aground, when facilities leak, or when petroleum products are not disposed of properly.

Sewage, radioactive and hazardous metals, medical wastes and all manner of dissolved solids contribute heavily to the pollution of our waterways. Of particular importance is mine waste because it is continuous, commercially important on a large scale, and involves pollution of water at several different points in processing. In coal mines in particular, sulfuric acid (H2S) is a problem. Coal is mineralized plant and animal matter that was not decomposed by microbes millions of years ago because it was in an oxygen-free environment. Without oxygen, microbes breathed sulfates instead and reduced them to sulfuric acid. This reaction is very inefficient, so these microbes were unable to decompose the carbon rich plant material. H2S is a natural and necessary part of coal deposits, but it is also a very strong acid. Poured onto soil, it causes aluminum and iron toxicity in crop plants and kills nitrogen fixing organisms, leading to crop deficiencies in nitrogen. The H2S that gets to the smelting stage of processing becomes gaseous H2SO4, the main ingredient in acid rain. Many other harmful minerals are present in the ores themselves so that even slurries of crushed rock may be harmful to the environment.

Many pieces of legislation have been put forth to eliminate point source pollution. The General Mining Law of 1872 says that miners who pollute canals that settlers rely upon must pay reparations for the damages they have caused. The Refuse Act of 1899 required a federal permit for the dumping of anything into navigable waters, and the Clean Water Act of 1972 regulated a new program of permits to replace the permits of the 1899 law with stricter more efficient enforcement.

Nonpoint source pollution is pollution generated from diffuse sources rather than one specific, identifiable source. The primary contributors to nonpoint source pollution include urban runoff, agriculture, silviculture, storm water, livestock waste, and raw domestic wastes. It may include contaminants such as sediment, bacteria, oil and oil-related chemicals, pesticides, heavy metals, and other toxic substances. Heavy rainfall often increases nonpoint source pollution by washing sediment, chemicals, and other contaminants from fields, towns, and cities into surface water areas and eventually into areas of possible groundwater recharge. Many federal, state, local agencies and groups have programs to help reduce nonpoint source pollution.

Terms

point source pollution: pollution that can be traced to a single point source, such as a pipe or culvert (e.g., industrial and wastewater treatment plant discharges).

nonpoint source pollution (NPS): pollution that cannot be traced to a single point, because it comes from many individual places or a widespread area (Example: urban and agricultural runoff).

hydrocarbons: a very large group of chemical compounds consisting primarily of carbon and hydrogen. The largest source of hydrocarbons is petroleum (crude oil).

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

ADVANCE PREPARATION

A. Set up three stations consisting of three different procedures for removing oil from water. **(Note: Oil may be added to each container by the teacher or by each group. The quantity of oil should be determined by the teacher. Each group must add the same amount of oil.)**

B. Place the following materials at the designated station:

Station 1:	Station 2 :	Station 3:
spoon	straw	medicine dropper
two clear plastic cups	two clear plastic cups	two clear plastic cups
student sheet	student sheet	student sheet
paper towels	paper towel	paper towel
motor oil	motor oil	motor oil

PROCEDURE

I. Setting the stage

A. Have students brainstorm the best ways to remove oil pollution from water. Have them research and discuss the oldest methods and compare them to newer methods used today.

B. Have students predict the most effective cleanup method of the three methods they will be using.

II. Activity

A. Station 1: You will have two minutes to perform the following activities:

1. Work with your group and estimate the pollution (oil) in each of the three samples. Enter your findings on the data table.

2. Have one member of the group use the spoon to try to remove all of the oil from the sample. Place the oil in an empty plastic cup.

3. Measure the amount of oil removed and calculate the percentage of pollutant removed from the sample with the spoon (old technology). Divide the amount of oil removed by the amount of water.

4. List any spills on the data chart.

5. Mark down any instances of habitat disturbance, such as water being removed with the cleanup.

B. Station 2: You will have two minutes to perform the following activities:

   1. Have another member of your group use the straw and try to remove all of the oil from the sample. Save the oil in an empty plastic cup.

   2. Measure the amount of oil removed and calculate the percentage of pollutants removed from the sample with this newer technology (straw). **Do not use your mouth!** Divide the amount of oil removed by the amount of water.

   3. Mark down any spills on the data chart.

   4. Mark down any instances of habitat disturbance, such as water being removed with the cleanup.

C. Station 3: You will have two minutes to perform the following activities:

   1. Have another member of your group use the medicine dropper and try to remove all of the oil from the sample with the dropper (newer technology).

   2. Measure the amount of oil removed and calculate the percentage of pollutant removed from the sample with the dropper. Divide the amount of oil removed by the amount of water.

   3. Mark down any spills on the data chart.

   4. Mark down any instances of habitat disturbance, such as water being removed with the cleanup.

D. Analyze the data collected from each group and discuss the most effective oil removal method. Brainstorm how cost-effective each method is on a global basis.

III. Follow-Up

A. Perform the same steps, but substitute various pollutants other than oil.

B. Have students research major oil spills in the world that are presently being cleaned and the methods by which they are being cleaned.

C. Have students discuss disposal alternatives for removed oil (Examples: burning, re-refining, coating surfaces for protection, use as fuel, etc.).

IV. Extensions

A. Secure a speaker from the Coast Guard or Environmental Protection Agency that has participated in a coastal cleanup.

B. Have students participate in a coastal cleanup, Earth Day activities, a clean campus organization, or other environmental activities.

RESOURCES

Arms, K. Environmental Science, Holt, Rinehart, and Winston, Austin, TX, 1996.

The Changing Definition of Point Source Pollution in the Clean Water Act of 1972: http://moby.ucdavis.edu/GAWS/161/2bravo/1.htm

Nonpoint Source Pollution: http://www.deq.state.la.us/owr/owrnps.html

Directions: Complete the data table for each of the three types of technology.

Technology	Original Cup Estimated mL Oil	Dump Cup % Oil Removed	Oil Spills While Cleaning Up	Water Removed Estimated mL Water
Spoon				
Straw				
Medicine Dropper				

Analysis and Conclusions

1. Which technology resulted in the most spills during cleanup?

2. Which technology caused the least disturbance of the habitat (removed the least water from the sample)?

3. Which technology would result in the highest fine?

4. Were the three technologies equally effective in helping you remove 50% of the pollution?

5. State a conclusion which relates to your original hypothesis.

COLIFORM BACTERIA AND OYSTERS

6-8

OBJECTIVES

The student will do the following:

1. Explain why coliform tests are performed to aid in the protection of oyster reefs.
2. List three common sources from which coliform bacteria enter a body of water such as a bay or estuary.
3. Perform an experiment to measure the amount of coliform bacteria in a water sample from different areas of bays and estuaries.
4. Define and interpret verbal materials concerning the vocabulary used in the terms list.

SUBJECTS:
Art,Geography, Microbiology, Math,

TIME:
50 minutes for experiments plus four observation days

MATERIALS:
film for camera
water samples from coastal areas
membrane filtration apparatus
hand-operated vacuum pump
MF-Endo broth in premeasured 2 mL ampuls (bio. supply co.)
absorbent media pads and gridded membrane filters
50- or 60-mm (about 2 inch) diameter petri dishes
1 mL plastic pipette
alcohol lamp
forceps
sterile or dechlorinated tap water
sterile glass or plastic petri dishes
1 mL plastic pipette
EMB (eosin-methylene-blue) agar-agar
Means Option B test materials
student sheets

BACKGROUND INFORMATION

Oyster farming in coastal areas is a valuable activity. The collection, processing, transporting, and selling of these oysters provide an income for many people. As is the case with fisheries, state laws regulate oystering. These laws are designed to protect the health of the consumer and the size of the oyster population.

Oysters are common bivalves that live in shallow estuarine waters. Their soft body tissue is enclosed by a two-part shell which is held together by a strong hinge. The shell of an oyster is usually attached to another oyster or some other hard object, forming clumps of oysters. Large areas covered with these clumps are called oyster reefs.

Oysters take in oxygen from the water by pumping water through their bodies and across their gills. During this process, tiny plants and animals are filtered from the water and are eaten by the oyster. The oyster cannot choose what is filtered from the water. Whatever is present in the water is filtered and taken into the oyster. Thus, any toxins or harmful microbes in the water are likely to be present in the oyster also.

State conservation, natural resources, and public health agencies are authorized to regulate the opening and closing of the oyster reefs. An open oyster reef is one from which you can legally collect oysters. A closed reef is off-limits to oyster collecting. Numerous tests and measurements are performed to provide information that will influence decisions to open or close the reefs. One of these tests measures the amount of a certain type of bacteria called coliform bacteria. These indicator bacteria are commonly found in the intestinal tract of many animals, including humans. They aid in digesting many foods that animals cannot digest alone. When animals defecate, some of the coliform bacteria in the intestinal tract are also passed. Although coliforms are relatively harmless, their quantity in the water is measured because it may be an indication that other harmful microbes are present. If these microbes are present in the water, they are probably also present in the oysters that live in that water.

Sewage outfalls are the most common causes of increased coliform levels. Although many environmental factors influence the closing of an oyster reef, an outfall located too close to a reef may be responsible for its permanent closing. The decision of where to put a new sewage outfall is always an intensely debated issue. Sometimes it is difficult to utilize one resource without affecting or destroying another. People are continually seeking better ways of using one resource without harming others.

In this activity, you will perform a test to measure the amount of coliform bacteria present in water samples taken from different areas. The tests actually used by state authorities are too difficult to be used in this case. Three quick and easy tests for measuring the amount of coliform are provided here.

Terms

bivalve: a mollusk that has two shells hinged together, such as the oyster, clam, or mussel.

coliforms: bacteria found in the intestinal tract of warm-blooded animals; used as indicators of fecal contamination in water.

defecate: to void excrement or waste through the anus.

estuarine: of an area where a river empties into an ocean; of a bay, influenced by the ocean tides, which has resulted in a mixture of saltwater and freshwater.

fishery: a place engaged in the occupation or industry of catching fish or taking seafood from bodies of water; a place where such an industry is conducted.

microbe: a microorganism; a very tiny and often harmful plant or animal.

sewage outfall: the point of sewage discharge, often from a pipe into a body of water, in turn called the outfall area.

ADVANCE PREPARATION

A. The teacher should be the one to collect appropriate water samples to be tested. Pictures should be taken of the various areas in which samples were collected. It is important that students can relate the samples to particular areas along the bay.

B. Make sure that the body of water from which you collect the samples is not heavily polluted. You do not want your students working with a water sample with harmful toxins or bacteria.

C. A special lab session should be given to show and explain how to use alcohol lamps and hand-operated vacuum pumps, as well as give instructions on how to sterilize equipment. Leave the lab set up for the experiments the following day.

D. Ask students during the prior weeks to look in the newspapers and magazine for articles concerning the oyster season's opening or closing.

PROCEDURE

I. Setting the stage

A. Pass out developed pictures of the different areas where the samples were taken. Ask students to try to identify the particular areas in a nearby bay or estuary.

B. Post all the pictures of each particular area together on different bulletin boards or showboards. Leave them out for students to look at during and after their experimenting.

C. Have an area map to plot the locations where samples were taken.

II. Activity

A. Light the alcohol lamp and sterilize the forceps by dipping them in alcohol and igniting by passing the tip through the flame.

B. Use the sterilized forceps to place a white absorbent media pad into a petri dish. Break an ampul of MF-Endo medium and pour the contents onto the absorbent pad. Close the petri dish.

C. Resterilize the forceps in the flame. Then use it to place a gridded membrane filter on the filter funnel. Close the apparatus.

D. Pour about 100 mL (the amount does not affect the outcome) of sterile or chlorine-free tap water into the funnel of the machine. The sterile water is used to dilute the test sample so coliforms (if present) will be distributed evenly on the filter and, therefore, be easier to count.

E. Pipette one mL of the "test sample water" (river or bay water) into the funnel of the apparatus. **Students should not put the pipette to their mouths.** The pipette will fill by capillary action if it is held vertically in the water, or a pipette bulb may be used.

F. Cover the apparatus and swirl it to mix the sterile dilution water and the one-mL test sample water.

G. Attach the hand pump to the equipment and filter the water. Sterilize the forceps. Then remove the filter and set it into the petri dish on top of the MF-Endo saturated pad. Close the petri dish.

H. Store the dish upside down in a dark place at room temperature. (Petri dishes are incubated in an inverted position to prevent condensation or moisture from falling on bacterial colonies: It causes them to "run together.")

I. Observe and describe the dishes each day for five days. Fill in the student data.

J. Counting the coliforms: Coliform colonies have a distinct metallic green sheen. Count only the obvious coliform colonies.

III. Follow-Up

A. The following is another convenient way to test for the "quantitative" presence of coliform bacteria without using an expensive membrane filtration kit.

   1. Make up one or more sterile EMB agar-agar plates per group.

   2. If you are using 100-mm sized petri dishes, pipette one mL of test sample (river or bay water) directly into the dish. Cover the dish and swirl the sample so the water covers as much agar as possible.

   3. Store the petri dish upside down in a warm dark place at room temperature.

   4. The presence of metallic green colonies is a positive test for coliform bacteria. Count the coliform colonies.

B. Due to crowding of the bacteria, it may be impossible to count all the colonies. Nevertheless, this experiment will give you a rough idea of the relative numbers of coliforms present in the water sample. Though relatively inaccurate, this procedure is fast, simple and very inexpensive. In addition, it requires a minimum amount of equipment. Even if you don't find coliforms, you will discover other kinds of bacteria, which in itself is interesting. A third simplified plate technique exists. Contact Alabama Water Watch for name, cost, and procedure.

C. Contact the local wastewater treatment plant. The plant operator might be willing to provide equipment or split a sample to verify students' results. The telephone and name can be gotten by calling the city hall, township hall, or village hall.

IV. Extensions

A. Take additional pictures of the results from the experiment and place the colony pictures with the correct photos taken from the different areas of the water you tested.

B. Have students correlate and graph the results of the experiments.

C. Students will then take the information and put it on the computer to send to their Conservation, Natural Resources, or Public Health agencies. Comparisons are requested from these departments.

RESOURCES

Biggs, A., Kapitka, C., and Lundgren, L., Biology: The Dynamics of Life, Glencoe, NT, 1995.

Cunningham, W. and Saigo, B., Environmental Science, Brown Publishers, Dubuque, IA, 1995.

STUDENT SHEET *COLIFORM BACTERIA AND OYSTERS*

6-8

Directions:
Label each of the three petri dishes with the source of the water used.
Inoculate each dish with water, tape the lids on, and place it in a warm (not hot), dark place.
Draw and describe what is observed each day on each dish by filling in the information below.

Day 1 Date ________________________

Inoculate three dishes with water from (1) ____________, (2)____________, and (3) ______________.

Day 2 Date ________________________

1

Description

2

Description

3

Description

Day 3 Date ________________________

1

Description

2

Description

3

Description

STUDENT SHEET COLIFORM BACTERIA AND OYSTERS

6-8

Day 1 Date ____________________________

Inoculate three dishes with water from (1) _____________, (2)_____________, and (3) ________________.

Day 2 Date ____________________________

1 2 3

Description Description Description

Day 3 Date ____________________________

1 2 3

Description Description Description

ALGAE GROWTH

6-8

OBJECTIVES

The student will do the following:

1. Test the effects of common pollutants on algae growth in water.

2. Observe the growth of algae in a water sample.

SUBJECTS:
Biology, Botany, Math

TIME:
2 weeks

MATERIALS:
1-L soda bottles with labels
distilled water
three types of laundry or dishwashing detergents (two with and one without phosphate)
lawn fertilizer
graduated cylinder
pond water samples
microscope
student sheets
various algae

BACKGROUND INFORMATION

Algae are simple plants. They generally do not have vascular tissue, and they do not show the high level of organ differentiation of the familiar, more complex plants. Most algae are photoautotrophic, which means that they can make their own food materials through photosynthesis by using sunlight, water, and carbon dioxide.

Algae are the chief food source for fish and for all other types of organisms that live in the water. They also contribute substantially to the store of oxygen on Earth. There are approximately 25,000 species of algae. The simplest algae consist of a single cell of protoplasm, a living jelly-like drop. No larger than three microns, the size of a large bacterium, it is visible only under a microscope. The most complex algae are the giant kelps of the ocean that may be 200 feet (60 meters) long.

Algae are found all over the Earth, in oceans, rivers, lakes, streams, ponds, and marshes. They sometimes accumulate on the sides of glass aquariums. Algae are found on leaves, especially in the tropics and subtropics, and on wood and stones in all parts of the world. Some live in or on higher forms of plants and animals. And some exist in places where few living things are able to survive. One or two species capable of tolerating temperatures of 176 degrees F (80 degrees C) dwell in and around hot springs. A small number live in the snow and ice of the Arctic and Antarctic regions.

Marine algae, such as the common seaweeds, are most noticeable on rocky coastlines. In northern temperate climates, they form an almost continuous film over the rocks. In the tropics they are found on the floors of lagoons. They are associated with coral reefs and island atolls. A few saltwater species of green algae secrete limestone that contributes to reef formation. In freshwater, algae are not noticeable unless the water is polluted.

All algae contain the green pigment chlorophyll. This substance makes it possible for algae to perform photosynthesis. Other pigments also are present, giving different algae the distinct colors that are used as a basis of classification.

Algae are of special interest because they include the most primitive forms of plants. They have no true roots, stems, or leaves, and they do not produce flowers or seeds, as higher plants do. Yet all other groups of plants may have evolved from algae.

Algal blooms are a serious consequence of human activities effect upon the water quality and temperature. When massive amounts of algae literally overtake an area of water due to excessive nutrients, it is considered an algal bloom. In addition to being unsightly and smelly, masses of blue-green algae can literally choke the life out of a lake or pond by depriving it of much needed oxygen. At first glance this may seem like something of a paradox: since blue-green algae undergo photosynthesis, they should produce more oxygen than they consume. However, after large concentrations of algae have built up, aerobic processes such as respiration and the decomposition of dead algal cells becomes increasingly significant. Under extreme conditions, a eutrophic lake or pond may be left entirely devoid of fish.

Terms

algae: any of a large group of simple plants that contain chlorophyll; are not divisible into roots, stems and leaves; do not produce seeds; and include the seaweeds and related freshwater and land plants.

nonpoint source pollution (NPS): pollution that cannot be traced to a single point, because it comes from many individual places or a widespread area (Example: urban and agricultural runoff).

non-vascular plant: a plant that does not have specialized tissue for transporting water, minerals, and food.

nitrates: used generically for materials containing this ion group made of nitrogen and oxygen (NO_3^-); sources include animal wastes and some fertilizers; can seep into groundwater; linked to human health problems, including "blue baby" syndrome (methemoglobinemia).

phosphate: used generically for materials containing a phosphate group (PO_4^{3-}); sources include some fertilizers and detergents; when wastewater containing phosphates is discharged into surface waters, these chemicals act as nutrient pollutants (causing overgrowth of aquatic plants).

ADVANCE PREPARATION

A. Collect soda bottles and place labels on them. Collect several water samples from ponds and other local sources.

   1. Label the bottles "A," "B," "C," "D," and "E."

B. List these figures and compute their corresponding percentages on the chalkboard: If we represent the Earth's entire supply of water as 1,000 mL, then 28 mL represents the total freshwater supply and the remaining 972 mL is saltwater that occurs primarily in oceans.

PROCEDURE

I. Setting the stage

A. Explain to the students the importance of unicellular algae to worldwide oxygen production. Have them observe some examples of various algae both with a magnifying glass and under a microscope.

B. Display several detergent and fertilizer containers. Notice on the list of ingredients whether or not they contain nitrates and phosphates and in what amounts.

II. Activities

A. Pour 900 mL distilled water into each of the five bottles.

   1. Add 90 mL pond water to Bottle A.

   2. Add 90 mL pond water and 15 mL detergent # 1 to Bottle B.

   3. Add 90 mL pond water and 15 mL detergent # 2 to Bottle C.

   4. Add 90 mL pond water and 15 mL detergent # 3 to Bottle D.

   5. Add 90 mL pond water and 15 mL fertilizer to Bottle E.

B. Ask students to make predictions as to what they think will occur.

C. Set the uncovered bottles in a well-lighted place for about two weeks, ensuring that each bottle receives an equal amount of light each day.

D. Have students compare and record their observations on the student sheet. Take note of any algae growth that they notice.

III. Follow-Up

A. Have the students write up the lab activity by completing the student sheet.

B. Have students list and draw several different types of algae that may be present.

C. Have students locate several different types of detergents used in their home and list the phosphate and nitrate content of each.

D. What are the environmental implications of algae blooms to lakes and streams? Which are most severely affected? Why?

IV. Extensions

A. Look up algae blooms that occur when fire algae reproduce rapidly. Have students investigate how these blooms affect the animals in the water.

B. Have students go the supermarket and take notes on which detergents contain phosphates (list amount) and those that do not.

C. Contact a local nursery and find alternatives to processed fertilizers. How are they better for the environment?

D. Use a microscope to examine the microorganisms found in each bottle.

RESOURCES

Algal Bloom: http://pasture.ecn.purdue.edu/agen521/epadir/wetlands/algal_bloom.html

Introduction to Algae: http://www.botany.uwc.ac.za/presents/algae1/index.html

Compton's New Media, Inc., Compton's Interactive Encyclopedia, 1995.

Directions: Complete the following information about your investigation.

1. Problem Statement

___

___

___

2. Procedure (number the steps you performed)

   a.

   b.

3. Data collected

Bottle	Contents	Amt	Amt Phosphate	Amt Nitrate	Algae Growth After 4 Days	After 8 Days	After 12 Days
A	distilled water pond water	900 mL 90 mL	0	0			
B							
C							
D							
E							

4. Data Analysis

a. Which bottle had the smallest amount of algal growth? ____________________________

b. Which bottle had the largest amount of algal growth? ____________________________

c. Which detergent produced results most similar to the fertilizer? _____________________

Tentative Conclusions

a. What effect does the amount of phosphate and nitrate have on algal growth?

b. List all of the things you and people in your home can do to keep phosphates and nitrates from entering the water.

SMALL FRYE

6-8

SUBJECTS:
Art, Microbiology

TIME:
2 class periods

MATERIALS:
one gallon jar of pond water
18 hand lenses
one microscope for every team of two students
pens
pencils
3 packs assorted colors of poster paper
kite string or fishing line
75 plastic straws
35 wire coat hangers
teacher sheet
student sheet

OBJECTIVES

The student will do the following:

1. Identify various forms of microscopic life that live in water.
2. Compare the relationship of various aquatic plants and animals.

BACKGROUND INFORMATION

When Robert Hooke and Anton Van Leeuwenhoek, inventors of the microscope, observed the small world of ponds and streams, they were amazed to find life forms. It was obvious that thousands of small organisms lived in water. Microorganisms, both plants and animals, are essential in the food supplies of fish, aquatic birds, amphibians, and mammals—yes, even humans.

Microorganisms can be divided into the following categories:

Bacteria: Bacteria are single-cell microbes that grow in nearly every environment on Earth. They are used to study diseases and produce antibiotics, to ferment foods, to make chemical solvents, and in many other applications.

Protozoans: Protozoans are small single-cell microbes. They are frequently observed as actively moving organisms when impure water is viewed under a microscope. Protozoans cause a number of widespread human illnesses, such as malaria, and thus can present a threat to public health.

Algae: These are organisms that carry out photosynthesis in order to produce the energy they need to grow.

Fungi: These are well-known organisms, such as mushrooms and bread mold, that lack chlorophyll. Fungi usually derive food and energy from parasitic growth on dead organisms.

Viruses: Viruses are the smallest form of replicating microbes. Viruses are never free-living; they must enter living cells in order to grow. Thus, they are considered by most microbiologists to be nonliving. There is an infectious virus for almost every known kind of cell. Viruses are visible only with the most powerful microscopes, namely electron microscopes.

One way to eliminate microorganisms from water supplies is to add chlorine. Adding chlorine to drinking water virtually eliminates waterborne diseases, such as cholera, by destroying these disease-causing microorganisms.

Microorganism's habitats may be as large as an ocean or smaller than a grain of sand. The ubiquity or extreme prevalence of microorganisms is due to the following characteristics and abilities:

1. Small size allows for easy dispersal.
2. Energy conversion is not restricted to aerobic condition, they survive and thrive in anaerobic conditions (without oxygen).
3. Extreme metabolic versatility, they can utilize a broader range of nutrients than eukaryotes; unique ability to fix atmospheric nitrogen.
4. Tolerate unfavorable environmental conditions.

Terms

microorganisms: organisms too small to be seen with the unaided eye, including bacteria, protozoans, yeasts, viruses, and algae.

pond: an enclosed body of water usually smaller than a lake.

food web: the connections among everything organisms in a location eat and are in turn eaten by.

food chain: a succession of organisms in a community that constitutes a feeding order in which food energy is transferred from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.

habitat: the arrangement of food, water, shelter, and space suitable to an organism's needs.

ADVANCE PREPARATION

A. Introduce students to the term "microorganisms." Ask them to list what they have heard, learned, or read about these microorganisms.

B. Ask students to write a one-page essay of what life would be like if they were microscopic.

PROCEDURE

I. Setting the stage

A. Students will take a field trip to an environmental center or area in their neighboor or town to observe life in a pond or view a video or film about pond life.

B. Have students share their observations with other members of the class, either orally or in writing.

II. Activity

A. The teacher will collect pond water samples and furnish each team with one tablespoon of the water sample. Samples are to be taken from within the container and not just at the surface. Students are to examine the water with microscopes and hand lenses.

B. Students are to draw or make sketches of the microorganisms they observe.

C. After they have sketched several organisms, they are to select a favorite life form from which to construct a microorganism mobile.

III. Follow-Up

A. Invite a laboratory technician who works for a water or wastewater treatment plant that uses microorganisms to break down wastes into harmless substances.

B. Have the students collect samples of pond water from various ponds and observe the microorganisms.

IV. Extensions

A. Have a contest for the best constructed "Microorganism Mobile."

B. Read aloud stories written by the students about their life as a microscopic organism.

C. Have pictures of common microorganisms that are found in pond water and have students identify their sketches with the pictures.

RESOURCES

Aquatic Project Wild, 1987. P.O. Box 18060, Boulder, CO 80308-8060. (303) 444-2390.

Compton's Interactive Encyclopedia. Compton's NewMedia, Inc., 1994, 1995.

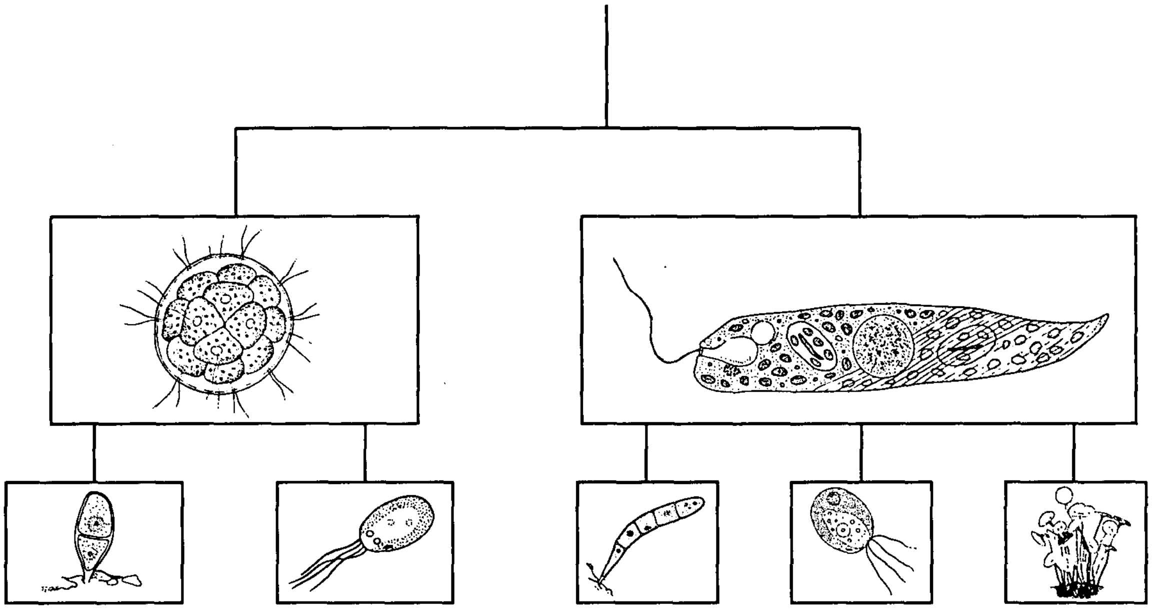
Eliminating Microbes from Water: http://c3.org/curriculum/bbc5.html

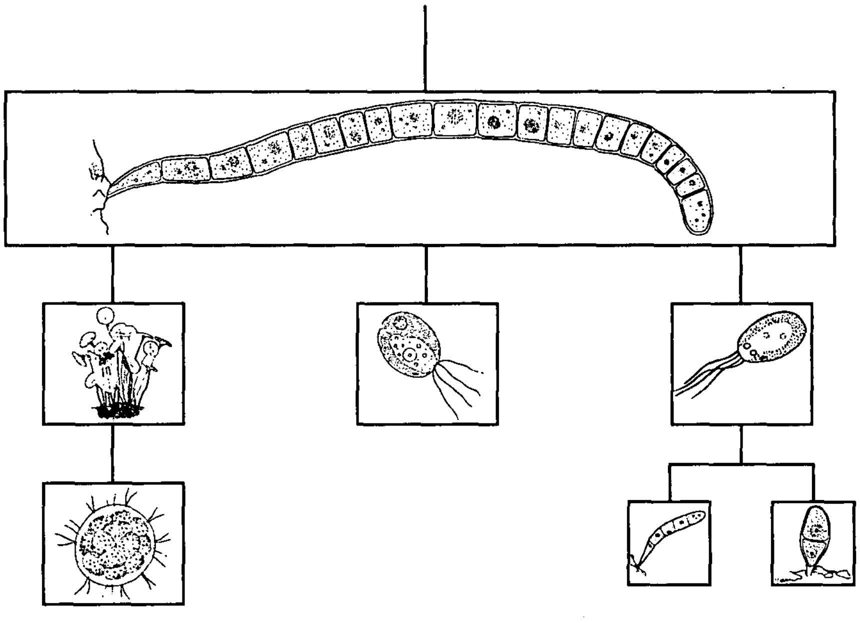
Life Science, Grade 7, Prentice Hall, 1991.

Microorganisms in Their Natural Environment: http://www.towson.edu/~wubah/miceco/natural_envts.html

6-8

Directions: Draw the organisms you observe in the pond water.





SURFACE FREEZING

6-8

SUBJECTS:
Chemistry, Math

TIME:
50 minutes

MATERIALS:
clear plastic soda container
ice cube trays
water
blue and yellow dye
scissors
colored pencils
graph paper
stapler
student sheet

OBJECTIVES

The student will do the following:

1. Create a moving picture of the circulation of water in a pond thawing after a winter freeze.

2. Explain the impact of surface freezing on the life of a pond.

BACKGROUND INFORMATION

The surface of a body of water receives adequate sunlight to sustain a diverse population of organisms. The region of water which receives this sunlight is known as the littoral zone. Autotropic organisms cannot, however, survive in zones inaccessible to sunlight. This zone, known as the benthic zone, is host to other types of organisms called heterotrophs. In addition, organisms that die will sink to the bottom and decompose, replenishing the pond with nutrients.

As the air temperature decreases and falls below zero degrees Celsius, the freezing point of water, the surface water will begin to freeze. Sustained below-freezing temperatures will allow the pond or lake to maintain a blanket of ice at its surface. Life at the surface will decrease due to the lack of adequate sunlight, and competition for food will increase among heterotrophs. As the surface ice begins to melt in the springtime, this colder, denser water will sink to the bottom. As it does, it creates a convection current in the pond which will carry the nutrients resting on the bottom to other zones in the pond, including the littoral zone. After the surface ice has completely melted, the littoral zone, as well as other zones, will once again contain a diverse population of life.

Terms

autotroph: an organism that can make its own food (usually using sunlight).

benthic zone: the lower region of a body of water including the bottom.

convection current: the transfer of heat by the mass movement of heated particles.

heterotroph: an organism that is not capable of making its own food.

littoral zone: region in a body of water that sunlight penetrates.

ADVANCE PREPARATION

A. Have each student bring an empty one- or two-liter plastic soda container.

B. Prepare colored ice cubes (blue in color).

C. Run off a student sheet for each student.

D. Remove the label and clean the inside of the container.

E. Cut off the top portion of the container.

PROCEDURE

I. Setting the stage

A. Discuss the background information to be sure the students understand the terms.

B. Explain the behavior of water in its three states.

II. Activity

A. Gather the materials.

1. Fill the container three-fourths full with hot water.

2. Add a few drops of yellow dye to the container and let stand for several minutes or until the water is no longer circulating.

3. Place one colored ice cube in the container and observe.

4. Have students write down observations as the ice is melting.

5. Have the students use the student sheet to make a precise drawing of the appearance of the container every 30 seconds until the ice has completely melted. (Be sure to instruct them to note the position and size of the ice over time in their drawing, as well as the color of the water in the rest of the container.)

6. Color the drawings with the proper colors and place the sheets in the proper sequence and staple together.

III. Follow-Up

A. Have the students observe the moving picture of their experiment and compare it to others in the class. Have them explain the similarities and differences between their results.

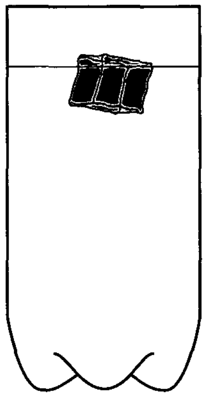
B. Have the students write up this activity in proper scientific form including a purpose, materials, procedure, results, and conclusion.

IV. Extension

A. Use real samples of pond water (obtaining both bottom sediments and water) and compare the quantity of organisms in each zone before and after melting a top layer. Use a microscope to observe and draw the organisms and graph results.

RESOURCE

Robson, P. and Seller, M., Encyclopedia of Science Projects, Shooting Star Press Inc., New York, 1994.



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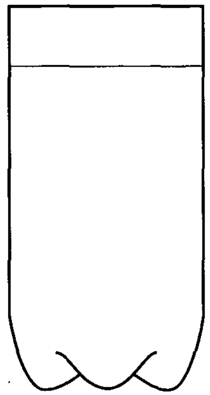
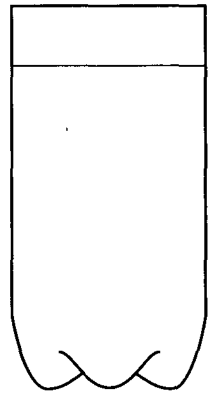


Time 30 Sec./.5 Min.



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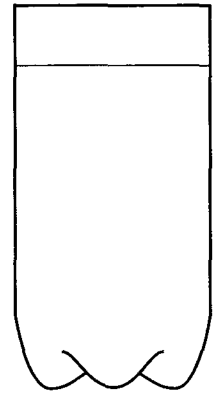
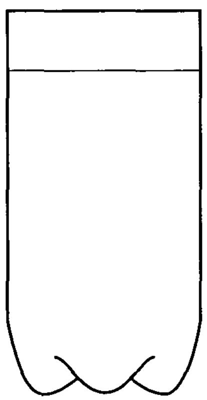


Time 1.5 Min.



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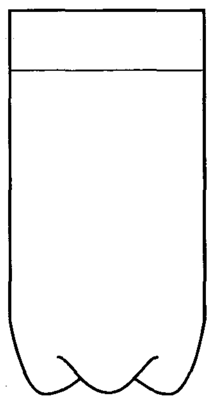
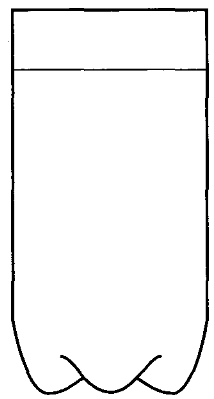
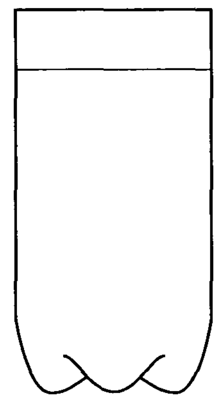


Time 2.5 Min.



Time 3.0 Min.



Time 3.5 Min.

SURFACE TENSION

6-8

SUBJECTS:
Chemistry, Language Arts, Physical Science

TIME:
50 minutes

MATERIALS:
petri dish
container of water
loop of thread
dishwashing detergent
toothpicks
list of vocabulary words for follow-up activity
student sheet

OBJECTIVES:

The students will do the following:

1. Explain the concept of surface tension.
2. Identify the process by which surface tension can be broken by the addition of detergents.

BACKGROUND INFORMATION

The tendency of a liquid to form a relatively tough "skin" or film on its surface is known as surface tension. Surface tension is caused by the attraction between the molecules of the liquid; it is surface tension that causes water molecules to stick together and to form droplets. The surface tension that holds drops together makes it difficult for the water to penetrate or "wet" fabrics or skin; consequently, many soaps or detergents contain "wetting" agents designed to reduce surface tension and to increase fabric penetration by water.

If you could see molecules of water and how they act, you would notice that each water molecule electrically attracts its neighbors. Each has two hydrogen atoms and one oxygen atom, H_20. The extraordinary stickiness of water is due to the two hydrogen atoms, which are arranged on one side of the molecule and are attracted to the oxygen atoms of other nearby water molecules in a phenomenon known as "hydrogen bonding." (If the molecules of a liquid did not attract one another, then the constant thermal agitation of the molecules would cause the liquid to instantly boil or evaporate.)

Hydrogen atoms have single electrons which tend to spend a lot of their time "inside" the water molecule, toward the oxygen atom, leaving their outsides naked, or positively charged. The oxygen atom has eight electrons, and often a majority of them are around on the side away from the hydrogen atoms, making this face of the atom negatively charged. Since opposite charges attract, it is no surprise that the hydrogen atoms of one water molecule like to point toward the oxygen atoms of other molecules. Of course in the liquid state, the molecules have too much energy to become locked into a fixed pattern; nevertheless, the numerous temporary "hydrogen bonds" between molecules make water an extraordinarly sticky fluid.

Within the water, at least a few molecules away from the surface, every molecule is engaged in a tug of war with its neighbors on every side. For every "up" pull there is a "down" pull, and for every "left" pull there is a "right" pull, and so on, so that any given molecule feels no net force at all. At the surface things are different. There is no up pull for every down pull, since of course there is no liquid above the surface; thus the surface molecules tend to be pulled back into the liquid. It takes work to pull a molecule up to the surface. If the surface is stretched - as when you blow up a bubble - it becomes larger in area, and more molecules are dragged from within the liquid to become part of this increased area. This "stretchy skin" effect is called surface tension. Surface tension plays an important role in the way liquids behave. If you fill a glass with water, you will be able to add water above the rim of the glass because of surface tension.

You can float a paper clip on the surface of a glass of water. Before you try this you should know that it helps if the paper clip is a little greasy, so the water doesn't stick to it. Place the paper clip on a fork and lower it slowly onto the water. The paper clip is supported by the surface-tension skin of the water.

The water strider is an insect that hunts its prey on the surface of still water; it has widely spaced feet rather like the pads of a lunar lander. The skin-like surface of the water is depressed under the water strider's feet.

Terms

surface tension: the elastic-like force in a body, especially a liquid, tending to minimize, or constrict, the area of the surface.

polar: of or relating to a pole of a magnet.

adhesion: the molecular attraction exerted between the surfaces of bodies in contact.

cohesion: the force of attraction between the molecules in a mass.

polarity: the quality or condition inherent in a body that exhibits opposite properties or powers in opposite parts or directions or that exhibits contrasted properties or powers in contrasted parts or directions.

positive charge: of, being, or relating to electricity of a kind that is produced in a glass rod rubbed with silk.

negative charge: of, being, or relating to electricity of which the electron is the unit and which is produced in a hard rubber rod which has been rubbed with wool.

ADVANCE PREPARATION

A. Place petri dishes, containers of water, loops of thread, and small containers of detergents at each lab station.

B. Prepare the list of words for use in the follow-up activity.

PROCEDURE

I. Setting the stage

A. Students will perform the activity before it is discussed. This activity is best discussed *after* students have manipulated the thread in the water and observed the results.

B. Students are reminded to make careful observations about the loop of thread during each step of this activity.

II. Activity

A. Have students fill the petri dish about half full of water. The petri dish is more visible placed on a white sheet of paper. Place the loop of thread on the surface of the water. The thread will float, but have an irregular shape. Students will observe and make inferences about the shape of the loop.

B. Students will touch the surface of the water within the loop with the end of a clean toothpick. The thread should move slightly, but not change shape. Students will observe the floating loop and discuss how surface tension is responsible for supporting the thread.

C. Students will next dip the end of the toothpick into the dishwashing detergent and carefully place a drop of soap inside the loop of thread by touching the toothpick to the surface of the water.

D. Students will describe what happened when the drop of dishwashing soap was placed inside the loop of thread. Have them speculate about what would happen if the drop of detergent were placed outside the loop of thread rather than inside the loop of thread.

III. Follow-Up

A. Students will explain what happened to the loop of thread and why it happened using the following terms in the explanation. All terms must be used and can be used more than once.

bound	circle	surface tension
cohesion	polar	positive charge
lowers	higher	negative charge
attractive forces	strong	adhesion
polarity		

B. Have the students highlight or circle all of the above words used in their explanation.

IV. Extensions

A. Research different types of detergents. Compare results obtained when these detergents are placed into the loop.

B. Double the amount of detergent to observe if there is a noticeable difference in the loop of thread.

C. Change the temperature of the water for each group to determine if thermal pollution is a factor in surface tension.

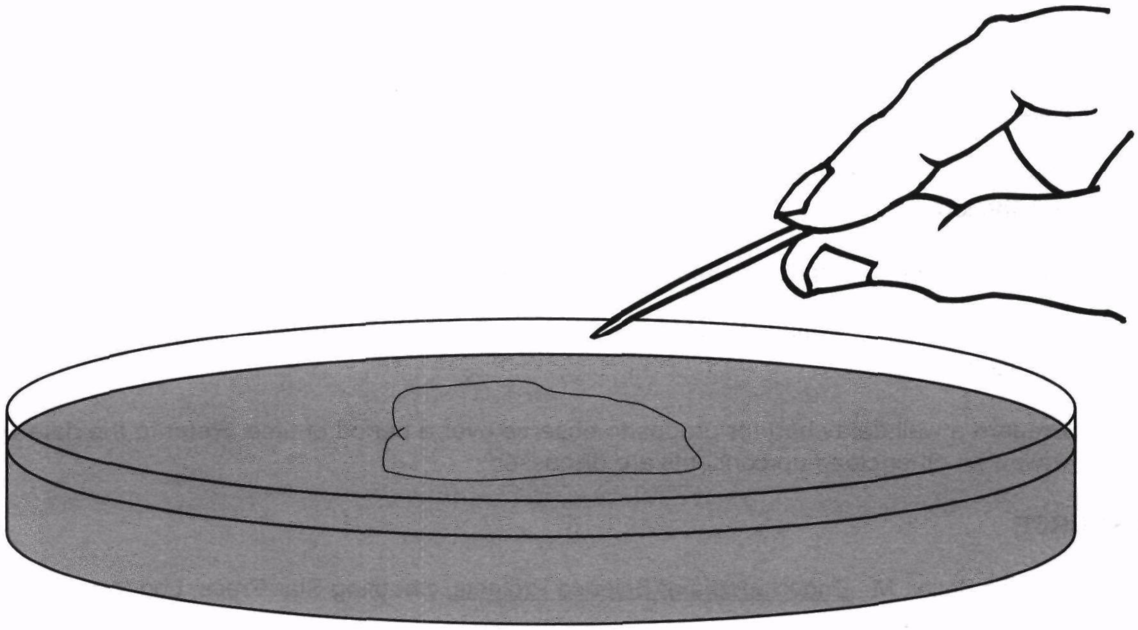
D. Prepare a wall data chart for groups to observe over a period of time. Refer to the data collected and review as other clean-up concepts are discussed.

RESOURCE

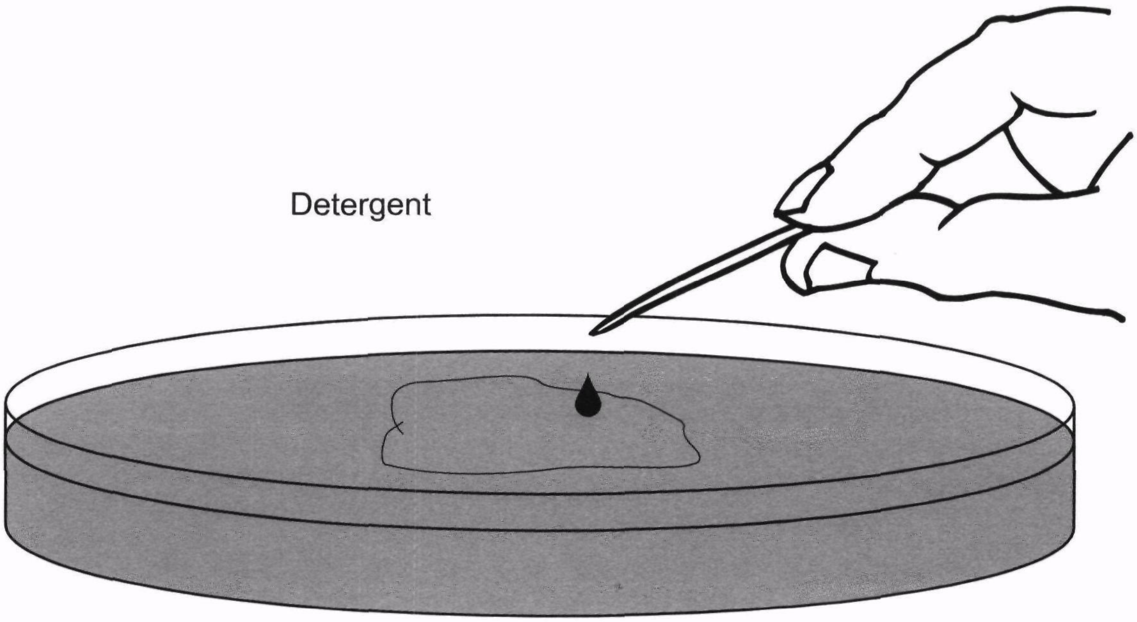
Robson, P. and Seller, M., Encyclopedia of Science Projects, Shooting Star Press, London, 1994.

Surface Tension, WQA: http://www.wqa.org/WQIS/Glossary/surftens.htm

http://www.whitman.edu/Departments/Biology/classes/B111/Modules/Water/Cohesion.html



Gently touch surface of water with a clean toothpick and observe



Place one drop of detergent inside the loop of thread and observe

RUNOFF

6-8

SUBJECT:
Biology, Geology

TIME:
1-2 class periods

MATERIALS:
county map / state map of your area
student notebooks
plastic box or pan at least one foot by two feet
sandbox sand, enough to fill half the box
two 250 mL cups
65 mL chocolate syrup
one 20 cm by 20 cm square of sod or several smaller grass plugs
a metric measuring cup
water
bucket or pot
teacher sheet

OBJECTIVES

The students will do the following:

1. Define surface water, runoff, drainage basin, permeable, and impermeable.
2. Identify factors affecting runoff in a drainage basin.
3. Perform an experiment on drainage basins.

BACKGROUND INFORMATION

Water found above the ground is called surface water. That is because it is located or seen on the Earth's surface. Oceans and rivers are examples of natural surface water bodies. Most surface water bodies are natural; however, there are many bodies of surface water that are made artificially.

The area where water drains off the land into a river or lake is called a drainage basin. Water that drains off the land into the basin is called runoff. Many things determine the runoff in a drainage basin. Water moves slowly along flat land or a gently sloping hill. When the water moves more slowly, it can evaporate or soak into the ground. A steep slope will cause water to flow more quickly into a surface water body. That is why drainage basins with steep slopes often flood.

Vegetation such as plants, trees, and grass help slow the water flowing through a basin. Trees and other plants also help to hold water on or above the ground. By doing so, they allow the water time to soak into the ground or to evaporate. Different kinds of soil have differing abilities to hold water. Water moves more quickly and easily through layers of sand and gravel than through clay. This is because clay is not as permeable as sand or gravel. Permeability is how fast water can flow through an object. Because clay particles fit tightly together, water does not flow through clay very easily. Clay is said to be impermeable. The next time it rains, watch what happens to the water running off the sidewalk or street near your home, then watch the water that falls on ground covered with trees, grass, or other plants. Notice which type of surface has the faster-flowing water. Rainwater that runs off a paved surface and does not soak into the ground is called storm water runoff. This water usually flows into the nearest body of water.

Terms

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

drainage basin: an area drained by a main river and its tributaries.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

permeable: passable; allowing fluid to penetrate or pass through it.

impermeable: impassable; not permitting the passage of a fluid through it.

storm water runoff: surface water runoff that flows into storm sewers or surface waters.

ADVANCE PREPARATION

A. Study the background information so it may be presented to the class in an organized manner.

B. Write the vocabulary words on the board so the students may view the words that will be covered in this lesson.

C. Have materials ready for the experiment.

PROCEDURE

I. Setting the stage

A. Have materials set out on a table in the front of the room. Tell the students that they will be learning about surface water and will be performing an interesting experiment.

II. Activity

A. Discuss the background information with the students.

B. Ask the following questions:

1. What is water above the ground called?
2. What makes water drain from one area to another?
3. What does permeable mean?
4. Through what soils does water move quickly?
5. Why does water move slowly through clay?
6. What does storm water runoff mean?
7. Name some examples of things storm water can pick up as it travels over land.
8. Where might storm water runoff go in rural areas?

C. Have the students perform the following experiment.

1. Fill the box or pan half full of sand. Diagonally, from the top corner of the box to the bottom corner, make a surface water (river) channel. Scoop sand from the middle of the box up onto the sides to form river banks. Make a steep slope on one side of the river and a gentle slope on the other side.
2. Place the sod square or several grass plugs on the side with a gentle slope. This represents wetlands vegetation.
3. Place bucket or pot under opening.
4. Position one student on each side of the "river" holding the 8-ounce cups of water. These students will make it "rain" on the river. Very slowly and at the same time, have one student pour water on the sandy side, while the other pours water on the grassy area. Observe which runoff flows faster and drains into the "river" first.

D. Repeat Step C, using 65 mL of chocolate syrup. The syrup represents storm water pollution. Observe what happens.

E. Repeat Step C, again, pouring 125 mL of water on the syrup. Observe what happens.

F. Ask the following questions:

1. Which side of the river had the fastest runoff?

2. What effect did the grass or sod have on storm water runoff? On pollution?

3. Did you see anything in this experiment that would help you decide whether the sand is permeable or impermeable? If so, what?

4. List several things that determine the speed of runoff in a drainage basis.

III. Follow-Up

A. Have the students list examples of surface water bodies in their county and state. Let your students see how many water bodies they can name before posting the maps.

B. Have the students determine where the school's storm water runoff drains.

1. Are there steep or gentle slopes around the school yard?

2. What types of pollution would this storm water pick up as it drains from the school yard?

IV. Extensions

A. Ask students to find out the average rainfall for their city or county.

B. Have students bring in various types of soil and design their own experiments to test which soils are permeable or impermeable.

C. Have students do research in the library to locate information on how to make a rain gauge.

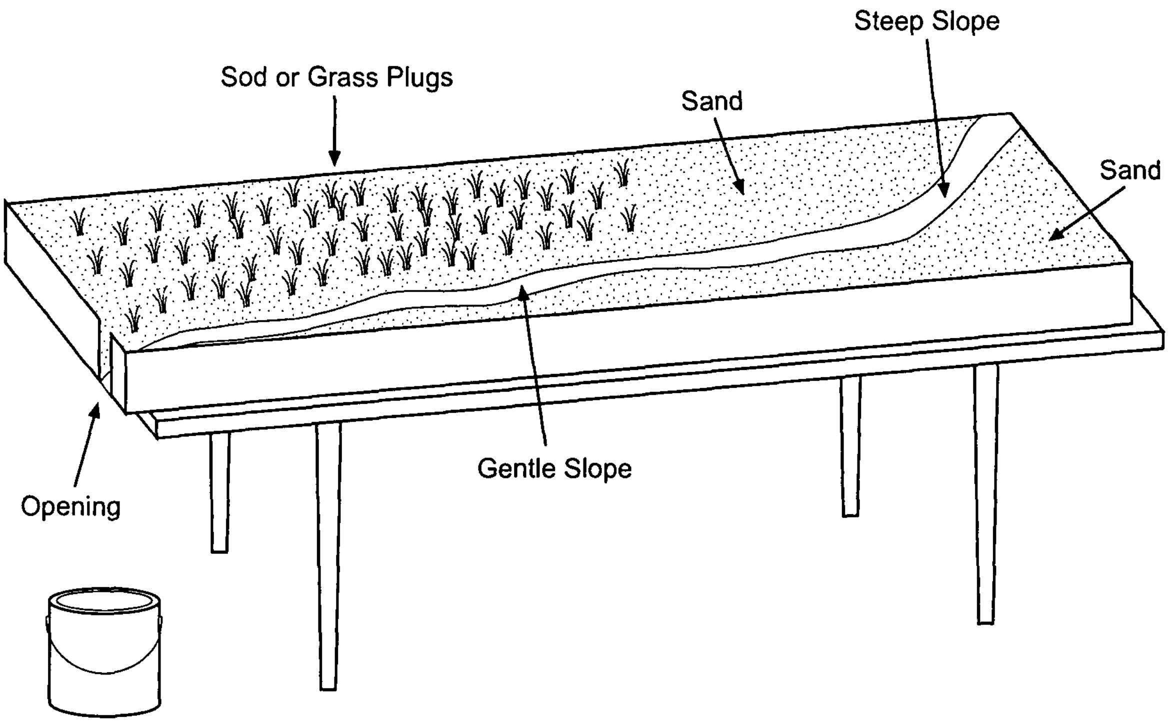
1. Help students make their own rain gauges and have them keep track of rainfall amounts for one month in their waterways notebook.

2. Have them design a bar graph to show rainfall totals. Have students do this at home and then compare their findings with others in their class. Sometimes it will rain on one side of the street and not on the other.

D. Contact the local office of the Natural Resources Conservation Service (formerly known as the Soil Conservation Service, or SCS) to request a guest speaker on the "soil profile" of your area. Ask the SCS representative for more information and experiments on soil types.

RESOURCE

Johnson, C., Waterways: A Water Resource Curriculum, St. John's River Management District, Jacksonville, FL, 1991.


Steep Slope
Sod or Grass Plugs
Sand
Sand
Gentle Slope
Opening

THE SHRINKING ANTACID

6-8

SUBJECTS:
Chemistry, Earth Science

TIME:
20 minutes

MATERIALS: (for each group)
small clear cup
I tablespoon
white vinegar
antacid tablet containing calcium carbonate
student sheets

OBJECTIVES

The student will do the following:

1. Define acid rain.
2. Explain what causes acid rain.
3. State various substances found in acid rain.
4. Describe the effects of vinegar on antacid tablets.

BACKGROUND INFORMATION

Normal rain has a pH of between 5.6 and 6.0, whereas acid rain has a pH between 2.0 and 5.6. Acid rain leads to several detrimental effects in the ecosystem. A very highly publicized problem is the effect of acid rain on trees. Conifers appear to be particularly affected, with needles dropping off and seedlings failing to produce new trees. The acid also reacts with many nutrients the trees need, such as calcium, magnesium, and potassium. The trees then starve, which makes them much more susceptible to other forms of damage, such as being blown down or breaking under the weight of snow.

Acid rain also causes lakes and rivers to become acidic, causing fish populations to decline. Short-term increases in acid levels kill many fish, but the greatest threat is from long-term increases. A long-term increase stops the fish from reproducing. The extra acid also frees toxic metals, especially aluminum, that were previously held in rocks. This metal can prevent fish from breathing. Single-celled plants and algae in lakes also suffer from increased acid levels, with numbers dropping off quickly once the pH goes below 5. By the time the pH gets down to 4.5, almost no life is sustainable.

Many toxic metals are held in the ground in compounds. However, acid rain can break down some of these compounds, freeing the metals and washing them into water sources such as rivers. As the water becomes more acidic, it can also react with lead and copper water pipes, contaminating drinking water supplies. Too much copper can cause diarrhea in young children and can damage livers and kidneys in adults and children.

Terms

acid rain (or acid precipitation): rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels or from volcanic activity; may cause damage to crops, forests, wildlife habitats, aquatic life, as well as damage to buildings, monuments, and car finishes.

calcium carbonate: a powder occurring in nature in various forms, as calcite, chalk, and limestone, which is used in polishes and the manufacture of lime and cement.

pollutant: an impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that may be harmful to or affect the health, survival, or activities of humans or other living organisms.

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

ADVANCE PREPARATION

A. Divide the class into groups of three.

B. Gather enough materials for each group.

PROCEDURE

I. Setting the stage

A. Show the students some calcium carbonate tablets.

B. Ask them to guess what they are.

C. Tell them what they are and explain to them that these substances are found in many different kinds of rocks.

II. Activity

A. Give each group a cup with an antacid tablet in it.

B. Ask them to pour 15 mL vinegar over the antacid tablet.

C. Ask the students to observe the antacid and vinegar for about 5 minutes.

D. Tell the students to record the action between the vinegar and the antacid tablet.

E. Ask the students to answer the following questions:

1. What happened to the antacid tablet?
2. How can this experiment relate to the effects of acid rain in various areas?
3. What causes acid rain?
4. What measures can we take to prevent or stop acid rain?
5. Why is acid rain such an important topic to study?

III. Follow-Up

A. Ask the students to write a report on the effects of acid rain on the environment.

B. Ask the students to draw or cut out pictures from a magazine showing the effects of acid rain.

C. Ask the students to do research and write a paper about acid rain.

IV. Extensions

A. Have the students use other substances that will act on the antacid tablet.

B. Have the students research and plot various areas on a geographic map that have problems with acid rain.

RESOURCES

Tippens, Tobin, Instructional Strategies for Teaching Science, Macmillan, New York, 1994.

Cable, Charles, Dale Rice, Kenneth Walla, and Elaine Murray, Earth Science, Prentice Hall, New Jersey, 1991.

http://nis.accel.worc.k12.ma.us/www/projects/WeatherWeb/acidrain.html

Directions – Record your observations at the specified times and answer the questions.

Time	Add 15 mL vinegar to antacid in cup
1 minute	
1.5 minutes	
2 minutes	
2.5 minutes	
3 minutes	
3.5 minutes	
4 minutes	
4.5 minutes	
5 minutes	

1. What happened to the antacid tablet?

2. How can this experiment relate to the effects of acid rain in various areas?

3. What causes acid rain?

4. What measures can we take to prevent or stop acid rain?

USING TOPOGRAPHIC MAPS AND DATA TABLES TO DETERMINE SURFACE WATER QUALITY

6-8

SUBJECTS:
Ecology, Geography

TIME:
2 class periods

MATERIALS:
topographic or relief map of watershed area
student sheet

OBJECTIVES

The student will do the following:

1. Describe the physical features of land areas surrounding area waters.

2. Distinguish drainage areas that will flow into existing bodies of water.

3. Analyze data obtained from a sampling of surface waters.

BACKGROUND INFORMATION

A watershed is a drainage area that includes all the rivers, streams, and sloping land which flow into a specific body of water. A watershed is impacted by activities that occur within the specific sloping area. Pollution from industries and individuals can affect the quality of water in a watershed. Other activities that can damage a watershed include farming, construction, and industrial activities.

Water monitoring sites can be established along watershed drainage areas to determine the quality of the water entering the downstream body of water. Data can be collected and analyzed at various sites along the drainage areas. Downstream impact can be determined by measuring the dissolved oxygen content, pH of the water, turbidity, and the biological diversity of organisms located in the drainage areas. By analyzing these parameters, students can compare information from several monitoring sites and determine the relative quality of the surface waters in the watershed area.

Geological watershed maps can be obtained from state geological surveys, the United States Geological Survey, or from local map dealers.

Terms

biological diversity: a wide variety of plant and animal life.

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water.

drainage basin: an area drained by a main river and its tributaries.

monitoring: scrutinizing and checking systematically with a view to collecting data.

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (Example: outlet or pipe) because it comes from many individual places or a widespread area (typically, urban, rural, and agricultural runoff).

pH: a measure of the concentration of hydrogen ions in a solution; the pH scale ranges from 0 to 14, where 7 is neutral and values less than 7 are progressively acidic, and values greater than 7 are progressively basic or alkaline; pH is an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

point source pollution: pollution that can be traced to a single point source, such as a pipe or culvert (Example:

industrial and wastewater treatment plants, and certain storm water discharges).

topographic map: a map showing the relief features or surface configuration of an area, usually by means of contour lines.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter.

watershed: land area from which water drains to a particular water body.

ADVANCE PREPARATION

I. Setting the stage

A. Display a topographic map of the local area and define the watershed area.

B. Discuss the major streams, rivers, and sloping areas indicated on the map.

C. Hypothesize the factors that could cause pollution problems in the drainage area of the watershed.

D. Prepare copies of the student sheet for each student.

II. Activity

A. Have the students use the student sheet to answer the questions about the streams located in the watershed.

B. Have the students analyze the information, discuss possible contributing factors, and determine what other types of investigations will be necessary.

III. Follow-Up

A. Have the students make visual observations of local streams and creeks and locate these on the watershed map.

B. Display topographic maps of other watersheds in other areas. Ask the students to compare the size of the drainage areas.

IV. Extensions

A. Take a field trip to a local park located on the watershed.

B. Develop site monitoring groups for area streams and rivers.

C. Develop a resource file of organisms known to indicate biological diversity in local waters.

RESOURCES

United States Geological Survey (USGS) topographic map of local watershed.

Person, Jane L., Environmental Science: How the World Works and Your Place in It, Lebel Enterprises, Dallas, Texas, 1995.

SAMPLING INFORMATION OBTAINED FROM WATERSHED MONITORING SITES

SITE #	DO	pH	DIVERSITY	TURBIDITY (M)
1	.6	7.0	GOOD	.2
2	.8	7.5	POOR	.4
3	.7	7.0	GOOD	.1
4	.9	6.2	FAIR	.4
5	.4	5.0	POOR	0

QUESTIONS

1. At which site was the water most turbid?____________________
2. Does the topographic map indicate any reasons for the high turbidity at that site? __________
   Explain.____________________
3. Which site illustrates the lowest dissolved (DO) oxygen content? __________
   What could have caused the low DO at this site?____________________
4. What could have caused the pH to be more acidic at site 5?
5. Does DO seem to cause poor biodiversity? ____________________Explain. __________
6. What variables are present in monitoring of test sites?____________________
7. List the types of land use that might have an effect on each of the following:

   dissolved oxygen____________________

   pH____________________

   turbidity____________________

   other____________________
8. Based on the information given for each of the five sites, which site do you consider to be the healthiest?
   Explain.____________________

WHIPPED TOP WATER

6-8

SUBJECTS:
Ecology

TIME:
50 minutes

MATERIALS:
6 large containers of cool whip
chart on water use (state/ national)
red, yellow, blue, and green food colors
plastic spoons and knives
six pieces of construction paper
paper plates for everyone
teacher sheet

OBJECTIVES

The student will do the following:

1. Read a graph.
2. Frost a pie using the information from the graph.

BACKGROUND INFORMATION

Water conservation does not mean doing without water. Rather, it means using water wisely and not wasting a drop. In certain areas of the country, the limited availability of drinking water has made water conservation mandatory. In other areas, reducing water use is necessary because supplies have been contaminated by landfills, toxic wastes, oil spills, or drought conditions.

On the average, each American uses about 150 gallons of water a day—most of it in the home. Nationwide, home use accounts for 57 percent of publicly supplied water. Public use for fire fighting, street cleaning, parks and recreation, and unaccounted for losses average 11 percent. The remaining 32 percent is used by businesses and industries.

Water conservation measures can stop the waste and help protect our water resources. Widespread reduction in water use can reduce the need for additional water projects that dam rivers, drain aquifers, and dry up wetlands and wells. It also can reduce the need for new or expanded sewage treatment facilities and reduce the amount of energy needed to clean pump, distribute, and heat water. By diverting less water, we leave more water to maintain stream flow, which improves water quality. Long-term conservation strategies can make our clean water supplies last longer.

ADVANCE PREPARATION

A. Divide students into teams of four or five.

B. Have each team make a no-bake cheesecake at home the night before the activity.

C. Prepare different colored frostings by using cool whip and food color. This will be done for each team, so make sure you have enough of each color. Each food color will represent a type of water use:
red = power generation
yellow = industrial
black (combine green and blue) = mining
blue = public water supply
green = agriculture
white = other

D. Have each color set up at different stations around the room. Also have on the table a piece of construction paper that has printed on it the amount of water used for that particular area. Arrange it so that the colors match the food color.

E. Bring at least one pie in case a group does not have a pie or does not make it to class with the pie they made.

PROCEDURE

I. Setting the stage

A. Explore the students' knowledge on the subject prior to the lesson by asking questions such as:

1. How many of you use water?

2. List some ways you use water.

3. How is water used in our society and our environment?

B. Show the chart on water use. Discuss how the water is used. Stress the amount used in each area.

II. Activity

A. Show the students that different colored cool whip is located at different stations in the room. Each colored cool whip represents a water use. Example, agricultural uses are signified by the green cool whip.

B. When they arrive at that station, they will frost that percent of their pie used for agriculture with the green cool whip. This will give them an idea of how much water is used for agriculture.

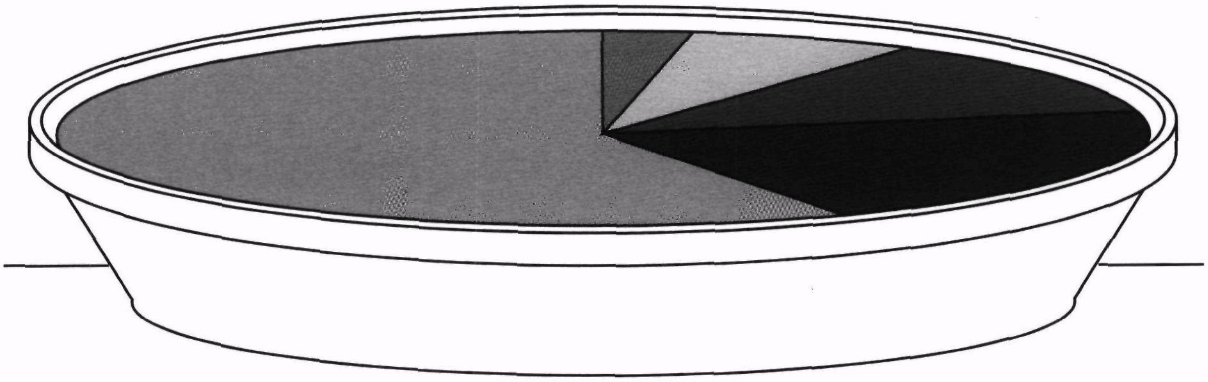
C. Then the students are to rotate to another station and top their pie with the correct amount of colored cool whip represented on the chart.

III. Follow-Up

A. When finished, all pies should be decorated and the students may then reward themselves by eating a piece of their pie.

RESOURCE

Clean Water Foundation 1992 Calendar.



Amounts of each color will vary depending upon the water use in your particular area.

XERISCAPE - SEVEN STEPS TO WATER - WISE LANDSCAPING

6-8

SUBJECTS:
Botany, Ecology

TIME:
3 class periods
2 to 3 weeks for students to complete survey at home and design landscape

MATERIALS:
teacher sheets
student sheets

OBJECTIVES

The student will do the following:

1. Define xeriscape and identify specific landscaping methods that support xeriscape practices.

2. Differentiate between water conservation practices and standard landscaping practices.

3. Survey xeriscape practices currently in use at home and initiate new conservation practices indicated by the survey.

BACKGROUND INFORMATION

As increases in population and land development occur, the supply of usable water will continue to decrease and will lead to greater restrictions of water use. In recent years, droughts in many areas of the United States have forced residents to limit their use of water.

By using landscaping and horticultural techniques that reduce water use, many landowners can drastically reduce the overall need for water in landscaped areas. Xeriscape is the wise use of these strategies to minimize water use, reduce maintenance, and produce more drought-resistant gardens and landscaped areas.

A Xeriscape-type landscape can reduce outdoor water consumption by as much as 50% without sacrificing the quality and beauty of a home environment. It is also an environmentally-sound landscape, requiring less fertilizer and fewer chemicals. A Xeriscape-type landscape is low maintenance - saving time, effort, and money. Any landscape, whether newly-installed or well-established, can be made more water-efficient by implementing one or more of the seven steps. A landscape does not have to be totally redesigned to save water. Significant water savings can be realized simply by modifying the watering schedule, learning how and when to water, using the most efficient watering methods and learning about the different water needs of landscape plants.

There are several general principles that can be used in most home Xeriscape projects. These strategies include grouping plants with similar water uses, reducing the amount of irrigated turfgrass areas, using sufficient amounts of organic material, using an efficient watering system, and managing landscapes to reduce water demand.

Xeriscape can conserve water and also produce attractive, low-maintenance landscaped areas. Each person can make a difference in conserving water.

Terms

Xeriscape: the use of landscaping and horticultural strategies to minimize water use, reduce maintenance, and produce more drought-resistant gardens and landscaped areas.

mulch: a protective covering of various substances, especially organic; placed around plants to prevent evaporation of moisture and freezing of roots and to control weeds.

organic material: material derived from organic, or living, things; also, relating to or containing carbon compounds.

inorganic material: material derived from nonorganic, or nonliving, sources.

pruning: trimming or cutting off undesired or unnecessary twigs, branches, or roots from a tree, bush, or plant.

turfgrass: lawns

drought: a lack of rain or water; a long period of dry weather.

topography: the detailed mapping or description of the features of a relatively small area, district, or locality; the relief features or surface configuration of an area.

landscaping: improving the natural beauty of a piece of land by planting or altering the contours of the ground.

ADVANCE PREPARATION

A. Make overheads or handouts of Teacher Sheets.

B. Prepare copies of Student Sheets for each student. Run copies back and front to get on one sheet.

C. Read the Water Conservation Fact Sheets on pages F - 37 & 38 to become familiar with the seven steps used in Xeriscape-type landscaping.

PROCEDURE

I. Setting the stage

A. Discuss what happens to plants when there is insufficient rain or drought conditions. Ask students what restrictions are often placed on water use during these times.

B. Ask students if they have noticed that often plants in people's yards sometimes look wilted but plants in woods and fields do not. Discuss how native plants are adapted to a wider range of conditions than some plants used in yards.

C. Introduce the term Xeriscape. Explain that it was derived by combining the Greek word "Xeros," meaning dry, with the word "landscape." Give students the definition of Xeriscape.

D. Discuss each of the seven steps of Xeriscape landscaping given in the Water Conservation Fact Sheet. List steps on the board and tell students they will be using these steps later in the activity.

Step 1 - Planning and Design
Step 2 - Soil Analysis
Step 3 - Appropriate Plant Selection
Step 4 - Practical Turf Areas
Step 5 - Efficient Irrigation
Step 6 - Use of Mulches
Step 7 - Appropriate Maintenance

II. Activity

A. Pass out Student Sheet 1 - Landscape Symbols. Show Teacher Sheet 1 - Base Map and Site Analysis. Explain to students they are going to conduct a survey of their yards. If possible, pair students that live close together. If a student lives in an apartment, pair with a student who has a yard. The first step in Xeriscape landscaping is to begin with a Base Map of the existing area and conduct a Site Analysis. Point out the features in Teacher Sheet 1 and make sure students understand the extent of their assignment. You may want to call one student to the board to draw a base map of his or her yard. Explain that they will need to walk around the yard to get all the details. Use the landscape symbols to indicate the existing vegetation. Give students a couple days to complete this assignment.

B. Show Teacher Sheet 2 - Water Use Zones. Discuss why certain areas need more water than others and how shade affects water use. Using their Site Analysis, have students determine water use zones of their yards. There are plant exceptions to each of these use zones. It is best to find out from a local nursery person or Extension Agent which plants fit these zones for your particular area. Generally, these guidelines can be followed:

High - regular watering - some flower beds, turf grass in direct sun
Moderate - occasional watering - well established plants, plants in partial shade
Low - natural rainfall - do not need watering except in extremely dry conditions, full shade, woody ornamental trees, some turfgrasses.

C. Show Teacher Sheet 3 - Landscaped Water Use Zones. Ask students to describe the changes that have been made in the landscapes. Discuss the water use based on the "before" landscape as compared to the "after" landscape. Discuss what factors (shade-tolerant ground cover, mulch, native trees and shrubs, less turfgrass) changed the water use zones.

D. Pass out Student Sheet 2 - Survey of a Landscaped Area. Students should use the checklist to determine the ways that Xeriscape is or can be used in their home landscaped areas to reduce the amount of water used. Give students a couple days to complete this assignment.

E. Show Teacher Sheet 4 - Professional Landscaping. Discuss what was done to change the landscape. Also note the change in water use zones. You may need to review the landscape symbols so students are familiar with each one. Explain to students they are going to "landscape" their yards using Xeriscape practices and create a Master Plan for their yard. If students have yards that are already fully landscaped, pair with students whose yards are not landscaped. Remind students to include each Xeriscape Step including their plan for Appropriate Maintenance in the future. Soil analyses can be done by your local county Extension office. You may want to check with your local office before you have a large number of students sending in soil samples at the same time. Have students use their Base Map to create their Master Plan. Give students several days to complete this assignment.

F. Display completed plans in the room. You may want to have students "judge" the plans and award a Yard of the Month - type award for the plan that best adheres to Xeriscape principles and practices.

III. Follow-Up

A. Have the students take photographs of an area before it is xeriscaped and compare it to later photographs.

B. Have students keep a journal of differences in maintenance, weed control, pests, and diseases on plants, and the overall appearance of the site.

IV. Extensions

A. Invite speakers from landscaping associations or master gardners to speak to the class about xeriscape.

B. Have students develop a miniature Xeriscape terrarium that models the landscaped area at home.

C. Have students create a Xeriscape landscape plan for the school campus.

D. Have students observe other yard and business landscapes and determine if Xeriscape practices were followed.

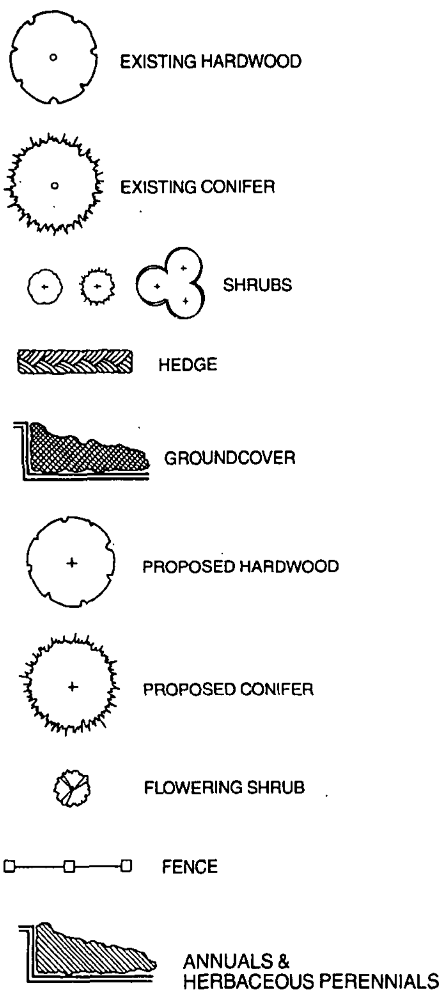
RESOURCES

National Xeriscape Council, Inc., Post Office Box 767836, Roswell, GA 30076.

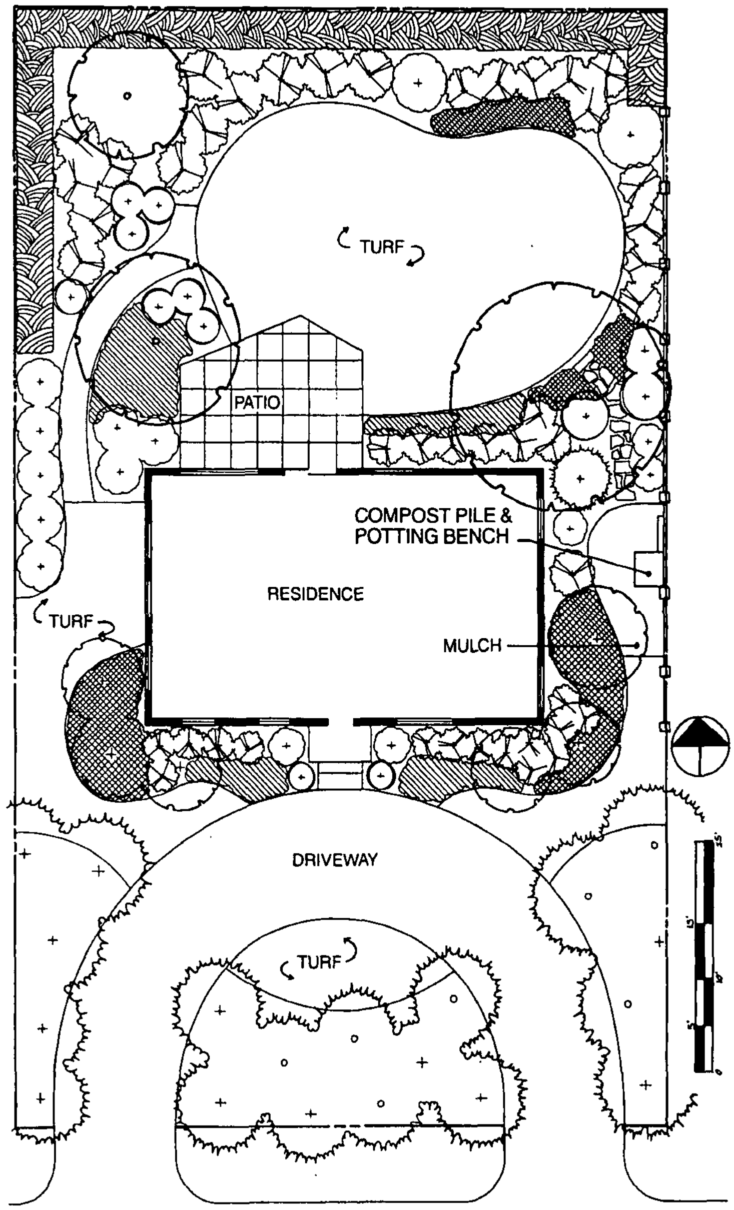
Water Ways: A Water Resource Curriculum. St. John's Water Management District, Jacksonville, FL, 1991.

Xeriscape: A Guide to Developing a Water-wise Landscape, Cooperative Extension Service, University of Georgia, 1992.

Symbols



EXISTING HARDWOOD
EXISTING CONIFER
SHRUBS
HEDGE
GROUNDCOVER
PROPOSED HARDWOOD
PROPOSED CONIFER
FLOWERING SHRUB
FENCE
ANNUALS &
HERBACEOUS PERENNIALS



TURF
PATIO
COMPOST PILE &
POTTING BENCH
RESIDENCE
TURF
MULCH
DRIVEWAY
TURF

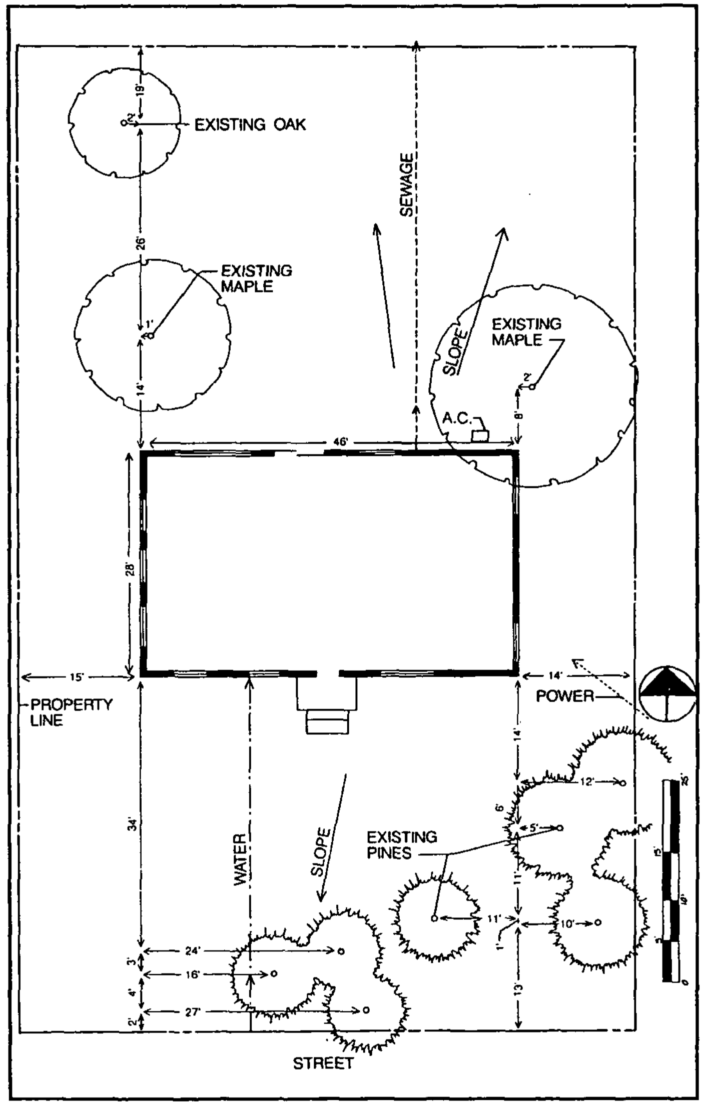
6-8

Survey of a Landscaped Area

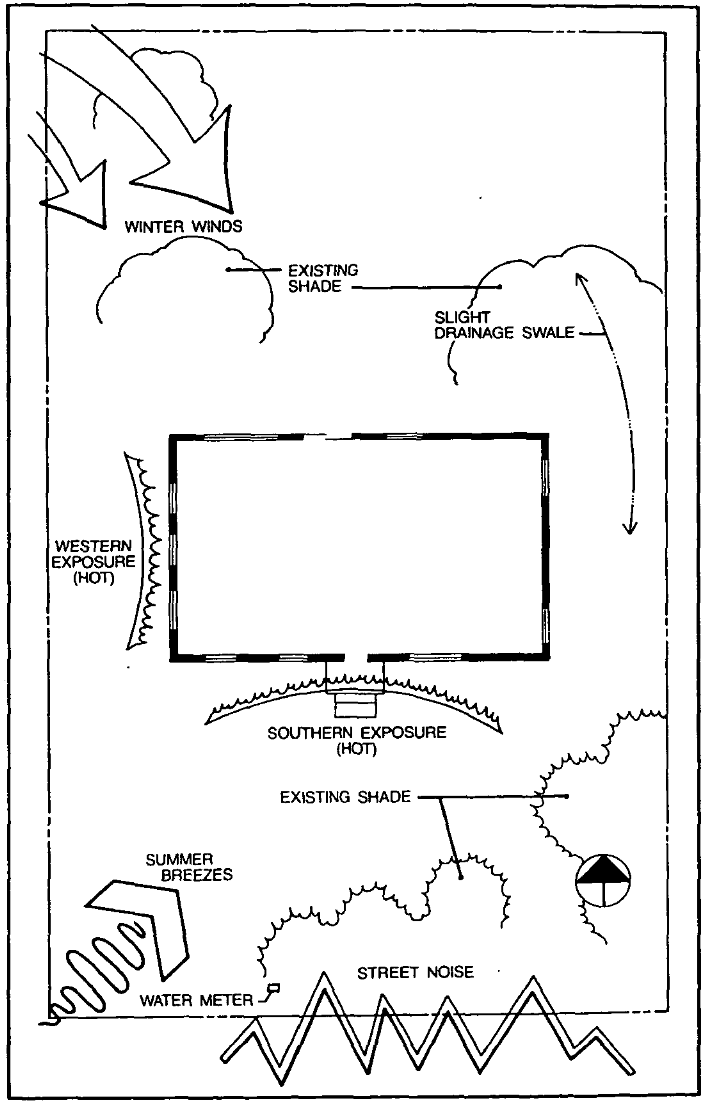
Directions: For each practice, indicate which of the seven xeriscape steps it illustrates. Refer to Fact Sheet on Water Conservation, pages 37 and 38. Also determine what landscaping practices are currently being used in a landscaped area and if there are xeriscape practices that can be implemented to conserve water.

Step Number	In Use	Can Implement	
_____	_____	_____	Plant varieties that are well adapted to this locality and soil conditions.
_____	_____	_____	Group plants with similar water needs together.
_____	_____	_____	Use moisture-loving plants for wet, poorly drained areas.
_____	_____	_____	Use drought-tolerant plants for drier, sunnier areas.
_____	_____	_____	Use turfgrass to cover excessively large areas.
_____	_____	_____	Grow grass under a densely shaded area of shallow-rooted trees
_____	_____	_____	Grow grass around shrubs.
_____	_____	_____	Grow grass on steep slopes, in rock outcroppings, or in very narrow spaces.
_____	_____	_____	Grow grass in areas where play tramples all vegetation.
_____	_____	_____	Check pH regularly to maintain pH of 6.0 to 7.0.
_____	_____	_____	Fertilize three times per year.
_____	_____	_____	Add lime to create a higher soil pH and to make lawn more drought-resistant.
_____	_____	_____	Control weeds.
_____	_____	_____	Maintain a cut-lawn height of 2–1/2 to 3 inches during the summer for cool season grasses or between 1 to 1–1/2 inches for warm season grasses.
_____	_____	_____	Water the lawn only as needed.
_____	_____	_____	Check for stress areas and water them first.
_____	_____	_____	Water only in the cool of the morning or when the area is shaded.
_____	_____	_____	Check sprinklers for accurate spraying. Avoid watering pavement, sidewalks, and driveways.
_____	_____	_____	Mulch is used around trees, shrubs, and perennials rather than turfgrass.
_____	_____	_____	Transplant smaller trees into areas rather than large trees that experience greater transfer shock.
_____	_____	_____	Transplant trees in the fall when feeder-root systems can be established.

Step Number	In Use	Can Implement	
_____	_____	_____	Avoid planting during drought periods. Use natural periods of rainfall in the fall or spring.
_____	_____	_____	Prepare planting holes that are broad, saucer-shaped and two to three times the size of the root ball.
_____	_____	_____	Incorporate compost into the soil to improve the water-holding capacity rather than adding organic matter as fill in the planting hole.
_____	_____	_____	Use a trickle of water in newly planted trees and shrubs to settle the soil and prevent dry pockets of air.
_____	_____	_____	Create a saucer around newly placed plants to create a water basin.
_____	_____	_____	Use two to three inches of mulch around newly planted trees and shrubs.
_____	_____	_____	Control weeds around newly planted shrubs and trees by mulching, pulling, mechanical cultivation, or herbicides.
_____	_____	_____	Use organic mulch that includes straw, leaves, manure, pine needles, leaf clippings, shredded bark, sawdust, compost, etc.
_____	_____	_____	Use inorganic mulch that includes gravel, pebbles, cobblestones, or weed control mats.
_____	_____	_____	Use white marble chips that raise soil pH and cause iron deficiency, leaf scorch, and glare.
_____	_____	_____	Use natural stones to break the force of splashing water and provide area for planting of annuals and perennials.
_____	_____	_____	Use a recommended watering schedule for the area when there is insufficient rainfall.
_____	_____	_____	Water newly planted sod and freshly planted grass seeds daily for the first week and every other day until the lawn is green.
_____	_____	_____	Use a water gauge to measure water applied to lawns when there is not 1 to 1/2 inches of rain per week.
_____	_____	_____	Water lawns when there are visible signs of wilting.
_____	_____	_____	Avoid watering dormant lawns.
_____	_____	_____	Use a deep soaking method (about one inch of water) to encourage deep root development.
_____	_____	_____	Avoid overhead sprinklers that are 75% efficient as compared to drip or subsurface sprinklers that are 90% efficient.
_____	_____	_____	Use an alarm on sprinkler systems to remind you to turn them off.

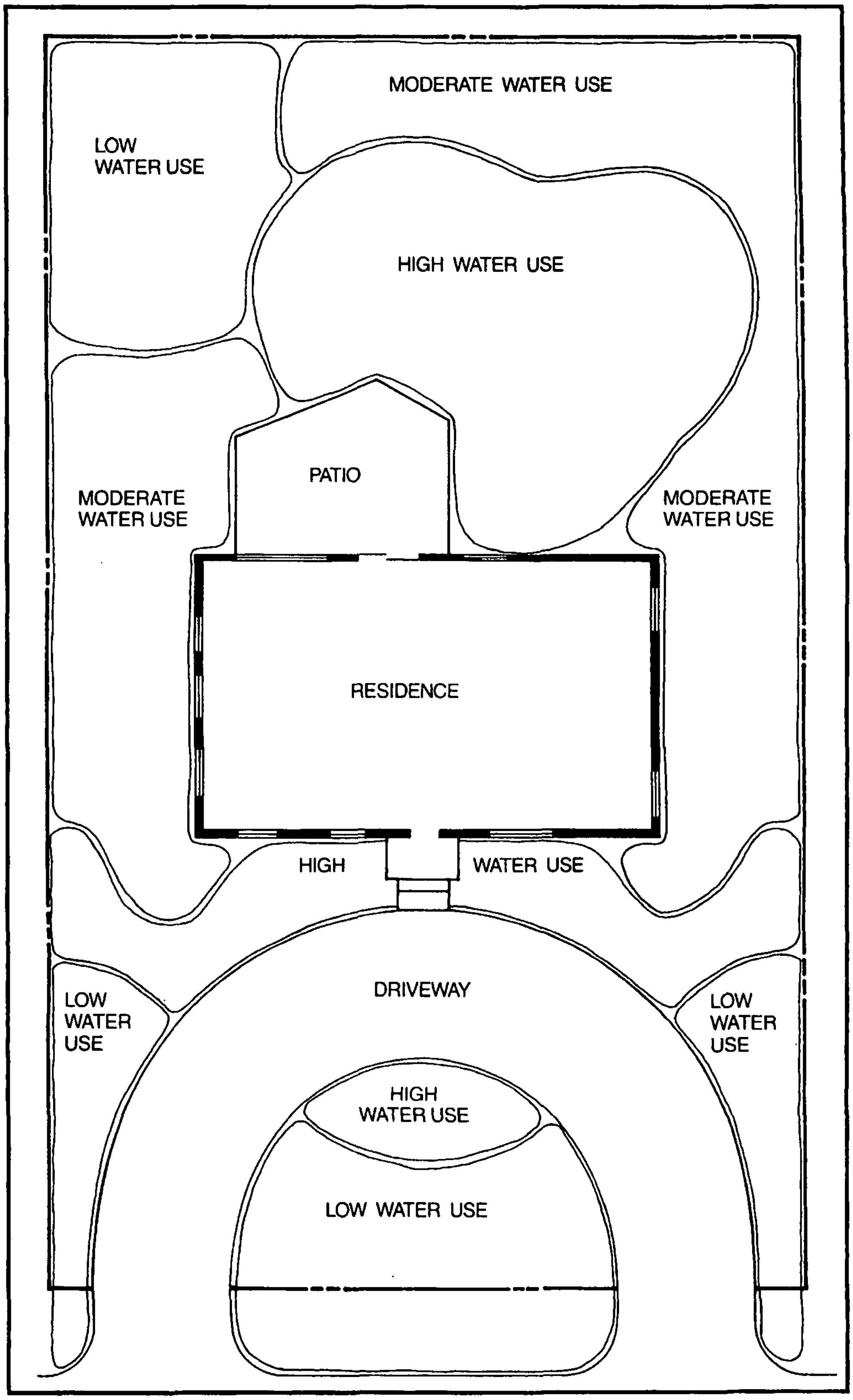


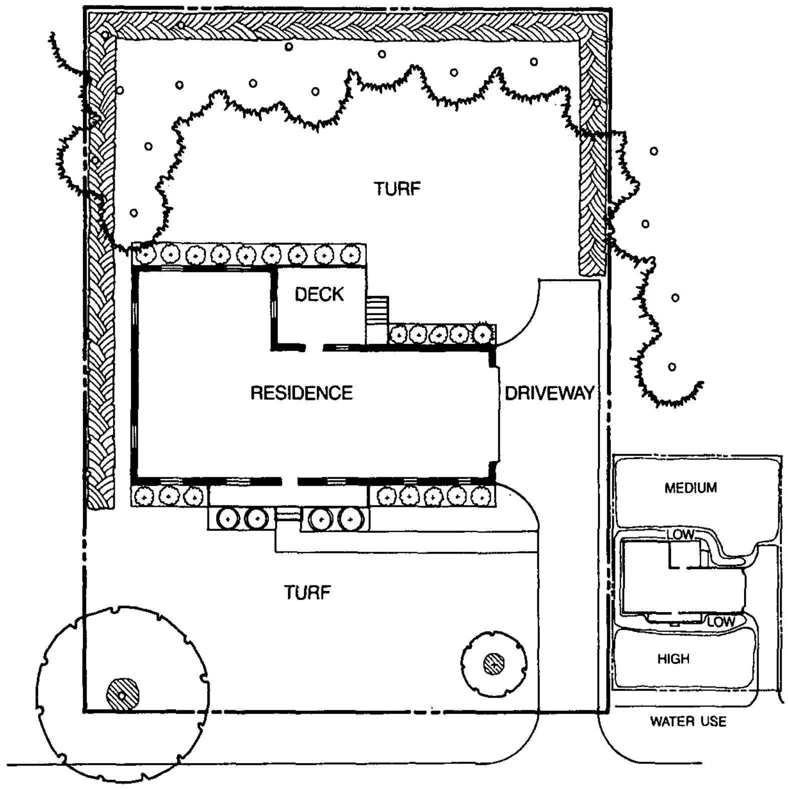
Base Map of Property



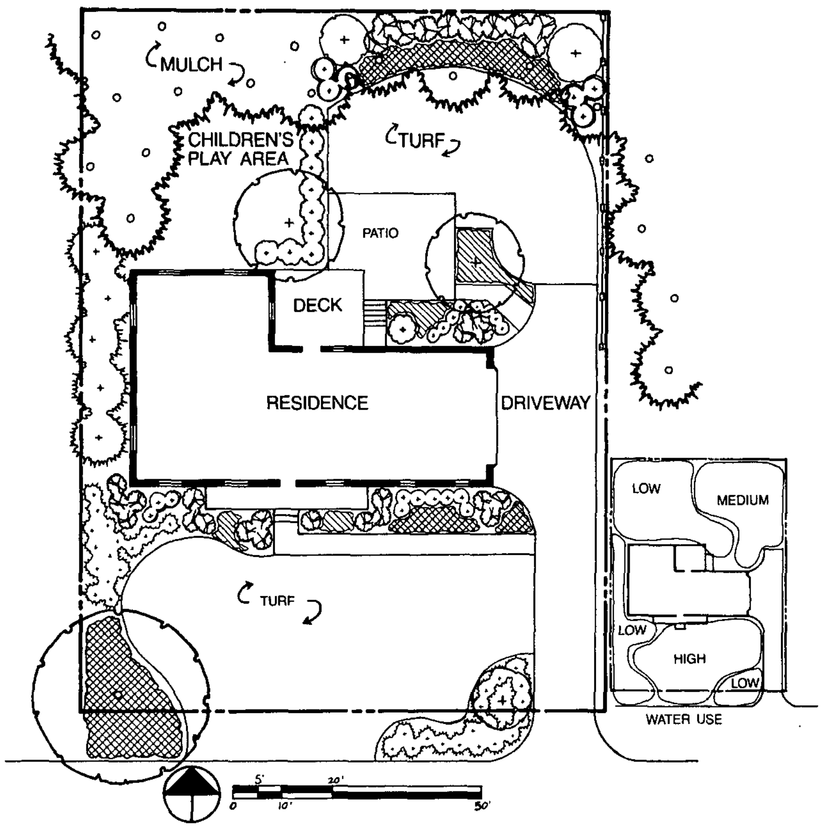
Site Analysis of Property

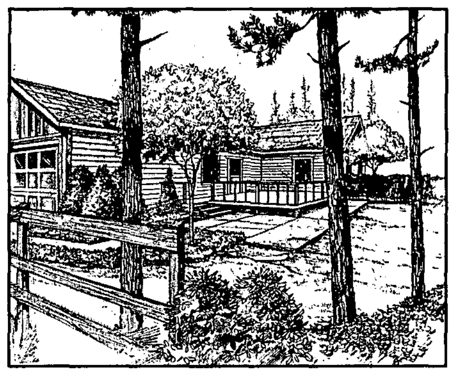
WATER USE ZONES





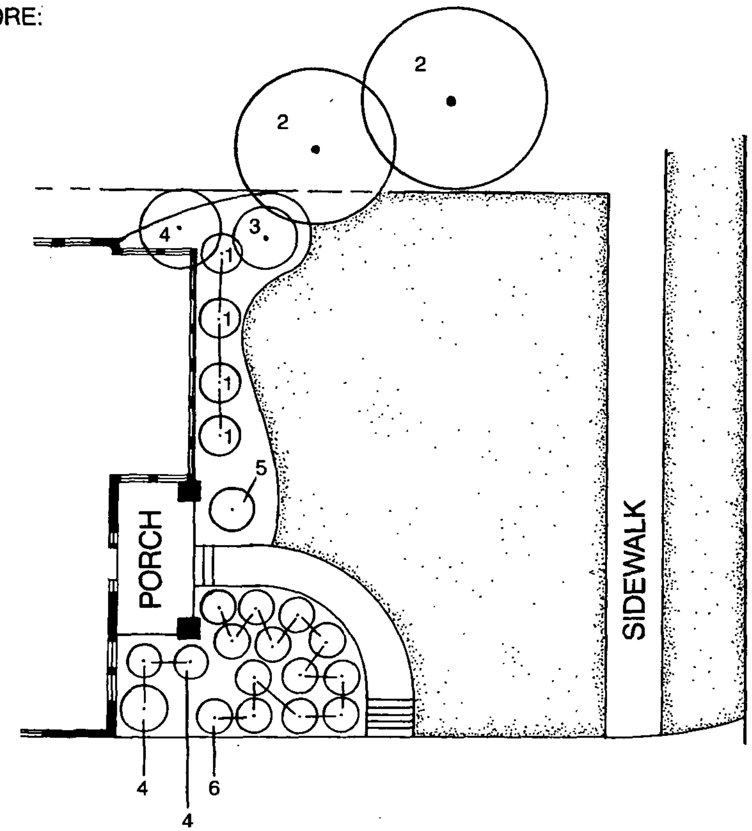
BEFORE





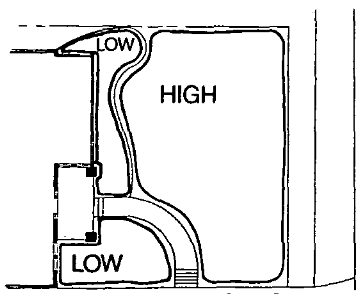
AFTER

BEFORE:



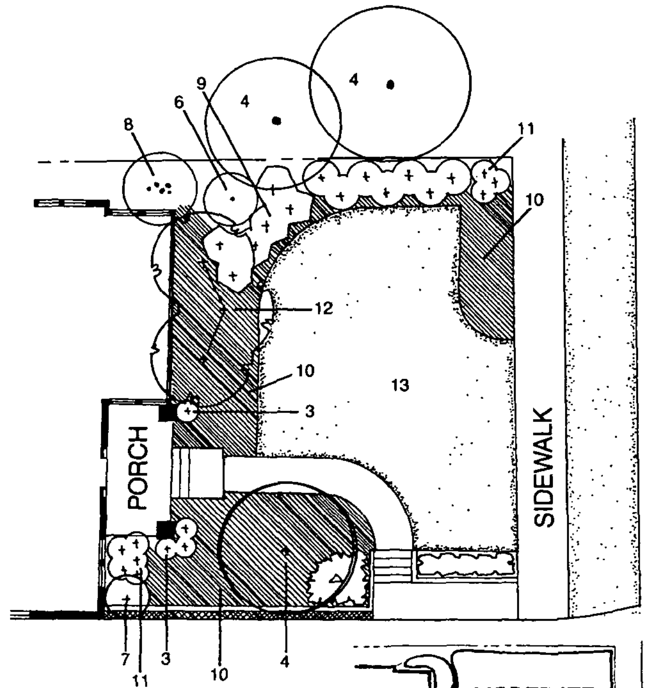
PLANT LIST

1. Boxwood
2. Dogwood
3. Eleagnus
4. Holly
5. Nandina
6. Pfitzer Juniper



WATER USE ZONES

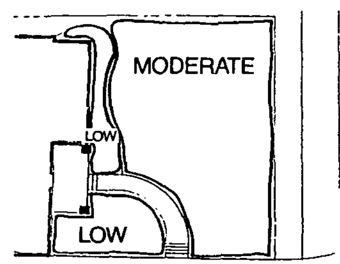
AFTER:



PLANT LIST

1. Azalea, George Tabor
2. Azaleas, Gumpo
3. Boxwood, American
4. Dogwood
5. Dogwood, Existing
6. Eleagnus, Existing
7. Foster Holly
8. Holly, Existing
9. Hydrangea, Bigleaf
10. Mondo Grass
11. Otto Luyken Laurel
12. Yaupon Holly (Tree Form)
13. Zoysia Turf

Credit: Design Courtesy of William T. Smith & Associates Atlanta, Georgia Redd-Chezmar Residence Designer: William T. Smith



WATER USE ZONES

THE WATER SOURCEBOOK

GROUNDWATER

DISPOSAL OF OLD PAINT

6-8

SUBJECT:
Chemistry, Drama

TIME:
3 class periods

MATERIALS:
video camera, if desired
camera for slides or pictures, if desired
microphone
pictures of toxic products and landfills
student sheet

OBJECTIVES

The student will do the following:

1. Identify toxic household products that should not be disposed of in a landfill.
2. Select alternative disposal procedures involving toxic products.
3. Write a news program for a local TV station explaining and identifying toxic substances that should not be placed in a landfill.

BACKGROUND INFORMATION

Our society produces immense quantities of waste. According to estimates by the U.S. Environmental Protection Agency (EPA), our society produces over ten billion tons of waste per year. This quantity comes not only from municipal waste but from agriculture, mining, and industry. According to U.S. EPA figures from the 1990s, about 180 million tons of municipal waste are produced each year in the U.S. Without source reduction, the EPA estimates that U.S. citizens will generate approximately 216 million tons of municipal waste in the year 2000.

Waste volumes are growing even faster than our population. The U.S. produces about four pounds per person per day of municipal solid waste in the late 1990s, up from about 3.5 pounds per person per day in 1960. This is projected to be about 5 pounds per person per day in the year 2000.

Of major concern is groundwater pollution. Pollutants in waste can cause health and environmental problems if allowed to enter the groundwater, which is used for drinking by 70 percent of the nation. Chemical reactions during the degradation of material in a landfill can allow pollutants such as metals to become soluble and to migrate, if not contained, into surrounding water supplies. Today's landfill designs seek to contain these waste materials and to monitor the groundwater to ensure that containment is secure.

Terms

landfill: a large, outdoor area for waste disposal; landfills where waste is exposed to the atmosphere (open dumps) are now illegal; in "sanitary" landfills, waste is layered and covered with soil.

toxic: having the characteristic of causing death or damage to humans, animals, or plants; poisonous.

ADVANCE PREPARATION

A. Make arrangements to use a video camera to tape the news program.

B. Create a news station atmosphere.

PROCEDURE

I. Setting the stage

A. Show a video depicting hazardous products and materials.

B. Discuss problems with storing toxic products in a landfill.

C. Discuss alternative disposal of hazardous materials.

II. Activity

A. Divide the students into groups. Each team will represent a different TV station news team.

B. Have students choose who will be the interviewer and who will be interviewed.

C. Have student choose two anchor people.

D. Have students choose reporters.

E. Have each team practice, then present its news report.

III. Follow-Up

A. Ask the students to determine what constitutes a "good" news report, thereby establishing "criteria" for "evaluation." Introduce them to these concepts.

B. Using their criteria, have the students vote on the best news report in the class.

IV. Extensions

A. Have students determine the availability of toxic product disposal in their communities. For example, where can used motor oil be recycled to prevent it from reaching landfills and polluting groundwater?

B. Have the students call oil-changing stations or service stations to find out how they dispose of their used oil.

RESOURCE

American Water Works Association, Household Hazardous Waste Brochure, West Quincy Avenue, Denver, CO 80235.

Earth Science, Prentice Hall, 1991.

LFG Control and Recovery, by author: SCS Engineers, http://204.240.184.66/landfill.html

Solid Waste Landfills: http://wissago.uwex.edu/uwex/course/landfill/

POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION

Source	Possible Major Contaminants
Landfills	
Municipal	Heavy metals, chloride, sodium, calcium
Industrial	Wide variety of organic and inorganic constituents
Hazardous waste disposal sites	Wide variety of inorganic constituents (particularly heavy metals such as hexavalent chromium) and organic compounds (pesticides, solvents, PCBs)
Liquid waste storage ponds (lagoons, leaching ponds, and evaporation basins)	Heavy metals, solvents, and brines
Septic tanks and leach fields	Organic compounds (solvents), nitrates, sulfates, sodium, and microbiological contaminants
Deep-well waste injection	Variety of organic and inorganic compounds
Agricultural activities	Nitrates,herbicides, and pesticides
Land application of wastewater and sludges	Heavy metals, organic compounds, inorganic compounds, and microbiological contaminants
Infiltration of urban runoff	Inorganic compounds, heavy metals, and petroleum products
Deicing activities (control of snow and ice on roads)	Chlorides, sodium, and calcium
Radioactive wastes	Radioactivity from strontium, tritium, and other radionuclides
Improperly abandoned wells and exploration holes	Variety of organic, inorganic, and microbiological contaminants from surface runoff and other contaminated aquifers

CONTAMINATION OF GROUNDWATER

6-8

SUBJECTS:
Earth Science, Geology

TIME:
50 minutes

MATERIALS:
clear plastic boxes
clay
water
student sheet
teacher sheet

OBJECTIVES

The student will do the following:

1. Demonstrate how precipitation on a farming field or nursery can leak chemicals into groundwater, contaminating wells, ponds, and streams.

2. List safe and unsafe farming methods.

BACKGROUND INFORMATION

Almost all groundwater is formed by the downward percolation of precipitation through the zone of aeration. Small amounts of groundwater also originate from seawater trapped in rocks when they were deposited (known as connate water).

The distribution of water can be split into four zones. The soil zone and the intermediate zone form the unsaturated zone of aeration which contains soil moisture and air in pores or voids (interstices) between the soil particles. Water pressure is lower than atmospheric pressure due to capillary forces. The capillary fringe forms the zone of movement and, together with the underlying aquifer, form the zone of saturation. The most significant quantity of water is held in the aquifer where nearly all the interstices are full of water.

The underground storage of water can be considered in terms of changes in storage, recharge, and discharge. The change in storage equals the recharge minus the discharge. Thus, the groundwater balance can be represented as:

D S (storage) = Q_r (recharge) - Q_d (discharge)

Recharge occurs by infiltration and subsequent percolation of water as the result of a precipitation event.

River channels include influent and effluent streams. Influent channels occur when groundwater is discharged into the river channel. Effluent channels occur when river channels and lakes in contact with the groundwater body discharge water to the underlying aquifer.

The movement of groundwater is dependent upon the slope of the water table (or hydraulic gradient) of the aquifer. Other physical factors also affect groundwater movement, such as the geology (type of sand and gravel, mineral deposits, etc.).

Wetlands often act as links between ground and surface water. After a rainstorm, wetlands act as catchment basins. If the wetland is located above the water table and its underlying soil allows water movement, water will gradually move from the wetland into the underlying soil. If wetlands are drained, the water which would normally enter the groundwater supply is likely to remain above ground, leading to erosion, sedimentation, and flooding of lakes and rivers.

Terms

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

ADVANCE PREPARATION

A. Have on hand clear plastic boxes, water, and clay.

B. Divide students into groups.

PROCEDURE

I. Setting the stage

A. Show a video of groundwater pollution.

B. Gather pictures that explain groundwater leaching and discuss how what we place in the soil can eventually leak into groundwater.

II. Activity

A. Have students put clay in the clear plastic box, making one end a sloping hill that drains into a pond. Be sure the ridges in the clay cause the water to drain into the pond area when poured into the clear box.

B. Have students change the ridges in the clay so the water does not drain into the pond.

C. Have them compare the results of the two activities.

III. Follow-Up

A. Discuss what happened in each setup and why.

B. Relate the direction of plowing to the runoff that occurs into bodies of water.

C. Ask students to recall farms and how they were plowed with respect to the land.

IV. Extensions

A. Students can create a poster show that depicts groundwater contamination.

B. Have students explain the relationships between surface and groundwater that might exist over the four seasons of the year.

C. Visit an area where wetlands contain water or where storm water detention ponds exist. Test the water for contamination (Examples: solids, pH).

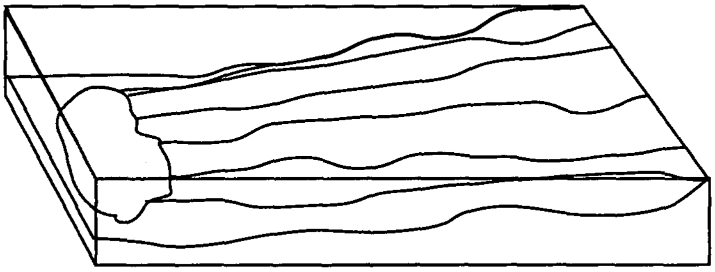
RESOURCES

Earth Science, Prentice Hall, 1991.

Groundwater video. Obtain through the Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994 (phone: 703-684-2400, FAX: 703-684-2492, or http://www.wef.org)

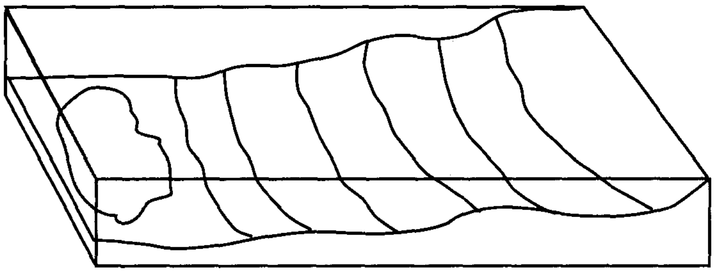
Groundwater: http://giswww.king.ac.uk/aquaweb/main/groundwa/gw1.html

Water Purification Capabilities: http://hermes.ecn.purdue.edu:8001/http_dir/Gopher/agen/agen521/Lessons/Wetlands/purification.html



Hill w/ ridges that drain into pond

Set-Up A



Contour plowing

Set-Up B

1. What did you observe in A?

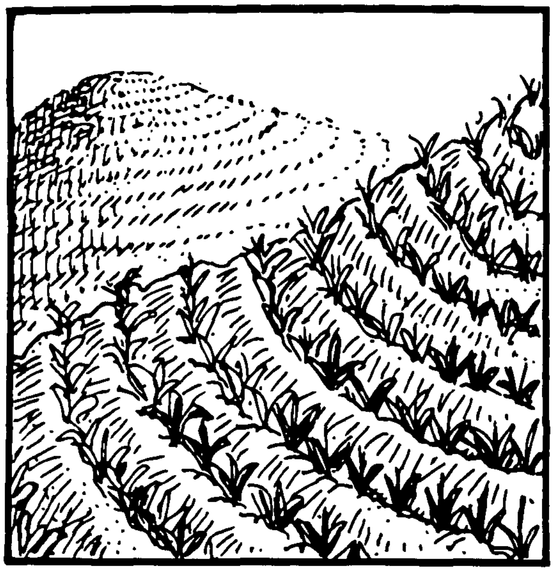
2. What did you observe in B?

3. How does plowing affect erosion?

4. How can groundwater be contaminated by poor farming practices?

SOIL CONSERVATION

CONTOUR FARMING



TERRACING

WINDBREAK

GROUNDWATER

6-8

SUBJECTS:
Chemistry, Geology

TIME:
50 minutes

MATERIALS:
oblong balloon
plastic box
sand
gravel
plastic cup
straight pin
teacher sheets

OBJECTIVES

The student will do the following:

1. Define groundwater.

2. Identify groundwater's relationship to springs, artesian wells, ordinary wells, and sinkholes.

3. Explain the process by which sinkholes are formed.

4. Explain saltwater contamination and explain its causes.

BACKGROUND INFORMATION

Sinkholes form in carbonate terraces when acidic groundwater dissolves the underlying rock. They are typically closed depressions, in which water drains down into the underlying rock rather than over a surface stream or gully. Sinkholes are common in a type of topography called karst, which is characterized by abundant sinkholes, caves, springs, and disappearing streams. Although common in many parts of the world, such as the Southeastern United States, karst is uncommon in the western United States.

Sinkholes, caves, and other karst features form when carbonate rock dissolves in acidic groundwater. Normal rainwater becomes acidic as it percolates through the soil and picks up carbon dioxide (CO2) produced by organisms in the soil. The CO2 dissolves in the water and forms carbonic acid: CO2 + H2O = H2CO3 (carbonic acid), which disassociates into a hydrogen cation and bicarbonate anion to form carbonic acid:

H2CO3 = H+ + HCO3- (bicarbonate anion)

The hydrogen of the carbonic acid then attacks the calcium carbonate of which the marble is composed:

CaCO3 (calcium carbonate) + 2H+ = Ca++ + 2HCO3-

(The two +'s near the Ca refer to the double positive charge of the Ca ion.) The Ca++ and HCO3- ions then flow away in the groundwater.

This process can form underground caves and passageways. If one of these underground cavities collapse, a sinkhole forms. Groundwater flows along joints and fractures dissolving the marble and forming sinkholes, caves, and other karst features. With time, the joints and fractures widen and turn into cracks and canyons.

Terms

artesian well: a well in which the water comes from a confined aquifer and is under pressure. One type of artesian well is a **free-flowing artesian well** where water just flows or bubbles out of the ground without being pumped.

drought: a lack of rain or water; a long period of dry weather.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.
karst: topography formed mainly by underground drainage characterized by sinkholes, caves, springs, and

disappearing streams.

percolate: to drain or seep through a porous substance.

saline (or saltwater) intrusion: the saltwater infiltration of freshwater aquifers in coastal areas, when groundwater is withdrawn faster than it is being recharged.

sinkhole: a natural depression in a land surface connected to a subterranean passage, generally occurring in limestone regions and formed by solution or by collapse of a cavern roof.

ADVANCE PREPARATION

A. Gather all materials before hand so they are ready for the activity.

B. Have on hand enough sand for everyone to build boxes.

PROCEDURE

I. Setting the stage

A. Show the students a bag of sand, soil, and gravel. Ask them to describe each.

B. Fill a plastic box with gravel first, then soil, and finally sand. Discuss the fact that all make up the surface of the Earth. (Have students observe the layers.)

C. Explain and illustrate how water moves from the Earth's surface to underground. Explain and discuss springs.

D. Talk about the removal of water from underground for our use.

II. Activity

A. Have each student cover bottom of the box with about 2 1/2 inches each of gravel, soil, and sand (top).

B. Blow up and tie the balloon. Place it in the center of the box on top of the sand.

C. Cover the balloon by placing sand over it, packing the balloon down.

D. Put a paper cup on top of the sand that is over the balloon.

E. Use your straight pin to burst the balloon. The results will illustrate how sinkholes are formed.

III. Follow-Up

A. Have students use the scientific method to write up the activity.

B. Have students discuss in writing the importance of groundwater.

C. Have students illustrate what was observed in the activity.

D. Have students explain the relationship between groundwater and sinkholes.

IV. Extensions

A. Go to the library and research sinkholes. Find out if you live near an area where sinkholes occur.

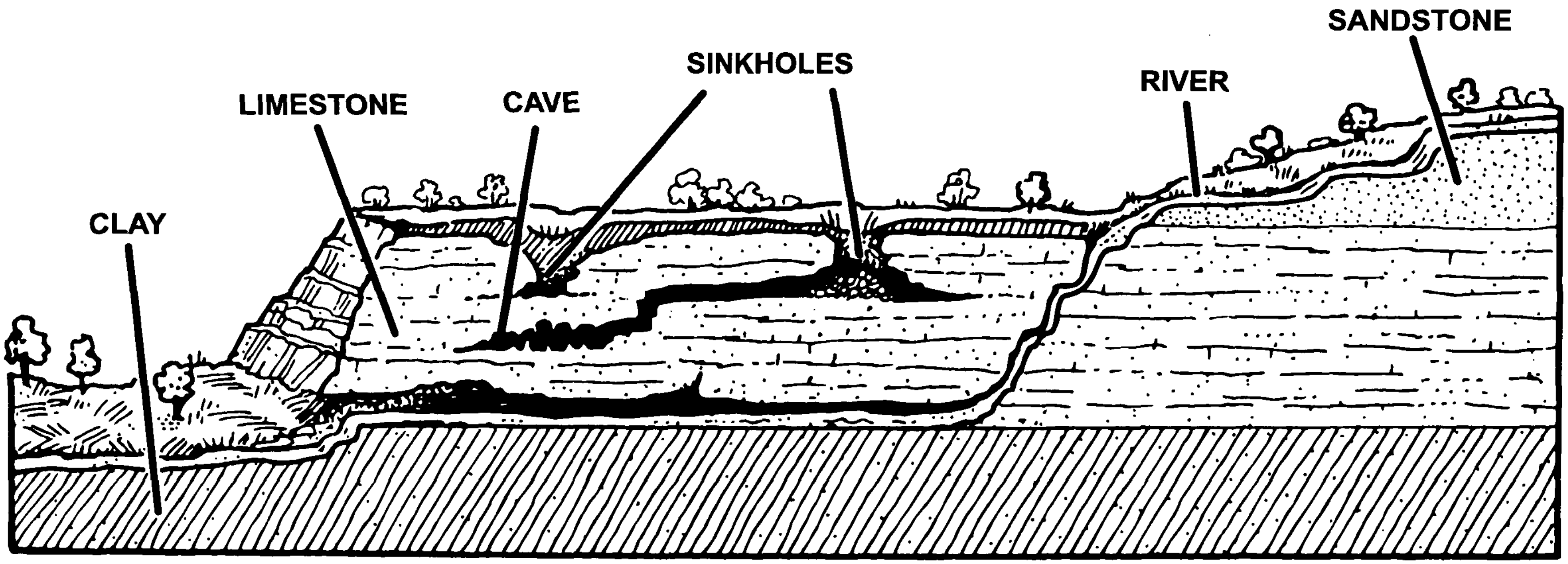
B. If you have a chance, plan a field trip to the nearest sinkhole. Remember: some plants and animals may live only in this one place. Therefore, try to protect their habitat. Stay on marked trails. Try to leave no evidence of your visit—only your footprints.

C. Obtain a piece of limestone and some carbolic acid. Put the acid on the stone and observe how it dissolves the limestone.

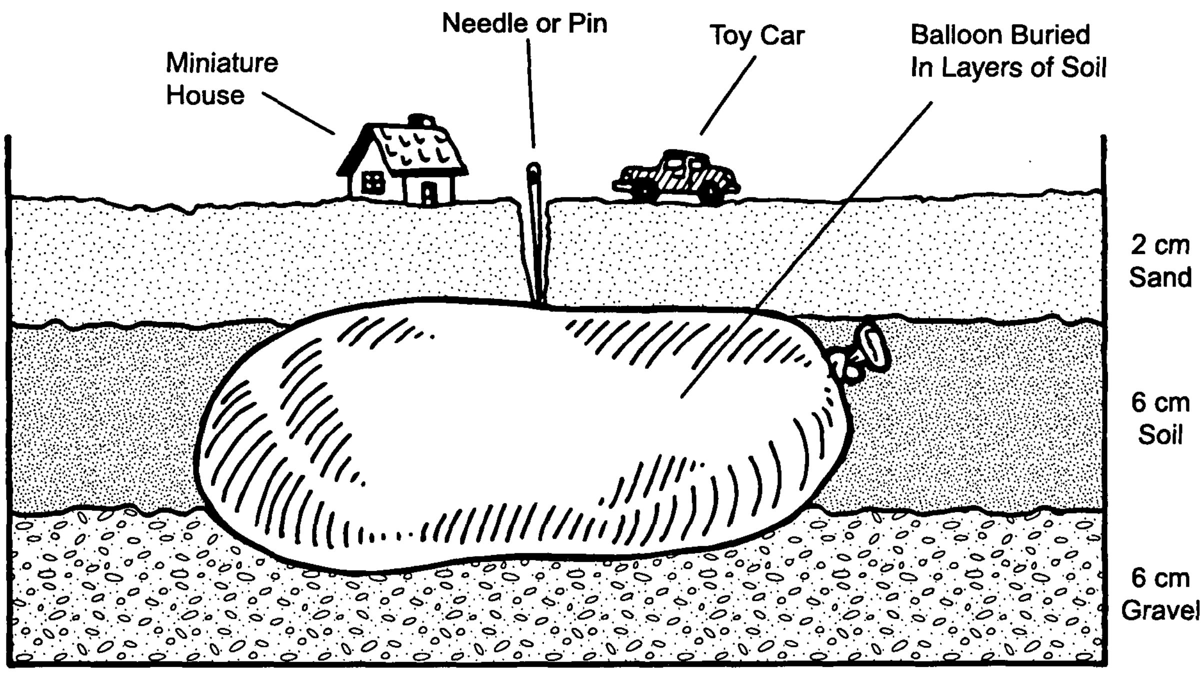
RESOURCES

Environmental Science, Teacher's Edition, Holt, Rinehart and Winston, 1996.

Sinkhole: http://emerald.ucsc.edu/~es10/fieldtripUCSC/sinkhole.html


SANDSTONE
SINKHOLES
RIVER
LIMESTONE
CAVE
CLAY

A MODEL KARST FORMATION



INVISIBLE WATER

6-8

SUBJECTS:
Art, Earth Science, Math

TIME:
50 minutes

MATERIALS:
- a large display relief map of the world
- a 12-inch diameter globe (one showing the ocean bottom is best)
- a five or ten gallon aquarium
- writing materials
- calculators
- measuring cup
- one quart container for every three students

OBJECTIVES

The student will do the following:

1. Define groundwater, aquifer, and hydrologic cycle or water cycle.
2. Describe the amount and distribution of groundwater on planet Earth.
3. Make inferences about the importance of responsible use of groundwater.
4. Calculate water volumes using the statistical information provided.

BACKGROUND INFORMATION

The Earth has been called the water planet. Between two-thirds and three-fourths of the Earth's surface is water, which is visible in rivers, ponds, lakes, icecaps, and clouds. The Earth's invisible source of water (groundwater) is more difficult to see and understand, yet all these forms of water are part of the interrelated flow of water that we call the water cycle or hydrologic cycle.

Water, a renewable natural resource, is continuously being renewed through the hydrologic or water cycle. The hydrologic cycle is powered by the sun's energy and gravity. In this circulation process, water is constantly in motion, cycling through sky, earth, and oceans.

When precipitation (snow, sleet, rain, or hail) falls on the Earth's surface, several things may occur. When precipitation builds up on the soil surface, surface runoff occurs. Surface water moves by overland flow into stream, ponds, lakes, or other bodies of water. When precipitation falls on a porous soil surface, some of the water will seep into the ground through infiltration. Some water clings to soil particles and is drawn into the roots of growing plants; it is then transported to leaves, where it is lost to the atmosphere as vapor in the transpiration process.

Some of the water that enters the soil moves either laterally or vertically through the soil. Lateral movement of water through the soil is called throughflow or interflow. Vertical or downward movement of water through the soil is called percolation. The percolating water eventually enters the zone of saturation, where all spaces between the rocks and soil particles are filled with water. The water filling all the spaces between the rocks and soil particles in the saturated zone is known as groundwater.

Groundwater is stored in two geologic regions: aquitards or aquifers. If water cannot move through the particles of the geologic region, the region is called an aquitard. If water can move through or permeate through the material of the geologic region, the region is called an aquifer.

Aquitards and aquifers vary in their depth, thickness, and even where they occur. An aquifer that is bounded on the top and bottom by aquitards is known as a confined aquifer. Generally, unconfined aquifers are overlaid by permeable layers and are usually found near the land surface.

Groundwater flows through the rocks and layers of earth until it discharges in springs, streams as baseflow, and oceans. The sun warms up the water surface, changing water into vapor, a process known as evaporation.

Each of the segments of the water cycle shares a portion of the total amount of the water on planet Earth. Fresh water is not evenly distributed throughout the world. Some people take fresh, clean water for granted, while others treasure every drop. Yet, simple calculations demonstrate the fact that the amount of water is limited. Scientists believe that all the water that we will ever have is on the Earth right now. Whatever amount is available for human and animal consumption depends on how the quality is maintained. We, as human beings, have the responsibility to conserve water and use it wisely while protecting its quality.

The purpose of this activity is for students to understand how fragile and important water is as a natural resource.

Terms

aquifer: an underground layer of unconsolidated (porous) rock or soil that holds (is saturated with) usable amounts of water.

aquitard: an underground layer of consolidated (nonporous) rock or impermeable soil through which water cannot move.

baseflow: groundwater contribution to a stream.

confined aquifer: an aquifer that is sandwiched between two layers of impermeable materials and is under great pressure.

evaporation: conversion of a liquid to the vapor state by the addition of heat.

groundwater supply: the amount of fresh water stored beneath the Earth's surface.

infiltration: when precipitation falls on a porous soil surface and some of the water seeps into the ground.

interflow: significant lateral movement of water through the soil.

overland flow: when precipitation moves quickly over the surface of the land into a stream channel or other body of water.

percolation: downward movement of water through the soil.

precipitation: any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.

surface runoff: when precipitation builds up on the soil surface and water moves by over land flow into a stream channel or other body of water.

throughflow: significant lateral movement of water through the soil.

transpiration: the passage of water from plants and animals directly into the air in the form of a vapor.

unconfined aquifer: an aquifer overlaid by permeable layers, generally found near the Earth's surface.

water cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans. The cycle consists of three principal phases: precipitation, runoff in surface waters or groundwater, and evaporation and / or transpiration in the air.

zone of saturation: that region below the surface in which all voids are filled with liquid.

ADVANCE PREPARATION

A. Have students make a panel mural of the water or hydrologic cycle, emphasizing the location of groundwater.

B. Make transparencies of the hydrologic or water cycle and the relative percentages of water on Earth.

C. Make a student facts sheet showing the percentages of water locations on Earth.

PROCEDURE

I. Setting the stage

A. Introduce the unit with a film on groundwater or groundwater resources.

B. Have students read and identify the terms used in the background information.

II. Activity

A. Using a relief map of the Earth and the transparency of relative percentages of water on Earth, begin the discussion by pointing out that groundwater is less than 1% of the total amount of water on the Earth. Relate this fact to the percentage of ocean water that is between two-thirds and three-fourths of the surface of the Earth.

B. Discuss the relative percentages.

C. Provide students with a facts sheet. Have the students calculate the estimated amount of fresh water potentially available for human use:

Groundwater	0.62%
Freshwater lakes	0.009%
Rivers	0.0001%
Icecaps/glaciers	2.0%
	2.6291%

D. While discussing the relative percentages of freshwater, emphasize that the usable percentage of existing fresh water is reduced by pollution and contamination, the fact that all groundwater is not available, and the fact that water from icecaps is not readily available.

E. Ask the students to discuss the following:

1. The amount of water used by humans daily for drinking, food preparation, bathing, laundry, and recreation.

2. That other life forms (plant and animal) need fresh, clean water as well as saline (salt) water.

F. Have the students assume that five gallons (or 1280 tablespoons) represents all the water on Earth. Have the students calculate the volume of all the quantities on the water percentage list. Ask the students to consider the following:

1. Remind students hat for multiplication, all the decimal places must be shifted two places to the left so 97.2% becomes 0.972 prior to multiplication:

Example: 0.972 X 1280 tablespoons = 1244.16 tablespoons

VOLUME OF WATER ON THE WATER PERCENTAGE LIST

5 gallons		1280.00
Oceans		1244.16
Icecaps/glaciers		26.24
Groundwater		7.93
Freshwater lakes		0.11
Inland seas/salt lakes		0.1
Atmosphere		0.0128
Rivers		0.0012
	approx.	1280.0000 Tablespoons

2. Once the values are obtained, ask the students to calculate the total volume of all water other than ocean water. (It is approximately 34 tablespoons.)

3. Explain to the students that the volume of water on the water percentage list will be used in the science class.

G. SCIENCE CLASS:

1. Have students make a data table using the volume of water on the water percentage list that was completed earlier in mathematics, being sure to show the total volume of water other than saline water.

2. Once the values are placed on the data table, divide the students into teams of three. Have the gopher for each team place 34 tablespoons of water in a container and take it to the team's workstation.

3. Ask students to remove the amount of water representing all freshwater lakes (approximately 0.11 tablespoon).

4. Ask students to remove the amount of water representing all the rivers (approximately 0.001 tablespoon, which is less than a drop).

5. Ask students to remove the amount of water representing all groundwater (approximately 7.9 tablespoons).

6. Have the students discuss the following:

   a. The fragile nature of the freshwaters (especially groundwater), wetlands, and oceans of our planet.

   b. The vast number of species (both plant and animal) that are dependent on clean, usable groundwater for survival.

   c. How fresh water is replenished by the water cycle (Example: by evaporation from the snows and inland rainfall that recharges streams and aquifers).

III. Follow-Up

A. Present the film Groundwater. Have students draw and label typical soil profiles.

IV. Extensions

A. Have students find our where the local drinking water supply is obtained by calling the city or county water supply department. Research the number of wells in the area: Hown many are there? How deep is the average well? What are the most common minerals and compounds in the water? Does composition vary with locale?

RESOURCES

Aquatic Project Wild, Western Regional Environmental Education Council, 1987. Obtain from Aquatic WILD, PO Box 18060, Boulder, CO 80308-8060 (phone: 303- 444-2390).

Coble, Rice, Walla, Murry, et al. Earth Science, Prentice Hall, Englewood Cliffs, NJ; Needham, MA, 1994.

Groundwater video. Obtain through the Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994 (phone: 703-684-2400, FAX: 703-684-2492, or http://www.wef.org).

PERCOLATION

6-8

SUBJECT:
Geology

TIME:
30 minutes

MATERIALS:
aquarium or ant farm type glass case
clean sand (white or yellow)
water
food coloring
dish detergent bottle or similar one with a nozzle
student sheet

OBJECTIVES

The student will do the following:

1. Observe how water travels through soil over a short period of time.

2. Learn that the movement of water through soil can carry surface contamination to deeper levels (including groundwater).

3. Predict how they believe the water will travel through the soil.

BACKGROUND INFORMATION

During precipitation, water reaching the ground will infiltrate into the underlying soil. Water that is not taken up by plant roots can percolate through the ground to join the groundwater. The rate of percolation is dependent upon rock type and composition.

The infiltration capacity is the constant rate at which water percolates into the ground. Infiltration capacity is dependent upon soil porosity. Sandstones have high porosity and, therefore, high infiltration capacities while clays have low porosity and, therefore, low infiltration capacities.

Infiltration is measured using an infiltrometer.

Terms:

percolation: the drainage or seepage of a liquid through a porous substance.

leach: to remove soluble constituents by the actions of a percolating liquid.

point source: known source of contamination.

ADVANCE PREPARATION

A. Prior to the lesson, pack the sand tightly and uniformly in the glass case. (An ant farm case will work best because it will be easier to see the movement of the water through the sand; however, be sure it is sealed so that it will not leak.) Prepare the colored water in the bottle.

PROCEDURE

I. Setting the stage

A. Discuss the topic of percolation and explain how it can carry contamination to deeper levels of the soil and to the groundwater. Explain what a point source of contamination would be.

II. Activities

A. Have the students guess how they think the water will move through the soil and sketch a picture of it.

B. Place the glass case so that all the students can see it.

C. Add the water. If using an aquarium, add the water near the front edge so that all students can see it. Make sure to put the water in one location. Do not move the bottle as it is added. This will illustrate a point source contamination.

D. Observe the way the water moves through the sand.

III. Follow-Up

A. Have the students compare their guesses (either orally or written) as to what actually happened.

IV. Extensions

A. Use sand with a different grain size and try the experiment again. Or, use clay as a layer with the sand. Demonstrate why liners are used for landfills.

RESOURCE

Groundwater: http://giswww.king.ac.uk/aquaweb/main/groundwa/gw1.html

Directions: Fill in the information as you do your investigation.

Soil Type	Estimated Percolation Time	Actual Percolation Time

1. Which soil was most porous?

2. Which soil was least porous?

3. How does percolation time affect groundwater?

4. How does percolation time affect leaching?

POROSITY? PERMEABILITY?

6-8

SUBJECTS:
Geology

TIME:
50 minutes

MATERIALS:
four 500 mL beakers
3 soil samples
water sample
stop watch
student sheet

OBJECTIVES

The student will do the following:

1. Define the terms porosity and permeability.

2. Explain the way water moves through the Earth.

3. Make a table in which to compile and interpret results.

BACKGROUND INFORMATION

Because of gravity, rainwater travels downward into the tiny openings in the Earth. These openings or spaces are called pores. The more porous the land, the greater the volume of water that the soil can hold. When you measure the volume of water the soil can hold, you are measuring the porosity.

Different soils let water pass through them at faster rates. This is called permeability. When you measure the time it takes for water to reach the bottom of the soil, the measure taken is the permeability of the soil. When all the pores of the soil are filled with water, the extra water makes its way down to lower levels. Eventually water begins to collect below the Earth's surface. This water is then called groundwater. Groundwater is liquid water that lies in the subsurface in fractures in rocks and in pore space between grains in sedimentary rocks. Groundwater is a type of freshwater that humans use for their everyday life.

Porosity is the percentage of open space in a rock. Porosity can be as high as 50 percent in loose sand to 5 percent in cemented, lithified sandstone, to near zero in unfractured igneous rocks. The porosity is due to pore spaces in the rock between the mineral grains. Compaction and cementation due to burial destroy porosity. Sediments may have up to 40 percent initial porosity before cementation.

Permeability is the ability of fluids to flow through rock, which depends on the connectivity of the pore space. Permeable rocks include sandstone and fractured igneous and metamorphic rocks and karst limestone. Impermeable rocks include shales and unfractured igneous and metamorphic rocks. The permeability depends on the communication of the pores in a rock. Permeability determines whether fluids such as gas, oil, or water can be produced from a reservoir. Rocks such as shales can have very good porosities (20 percent plus) but have very poor permeabilities. Permeability can be enhanced naturally due to fractures or can be stimulated artificially.

Natural cements form in the pore space between grains due to various chemical reactions. Common cements include calcite, hematite, dolomite, silica, and clay. Cementation of sedimentary rocks changes the ability of the rocks to contain fluids and the ability of fluids to move through the sedimentary rock.

Terms

gravity: the force of attraction, characterized by heaviness or weight, by which terrestrial bodies tend to fall toward the center of the Earth.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

permeability: the property of a membrane or other material that permits a substance to pass through it.

porosity: the property of being porous, having pores; the ratio of minute channels or open spaces (pores) to the volume of solid matter.

ADVANCE PREPARATION

A. A day before the lab, gather sufficient materials for the class, assuming four students per group.

PROCEDURE

I. Setting the stage

A. Discuss with the class that porosity is the number of pore spaces in a given material. Stress that the more pore space in the soil, the more water the soil will hold.

B. Have the students read the lab.

  1. Have the students make an educated guess as to which soil type will hold the most water. Why?

II. Activities

A. Divide the class into teams and have each group complete the following exploration.

  1. Fill 3 beakers with 3 different soil types. Do not pack soil in the containers.

  2. Write a hypothesis after looking at the three samples, predicting which sample will hold the greatest amount of water. Also predict which sample will cause the water to move through the fastest.

  3. Fill the empty beaker with 75 mL of water. Slowly pour the water into the first soil sample. Stop when the sample can hold no more.

  4. At the same time you are pouring the water, time with the stop watch how long it takes for the water to reach the bottom. Repeat steps 3 and 4 for the other two soil samples.

  5. Use the table on the student sheet to record your data. Complete the table as you obtain your results.

III. Follow-Up

A. Have the students analyze the data, then answer the following questions.

  1. Which soil had the greatest permeability?

  2. Which soil had the least permeability?

  3. Which soil held the most water?

  4. Which soil held the least amount of water?

  5. If your city was said to be the wettest city in the country, how would this affect the soil?

IV. Extension

A. Walk students around the school grounds discussing the different soil types that are seen.

  1. On your walk, test presoaked permeability by using a coffee can with both ends cut off. Pour water into the can and time how long it takes the water to be absorbed into the ground. This presoaking will determine the initial filling of the soil space.

2. Wait five minutes after all the water has been absorbed. Pour the same amount of water into the can and time how long it takes the water to be absorbed into the ground. This will be the actual absorption rate after the soil space has been filled.

RESOURCES

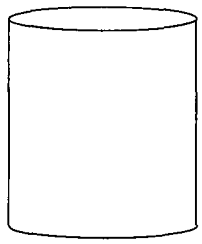
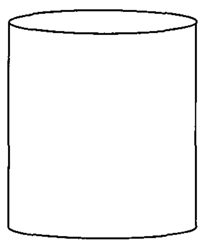
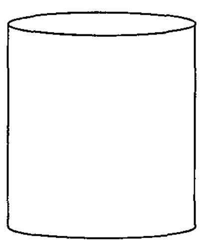
Merrill, Focus on Earth Science, 1984.

Groundwater: http://xtl5.colorado.edu/~smyth/G101-12.html

University of Tulsa - Department of Geosciences, author: Sedimentary Rocks: http://arbuckle.utulsa.edu/epe/sed-rocks.html

POROSITY? PERMEABILITY?

6-8

Type of Soil	Time to Pass Through (in seconds)	Amount of Water Absorbed
 ______________		
 ______________		
 ______________		

1. ______________ had the greatest porosity.
2. ______________ had the least porosity.
3. ______________ had the greatest permeability.
4. ______________ had the least permeability.
5. ______________ held the most water.
6. ______________ held the least water.
7. What is the difference between porosity and permeability?

AQUIFERS AND RECHARGE AREAS

6-8

SUBJECTS:
Art, Geology

TIME:
50 minutes

MATERIALS:
3-liter soda bottle – demo
three large syringes
ruler
gravel
builder's sand
topsoil
measuring cup
water
food coloring
clear plastic cups (10 oz.)
student sheet
teacher sheets

OBJECTIVES

The student will do the following:

1. Create a model of an aquifer.
2. Describe how an aquifer works.
3. Describe how pumping affects an aquifer.
4. Prepare a model presenting to local planners the important aspects of protecting recharge areas.

BACKGROUND INFORMATION

An aquifer is a layer of underground rock or sand which stores and carries water. A recharge area is the place where water is able to seep into the ground and refill an aquifer because no confining layer is present. Recharge areas are necessary for a healthy aquifer. Few rules and regulations were made to protect these areas.

Aquifers form significant natural reservoirs of water and can form a large proportion of water used for drinking purposes. In some countries the supply of water from underground can be the only source of water available. The location and extent of aquifers is dependent upon the geological conditions of the underlying rock. There are three types of aquifers: perched, unconfined, and confined.

Perched aquifers occur in isolation as small quantities of water in suitable confining strata above the water table. Unconfined aquifers form when the permeable strata forms an outcrop on the surface. The upper part of the aquifer is represented by the water table whose levels fluctuate according to the groundwater balance. Confined aquifers have impermeable strata above and below and are not recharged by percolating rainwater.

Note that impermeable strata do not always represent a complete barrier to water movement and that recharge of the aquifer may take place many kilometers away where the strata forming the confined aquifer form a surface outcrop.

Terms

aquifer: an underground layer of unconsolidated rock or soil that is saturated with usable amounts of water (a zone of saturation).

recharge area: an area where water flows into the Earth to resupply a water body or an aquifer.

ADVANCE PREPARATION

A. Gather information from the city planning staff concerning a local recharge area that needs special protection from pollution and development.

B. Have the students visit the site and take pictures of the area.

C. After the trip have the students divide into groups of four.

PROCEDURE

I. Setting the stage

A. Tell the groups that they are going to conduct an experiment that includes creating an aquifer.

B. Explain what an aquifer is and the importance of a recharge area.

C. Brainstorm how this information will help us develop a plan to protect our recharge area.

II. Activities

A. Have each group mimic you as you:

1. Place 4 inches of gravel in a bowl. Measure correct amounts of gravel, topsoil, and sand with the ruler.

2. Put three syringes upright in the gravel. Do this before Step 3, or they will clog with sand. The syringes show an example of wells pumping from the aquifer.

3. Hold the syringes and at the same time put 3 inches of sand on top of the gravel and 2 inches of topsoil over the sand.

4. Add food coloring to 2 cups of water.

5. Slowly pour enough water over the topsoil to saturate. This is the example of rain seeping into the aquifer and becoming groundwater.

6. Put the bowl at eye level, observe, and record changes.

7. Pull the stopper up to fill one syringe. This is an example of how water well pumping affects the aquifer.

8. Repeat Step 6 using two syringes at once. Record changes in groundwater.

9. Repeat Step 6 again using all the syringes. Record changes in groundwater.

III. Follow-Up

A. Each group must answer the following questions:

1. Is this aquifer model a recharge area?

2. How do you know?

3. Describe how an aquifer works.

4. Are the sand and topsoil permeable or impermeable? Why?

5. What do you think would happen if more syringes were used?

6. Why is it necessary that we protect recharge areas?

IV. Extensions

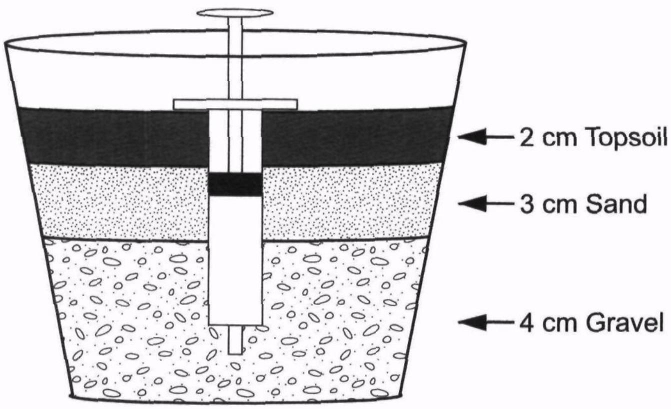
A. Each group should brainstorm ways to construct a model that they could present to the city planning committee. This model will show why this area needs protection. The model will show pictures of the site, the results of the experiments, and why a recharge area is important.

B. The winning group may present their model to the planning committee.

RESOURCES

Johnson Cynthia C., Waterways, Division of Public Information St. John's River Water Management District, Jacksonville, FL, 1991.

Groundwater: http://giswww.king.ac.uk/aquaweb/main/groundwa/gw1.html


2 cm Topsoil
3 cm Sand
4 cm Gravel

Directions: Draw your investigation set-up, record your observations, and answer the questions.

1. Fill the syringe 1/3 full. Record changes in groundwater.

2. Fill the syringe 2/3 full. Record changes in groundwater.

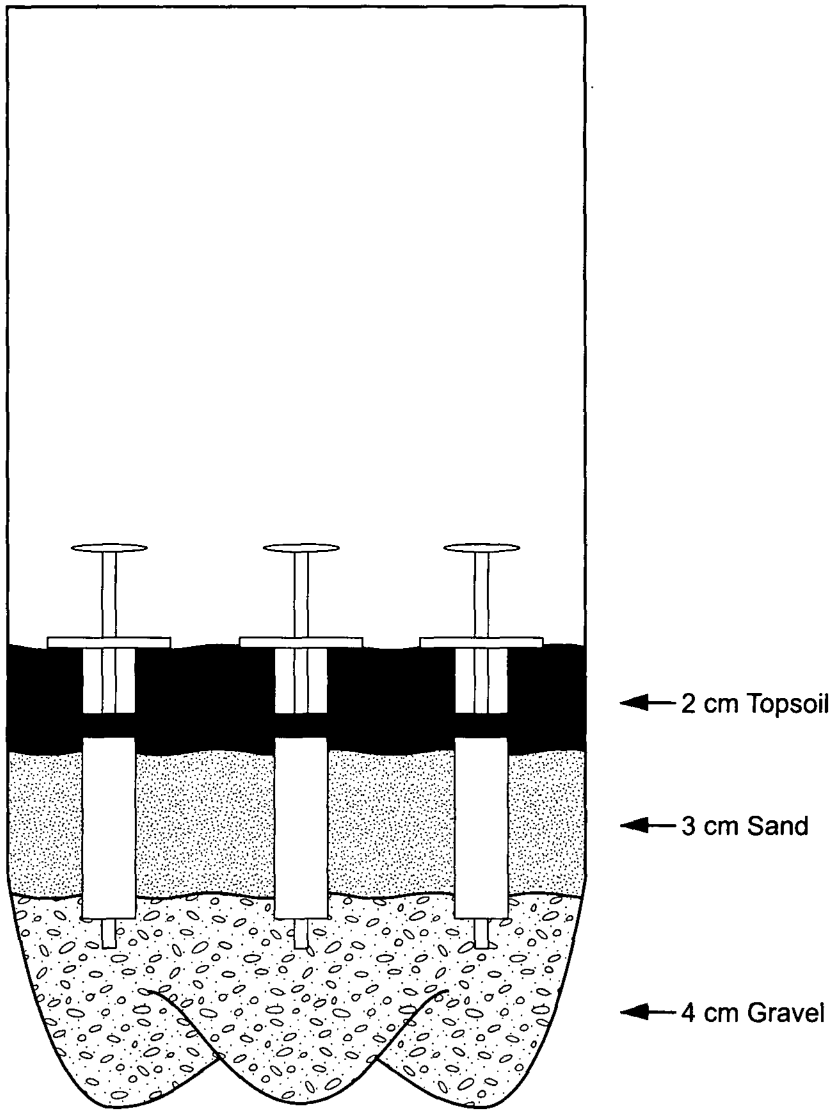
3. Fill the syringe all the way. Record changes in groundwater.

4. Is this aquifer model a recharge area? Why or why not?

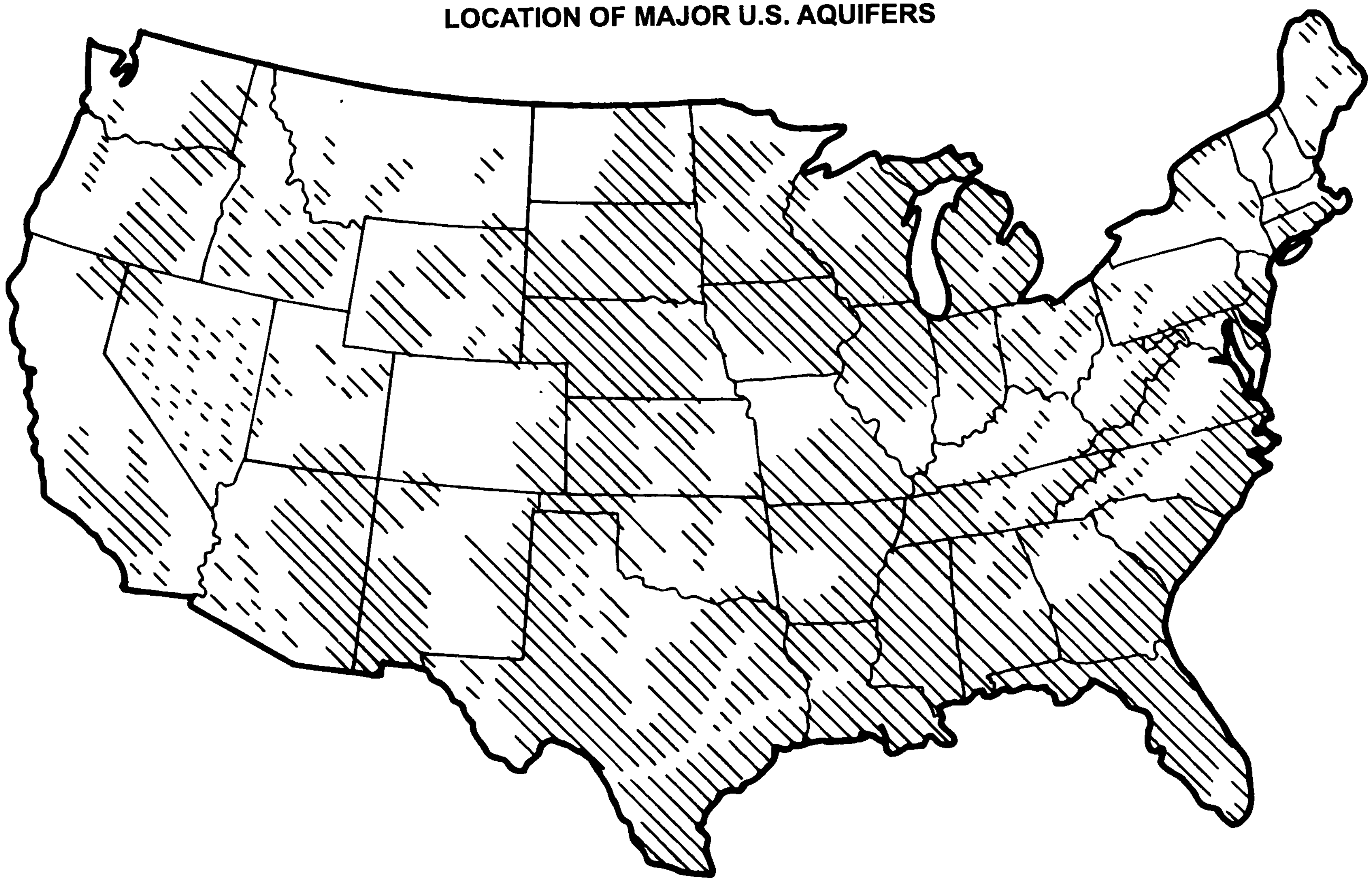
5. How does an aquifer work?

6. How are the syringes similar to wells in an aquifer?

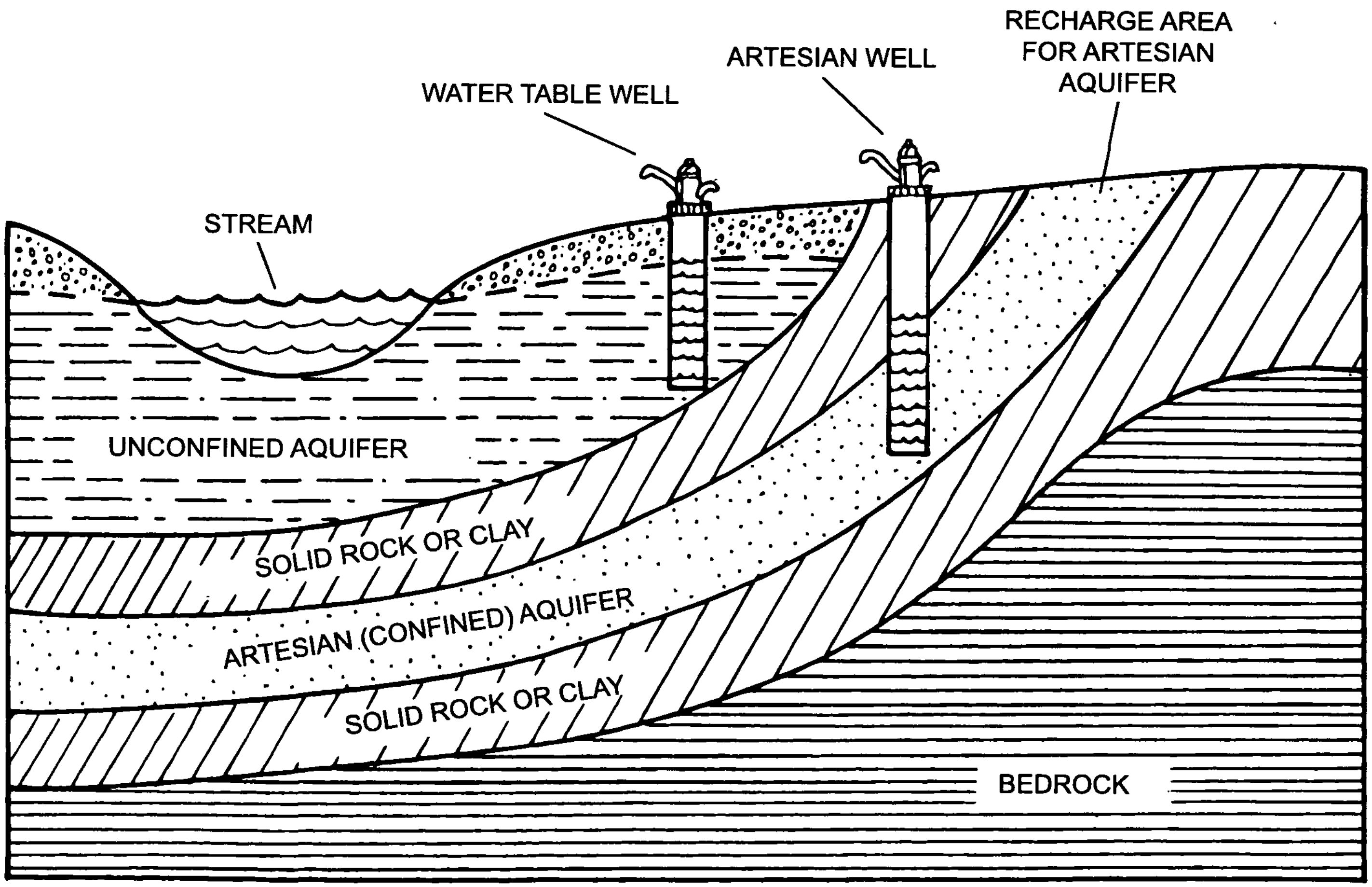
7. Why is it necessary to protect recharge areas?

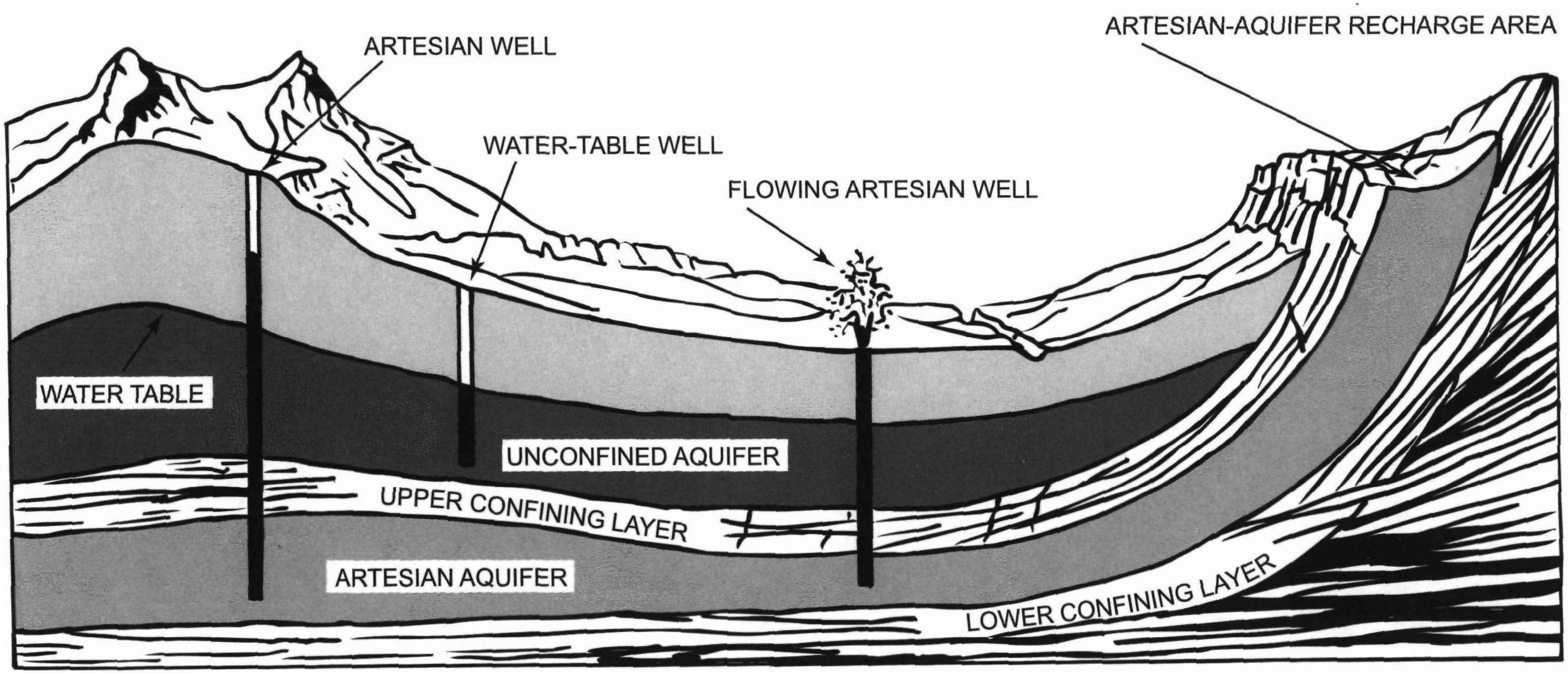

2 cm Topsoil
3 cm Sand
4 cm Gravel

LOCATION OF MAJOR U.S. AQUIFERS



AQUIFER DIAGRAM





The Groundwater Resource

WATER—THROUGH AND THROUGH

6-8

SUBJECTS:
Geology, Math, Language Arts

TIME:
2 class periods

MATERIALS:
pieces for rock samples
water
large beakers
triple beam balance
magnifying glass
student sheet

OBJECTIVES:

Students will be able to:

1. Observe rock samples of characteristics using the naked eye and magnifying glass.

2. Determine how much water different rock samples hold.

BACKGROUND

Each year worldwide 517,000 cubic kilometers of water are evaporated. About 108,000 cubic kilometers of water fall to the Earth as precipitation. What happens to this water? Some water is used by plants to survive. Some runs into lakes; most of the excess flows back into the ocean. The other is called groundwater since it sinks into the porous parts of the Earth's crust. Depending on the rock, water can pass through the layer or be trapped. These two layers are called impermeable and permeable.

Terms

aquifer: an underground layer of unconsolidated rock or soil that is saturated with usable amounts of water; a zone of saturation.

artesian well: a well in which the water comes from a confined aquifer and is under pressure. One type of artesian well is a **free-flowing artesian well** where water just flows or bubbles out of ground without being pumped.

impermeable: impassable; not permitting the passage of a fluid through it.

permeable: passable; allowing fluid to penetrate or pass through it.

porosity: the property of being porous, having pores; the ratio of minute channels or open spaces (pores) to the volume of solid matter.

ADVANCED PREPARATION:

A. Collect egg-sized pieces of rock samples (sandstone, shale, and other rocks).

B. Get the students thinking by displaying a jar filled with pebbles. Ask if the jar is full. (No, there are air spaces.)

C. Fill the jar with water to demonstrate.

PROCEDURE

I. Setting the stage

A. Discuss the concepts of permeable and impermeable rock.

B. Explain and discuss aquifers and wells.

II. Activity

A. Have students find and record the mass of each rock.

B. Have students soak the rocks in water overnight.

C. The next day, have the students remove the rocks from the water. Again ask them to find and record the mass of each sample.

D. Have students complete the student sheet.

III. Follow-up

A. Ask students to discuss the following questions:

1. What information did you learn about each rock as it relates to the water?

2. Which rock makes the best aquifer? The worst?

3. How would water react to sand, clay, or coal?

IV. Extensions

A. Write a letter to the following organization to receive more information concerning geology:

American Geophysical Union
2000 Florida Ave. NW
Washington, DC 20009
http://www. AGU.org

B. Research local aquifers.

C. Have students discuss sinkholes and how they are related to aquifers.

D. Have students research where their local community drinking water originates.

RESOURCES

Hesser, D. and Leach, S., Focus on Earth Science, Merrill Publishing Company, Columbus, Ohio, 1987.

Cunningham, W. and Saigo, B., Environmental Science, 3rd Ed., William Brown Publishers, Dubuque, Iowa, 1995.

Directions: Fill in the data from your observations and answer the questions below.

Rock Sample	Mass Before Soaking	Mass After Soaking	Difference
1.			
2.			
3.			
4.			

1. What information did you learn about each rock as it relates to the water?

2. a. Which rock makes the best aquifer?____________________

   b. What rock makes the worst aquifer?____________________

3. How much water do you think each of the following would hold?

sand____________________

clay____________________

coal____________________

RAIN AND LEACHING

6-8

SUBJECT:
Chemistry, Earth Science

TIME:
50 minutes

MATERIALS:
For each group of 3-4 students:
1/4 cup topsoil
1/4 Tbsp powdered, red tempera paint
1 funnel
2-L soda bottle
1 coffee filter
1/4 cup water
student sheet

OBJECTIVES

The student will do the following:

1. State what leaching is and how it occurs.
2. Make a model simulating leaching.
3. State the results of leaching.

BACKGROUND INFORMATION

Most of our household waste is buried in landfills. An important factor in how landfills are built is how they contain waste and prevent waste from contaminating nearby soil and water sources. The possibility of leachate contaminating soil and groundwater exists wherever wastes are disposed.

Leachate is a fluid that has passed through or emerged from the waste in a landfill, picking up a variety of suspended and dissolved materials along the way. Leachate generation depends on the amount of liquid originally contained in the waste (primary leachate) and the quantity of precipitation that enters the landfill through the cover or that which comes in direct contact with the waste (secondary leachate) prior to being covered. Factors that affect leachate generation are climate (rainfall), topography (run-on/runoff), landfill cover, vegetation, and type of waste.

In unlined landfills, the leachate continues to leach into the ground and may contaminate groundwater. Many old landfills used a simple clay liner for containing leachate (clay is one of the most non-permeable soils). Newer landfills are required to meet federal and state requirements to prevent environmental contamination (Subtitle D landfills). These landfills have sophisticated liner systems often made of heavy-duty, high density polyethylene (HDPE) plastic, where leachate is routed to a wastewater treatment plant. Treated leachate can be disposed of in a number of ways (e.g., discharged to surface waters or recirculated back into the landfill). Some states also allow continued use of clay liners, if the liner meets federal and state performance standards, and if the leachate is properly collected, treated, and disposed of.

In this lesson, the landfill model represents the construction of a Subtitle D sanitary landfill to hold municipal waste.

A common convenient procedure for disposal of household and domestic garbage is to take it to the nearest ravine, hollow, or back road and leave it in a completely unprotected situation. Because this kind of behavior is such an accepted and uncontested way of life for many households, the effect of this garbage upon water quality can be overwhelming. Often, there is absolutely no regard for the contamination potential of some of these items. The results of this can be the introduction of very toxic substances into the streams and groundwater. An understanding of the long-term harmful effects of these actions would influence the future actions of students and their counterparts toward proper garbage disposal. Such an understanding of the part of the community leaders will possibly influence legislation and enforcement.

Terms

leaching: the removal of chemical constituents from rocks and soil by water.

leachate: the liquid formed when water (from precipitation) soaks into and through soil, picking up a variety of suspended and dissolved materials from the waste.

topsoil: the rich upper layer of soil in which plants have most of their roots.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

landfill: a large, outdoor area for waste disposal; landfills where waste is exposed to the atmosphere (open dumps) are now illegal; in "sanitary" landfills, waste is layered and covered with soil.

sanitary landfill: rehabilitated land in which garbage and trash have been buried.

ADVANCE PREPARATION

A. Divide the class into groups of 3-4.

B. Gather enough materials for each group to do the investigation twice.

PROCEDURE

I. Setting the stage

A. Discuss what can occur when rain hits the ground: evaporation, runoff, absorption into the ground.

B. Discuss the fact that nutrients in the soil are important for plant growth.

C. Review with students the definition of "leaching."

II. Activities

A. Tell students they will be constructing a model which illustrates leaching.

B. Have each group do the following with their materials:

1. Add 1/4 Tbsp (1.25 mL) red tempera paint to 1/4 cup (75 mL) topsoil. Mix thoroughly.

2. Set funnel in the 2-L bottle.

3. Place the coffee filter inside the funnel.

4. Pour the colored soil into the paper filter.

5. SLOWLY add 1/4 cup (75 mL) of water to the funnel.

6. Observe the liquid dripping into the bottle. **(Teacher Note: Results—The liquid will be red. This red** liquid represents the nutrients in the topsoil which have been leached.)

7. Repeat the process. This time, QUICKLY add 1/4 cup (75mL) of water until the filter is full.

8. Observe the liquid dripping into the bottle.

III. Follow-Up

A. Have the students write up the activity using the student sheet.

B. Ask the students the following questions:

1. What does the red tempera paint represent?

2. What happened to the paint/dirt mixture after water was added?

3. What was the result of the activity?

4. Why did the results occur?

IV. Extensions

A. Research landfills and how they are constructed.

B. Discuss what happens when it rains on an open dump, a landfill, and a sanitary landfill.

RESOURCES

Arms, K., Environmental Science, Holt, Rinehart and Winston, Austin, TX, 1996.

Cunningham, W., and Saigo, B., Environmental Science, Brown Publishers, Dubuque, IA, 1995.

Directions: Complete the following information about your investigation.

1. Problem statement

___

___

2. Procedure (number the steps you performed)

a.

b.

3. Data collected

Trial	Observation
Trial 1 Add Water Slowly	
Trial 2 Add Water Quickly	

4. Data analysis

a. Did the same amount of leachate come out of both trials?

b. Were the leachates a different color? If so, how were they different?

5. Tentative conclusions

a. What is the relationship between the rate at which water flows through soil and the amount of leaching?

b. In which cases would leaching be good?

c. In which cases would leaching be bad?

MAKING DRINKING WATER

6-8

SUBJECTS:
Chemistry, Earth Science, Health

TIME:
50 minutes

MATERIALS:
For each group:
600 mL water
10 mL teaspoon dirt
2 clear plastic cups (10 oz.)
2 pieces of cheesecloth to cover cup top
20 mL powered alum (from a drug store)
teacher sheets

OBJECTIVES

The student will do the following:

1. Describe methods of purifying water as used by the pioneers, as well as those being used today by water treatment facilities.

2. Explain how groundwater and drinking water can become contaminated.

BACKGROUND INFORMATION

The pioneers learned to drink from flowing waters and not from still waters. While water in lakes, rivers, and streams often contained impurities that made them look and smell bad, the water could be "cleaned" to make it safer to drink. The pioneers used citric acid or alum, which took suspended particles and allowed them to sink to the bottom of the bucket. Sedimentation, or allowing the water to sit for several hours, also took out some impurities. Finally, they would strain the water through material to take out the rest of the impurities. To further purify the water, especially if disease was suspected, they boiled the water before drinking it.

Several of these methods are used by water companies to treat our drinking water today. The water that is processed for most drinking water comes from rivers, lakes, streams, and groundwater and has usually been transferred and stored before processing.

Groundwater accounts for a major portion of the world's freshwater resources. Thousands of cities and towns rely on groundwater for their drinking water. Groundwater can become contaminated from a variety of sources. Because groundwater is such an important source of drinking water, we must be careful not to contaminate it through pollution or careless disposal of household chemicals.

Terms

aeration: exposing to circulating air; addition of oxygen to wastewater or water, as in the step of both activated sludge wastewater treatment process and drinking water treatment.

coagulation: the process by which dirt and other small suspended solid particles are chemically bound, forming flocs using a coagulant (flocculant) so they can be removed from the water (the second step in drinking water treatment).

chlorination: the addition of chlorine to water to destroy microorganisms, especially for disinfection.

filtration: the process of passing a liquid or gas through a porous article or mass (Example: paper, membrane, sand) to separate out matter in suspension, used in both wastewater and drinking water treatment.

sedimentation: (1) the process of depositing sediment, or the addition of soils to lakes that is part of the natural aging process; (2) the drinking water treatment process of letting heavy particles in raw water settle out into holding ponds or basins before filtration (also called "settling"); (3) the process used in both primary and secondary wastewater treatment that takes place when gravity pulls particles to the bottom of a tank (also called "settling").

ADVANCE PREPARATION

A. Make transparencies of the teacher sheets or run off copies for each group.

B. Collect sets of materials for each group.

C. On the day prior to the activity, at the beginning of the class, mix 275 mL water and 10 mL of dirt in a clear plastic cup. Note rate of settling during class and let settle overnight.

PROCEDURE

I. Setting the stage

A. Find out if groundwater is used for the community's drinking water.

B. Discuss groundwater with the students and show the transparencies. Discuss what your state uses for drinking water.

C. Discuss water purification and what your community does.

II. Activity

A. Give each group a set of materials.

B. Have the students mix 275 mL water and 10 mL of dirt in a clear plastic cup.

C. Have the students mix 10 mL teaspoon of alum into the water and watch the floc form.

D. Tell the students to allow the cup to sit undisturbed for several minutes, noting the rate of flocking.

E. Discuss the process of sedimentation while the materials are flocking.

F. Have the students cover the clean cup with cheesecloth and carefully pour the flocked water into the cup.

G. Ask the students to clean the first cup and repeat the process with the water and a new piece of cheesecloth.

H. Observe the differences in the material that was collected on the two pieces of cheesecloth.

III. Follow-up

A. Discuss how the final process for pioneers would be boiling, whereas today we use chemicals to purify drinking water.

B. Have the groups of students compare the results they obtained.

IV. Extensions

A. Repeat the investigation using different amounts of dirt and water.

B. Visit a water treatment facility and find out about water purification processes.

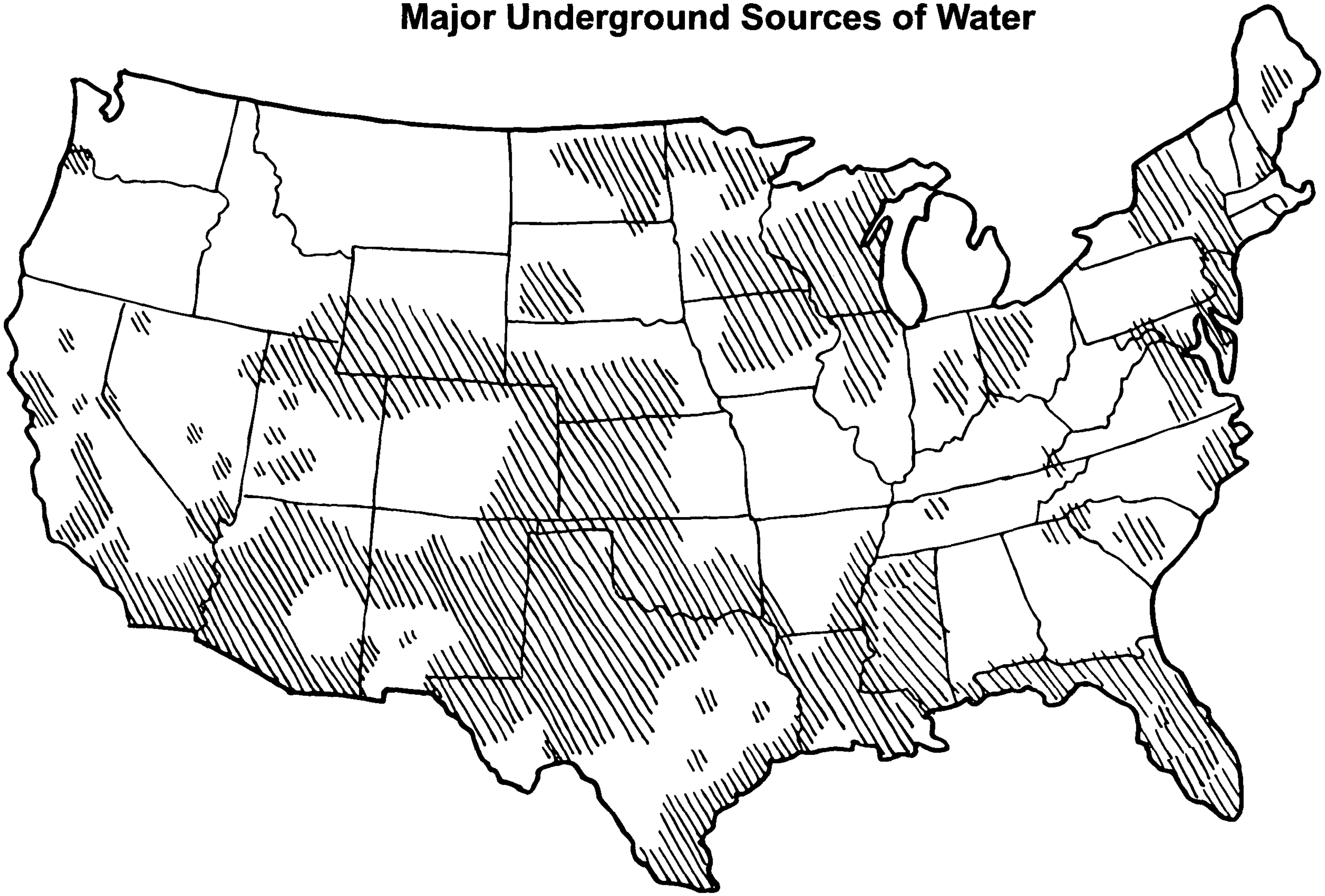
C. Find out what other countries use to purify their drinking water.

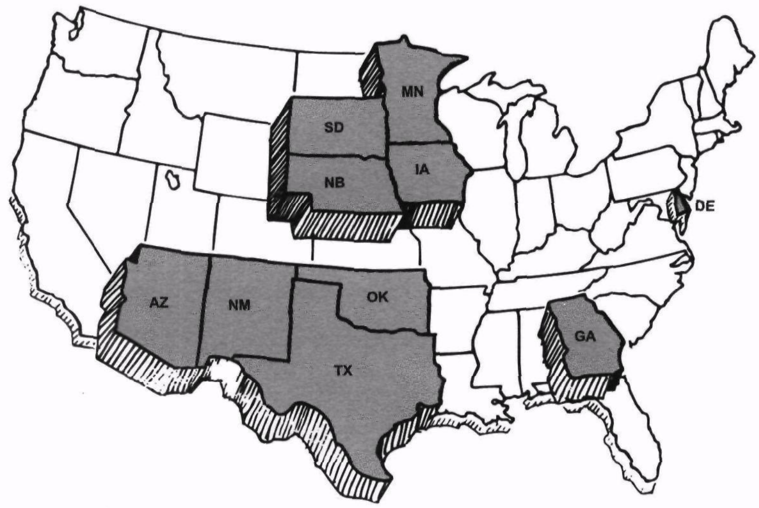
D. Interview a soldier or someone who spent time in an area where drinking water had to be purified by using alum.

RESOURCE

Children's Groundwater Festival Outreach Packet, the Groundwater Foundation, Post Office Box 22558, Lincoln, NE, 402-434-2740.

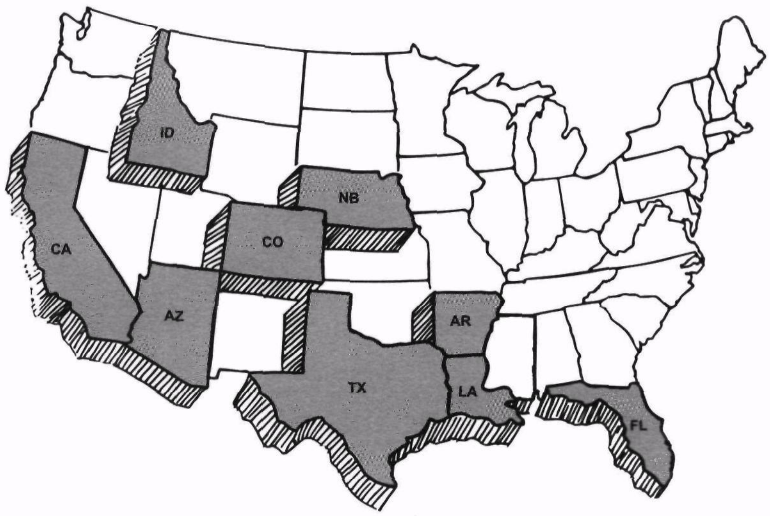
Major Underground Sources of Water





Ten states that rely most on groundwater as a source of water (percentage of all water used which is groundwater):

Iowa	**85%**	**Oklahoma**	**56%**
Texas	**61%**	**Minnesota**	**54%**
Nebraska	**59%**	**South Dakota**	**48%**
Delaware	**59%**	**New Mexico**	**47%**
Arizona	**58%**	**Georgia**	**41%**



Ten states that use the most groundwater (in GPD-Gallons Per Day):

California	**14,6000,000,000**	**Arizona**	**4,200,000,000**
Texas	**9,700,000,000**	**Florida**	**3,800,000,000**
Nebraska	**7,100,000,000**	**Colorado**	**2,800,000,000**
Idaho	**6,300,000,000**	**Louisiana**	**1,800,000,000**
Arkansas	**4,300,000,000**	**Mississippi**	**1,500,000,000**

RECHARGE AND DISCHARGE OF GROUNDWATER

6-8

SUBJECTS:
Geology,

TIME:
50 minutes

MATERIALS:
For each group:
clear plastic container (at least 15cm x 22cm x 6 cm deep)
enough pea-size gravel to fill container 2/3 full
two 472 mL paper cups
one pump dispenser
472 mL water
grease pencil
twigs or small tree branches
ruler with cm
colored powered drink mix or food coloring (optional)
teacher sheet

OBJECTIVES

The student will do the following:

1. Identify several sources of recharge and discharge for groundwater.
2. Discuss how water moves from recharge to discharge areas.
3. Discuss the connection between surface water and groundwater.
4. Explain how groundwater can become polluted.

BACKGROUND INFORMATION

Approximately half of the people living in the U.S. depend on groundwater for their drinking water. Groundwater is also one of the most important sources of irrigation water. Unfortunately, some of the groundwater in every state has become tainted with pollutants. Some scientists fear that the percentage of contaminated groundwater may increase as toxic chemicals dumped on the ground during the past several decades slowly make their way into groundwater systems.

Many people picture groundwater as underground lakes or rivers, but, it is actually water that fills the spaces between rocks and soil particles underground—much the same way water fills a sponge. Most groundwater is precipitation that has soaked into the ground. Groundwater sometimes feeds lakes, springs, and other surface water.

Recharge is the addition of water to an aquifer. Recharge can occur from precipitation or from surface water bodies such as lakes, rivers, or streams. Water is lost from an aquifer through discharge. Water can be discharged from an aquifer through wells and springs, and to surface water bodies, such as rivers, ponds, and wetlands.

Terms

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

groundwater discharge: the flow or pumping of water from an aquifer.

groundwater recharge: the addition of water to an aquifer.

infiltration: the flow of water downward from the land surface into and through the upper soil layers.

permeability: the capacity of a porous material to transmit fluids. Permeability is a function of the sizes, shapes, and degree of connection among pore spaces, the viscosity of the fluid, and the pressure driving the fluid.

saturated zone: a portion of the soil profile where all pores are filled with water. Aquifers are located in this zone. There may be multiple saturation zones at different soil depths separated by layers of clay or rock.

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

unsaturated zone: a portion of the soil profile that contains both water and air; the ozone between the land surface and the water table. The soil formations so not yeild usable amounts of free-flowing water. It is also called zone of aeration and vadose zone.

water table: upper surface of the zone of saturation of groundwater.

ADVANCE PREPARATION

A. Using a nail, punch 8 - 10 small holes in the bottom of the paper cups. When filled with water, this will simulate rain.

B. Gather materials and fill the clear containers 2/3 full with the gravel. The gravel should be level in the containers.

C. Make transparency or run off copies of teacher sheet showing model set up.

PROCEDURE

I. Setting the stage

A. Discuss groundwater and the reasons why people depend on it.

B. Discuss what your community uses for drinking water.

II. Activity

A. Divide the class into groups and distribute the materials.

B. Have students construct the model as shown with a valley in the middle. Explain that the gravel mounds on both sides of the container represent hills with a valley in between. Use the twigs to represent trees and vegetation.

C. Have one student fill the cup without holes with water then pour this water into the cup with holes holding it over one of this "hills" of the model. Observe how the water moves through the gravel.

D. Introduce the word "recharge" - the addition of water to the groundwater system. Have students observe that water is standing in the valley. Have the students use the grease pencil to draw a line identifying the water level under the hills and in the valley. Measure the height of the water and mark it on student diagrams of the model.

E. Explain that they have just identified the top of the groundwater in their model. The top of the groundwater is called the water table. Discuss how the groundwater becomes a pond in the valley because the water table is higher than the land surface.

F. Have students insert the pump into one of the hills on the side of the valley pushing the bottom down to the groundwater. Allow each of the students in the group to press the pump 20-30 times after the water in the pump has begun to flow. Catch the water in the cup with no holes.

G. After each student pumps the water, mark the level of the water with the grease pencil and measure it. Mark the level of the diagram.

III. Follow-Up

A. Have the students work as a group to fill in the student sheet. Have them discuss their answers as a class.

IV. Extensions

A. Sprinkle the colored powder drink mix or food coloring on top of one of the hills and repeat the activity. Discuss the movement of "pollution" from the hill to the groundwater to the pond.

B. Try the activity with sand and gravel of a different size and note the rate of recharge.

RESOURCES

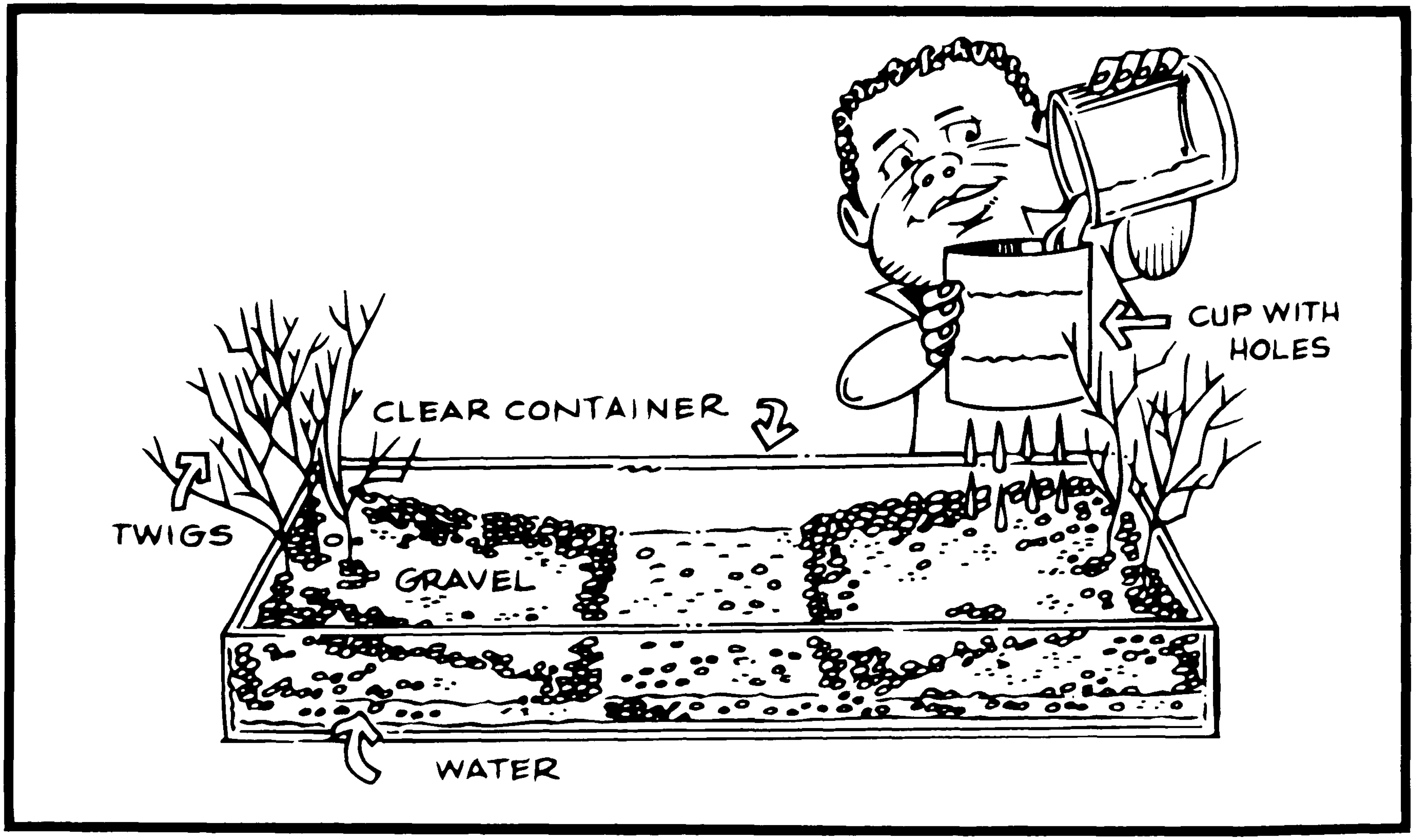
U.S. Geological Survey, Box 25286, Denver Federal Center, Denver, CO 80225, 303-236-7477.

The Groundwater Foundation, P.O. Box 22558, Lincoln, NE 68542, 404-434-2740.

Directions: Draw a diagram of your model in the space below. Make it at least 8cm high. You will be measuring the level of water in your model and marking it on your diagram.

Answer these questions as a group. Be prepared to discuss them with the class.

1. What was the highest level (in cm) of your groundwater? ______________
2. What was the level after one pumping? ____________________________
3. What was the level after two pumpings? ___________________________
4. What was the level after three pumpings? __________________________
5. Where does groundwater come from?
6. What could happen to groundwater if a well is drilled nearby?
7. Explain how groundwater can become polluted by human activity.
8. Devise a way to clean up polluted groundwater.


CUP WITH HOLES
CLEAR CONTAINER
TWIGS
GRAVEL
WATER

RURAL WASTEWATER

6-8

SUBJECTS:
Biology, Health

TIME:
2 class periods

MATERIALS:
For each lab station:
funnel
rubber tubing
glass bend
pneumatic trough
3 "T" connectors
250-mL side arm flask
1-hole stopper
wire gauge
coarse gravel
fine gravel
soil
Lamotte Water Test Kit (available through a biological supplies catalog)
student sheets

OBJECTIVES

The student will do the following:

1. Distinguish between aerobic and anaerobic digestion of waste.
2. Explain the difference between black water and gray water waste.
3. Explain how a septic tank drainage field system is constructed and functions.
4. Describe the symptoms of a failing septic system.
5. Explain how a failing septic tank system can cause groundwater contamination.

BACKGROUND INFORMATION

Many rural areas are not served by any type of wastewater systems, and household wastewater must be disposed of onsite. The septic tank, along with a soil absorption system (field lines), is the most common and effective method of wastewater treatment used in these rural settings. Cesspools, which are no longer approved for new installations in most areas, and pit privies are the other most widely known methods.

Other alternatives include the following: aerobic (requiring oxygen) treatment tanks; off- lot systems in which wastewater from several households is conveyed to a common disposal and treatment site (such as a soil absorption field); and evapotranspiration systems. Evapotranspiration is a process used for shallow soil depths. Grass or other plants are used to cover the field which receive the wastewater. The plants take the water and selected mineral but leave the rest for organic decomposition. The water leaves the plants by normal transpiration processes by which plants lose water to the air. Some of the more recent alternatives include the following: composting; low-flush; incinerating, or recycling toilet systems; and dual treatment systems which separate "blackwater" (human body wastes) from "graywater" (other domestic wastewater). On-site disposal systems, such as septic tanks, discharge wastewater to the subsurface.

A septic tank is simply a tank buried in the ground for the purpose of treating the sewage from an individual home. Wastewater flows into the tank where bacteria breakdown organic matter, allowing cleaner water to flow out of the tank, into the ground, through a subsurface drainage system. Periodically, sludge or solid matter in the bottom of the tank must be removed and disposed. Failing septic tanks and cesspools are frequent sources of groundwater contamination.

Terms

aerobic: in the presence of oxygen.

anaerobic: in the absence of oxygen; oxygen free.

sewage: the solid human waste and human-generated wastes that are normally discharged into wastewater transported through sewers.

sludge: solids removed from wastewater or raw water in the process of treatment; the heavy, partially decomposed solids found in the bottom of a septic tank.

evapotranspiration: molecules leaving the liquid state and entering the vapor or gaseous state through plant leaves.

blackwater: sewage that is from the solid human waste.

graywater: all sewage that does not contain solid human waste that comes form a household, (Examples: from sinks, laundry, and showers.

ADVANCE PREPARATIONS

A. Copy student sheets

B. Gather materials and put out at each station (only one water test kit is necessary for the class).

C. Prepare "blackwater" by adding to containers of tap water such materials as barn- yard animal manure or animal manure purchased from a garden shop. Prepare "gray water" by adding to container of tap water such materials as raw peanut hulls, ashes from burned peanuts, detergent, or grease.

II. Activities

A. Have students make working septic tank models.

B. Run "wastewater" into the septic tank (flash) until it rises to the outlet. Allow at least 24 hours (or a weekend) at room temperature. One group runs "blackwater" through the system and one runs "graywater" through the system.

C. After observing results of previous work, add an amount of the same type of "wastewater" to the septic tank (flask) and catch any effluent coming from the drain tubing. (A pinch clamp should be used on the tubing.)

D. Test final effluent for pH, odor, mineral content (hardness), color, and turbidity.

E. Have students compare effluents of wastewater types.

III. Follow-Up

Have the students complete the following:

A. Explain the difference between aerobic and anaerobic decomposition of wastes.

B. Define "blackwater" and "graywater."

C. Explain how a septic tank is constructed.

D. Explain how to install a drainage field system.

E. List ways of abusing a septic tank system.

F. Describe several symptoms that indicate that the septic tank system is failing.

IV. Extensions

A. Construct diagrams and specifications of systems for wastewater treatment making use of 1) an aerobic treatment tank and 2) evapotranspiration. After doing so, have students discuss the following questions:

   1. What factors limit the volume of wastewater that can be processed?

2. Is each system equally effective in swampy and hilly terrain?

3. How does each system treat wastewater so as to avoid offensive odors?

4. Discuss which system would work best in rural areas. What type of system is used by the schools? Where is the system and drainage field for the school located?

B. Have students do a "perk" test on the soil in the area. (See your local health department for instructions on how to perform this activity.)

C. Have rural students check the site of effluent discharge from the systems at their homes in relation to the drinking water source. Is it adequate? What are the regulations for location of waste treatment systems?

D. Have students explore problems created by concentrated housing (mobile home/trailer parks along a lake) when only a septic tank system is used for each habitat.

RESOURCE

Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36849.

ALABAMA COOPERATIVE EXTENSION SERVICE, AUBURN UNIVERSITY, ALABAMA 36849-5612

CIRCULAR ANR-790 Water Quality

On-Site Sewage Treatment

Understanding Septic System Design And Construction

Years of experience have shown that properly designed, constructed, and maintained septic systems pose no undue stress on the environment. All three tasks—design, construction, and maintenance are crucial if the system is to operate properly.

Typically, the homeowner does not become involved in the design details of a septic system. State and local regulations and design standards have been established to ensure properly designed systems. Similarly, if homeowners are careful in selecting a reputable construction contractor, they usually can be assured that the system will be installed properly.

But understanding septic system design and construction will enable homeowners to interact knowledgeably with local inspectors and contractors.

Conventional Septic System Design

Conventional septic systems have two key components: a septic tank and a soil absorption system. Each must function properly for the entire system to perform satisfactorily.

The Septic Tank.

The septic tank is simply a container usually prefabricated from concrete according to standard designs. It receives wastewater from the home generated in the bathroom, kitchen, and laundry. The septic tank retains the wastewater for approximately 24 hours allowing the solids to separate and settle out and allowing bacteria to partially decompose and liquefy the solids.

There are three layers in the septic tank:

1. Sludge, consisting of heavy, partially decomposed solids that will not float.
2. Liquid, containing dissolved materials such as detergents and small amounts of suspended solids.
3. Scum, consisting of fats and oils and other light-weight solids that float on the surface of the wastewater.

Solids and scum in the tanks are digested or decomposed by anaerobic bacteria (bacteria active in the absence of oxygen). This decomposition liquefies up to 50 percent of the solids and scum. The liquid is carried out into the absorption field, and the indigestible solids remain in the tank as sludge.

Each time raw sewage enters the tank, an equal amount of fluid is forced out of the tank. Tees or baffles at the inlet and outlet of the tank slow the velocity of incoming wastewater and prevent flow directly to the outlet of the tank. The tees also help prevent sludge from leaving the tank through outlet lines. The fluid leaving the tank is called effluent and can contain disease organisms. Small amounts of suspended and dissolved matter in the effluent not completely stabilized or digested also move out of the tank to the absorption field.

While typically designed to hold 1,000 gallons of liquid, the size of the septic tank varies, depending on the number of bedrooms in the home. Regulations require that septic tanks be a certain size based on the expected daily flow rate of wastewater. Proper sizing is important to allow adequate time for settling and flotation so that the soil absorption system is not clogged with sludge and scum.

The Soil Absorption System

The soil absorption system consists of a distribution box and up to 300 feet or more of tile or plastic drain lines buried in the soil. The soil absorption system receives wastewater from the septic tank. The partially treated liquid, called effluent, flows out of the septic tank to the distribution box, where it is evenly distributed throughout the absorption field. The effluent is allowed to trickle into the soil through perforated pipes placed at a certain depth throughout the absorption field. As effluent moves through the soil, impurities and pathogens are removed. The soil provides filtering and treatment to remove pathogenic microorganisms, organics, and nutrients from the wastewater. Just as the septic tank requires a certain amount of time to allow solids to settle and light materials to float, so the soil requires a certain amount of time to remove harmful materials from the wastewater leaving the tank.

The size of an absorption area is based on the volume of wastewater generated in the home and the permeability of the soil. Usually, the absorption field can fit within the front yard or the backyard of a typical 1-acre homesite. The precise area requirements will depend upon the kinds of soils at the homesite, the size of the house (the number of bedrooms), and the topography of the lot. Adequate land area must be available to install a replacement system in case it is ever needed. This replacement area must meet the same soil and site requirements as the original system.

Conventional Septic System Location

Unlike a sewer system, which discharges treated wastewater into a body of water, the septic system depends on the soil around the home to treat and dispose of sewage effluent. For this reason, a septic system should be installed only in soils that will adequately absorb and purify the effluent. In addition, the septic system must be located a specified distance from wells, surface waters, and easements.

To insure that your septic system is located properly, keep the following tips in mind:

1. The septic system should be installed where the soil tests were performed.

2. The location of individual septic system components should meet certain setback requirements. If a septic system is located too close to wells, streams, or lakes, wastewater may not be properly filtered and may contaminate surface water supplies. Generally accepted safe distances are shown in Table 1.

When the septic system is being installed, record the location of your septic tank, absorption field, and repair area. Measure and record distances from the septic tank, septic tank cleanout, and soil absorption system to above ground features such as buildings, fence comers, or large trees. Then after the area has grassed over, you can still find the system. A sample sheet for recording information is provided on another page.

Table 1. Recommended Horizontal Separation Distances For On-Site Sewage Disposal System Components.*

Part Of System	Water Supply (well or suction line)	Water Supply (pressure line)	Lake Or Stream	Dwelling	Property Line
	Feet				
Septic tank	50	30	50	10	10
Distribution box	50	30	50	20	10
Absorption field	100	30	50	20	10

*Distances may vary from state to state. Contact your local health department for specific guidelines.

Conventional Septic System Construction

While the construction of a septic system is a matter for professionals, homeowners can ensure proper construction by keeping the following tips in mind.

Keep heavy equipment off the soil absorption system area both before and after construction. Soil compaction can result in premature failure of the system. During construction of the house, fence off the area designated for the soil absorption system as well as the required placement area and the area directly downhill.

Water related issues are given below:

- Avoid installing the septic tank and soil absorption system when the soil is wet. Construction in wet soil can cause puddling and smearing and increase soil compaction. This can greatly reduce soil permeability and shorten the life of a system.
- Make sure the perforated pipes of the absorption system are level to provide even distribution of the septic tank effluent. If settling and frost action cause shifting, part of the soil absorption system may be overloaded.
- Divert rainwater from building roofs and paved areas away from the soil absorption system. This surface water will increase the amount of water the soil has to absorb and cause premature failure.
- Keep water from footing drains and water softener discharges out of the septic system. Water from footing drains can overload the capacity of the absorption field, reducing its ability to accept effluent. Water softener discharges contain high concentrations of sodium, which react with the soil to reduce permeability. Remember, the system was designed and sized to handle only the wastewater from plumbing fixtures and washing machines.

Do not plant trees and bushes near the septic tank or absorption field because their roots can enter the system and cause extensive clogging problems. Do not cover the absorption field with a driveway, patio, or other paving that would prevent the release of water vapor.

Allow accessibility for a pumper truck or backhoe to service your system. Septic tanks require routine pumping and periodic maintenance, so keep access to the area easy.

Alternative On-Site Sewage Treatment Systems

In locations where a conventional septic tank and soil absorption system is unsuitable (such as areas with high water tables or slowly permeable soils), you may be able to modify site conditions. For example, in areas with high water tables one option is to use underdrains or curtain drains to lower the water table. Another option is to raise the level of the soil surface with layers of fill soil.

When it is not practical to modify the site, consider an alternative system. The mound system and the aeration system are alternatives that may be used in areas with high water tables or slowly permeable soils.

With the mound system, the absorption field is built above the natural ground level. A distribution network supplies effluent to the mound, and the effluent is treated as it passes through the fill sand and natural soil.

The aeration system consists of a chamber that mechanically aerates (mixes air with) the effluent and decomposes the solids. Effluent is discharged to an absorption field or, after chlorination, to surface water or an evaporation pond.

Other alternatives include sand filters, lagoons, constructed wetlands, electro-osmosis systems, dropbox distribution systems, serial distribution systems, pressure-dosed distribution systems, and leaching chambers.

In general, alternative systems are more costly to install and operate than conventional septic tank and soil absorption systems and may require additional maintenance.

Conclusion

Improperly designed and constructed septic systems are doomed from the start. These systems usually fail in a few months because they are inadequately sized, installed in impermeable soils, or not properly constructed.

When on-site sewage disposal systems are installed on the proper site and are properly designed, constructed, and maintained, they provide a safe, cost-effective alternative to municipal and community sanitary sewage treatment.

References

Alabama Department Of Public Health. 1988. Location of On-Site Sewage Disposal Systems. Rules of State Board of Health. Chapter 420-3-1-. 22. Division of Community Environmental Protection. Onsite Sewage Branch. Montgomery, AL.

Bicki, Thomas J. 1989. Septic Systems: Operation And Maintenance Of On-Site Sewage Disposal Systems. Land And Water Number 15. Illinois Cooperative Extension Service. University of Illinois at Urbana-Champaign, IL.

Graham, Frances C. 1990. Correct Use Of Your Septic Tank. Information Sheet 1419. Mississippi Cooperative Extension Service. Mississippi State University. Mississippi State, MS.

Septic System Installation Record

Date installed: ______________________________

Building permit number: ______________________________

Name and address of licensed installer:

____

____

____

Size of septic tank: ______________________________ gal

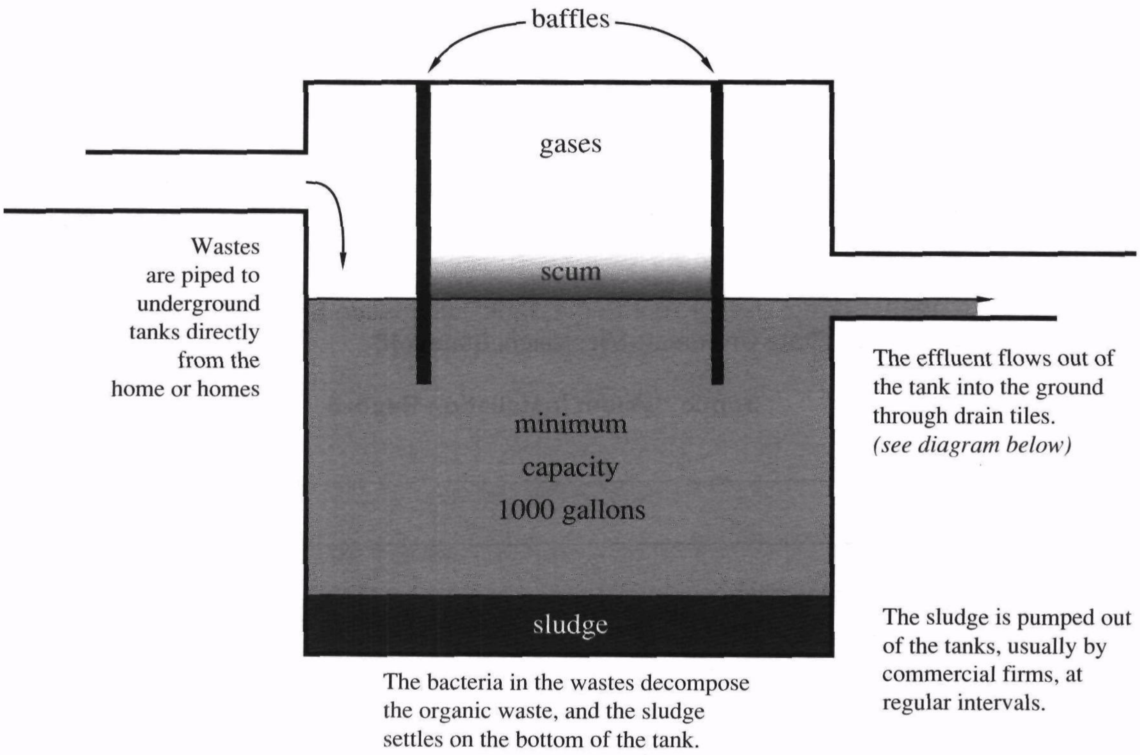
Amount of field lines: ______________________________ ft

Depth of trenches or bed: ______________________________ ft

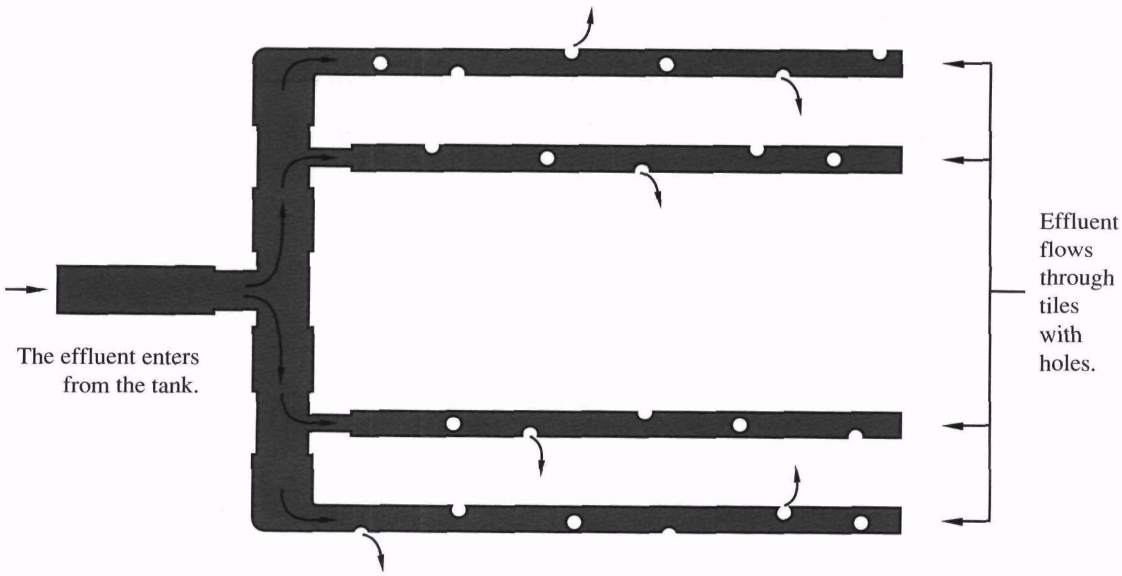
Sketch the layout of your septic system. (Include the distances from the tank and the absorption field to buildings and wells.)

Septic Tanks

Septic tanks are used for domestic wastes when a sewer line is not available to carry them to a treatment plant.



Aerial View of Drain Tiles



THE WATER SOURCEBOOK

WETLANDS/COASTAL

DILUTION AND POLLUTION

6-8

SUBJECTS:
Chemistry, Health, Math, Social Studies

TIME:
50 minutes

MATERIALS:
6 plastic cups per group
100-mL graduated cylinder
water
dropper
spoon
colored powdered drink mix without sugar
colored powdered drink mix with sugar
sugar (2 cups)
student sheet

OBJECTIVES

The student will do the following:

1. Compare pollution amounts in the same quantity of water.
2. Explain how even small amounts of pollution in a given water supply can be harmful.
3. Outline alternative waste removal techniques.

BACKGROUND INFORMATION

Water pollution is often difficult to detect. Large bodies of water have the capacity to dilute and disperse wastes. As a result of dilution and dispersion, the color, smell, and taste of contaminated water may not be any or much different than uncontaminated water. For this reason, seas and oceans have become a huge dumping ground for the world.

In 1988, the beaches on the northeast coast of the United States were closed because medical wastes such as hypodermic needles were washing up on shore. Each year during the 1990s, more than 500 tons of sewage is dumped into the Mediterranean from surrounding countries. Two thirds of this sewage has not been treated at all.

Minerals are naturally occurring chemicals that are dissolved in small amounts in our water sources. When small amounts of chemicals are dissolved in large bodies of water, the water is a dilute solution. When the levels of these chemicals increase due to ocean dumping, they may become harmful to the plants and animals of the area.

Swimmers in polluted areas can become ill with a variety of infections. Large amounts of contaminants can kill fish or make them unfit to eat. Shellfish such as oysters have the ability to concentrate certain toxins from polluted water in their tissues, making them harmful to eat. Algal blooms flourish in waters polluted with sewage and fertilizers. Much of the oxygen in water is used up during an algal bloom. This oxygen deficiency causes large amounts of fish to die and large deposits of slimy, odorous muck from dead vegetation on the bottom.

Terms

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

dilution: the act of making thinner or more liquid by adding to the mixture; the act of diminishing the strength, flavor, or brilliance of by adding to the mixture.

ADVANCE PREPARATION

A. *Prepare the unsweetened powdered drink mix for the students to taste. Add small amounts of sugar and have* the students keep tasting until the taste becomes sweet. Discuss the addition of the sugar in the drink and how the sugar cannot be seen but can be tasted. Relate this to the presence of chemicals in water.

B. Run off copies of the student sheet.

PROCEDURE

I. Setting the stage

A. Discuss any local bodies of water and the runoff that enters them. Have students brainstorm the various types of chemicals that may enter these waters.

B. Number the cups 1 through 6, using labels or a marker.

II. Activities

A. Mix the powdered drink mix using the recommended amount of sugar.

1. Use the graduated cylinder to place 100 mL of this prepared drink with sugar into cup 1 and 50 mL of water into cups 2 - 6. Have students taste the drink in cup 1 using a teaspoon. Make sure the students taste only 1 teaspoon at a time or you will run out of solution.

2. Now cup 1 is polluted. Place 50 mL of the "polluted water" from cup 1 into cup 2 using the graduated cylinder. Make observations and notes. Is this water less polluted than cup 1? What color differences did you notice? What is the difference in sweetness? (Have one student taste.) Record descriptions in chart.

3. Predict how dark the color will be and how it will taste in cups 3-6. Slowly add 50 mL of the "polluted water" from cup 2 to cup 3. Mix and record observations. Repeat this procedure for cups 4 - 6.

4. When these observations are recorded, compare cup 1 to cup 3, and then compare it to cup 6. Place a white sheet of paper underneath each cup to emphasize the color differences. Note the differences in taste.

B. Each student should complete the chart and answer these questions:

1. What signs were there that pollution still remained in the water even when the solution was diluted?

2. How many more times do you think the polluted water would need to be diluted in order not to cause color or taste changes?

3. Do you think that dilution is a good solution for pollution? Why or why not?

4. Does pollution always remain in the water? If not, where does it go? (Answer: sediments, air, bioaccumulates.)

III. Follow-Up

A. Have each student research at least two alternative waste treatment methods other than simply dilution.

IV. Extensions

A. Design a space ship that has a recycling system of waste and water management.

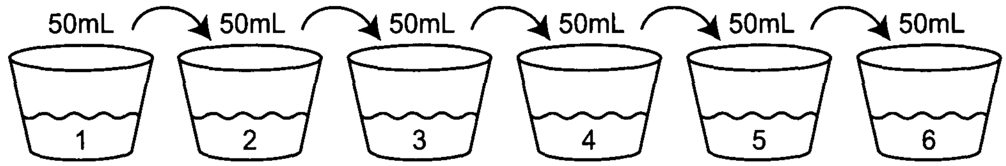
B. List different types of bacteria that are important in the breakdown of various pollutants in the water.

RESOURCES

Biological Science: An Ecological Approach, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1992.

Morgan, Sally, Ecology and Environment: The Cycles of Life, Oxford University Press, New York, 1995.

Directions: Dilute each water sample and record your color and taste observations.



Starting Liquid	100mL Kool-Aid	50mL water	50mL water	50mL water	50mL water	50mL water
Color						
Taste (Sweetness)						

1. What signs were there that pollution still remained even when the solution was diluted?

2. How many more times do you think that the polluted water would need to be diluted in order not to cause color or taste changes?

3. Do you think that dilution is a good solution for pollution? Why or why not?

CLEANING OIL SPILLS

6-8

SUBJECTS:
Chemistry, Drama, Math, Social Studies

TIME:
2 class periods

MATERIALS:
a large, deep pan for each group
water
a small aquarium net
motor oil in a small container for each group
pencils and paper
teacher sheet
student sheet

OBJECTIVES

The student will do the following:

1. List and compare the relative effectiveness of several methods and materials for cleaning up oil spills.

2. Explain why cleaning up an oil spill is usually difficult and only partially successful.

BACKGROUND INFORMATION

Each year more than three million tons of oil pollute the sea. The most visible source of oil pollution is accidents involving oil tankers. Oil spills caused by tankers such as the Amoco Cadiz off the coast of Normandy, France, in 1978 and the Exxon Valdez off the coast of Alaska in 1989 received a lot of media attention. The Amoco Cadiz accident spilled 223,000 tons of oil into the Pacific Ocean, while the Exxon Valdez spill dumped 10,080,000 tons of oil into Prince William Sound. The Exxon Valdez spill affected nearly 1,500 kilometers of the Alaskan coast line. Extensive damage was done to native wild life. These are only two examples of oil spills; there are many more.

Spills such as these, however, account for only a sixth of the oil that pollutes the sea each year. Half of the oil pollution is from land-based sources. Each time a tanker is rinsed, for example, oil is released into the sea. This accounts for one-third of the oil that pollutes the sea each year. Oil spills also occur during loading and unloading of ships in port.

Oil pollution has extreme detrimental effects on the environment. Oil cannot dissolve in water. It floats on or near the surface. Birds whose feathers become coated with oil lose their water-proofing qualities. Birds with oil-coated wings cannot fly well; therefore, many of them drown. Marine mammals, such as seals, also lose the water-proofing qualities of their fur.

Several methods have been used to clean oil spills. A common method is to use detergents and solvents that disperse and break up the oil. These detergents, however, can also have damaging effects on the environment. A process called bioremediation is also being used to clean oil spills. Bioremediation is the use of organisms such as bacteria and fungi to remove pollutants. Organisms that eat oil and oil-based products are called petrophiles. These petrophiles need oxygen, oil, and nutrients to survive and grow in numbers. In the case of an oil spill, oxygen and oil are already in abundance, however, nutrients are not. Nutrients in the form of fertilizers must be added to promote the process of bioremediation.

Term

bioremediation: the use of oil-eating organisms such as bacteria and fungi to remove pollutants.

ADVANCE PREPARATION

A. A day before you begin the activity, ask several volunteers to prepare to role-play a TV newscast team reporting on an oil spill that has just occurred.

B. Ask them to write their own script and to end with the idea that a group of specialists is on the way to clean up the oil spill.

PROCEDURE

I. Setting the stage

A. To begin the activity, ask the news team to give their special report. Videotape these reports if you have a camera.

B. Then, inform students that they have just been mobilized to clean up the oil spill. Let them group into teams of four.

C. Each team should plan how it will clean up its spill. Team members should decide what materials they will bring and what procedure(s) they will use. Suggest that each team bring at least four materials to try (one per student). Brainstorm with students what materials they might use to clean up the spill—detergents, cloth, paper, cotton, and so forth.

II. Activity

A. The following day, students will try to clean up their oil spill. Have each group fill its pan at least 3/4 full with water and pour 15 mL (1 T) of motor oil on the water.

B. Students should try to clean up the spill, using the materials they brought. (Note: You may wish to have aquarium nets available for them to scoop up any oil-absorbing materials they place on the water.)

C. Allow the students to add more oil if needed.

D. Students may retest their oil-spill materials and methods if they wish.

III. Follow-Up

A. Following the activity, ask students to rank the effectiveness of their materials and cleanup procedures. (Use a scale of 1 - 5, with 1 being the least effective and 5 being the most effective.)

B. Let each group report to the class. (They may wish to report as if they were an official panel.)

C. Then guide a class discussion by asking them to explain why it was difficult to remove the oil, how the oil reacted to their efforts, and how they disposed of their oil-coated materials.

D. Ask them to consider what would happen to the environment if large quantities of their clean-up materials were put into the ocean.

IV. Extensions

A. Have teams simulate another oil spill. Have all teams use the same clean-up method, but vary the time each team waits before beginning to cleanup the spill. Have them determine how the lag time before reporting an oil spill might affect the effectiveness of the cleanup.

B. Let students pollute their pan of water with different types of petroleum products and determine which type is easiest to clean up.

C. Have each team write a follow-up newscast to present the results of their cleanup procedures to the class.

D. Have the students discuss at least three reasons why cleaning up an oil spill is difficult and only partly successful.

E. Have the students discuss the following:

   1. From your oil spill cleanup activity, which material seemed to be the most effective in removing the oil?

   2. Explain what you think might happen if large quantities of your cleanup material were placed in ocean waters.

F. Ask the students to respond individually or in teams to the following:

   1. You are in charge of cleaning up a major oil spill. The people in a community affected by the oil spill want to know how you will clean up the spill and how long it will take. What will you tell them? (Explain in detail.)

RESOURCES

Battling Sea Pollution, Prentice Hall Earth Science Video.

Biological Science: An Ecological Approach, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1992.

Dashefsky, Stephen, Environmental Science: High School Science Fair Projects, Tab Books, Blue Ridge Summit, Pennsylvania, 1994.

Morgan, Sally, Ecology and Environment: The Cycles of Life, Oxford University Press, New York, 1995.

Water, the Life-Giving Resource, Prentice Hall Earth Science Video.

Information packet from Exxon detailing their cleanup procedures for the Alaskan oil spill. Packets may be ordered from Exxon.

STUDENT SHEET — CLEANING OIL SPILLS

Directions: Add 15 mL of oil to the pan of water and try your different cleaning materials. Describe how well each cleaned up the oil.

Cleaning Material	What you did and how well it worked
______	
______	
______	
______	

Note: If your material cleaned the oil well, you may have to add more oil to the water before trying a new cleaner.

Which material worked best?

____

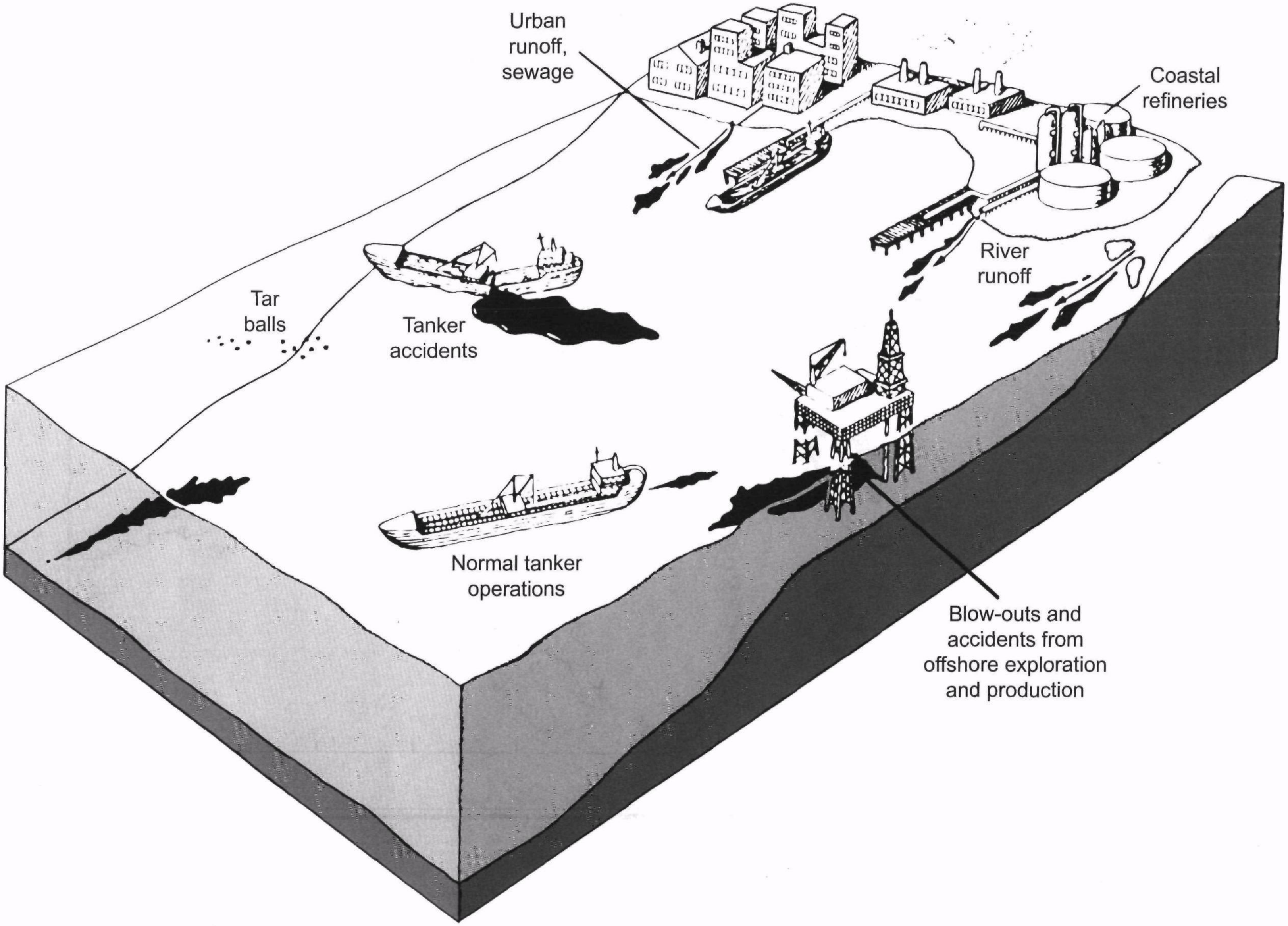
Which material(s) did not work well?

____

Would your material(s) work for oil cleanup in large areas? Why or why not?

____


N


Urban runoff, sewage
Coastal refineries
River runoff
Tar balls
Tanker accidents
Normal tanker operations
Blow-outs and accidents from offshore exploration and production

EFFECTS OF LOST SALT MARSHES

6-8

SUBJECTS:
Biology, Botany, Ecology

TIME:
2 class periods

MATERIALS:
magazines for "cut-out" pictures
transparencies
pens for transparencies
paper for drawing and charts
teacher sheets
student sheets

OBJECTIVES

The student will do the following:

1. Relate the importance of the salt marsh to the food chain.
2. Compose a position statement that will explain why the salt marsh should not be developed.

BACKGROUND INFORMATION

Salt marshes are coastal wetlands that exist in the intertidal zone. They are among the most productive ecosystems in the world. In fact, salt marshes produce more vegetation than tropical rain forests.

Wetlands perform functions that are helpful to people and the environment. Vegetation of the salt marsh is responsible for dampening the effects of wave action in coastal areas, which reduces the amount of erosion. Wetlands also have the ability to store excess storm water, which helps in flood control. Water is cleaned naturally as it flows through a wetland.

Another very important function of salt marshes is their "nursery" capability. They provide food and shelter to juveniles of many commercial and non-commercial animals. It is estimated that wetlands contribute between 60 percent and 90 percent of the fish caught for commercial reasons. A wide variety of birds depend on wetlands such as salt marshes for both breeding and feeding grounds.

Salt marshes, as well as other wetlands, provide many functions that are both valuable to people and important to the environment. These areas, however, are continuing to be destroyed to make way for commercial or home development. The long-term effects and costs of destroying wetlands will likely outweigh the short-term benefits of using the areas for industry or condominiums.

Terms

ecology: a branch of science concerned with the interrelationship of organisms and their environments; the totality or pattern of relations between organisms and their environment.

ecosystem: an ecological community together with its physical environment, considered as a unit.

salt marsh: estuarine habitat submerged at high tide, but protected from direct wave action, and overgrown by salt-tolerant herbaceous vegetation; aquatic grasslands ("coastal prairies") affected by changing tides, temperatures, and salinity.

ADVANCE PREPARATION

A. Gather magazines with pictures of salt marshes that show their inhabitants, plant life, and migratory life.

B. Gather magazines with pictures relating the importance of salt marshes to human life.

C. Have the following on hand: transparencies, pens, and paper for charts and drawing.

PROCEDURE

I. Setting the stage

A. Give the students the following scenario:

You are a local citizen whose total income depends on the seafood industry. You are the spokesperson representing the other fishermen in your area. It is your responsibility to convince the local government that it is not in the best interest of your community or of many surrounding communities for a condominium developer to dredge and fill in valuable marshlands in order to build a new condominium. You must include as many visuals as possible in order to get your point across. You may choose from the following materials or add to them if desired: transparencies, poster board, and pictures. You must also choose a speaker to present your report to the federal government.

II. Activity

A. Divide the students into teams to complete the assignment.

B. Have the teams choose a spokesperson who will present the position statements to the local government.

C. Have the teams write their position statements.

D. Have the teams create visuals to be used.

E. Be sure to have the teams choose a moderator to keep the team "on task."

III. Follow-Up

A. Have each team present its position statement and visuals.

IV. Extension

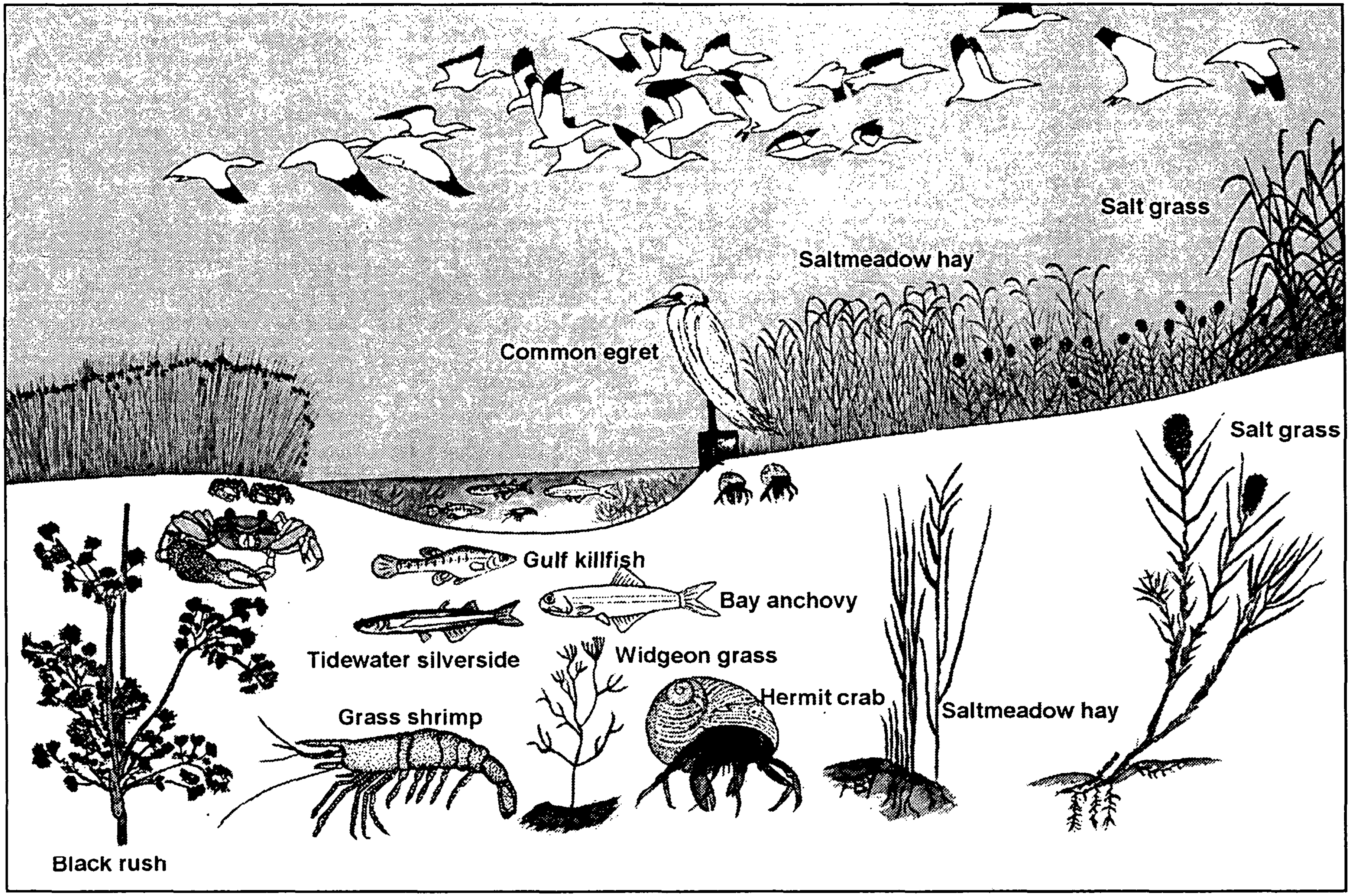
A. Choose teams to debate both sides of the issue. One team will support the developer's position and the other will support the environmentalists.

RESOURCES

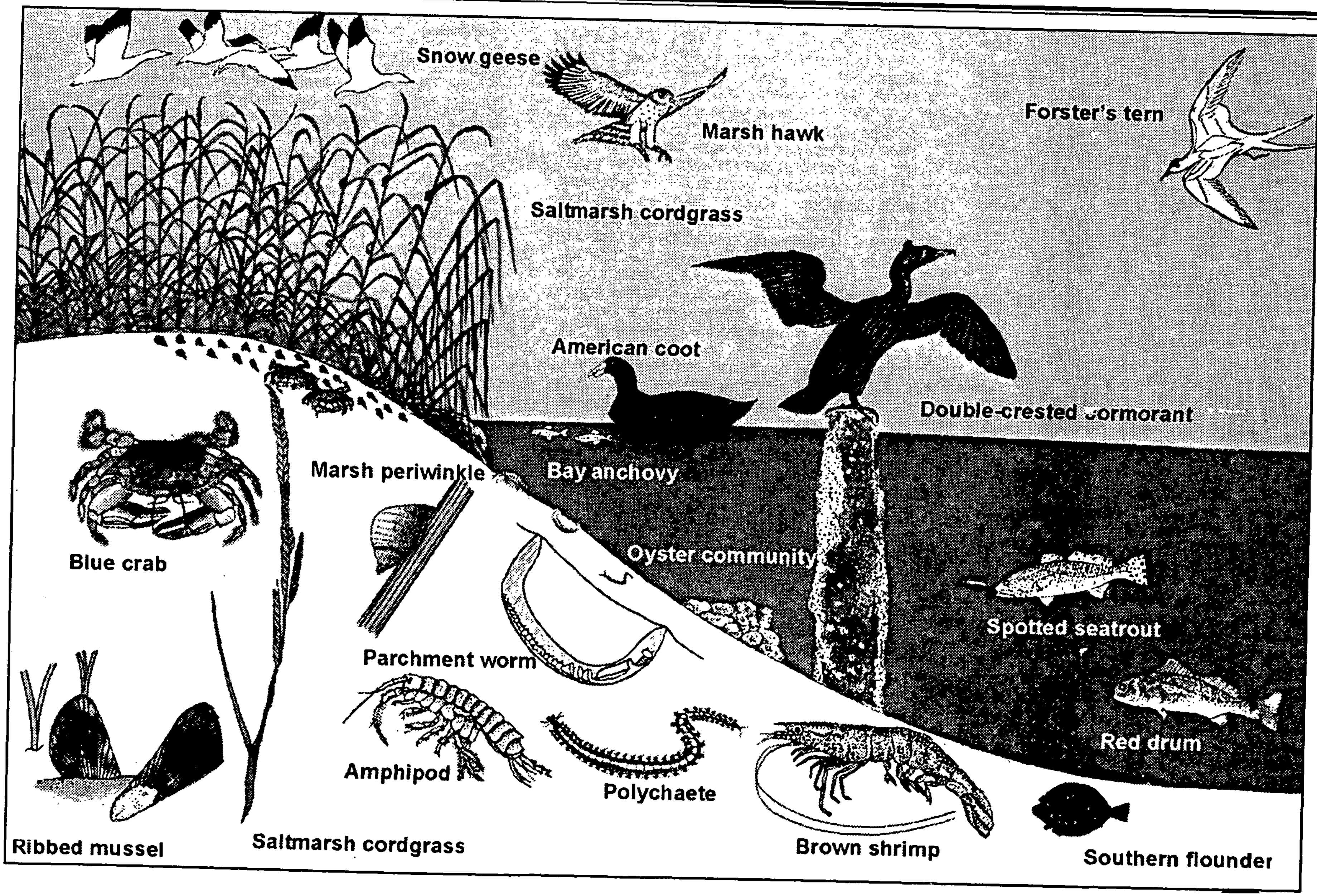
Dennison and Berry, Wetlands: Guide to Science, Law, and Technology, Noyles Publications, Park Ridge, New Jersey, 1993.

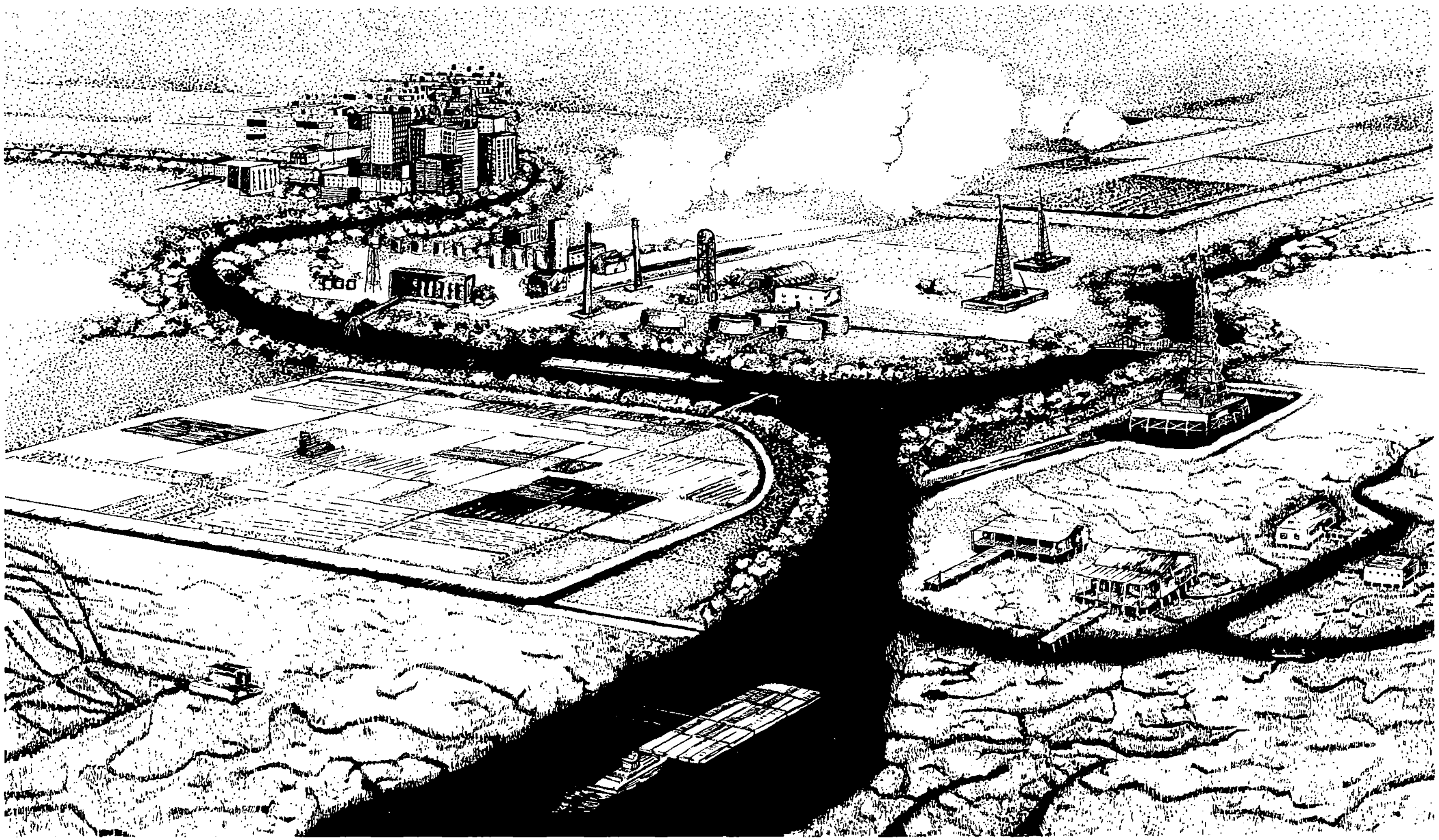
Smithey, William K., American Swamps and Wetlands, Gallery Books, New York, NewYork, 1990.

Tidal Salt Marshes: http://h2osparc.wq.ncsu.edu/info/wetlands/types3.html#sur

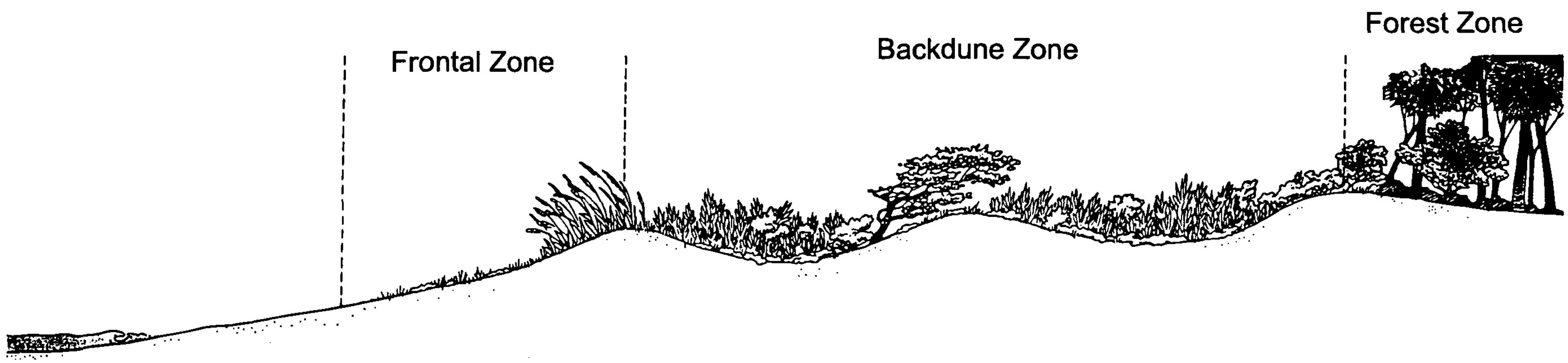

Salt grass
Saltmeadow hay
Common egret
Salt grass
Gulf killfish
Bay anchovy
Tidewater silverside
Widgeon grass
Hermit crab
Grass shrimp
Saltmeadow hay
Black rush

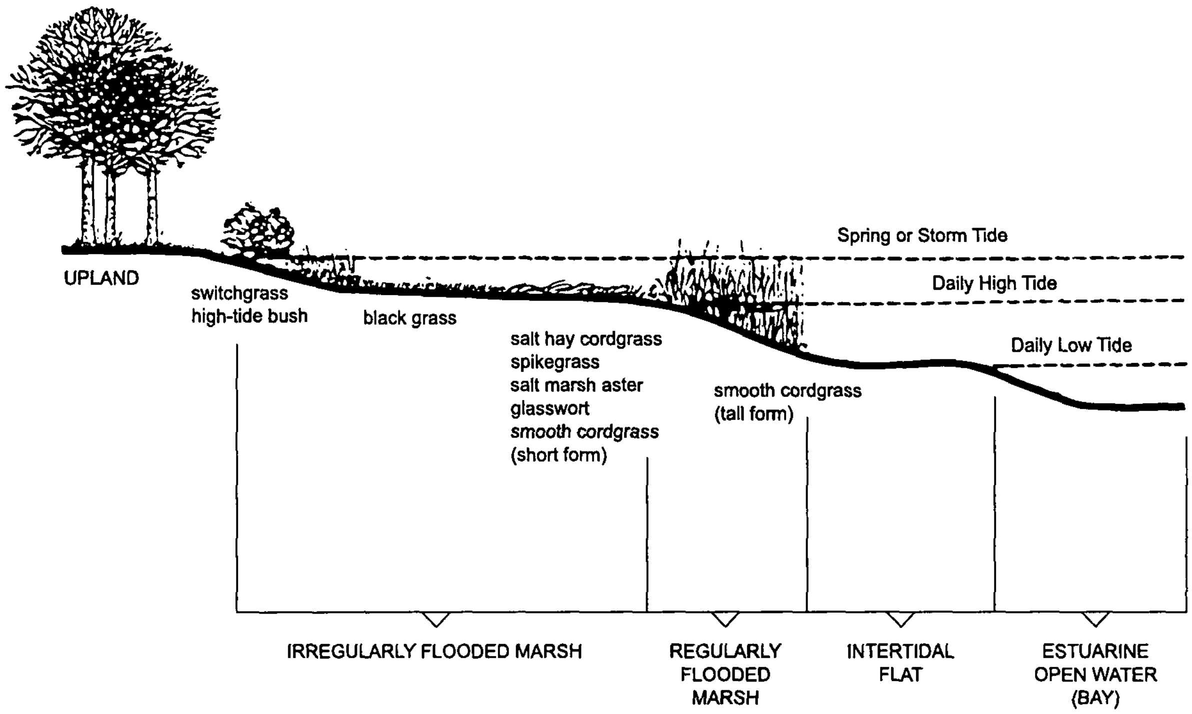
EFFECTS OF LOST SALT MARSHES





Two-thirds of the human population live on one-third of the world's land area adjacent to ocean coasts. Wetlands are drained for agriculture, housing, and industry. Man alters flooding patterns by constructing road embankments, canals with elevated spoil banks, and levees along streams. Ecological relationships are altered when man pollutes estuarine streams and lakes with sewage, fertilizers, and pesticides.


Frontal Zone
Backdune Zone
Forest Zone



A cross-section of a salt marsh.

LET'S GO FISHING!

6-8

SUBJECTS:
Biology, Ecology

TIME:
50 minutes

MATERIALS:
copies of state and federal fishing regulations for your area
student sheets

OBJECTIVES

The student will do the following:

1. List the freshwater and marine fish that are managed by state and federal regulations.

2. Explain the reasons for fishery management.

3. Discuss ethical/moral/legal reasons for abiding by regulations.

BACKGROUND INFORMATION

Overfishing, decreased habitat, and sometimes deteriorated water quality have caused a decline in some desirable fish populations. Management of a species may be mandatory if a species is to be saved from extinction. The National Marine Fisheries Service and, in most states, Departments of Conservation or Natural Resources are charged with monitoring fishery stocks and imposing regulations when necessary to protect a species. Fishing laws and regulations should maintain healthy fish populations while allowing recreational fishermen their sport and commercial fishermen the ability to make a living.

Regulations are flexible, changing from year to year to reflect changes in fish populations due to harvest, disease, predation, reproduction, weather, and so forth. In a good year, seasons may be extended or limits increased; in a bad year, seasons may be shortened and limits may be decreased. The objective is to maintain optimum numbers, with fish stocks neither depleted nor wasted.

Fishery biologists monitor the numbers of fish by sampling commercial and recreational catch tally reports of tagged fish, data on water quality, fish kills, bycatch, and weather events. After limits and seasons are set, enforcement is the province of the state departments of conservation, game and fish, and marine fisheries officers. Penalties include impoundment, fines, loss of license, and arrest.

Terms

bag limit: the number of a certain fish that can be caught each day.

bycatch: species other than shrimp that are caught in shrimp trawl nets

closed season: a time when a certain fish cannot be caught.

FL (fork length): the length of a fish from its mouth to the fork in its tail.

quota: the number or amount constituting a proportional share.

TL (total length): the length of a fish from its mouth to the end of its tail.

ADVANCE PREPARATION

A. Make copies for each student of the regulations for salt- and freshwater fish, the "catch" worksheets, and enough "fish" (slips of fish names) for each student to receive twenty slips (approximately 75 per page).

B. Cut the fish names apart.

PROCEDURE

I. Setting the stage

A. Discuss the students' knowledge of saltwater and freshwater fishing licenses, limits, and seasons for various game fish, who oversees compliance with regulations, and any anecdotes about confrontations with game wardens.

B. Ask them if they think fishing has changed much over the years (stories from parents or grandparents).

II. Activity

A. Tell the students to imagine they are going on a fishing trip. The weather is perfect, the fish are hungry, and everyone's having a wonderful time. Give them copies of fishing regulations and worksheet, and allow them to "catch" 20 fish each from your stock. Assign half the class to state waters and half to federal waters, and assign certain lakes and reservoirs by row or by lottery.

B. Ask the students to list on their worksheet each fish they caught, its size, and whether it was legal. Don't forget bag limits—even if the fish are legal size, you can only keep a certain number.

C. After they are all finished, find the tournament "winners" by number of fish, size, total number of fish inches, or any other categories you choose.

D. Select a couple of students to be "game wardens," checking on the legality of the "keepers" listed on the students' worksheets.

E. Ask the students the following questions:

1. Were any illegal fish kept? Why might a fisherman try to bend the law a bit?

2. Why shouldn't he or she?

III. Follow-Up

A. Ask the students to prepare graphs of their catches. Compare legal limits in state versus federal waters.

IV. Extensions

A. Invite a game warden as a resource speaker to class. Ask him or her to tell of the education and training required for his or her job description and to tell of interesting experiences he or she has had.

B. Find out more about the monitoring process. Visit a fish hatchery or tagging station. Ask a wildlife biologist to demonstrate the tests he or she makes on tagged fish (age using scales or otoliths, size, weight, range from release point, etc.).

RESOURCES

Cook, J. Coastal Concepts. Dauphin Island Sea Lab Special Report # 87-003.

Local Fish and Game, Wildlife Resources, or Marine Resources Departments.

Robins, C. Atlantic Coast Fishes. Houghton Mifflin, Boston, MA, 1986.

ling 30"

ling 33"

king mackerel 22"

spanish mackerel 14"

spanish mackerel 11"

bluefin tuna 28"

bigeye tuna 10 lb.

yellowfin tuna 6 lb.

white marlin 66" FL

sailfish 56" FL

red snapper 16"

vermillion snapper 10"

lane snapper 8"

misty grouper 10"

Nassau grouper 21" TL

black seabass 9"

Mako shark 50"

black seabass 11"

jewfish 300 lb.

red snapper 18"

scamp 6"

nurse shark 46"

lane snapper 7"

redfish 36"

bluefin tuna 24" FL

king mackerel 19"

mutton snapper 13"

ling 27"

ling 38"

king mackerel 20"

spanish mackerel 20"

red drum 12"

bluefin tuna 72"

bigeye tuna 6 lb.

yellowfin tuna 8 lb.

sailfish 58" FL

swordfish 65 lb.

red snapper 14"

yellow snapper 11"

gray snapper 12"

warsaw grouper 12"

black grouper 20" TL

amberjack 27"

blacktip shark 35"

amberjack 30"

red snapper 16"

red snapper 15"

scamp 18"

nurse shark 34"

lane snapper 8"

red drum 34"

bigeye tuna 8 lb.

king mackerel 23"

mutton snapper 14"

ling 34"

cobia 33"

king mackerel 24"

red drum 18"

redfish 20"

bluefin tuna 24"

bigeye tuna 7 lb.

blue marlin 85" FL

swordfish 60 lb.

blue marlin 90"

gray snapper 14"

mutton snapper 10"

red snapper 15"

speckled hind 7"

scamp 6"

jewfish 100 lb.

sand shark 30"

amberjack 36"

red snapper 17"

red snapper 14"

gag grouper 19" TL

tiger shark 60"

redfish 43"

cobia 33" FL

sailfish 58"

blue marlin 88"

mutton snapper 9"

speckled trout 15"

speckled trout 16"

striped bass 16"

striped bass 18"	striped bass 12"	black bass 14"
black bass 10"	black bass 16"	sauger 10"
walleye 6"	walleye 11"	sauger 15"
sauger 12"	sauger 14"	white bass 13"
white bass 10"	white bass 15"	crappie 9"
yellow bass 12"	yellow bass 13"	crappie 8"
crappie 10"	crappie 11"	crappie 8"
crappie 13"	crappie 10"	bream 7"
bream 6"	bream 6"	bream 8"
bream 7"	bream 7"	bream 9"
bream 8"	bream 8"	bream 10"
bream 9"	bream 10"	bream 13"
bream 11"	bream 12"	gar 15"
rainbow trout 10"	rainbow trout 9"	gar 20"
rainbow trout 13"	rainbow trout 14"	gar 24"
smallmouth bass 13"	smallmouth bass 12"	bream 12"
largemouth bass 15"	largemouth bass 16"	
speckled trout 13"	pompano 16"	
pompano 12"	pompano 11"	
striped bass 15"	striper 18"	
	striper 11"	

Assign half the class to be in federal waters, the other half in state waters. Assign certain lakes and reservoirs by rows or lottery.

A SAMPLE STATE RECREATIONAL FISHING CHART

SPECIES	**ZONE**	**WHEN**	**BEST**	**SAMPLE STATE**	**FEDERAL**	
					Size/Bag Limit	Size/Bag Limit
Amberjack	3, 4	year round	May – August	28" FL/3	same	
Black Grouper	4	year round	February – April	20" TL/5	same	
Bluefish	1, 2, 3	April – October	May – June	none	none	
Cobia (Ling)	2, 3, 4	April – October	April – May	37" TL/2	33" FL/2	
Croakers	1	year round	year round	none	none	
Dolphin (Mahi Mahi)	3, 4	May – October	July – October	none	none	
Flounder	1, 2	year round	November – February	none	none	
Jack Crevalle	1, 2, 3	April – October	July – August	none	none	
King Mackerel	2, 3, 4	April – October	July – October	none/2*	20" FL/2	
Pompano	2	April – October	April – October	12" TL/none	none	
Red Drum (Red Fish)	1, 2	year round	October – November	16" min – 26" max TL/3	CLOSED	
Sheepshead	1, 2	October – March	December – March	none	none	
Snapper (Red)	3, 4	year round	May – September	14" TL/7**	same	
Snapper (Vermillion)	3, 4	year round	May – September	8" TL/none	same	
Spanish Mackerel		2, 3	April – October	May – June	none/10	12" FL/10
Speckled Trout	1, 2	year round	September – December	14" TL/10	none	
Tarpon	1, 2	July – October	August	60" TL***	none	
Tuna (Yellowfin)	4	May – September	May – September	none	7 lbs.	
Wahoo	4	May – September	May – September	none	none	

LEGEND FL = Fork Length, measure tip of snout to fork in tail. TL = Total Length, measure tip of snout to tip of tail.

* = When federal season is closed, King Mackerel Bag Limit is reduced to 1 per person.

** = Bag Limit of 10 other snapper species combined (Gray, Mutton, and Yellowtail only) in addition to a limit of 7 Red Snapper.

*** = $50, tag required to possess, kill, or harvest each tarpon.

Zones: 1 = Bays, shorelines, wharves, inland waters, etc. 2 = Inshore waters of Gulf, off or near jetties, in surf, etc. (0-1 mile).
3 = Offshore blue water in open Gulf (1-9) miles). 4 = Deep water (10-60 miles).

NOTE: Bag Limits are PER DAY. Sample state waters = 0-3 miles; neighboring state waters = 0-9 miles. Federal waters = state boundary-200 miles.
ALL information subject to change. Contact State Marine Resources 968-7576.

FISH	SIZE	KEPT OR THROWN BACK

PICTURES, PEOPLE, AND POLLUTION

6-8

SUBJECTS:
Art, Biology, Language Arts

TIME:
one school day field trip plus 50 minutes in class

MATERIALS:
disposable camera for each group of five students
garbage bags
notebook for each student

OBJECTIVES

The student will do the following:

1. Chart types of marine litter, the causes, effects, and solutions for this problem.
2. Create a photo essay.

BACKGROUND INFORMATION

Certain visions and words automatically come to mind when describing a beach, lake, river, or pond: long expansions of snow white sand; sparkling, clean water with gulls methodically diving in and out; and rivers overflowing with an abundance of fish and other seafood.

The ocean covers about 70 percent of the Earth's surface. It is home to millions of fish, crustaceans, mammals, microorganisms, and plants. It is a vital source of food for both animals and people. Fishermen catch over 90 million tons of fish each year. Fish are the principal source of protein for many developing countries.

People also depend on the sea for many of their medicines. Marine animals and plants contain many chemicals that can be used to cure human ailments: an estimated 500 sea species yield chemicals that could help treat cancer.

Unfortunately, people have treated the sea as a dumping ground for thousands of years. Tons of garbage and sewage are dumped into the ocean each year. Industrial waste is also dumped into the sea. Types of marine pollution include heavy metals, toxic chemicals, pesticides, fertilizers, sewage, oil, and plastics.

Marine pollution frequently originates on land, entering the sea via rivers and pipelines. This means that coastal waters may be dirtier than the open seas, with estuaries and harbors badly affected. Some pollution enters the marine environment from the air when poisonous gases and aerosol particles drop into the sea. Additional pollution is actually created at sea by activities such as dredging, drilling for oil and minerals, and shipping.

Terms

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

water pollution: the act of making water impure; the state of water being impure.

ADVANCE PREPARATION

A. Collect magazine pictures and articles or newspaper articles on types of marine litter.

PROCEDURE

I. Setting the stage

A. Show a video about marine pollution.

B. Use the magazine or newspaper articles and pictures to lead a discussion on types of marine pollution.

II. Activity

A. The students will be divided into groups of four or five and taken on a field trip to a local beach, lake, or river to photograph types of marine litter. Each group will be given a disposable camera.

B. Students will collect and chart the types of marine litter found to use for a school-wide display on marine litter.

III. Follow-Up

A. Have each group compile a photo-essay to present to the class.

B. Have the students prepare and display their collection of marine litter for the entire school to view.

IV. Extensions

A. Students can display their collection of marine letter at a local library or even another school.

B. Students can present their displays and photo essays at the school P.T.A.

RESOURCE

Marine Pollution: http://www.panda.org/research/facts/fct_marine.html

PLASTIC WASTE

6-8

SUBJECTS:
Chemistry, Ecology, Social Studies

TIME:
50 minutes

MATERIALS:
plastic waste from home
outside or plastic litter
student sheets

OBJECTIVES

The student will do the following:

1. Describe the effects of plastic waste on aquatic wildlife.

2. Identify specific actions they can take to help remedy the problem.

BACKGROUND INFORMATION

Plastics are made from synthetic resins such as acrylic, cellophane, celluloid, Formica™, and nylon, which are moldable when they are heated. For this reason, plastics can be made into different shapes and put to a variety of uses. Some plastics become resistant to heat after they have been molded. This type can be used for cooking since it does not melt from the heat.

Plastics are extremely versatile, cheap to make, and lasting. For these reasons, plastics have revolutionized life in the twentieth century. Houses, offices, factories, cars—all contain items made from plastic. Because of their many benefits and favorable properties, the use of plastics is unlikely to decline.

The advantages of using plastics, however, can lead to disadvantages for the environment. The fact that plastic is cheap means that very often it is used to make low-value items such as bags and bottles that people do not bother to keep. It is also used by manufacturers and shops for packaging. This means that it usually gets thrown away as soon as people get their purchases home.

People throw away thousands of tons of plastic each year. It is estimated that by the year 2000, the amount of plastic we throw away will increase by 50 percent. Examples of plastic pollution include plastic holders for beverage cans, plastic bags, and lost or discarded fishing line. As a result of plastic pollution, millions of mammals, birds, reptiles, and fish die every year.

Plastic waste creates particularly severe problems at sea, where it entangles marine wildlife and gets eaten. A recent US report revealed that 100,000 marine mammals die each year because they eat or become entangled in plastic rubbish. Entangled plastic may kill slowly over a period of months or years, biting into the animal, wounding it, and causing it to lose blood or even limbs. Worldwide, 75 seabird species are known to eat plastic articles, which remain in their stomachs, blocking digestion, and possibly causing starvation. The world's sea turtle population has been greatly affected by plastic pollution. Turtles choke on plastic bags that they have mistaken for jellyfish. Plastic litter can be found on land as well as in the marine environment. Plastic holders for beverage cans, plastic bags, and lost or discarded fishing line on land can also be damaging to wildlife.

Terms

aquatic life: plants, animals, and microorganisms that spend all or part of their lives in water.

litter: rubbish discarded in the environment instead of in trash containers.

marine: of or relating to the sea.

nonbiodegradable: materials that cannot be broken down by livings things into simpler chemicals.

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

ADVANCE PREPARATION

A. Have students collect and save every piece of plastic waste produced in their home for a two-day period.

B. Have students clean all plastics at home before bringing them to school.

C. If possible, enlarge the plastic code system to poster size or make a transparency of it.

PROCEDURE

I. Setting the stage

A. Discuss plastics in background information. Ask students questions about places where they have seen plastics lying around.

II. Activities

A. Ask students to separate their plastics into categories according to the Plastic Code System and list them on the Plastic Code Analysis Sheet. Have them classify the plastics in terms of how they might be perceived by aquatic wildlife as food, e.g., very likely to be perceived as food, somewhat likely, or unlikely. Have the students with plastic code 1 items hold them up for the class to see. Repeat with each code number so students have a good idea of which items belong in each category. Identify the species that might attempt to eat the plastic.

B. Ask the students to hypothesize about how these materials might affect aquatic animals. Provide literature for them to check their hypothesis.

C. Ask students to summarize what they have learned about the potential hazards to aquatic wildlife from plastic waste material.

D. Ask students to list their collected litter by classifications given to plastics by the American Plastics Council. Which were most prevalent? Why?

II. Follow-Up

A. Invite the students to survey the school yard for plastic litter. Then have them separate the plastics into categories and identify them. Why might these certain types of plastics be found on a school campus? Investigate the negative impact on animals in the community. If there is damaging plastic litter in the school yard ask the students to create an action plan that will increase awareness of the problem and help take care of it by setting up a plastic recycling depot.

III. Extensions

A. Have students contact local environmental, animal welfare, and wildlife groups to see what is being done about the impact of litter on local wildlife and if specific help is needed.

B. Have students establish a litter patrol. Target areas in your school yard. Establish scheduled tours of these areas to pick up plastic and other forms of litter.

RESOURCES

Aquatic Project Wild, Western Regional Environmental Education Council, 1987. Project WILD and Aquatic WILD, PO Box 18060, Boulder, CO 80308-8060, (303) 444-2390.

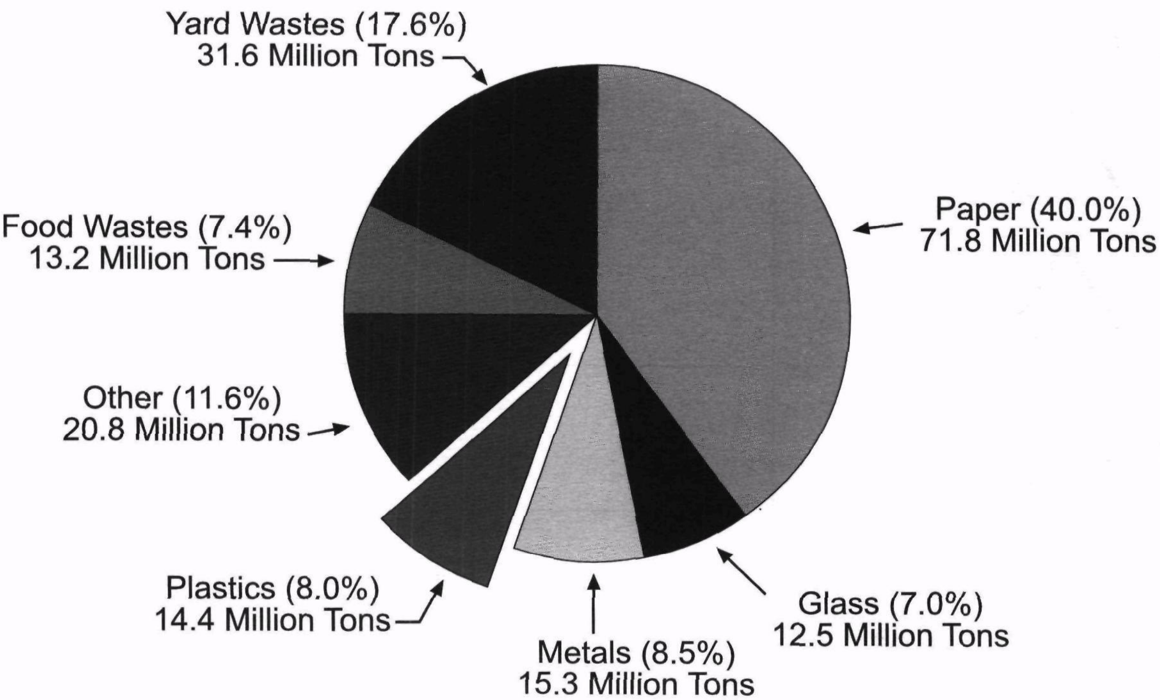
EPA Environmental Fact Sheet: http://es.inel.gov/techinfo/facts/epa/plstc4fs.html

Plastic Pollution: http://www.panda.org/research/facts/fct_plastic.html

Plastic Container Code System
(found on the bottom of coded containers)

Code / Abbreviation	1 PET	2 HDP	3 V	4 LDP	5 PP	6 PS	7 OTHER
Full Name	Polyethylene Terephthalate	High Density Polyethylene	Vinyl	Low Density Polyethylene	Polypropylene	Polystyrene	Other resins or a mixture of resin types
Percentage of Total Bottles	20 - 30%	50 - 60%	5 - 10%	5 - 10%	5 - 10%	5 - 10%	5 - 10%
Can Be Transparent	Yes	No	Yes	No	Yes	Yes	Yes
Typical Containers	soft drink, instant coffee	milk, laundry detergent	liquid dish soap, peanut butter	grocery bags, coffee can lids	deli tubs, bottle caps, straws	foam cups, trays, egg cartons	catsup and syrup bottles

Materials Generated in MWS by Weight, 1988



(Source: Characterization of Municipal Solid Waste in the United States: 1990 Update: U.S. EPA)

Plastic Code Analysis

NUMBER SYMBOL	LETTER CODE	PRODUCT	OBSERVABLE PACKAGE PROPERTIES
1 2 3 4 5 6 7	PETE HDPE V OR PVC LDPE PP PS OTHER	In this column, write the name of the product.	Flexible/Rigid Transparent/Opaque Translucent/Color White crease when crushed

POLLUTION . . . POLLUTION . . . POLLUTION

6-8

SUBJECT:
Art, Chemistry

TIME:
2 class periods

MATERIALS:
poster board
markers
magazines for pictures

OBJECTIVES

The student will do the following:

1. List specific types of water pollution.

2. Design a poster or T-shirt logo depicting specific types of water pollution.

BACKGROUND INFORMATION

Household chemical, fertilizers, and heavy metals are all hazardous materials. Worldwide, over 70,000 different chemicals are used daily, and each year between 50 and 1000 new synthetic compounds are introduced. More than six billion tons of waste are disposed of annually in the United States. Of that, 270 million tons—enough to fill the New Orleans Superdome 1500 times—are hazardous. Some of this waste is chlorine, which destroys aquatic habitat by upsetting the levels of the water and killing certain species of blue-green algae. Pesticides such as DDT have brought several bird species to the brink of extinction. Heavy metals, such as mercury, in water supplies can have a damaging effect on unborn fetuses. The list of hazardous materials could go and on. Some specific types are described in the following information.

Many of the shelves, coasts, lakes, and estuaries within U. S. waters, particularly near urban centers, contain polluted sediment. Heavy metals, radioactive waste, organic chemicals, and nutrients have been introduced to these environments through natural processes, by intentional disposal, and by accidental spills. The contaminants are derived from both point sources, such as industrial discharge and sewage treatment plants, and non-point sources, such as agricultural and urban runoff and atmospheric deposition. The presence of such materials in the Nation's coastal waters and lakes and their accumulation in sediment have created problems associated with health and safety, biological resources, and recreational activities. Dredging and environmentally sound disposal of contaminated and non-contaminated material is essential to the commercial viability of many U.S. ports. There is considerable public concern and political attention focused on the impact of past and present use of our waters as waste disposal sites.

It's easy to blame industry for putting toxic chemicals in the ocean, but have you looked under your sink or on the basement shelf lately? As much as 25 percent of all toxic waste originates in the home. Anything we put down the sink or toilet will eventually make its way to the ocean. Toxic chemicals are present in many cleaners, paints, antifreezes, solvents, and prescription drugs.

About 97 percent of marine litter comes from people who unthinkingly or intentionally throw garbage onto beaches or into the water. The other 3 percent is lost fishing gear. Pollution is not only an eyesore , it can injure, or even kill, marine wildlife. Animals often become entangled in ropes, six-pack rings, nets, and other refuse. Plastic bags, plastic fragments, and foam pieces are often mistaken for food. In one study in which 58 seabirds were sampled near the British Columbia coast, 75 percent had plastics in their stomachs.

When the Exxon Valdez ran aground, it spilled 42 million liters of oil. However, according to the Southam News Agency Environment Project, every year in Canada alone, 300 million liters of motor oil "vanish" into the environment. That's equivalent to seven and one-half Exxon Valdez disasters each year. Where does the oil go?

In reality, oil spills or engines leaking onto roads and driveways, or spilled fuel from automobiles and boats, all must go somewhere. These petroleum products are most often washed down storm drains where they ultimately flow out to the ocean. Oil spilled directly in the sea is another serious problem. It is estimated that 10 million liters of oil enter Georgia and Juan de Fuca Straits from the bilges of ships and pleasure boats each year.

Air pollution is not just a problem to the air – it's also a problem to the ocean. Car exhaust, wood burning, industrial emissions, sprayed herbicides and pesticides all add contaminants to the air which fall back to Earth when it rains. These polluting particles often fall directly in the ocean since most human populations live near the coast. Once air-borne pollutants enter the ocean, they can be absorbed by animals and plants in the plankton and enter ocean food chains.

Human sewage can contain intestinal bacteria, disease-producing organisms, viruses and eggs of intestinal parasites. About half of the dry weight of human solid waste is bacteria. One of the bacteria present in the feces of humans and other animals is the coliform bacteria, *Escherichia coli*, or *E. coli*. Ocean water samples are tested for the presence of *E. coli* using a "coliform count." Beaches are often closed and shellfish harvesting prohibited due to high coliform counts.

Terms

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

marine pollution: pollution found in the oceans, bays, or gulfs.

ADVANCED PREPARATION

A. Show a video on marine animals and their habitat.

B. Gather materials/products that cause pollution and magazines with pictures of products of pollution.

PROCEDURE

I. Setting the stage

A. Have a discussion using many visuals (especially actual products of pollution), pictures, or slides to help students identify types of pollution.

II. Activities

A. Have students do research to identify specific types of pollution. Research should include the following:

   1. Disposal of pollutants.

   2. Intended use of pollutants.

B. Students will design a poster or T-shirt depicting types of pollution.

III. Follow-Up

A. Students will turn in a written report on water pollution and its effects on the environment.

IV. Extensions

A. Students may present their reports in class.

B. Clubs might adopt the logo to be placed on their club T-shirt (Example: Science Club).

RESOURCES

365 Ways to Save Our Planet, Page a Day Calendar, Workman Publishing, New York.

Hazardous Waste: http://www.runet.edu/~geog-web/GEOG340/HazWasteProb.html

Marine Pollution: http://www.panda.org/research/facts/fct_marine.html

Pollution: http://walrus.wr.usgs.gov/docs/natplan/pollution.html

http://oceanlink.island.net/marpoll.html

SALT TOLERANCE OF PLANTS

6-8

SUBJECTS:
Botany,Math,Geography

TIME:
The experiment runs over a six-week period; in-class time 2-3 periods

MATERIALS:
four plants per pair of students
markers
poster paper
salt
rulers
student sheets

OBJECTIVES

The student will do the following:

1. Identify plants which can tolerate various levels of salt.

2. Demonstrate the steps of the scientific method by working through a classroom experiment.

3. Compare classroom results to actual plants found in a wetlands habitat.

4. Locate geographic areas of natural wetlands.

BACKGROUND INFORMATION

Salt marshes are a type of coastal wetland that occurs in temperate estuarine environments. These areas are flooded by incoming tides carrying saltwater. Salt marshes can also receive an inflow of freshwater from rivers, runoff, or groundwater. Freshwater inflow is important in diluting the salinity of the system. Salinity is the major stressor in this type of wetland system and limits species to those that have evolved adaptive mechanisms for living in a salty environment. Plants that have adapted to living in salty environments are called halophytes.

Salt marshes are flooded during high tide. As the tide recedes, land becomes exposed again. During this time the marsh often receives freshwater runoff. The plants in the high marsh, or irregularly flooded part of the marsh, are only covered on extremely high tides. The plants of the low marsh, or regularly flooded part of the marsh, are flooded daily by high tides. This produces an obvious distribution of plants that are adapted to specific conditions within the marsh. Plants are found in distinct zones as a result of salinity and tidal fluctuations. Plants living in the low marsh are limited to species that are extremely tolerant of water-logged soils.

Smooth cordgrass *(Spartina alternaflora)* is an example of a species that grows in the low marsh. Irregularly flooded marsh vegetation is more diverse. Species that grow in this area include salt marsh hay *(Spartina patens)*, salt grass *(Distichlis spicata)*, black grass *(Juncus gerardii)*, and black needle rush *(Juncus roemerianus)*. Both smooth cordgrass and black needle rush have a "short" and "tall" form. In both species, the tall forms occupy the areas closer to open water (low marsh). The short forms occupy the areas that are less frequently flooded (high marsh).

Terms

habitat: the arrangement of food, water, shelter, and space suitable to animal's needs.

marsh: wetland dominated by grasses.

population: the organisms inhabiting a particular area or biotope.

salinity: an indication of the amount of salt dissolved in water.

wetland: an area that is regularly wet or flooded and has a water table that stands at or above the land surface for at least part of the year.

ADVANCE PREPARATION

A. Contact any wetlands research area, if possible, and request information on the plants associated with the various water levels found in wetlands. Display in the classroom any posters or resource information that may be available.

B. Discuss background information with students. Show a film by Bill Nye, the Science Guy, about wetlands.

PROCEDURE

I. Setting the stage

A. Explain the importance of wetlands to students. Ask them to think about various reasons why some plants might not grow in a wetland environment.

II. Activity

A. Students will work with a partner. Each pair will need four plants of the same species and as close to the same size as possible. Make sure that each group uses different types of plants so that many different groups are represented.

B. Students will measure each plant and various mixtures of water and saltwater over a period of time. The experiment must last at least one month for results to be effective.

C. Keeping accurate records is extremely important so that the resulting graphs are accurate and easily comparable.

D. At the end of the experiment, each pair produces a graph of the data that has been collected. Use different colors to represent each of the four plants. Line graphs and bar graphs work well and are easy to see at a glance.

E. As a class, compare which plants grew better than others and therefore were better able to tolerate the salt.

III. Follow-Up

A. If possible, take a field trip to a local wetlands area. Any marsh, bog, or similar area will do. Observe the plants that are located in the area.

B. Each pair will produce a poster of plants found in a typical wetlands environment.

IV. Extensions

A. Use a world map and locate areas which may have natural wetlands and then research them to see if the habitats are still undisturbed.

B. Students will write letters to local, state, and government agencies that govern the destruction of wetlands, either for development or agriculture. Students will research programs that affect wetlands and remember the EPA wetlands hotline: 1-800-832-7828.

RESOURCES

The Alabama Cooperative Extension Service Publications, 1994.

Bill Nye the Science Guy videos. Available from Bill Nye, Outreach Dept., KCTS, 401 Mercer, Seattle, WA 98109.

Dennison and Berry, Wetlands: Guide to Science, Law, and Technology, Noyles Publications, Park Ridge, NJ, 1993.

Irby, B., McEwen, M., Brown, S., and Meek, E., Marine Habitats, University Press of Mississippi, Hattiesburg, MS.

Project Wet: Curriculum and Activity Guide, Watercourse and Western Regional Environmental Education Council, 1995. Obtain from Project Wet: Water Education for Teachers, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057 (Fax: 406-994-1919; e-mail: rwwet@msu.oscs.montana.edu).

Tidal Salt Marshes: http://h2osparc.wq.ncsu.edu/info/wetlands/types3.html#sur

Directions: Record your procedures and observations on this sheet. Write the actual dates (every three days) at the top of the chart. You will graph your results on the following sheet. (NaCl is sodium chloride, or salt.)

Date													
Plant 1 water only	height												
	color												
Plant 2 water & NaCl													
Plant 3 water & _____ NaCl													
Plant 4 water & _____ NaCl													

SEA LEVEL RISING

6-8

SUBJECTS:
Earth Science, Math, Geography, Language Arts

TIME:
5 class periods plus a day for field trip

MATERIALS:
notebook and pencil for information gathering
appropriate materials (suggested by students) for writing and presenting proposals (overhead transparencies, computer-generated visuals, pictures, samples taken, etc.)
teacher sheets

OBJECTIVES

The student will do the following:

1. List suggestion strategies for coping with possible effects of sea-level rise in coastal areas.
2. Investigate and graph the sea-level stages from one year to the next.

BACKGROUND INFORMATION

Increasing atmospheric concentrations of carbon dioxide and other greenhouse gases (Example: methane, nitrous oxide, ozone in the troposphere and stratosphere, and chlorofluorocarbons) are resulting from human activities such as the burning of fossil fuels. Increased carbon dioxide levels could cause the climate to warm. Scientists refer to this process as global warming. Global warming could result in changes in rainfall patterns, changes in sea level, and changes in ecosystems. This amounts to a serious environmental threat has never before been experienced in human history.

The global mean sea level may have already risen by around 15 centimeters during the past century. Climate change is expected to cause a further rise of about 60 centimeters (2 feet) by the year 2100. Forecasts of a rising sea level are based on tentative climate model results, which indicate that the Earth's average surface temperature may increase by 1.5-4.5°C over the next 100 years. This warming would cause the sea to rise in two ways: through thermal expansion of ocean water and through the shrinking of ice caps and mountain glaciers. Sea level would not rise by the same amount all over the globe due to the effects of the Earth's rotation, local coastline variations, changes in major ocean currents, regional land subsidence and emergence, and differences in tidal patterns and sea-water density. Higher sea levels would threaten low-lying coastal areas and small islands. The forecasted rise would put millions of people and millions of square kilometers of land at risk.

ADVANCE PREPARATION

A. This activity could be used during a unit on current environmental issues.

B. Prior to the activity, students should have studied global warming and sea-level rise in other coastal regions.

PROCEDURE

I. Setting the stage

A. This activity may be conducted in any coastal area.

B. Students will take a field trip to a shore to gather data for this activity.

C. They can observe (1) a marsh area, (2) a ship-building or industrial area, (3) a waterfront area, (4) a residential area, or (5) an unpopulated beach.

D. At each area, the teacher will indicate the height to which the sea level might rise if it rose two feet.

Students will understand that this amount of sea-level rise cannot be accurately determined at this time, and that an educated guess will have to be made. This should not affect the impact of the activity.

E. For the marsh area, students will note how the predicted sea-level rise would affect plants and animals. They will also note if there is sufficient undeveloped upland area for the marsh to move further inland.

F. For the other areas, students will concentrate on buildings and other structures that would be affected and the economic impact in terms of job loss, etc.

II. Activity

A. In class, students will use the information they gathered to develop a long-term strategic plan for the area.

B. They will form three planning teams—one representing the marsh area, one the ship building or industrial area, and one the waterfront property.

C. Each team will elect a "Coastal Planning Manager."

D. Using ideas from coastal action plans for sea-level rise in other coastal areas and their own ideas, teams will develop a series of proposals to help deal with the problems they identified.

E. Each team will present their proposals to the class. (Teams may decide on the manner in which they want to record and present the proposals.)

F. The class may suggest modifications to the proposals. When proposals are finalized, they will be typed and copied for each student.

III. Follow-Up

A. Students can present proposals to local government officials. They can urge the officials to consider the possible effects of sea-level rise in long-range planning.

B. Using a computer, students can print out their finalized proposals in large type or banner-style. They can then post these in a highly visible area of the school.

C. Students can start an "Environmental Solutions" display. Beginning with sea-level rise strategies, they would list and display solutions for each environmental crisis they study.

IV. Extensions

A. Ask students to imagine they are a city official in a coastal area. Have them describe the problems they envision concerning sea-level rise and strategies they would suggest for coping with them.

B. Have students identify the causes of the predicted rise in sea level. What strategies could they suggest for reducing the possibility that a rise in sea level will occur?

C. Have students describe the ideal coastal city, taking into account the predicted rise in sea level. Have them draw a map showing the locations of structures in their city.

RESOURCES

Biological Science: An Ecological Approach, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1992.

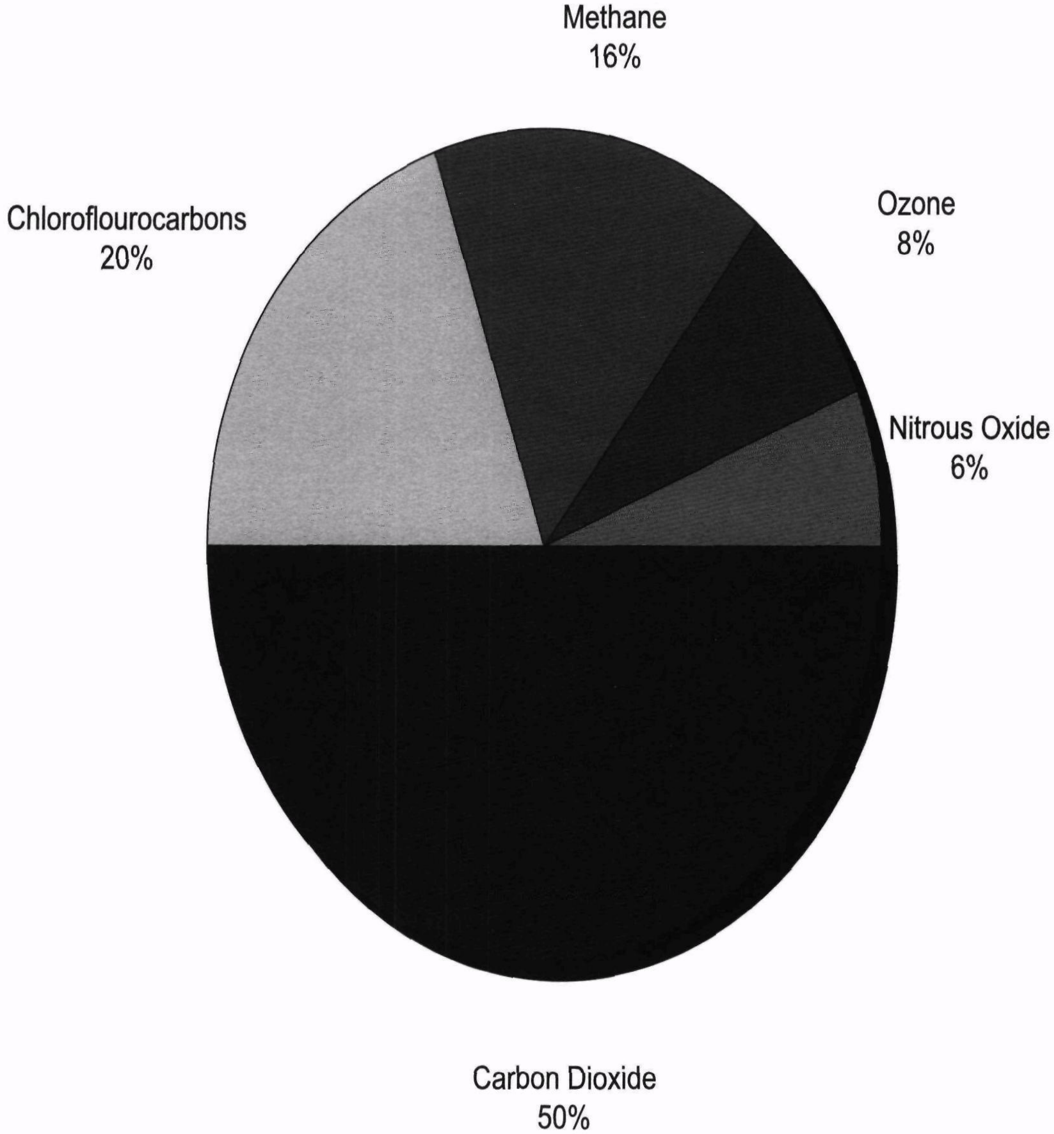
Climate Change and Sea-Level: http://www.unep.ch/iucc/fs102.html

Cownaw, Gregory. "The Significance of Rising Sea Levels," The Science Teacher, January, 1989.
Global Warming: http://se.eorc.nasda.go.jp/GOIN/JMA/htdocs/jmamajor/gwarm.html

Earth Science, Prentice Hall.

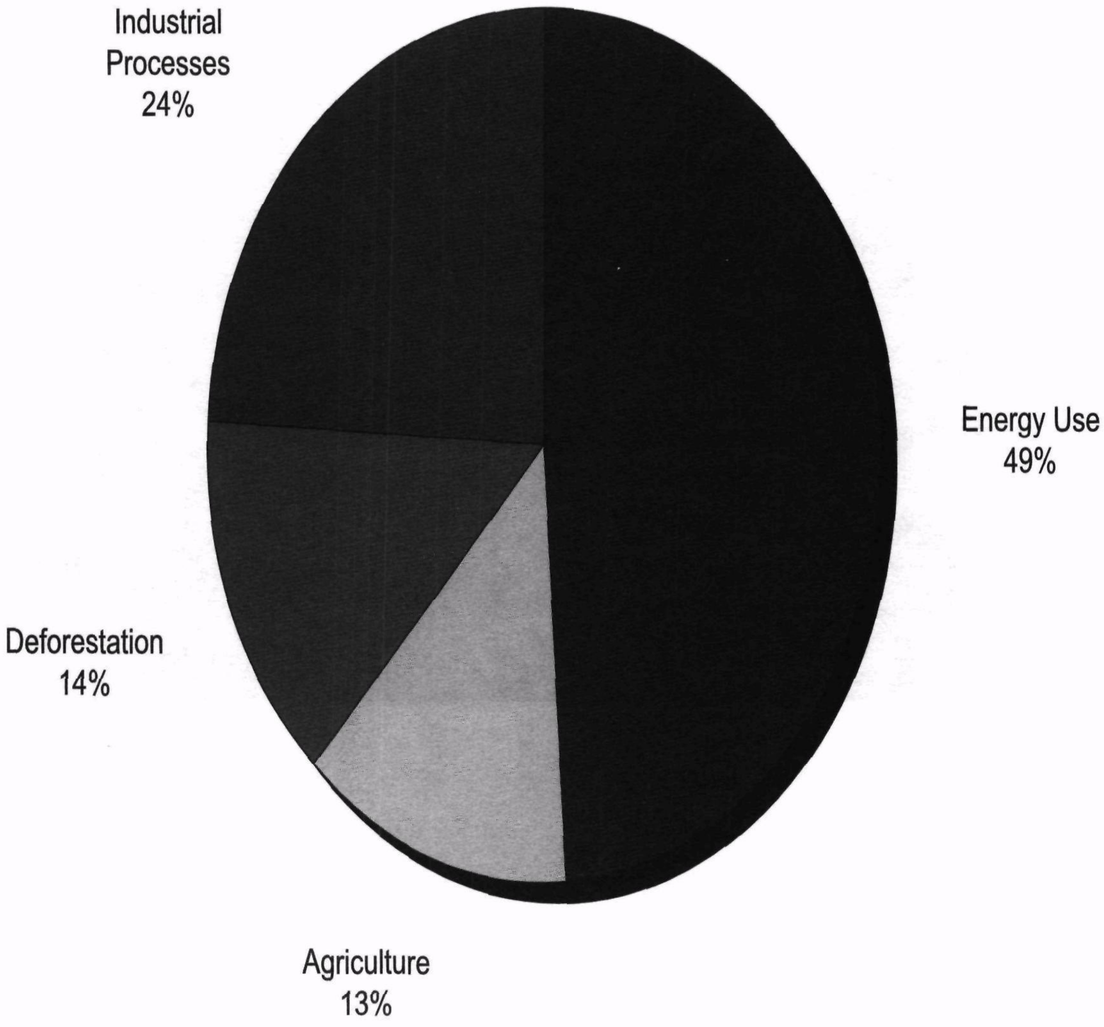
Handout titled "Planning for Relative Sea Level Rise," and The Rising Seas, Video (28 min.), Educational Dimensions/McGraw-Hill, 1988.

Marine Law Institute, University of Maine School of Law, April, 1992.



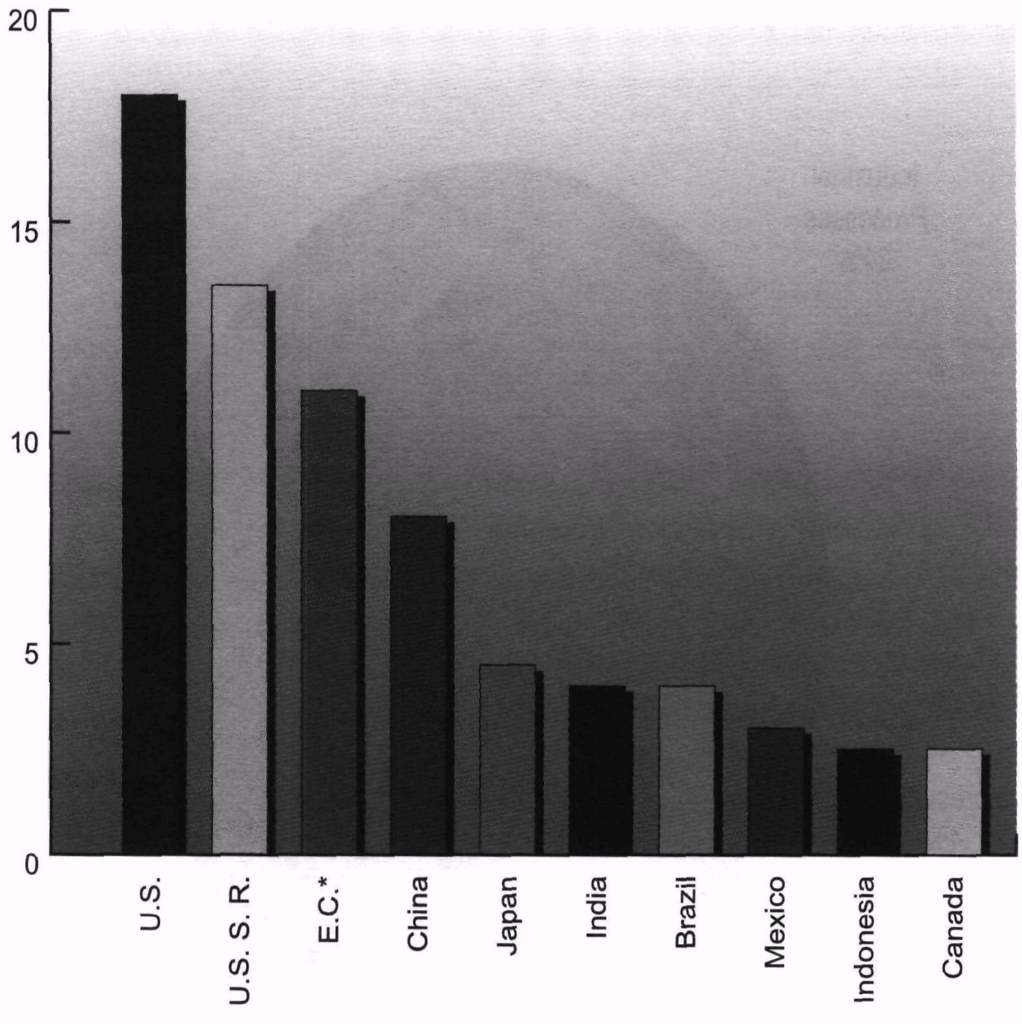
Relative contribution to global warming (percent of expected climate change) by anthropogenic (human-caused) releases of gases into the atmosphere. Notice that while far less methane and flourocarbons are released than carbon dioxide, they still are very powerful "greenhouse" gases.

Source: World Resources Institute and the United Nations Environment Programme.



Contributions to global warming by different types of human activities in 1990.

Source: Data from World Resources Institute.



Countries with the highest greenhouse gas emmissions in 1989. These countries account for two-thirds of all global warming.
* The European Community (EC) is comprised of 12 countries in Western Europe.

Source: Data from Intergovernmental Panel on Climate Change.

WAVE ACTIONS

6-8

SUBJECTS:
Earth Science, Physical Science

TIME:
2 class periods

MATERIALS:
1 plastic basin per group
sand
variety of small plants (monkey grass, etc.)
small houses (such as those from a Monopoly™ game)
drawing paper
markers or colored pencils
one aquarium for demonstration purposes
teacher sheets

OBJECTIVES

The student will do the following:

1. List ways in which the actions of waves affect shorelines.
2. Predict the impact of beach erosion when coastal vegetation is removed.
3. Compare high-energy wave environments with low-impact tidal zones.

BACKGROUND INFORMATION

A tremendous amount of energy exists in ocean waves. A wave is formed when the water's surface is disturbed. Waves consist of two motions: the forward progress of the energy of the wave (this energy originally came from the wind) and the circular motion of the water particles, which are being displaced by the moving energy.

There are different levels of energy attributed to various shorelines. This variation in tidal energy causes the formation of different habitats and, therefore, a significant difference in the organisms found living there. Waves and local currents interact with the shoreline, creating a high-energy environment.

The sediments that form our beaches are constantly moved and reshaped by winds, waves, and currents. A 50-meter wide beach can be created or removed by a single violent storm. Similarly, barrier islands and sandbars appear and disappear over time.

Early inhabitants of coastal areas recognized that the coastal beaches were hazardous places on which to live, and they settled on the bay side of barrier islands or as far upstream on coastal rivers as was practical. Modern residents, however, place high value on living on beach front property.

Construction on beaches and barrier islands, however, can cause irreparable damage to the whole ecosystem. Vegetation on beaches holds shifting sands in place. Damaging or removing beach vegetation to make way for construction promotes beach erosion and eliminates habitats for indigenous coastal species.

Terms:

crest: something forming the top of something else, such as the crest of the wave.

indigenous: native to or living in a specific area.

longshore current: a current that moves parallel to the shore.

trough: the lowest point in a wave; also a channel for water; a long channel or hollow.

wave frequency: the number of waves that pass a certain point in a given amount of time.

wave height: the distance from a wave's trough to its crest.

wavelength: the distance from a certain point on a wave, such as the crest, to the same point on the next wave.

ADVANCE PREPARATION

A. Discuss the shoreline with your students. List the vocabulary words on the board and discuss each definition.

B. Prepare plastic trays with sand and divide plants into group size numbers for the student groups.

C. Set up an aquarium of soil, freshwater, and plants. Leave this in the classroom as a demonstration of a calm lake environment with low tidal impact.

PROCEDURE

I. Setting the stage

A. Show students the materials and have them design (as a group) how they will use them to represent a shoreline.

B. Ask the students if they have ever been to a shore. List on the board some of the characteristics that they noticed. Pay particular attention to whether or not plants are mentioned.

C. Have students make a visual comparison between the particles of sand and some gravel from a local area.

II. Activity

A. Divide students into cooperative groups of four students. Each group will use one basin, sand, and plants to design a beach-front environment. They may use any features (such as Monopoly™ houses, etc.) to make the beaches as individual as they wish.

B. Fill the basin with water up to the created shoreline.

C. Ask students what the main differences are between their shoreline and the simulated lake environment in the teacher demonstration.

D. The students will tilt the basin back and forth, very slowly at first, to simulate the actions of waves. As the intensity gets greater, they will notice any changes in the beach environment.

E. Next, have the students remove all plants, and have some groups flatten out any dunes that had been created. They may want to leave buildings in place. Create wave action again with the tilting of the basin. Pay close attention to any changes in the shoreline.

III. Follow-Up

A. Ask your students to look for newspaper articles that are related to beach erosion. Read and discuss them in class.

B. Have the students turn in (by group) a written description of their shoreline and the consequences of wave action on it.

IV. Extensions

A. Take a field trip to a local shoreline, if possible. Have students draw what they see and compare this to their classroom shore.

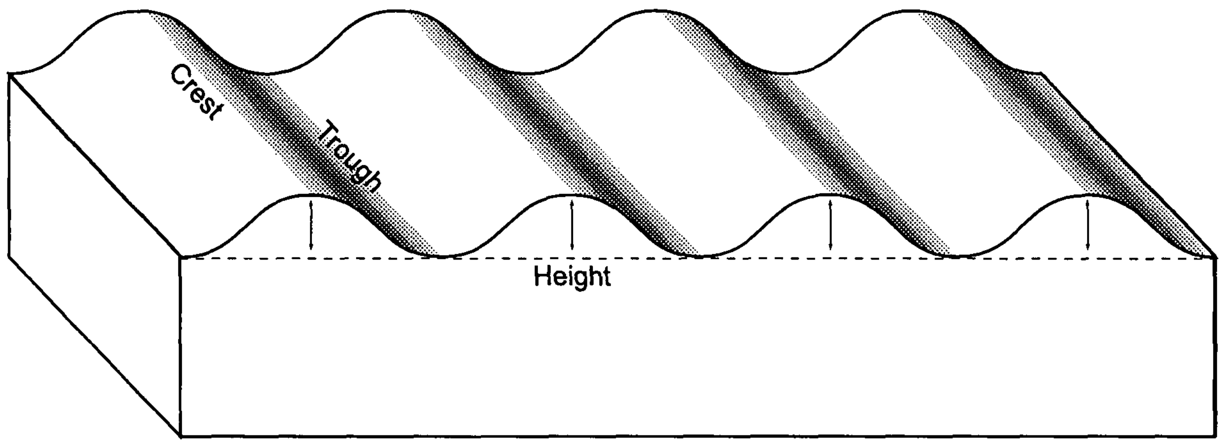
B. Ask the students to use reference materials to discover the various animals that live in an active high-energy wave zone and design a bulletin board to reflect these animals and how they have adapted to such a dynamic environment.

RESOURCES

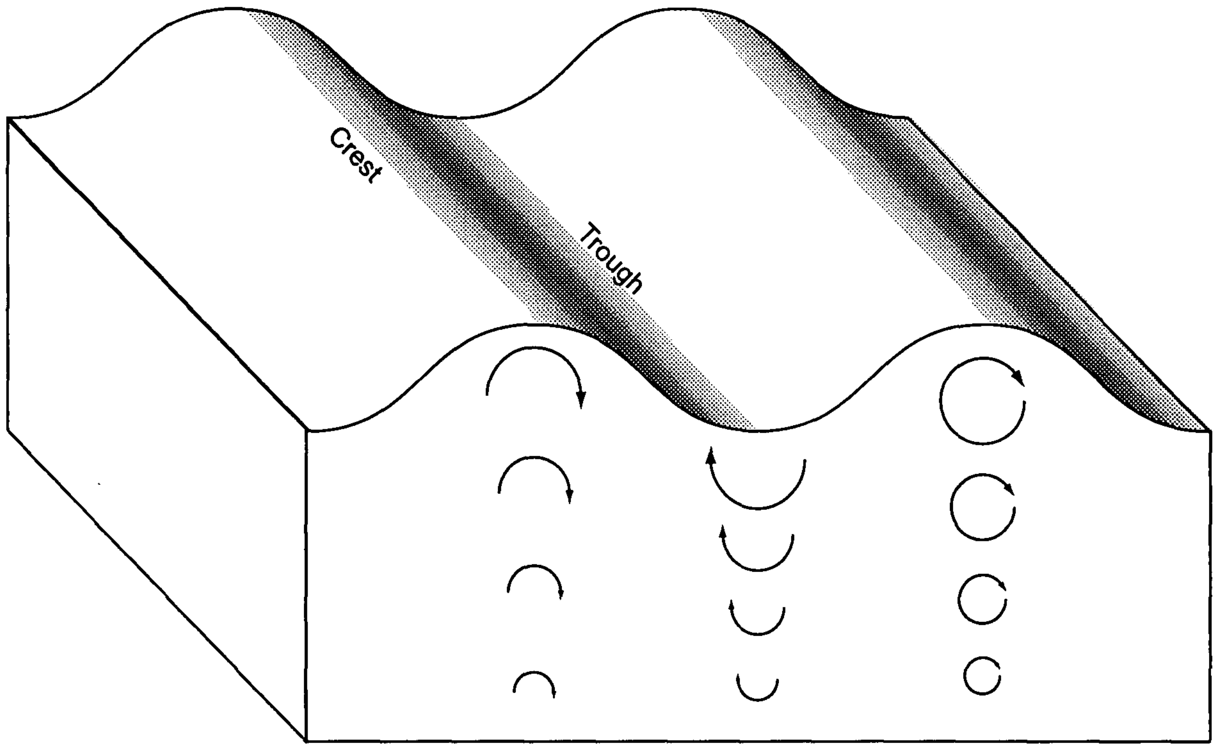
Cunningham, William P. and Barbara Woodsworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, Iowa, 1995.

Duxbury, Alison B. and Alyn C. Duxbury, Fundamentals of Oceanography, Wm. C. Brown Publishers, Dubuque, Iowa, 1996.

Ocean Waves: http://www.users.interport.net/~jbaron/waves.html



Parts of a Wave



Water Movement in a Wave

ROLE-PLAYING GAME

6-8

SUBJECTS:
Ecology, Drama

TIME :
2 class periods

MATERIALS:
copies of the illustrations of the farm and proposed development
copies of the character descriptions
student sheets

OBJECTIVES

Students will be able to:

1. List ways that development can impact wetlands and its habitants.
2. Present the interests of townspeople affected by development.
3. Present the reasons for the state, county, or town to purchase land or change zoning laws to preserve wetland as a student learning center.

BACKGROUND

Wetlands provide a healthy habitat for many different species of plants and animals. They depend on this environment for their survival. The total percentage of wetlands is decreasing every year at a rapid rate. This depletion is caused by many factors, most all caused by humans. Humans have blocked rivers, which are the main source for the water in these areas. The dams are built to provide energy, water, and food to the inhabitants upstream. Another reason that wetlands are disappearing is development. The moist rich soil is very attractive to farmers. Most farmers do not realize the effect they are directly having on the environment. Birds and other species of wildlife that once lived in the wetland are forced to find somewhere else to live.

Terms

development: a process by which the natural environment is altered to serve the needs of humans.

proposal: a plan for some activity that must be approved by one or more other people.

wetland: an area that is wet or flooded and has a water table that stands at or above the land surface for at least part of the year.

ADVANCE PREPARATION

A. Discuss with students the importance of wetlands and the diversity of organisms that live there.

B. Photocopy the illustrations of the Old Tillage Farm and the proposed development. A sketch or enlarged photocopy of both situations could also be hung on the board for marking up at the public meeting.

C. Discuss the Robert's Rules of Order for the actual town meeting.

PROCEDURE

I. Setting the Stage

A. The purpose of this activity is to have students play the roles of townspeople with conflicting interests at a public hearing on a new development that may have a negative impact on local wetlands.

B. Stress how their decision could affect different aspects of the environment in the future.

II. Activity

A. Hand out the illustrations of the Old Tillage Farm and the proposed development.

B. Next, read the situation to the class.

C. Assign the character roles to different students (or have them draw character names). Students who don't have specific roles to play can be townspeople.

D. Give them time to develop and become their characters as well as develop their positions on the issues. Students should talk with each other in character and develop relationships with other townspeople having similar feelings.

E. When it is time for the public meeting, the planning commission chair (either the teacher or an appointed student) should introduce the chair of the Waterton Zoning Board of Adjustment and start the meeting by having the developer present his proposal. Each person should take a turn presenting his/her views. The planning commission chair should decide how much exchange is allowed during the discussion. Alternatives to the developer's proposal should be sketched and discussed. The meeting should end with the chair of the Waterton Zoning Board of Adjustment reaching a decision that tries to protect the wetland ecosystems and address the needs and concerns of the community.

III. Follow-Up

A. Discuss the town meeting. Talk about issues that were brought up and how important they were to the real issue of development. How realistic was the town meeting?

IV. Extension

A. Visit a city council meeting in your area. Write a report predicting what effects a proposed development in the area may have on the environment.

RESOURCE

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THE SITUATION
Waterton is a small rural community of 950 residents. Its village center has a general store, hardware store, and a small service station. Most people in Waterton know each other or at least know of each other. No major change or development has occurred in town up until this time–growth has been slow and incremental. Recently, however, the Old Tillage Farm was sold to a development company in order to pay inheritance taxes when Sarah Tillage died. The developer has plans to subdivide the land and build 14 new houses. The farm includes Perch Pond, a shallow pond with a large marsh and shrub swamp on its northern end, as well as a wet meadow wetland located on Creeping Creek, downstream of the pond. The proposed development calls for filling the wetland along Perch Pond to make a lawn and to dredge the pond to make it deeper for swimming. In order to reach four of the homes, a road would be built across the downstream wetland, filling in about a half acre. As currently proposed, the developer would need a variance to have this many houses built on this land. The zoning allows for five-acre lots and the farm is only 55 acres total. The townspeople are divided over the development and will discuss the site plan at tonight's planning commission meeting. This meeting is held jointly with the Zoning Board of Adjustment, which has to approve or disapprove the variance request. People have been talking and preparing for this meeting for weeks.

CHARACTER DESCRIPTIONS:

AMY TILLAGE: You are the oldest child of Sarah and Paul Tillage and had to sell the family farm when your mother died recently. Your father died awhile ago. You hated to sell it, but you don't live in Waterton anymore. You and your siblings couldn't afford the inheritance tax without selling the farm. Unfortunately you didn't talk to the Appletrys and the Foleys before you sold the land to Alterland Development Company. Both of these neighbors were interested in buying portions of the farm. You have heard that they are upset with you. You are going to the planning commission meeting to see if there is any information you can offer that would help protect some of the characteristics of the farm that you love–the pond where you caught small fish and frogs, the wetland adjacent to the pond where you watched ducks raise their ducklings, the wetland along Creeping Creek where you picked irises, and the woodlot where you had trails and hiding places.

JOHN APPLETRY: You and your wife, Molly, own the house and orchard across the road from the Tillage Farm. You are outraged at the developer's plans for the farm. You don't blame Amy Tillage for selling the place, but you are somewhat hurt that she didn't think to find out if you were interested in some of the land. You had asked Sarah once about leasing her corn field and putting some more apple trees in there. Your kids played in and explored the wetland and pond beyond the cornfield–catching insects and having cattail sword battles when they were little, hunting ducks when they were older. You are attending the planning commission meeting to comment on the site plan for the project. You are opposed to agricultural land changing to high-density suburban residences.

BILL DOZER: You are a representative from Alterland Development Company and the project manager for the Tillage Farm site. You are from a city far away and feel this may work against you in such a small, close-knit community. You have invited Peggy Perc to the meeting as she is from the neighboring town and is an Alterland Development Company investor. Your plan calls for 14 houses to be built on the Tillage Farm. You have proposed more than you need to build in order to give yourself a better negotiating position. Since Waterton is a small community with no industry, you feel your housing plan can help the area by adding to the tax base. You are aware that filling the wetlands will probably be an issue, but you have a backup strategy: You could build another pond down by the road to replace the wetland you fill. A pond by the road would be good for fire protection and is certainly more useful in your mind than the area through which the road will pass. That area doesn't even have water in it in August.

PEGGY PERC: You live in a neighboring town and are an investor in Alterland Development Company. Bill Dozer has asked you to attend the Waterton planning commission meeting with him. Bill wants your sense of what the planning commission members and the zoning board of adjustment members are thinking after he makes his proposal. He thinks that since you are from the area, you will have a better feel for how people are reacting. Actually, you already know what some people are feeling because when you stopped in the Waterton General Store for your Sunday paper, you heard discussions. You know the Appletrys are mad and the Foleys are upset. You also know that Phoebe Byrd will be ready to speak about the wetland issues that will come up at the meeting. You think that Bill ought to be ready with different development proposals that will use less land. You think that the project will still make money for the company even if he builds fewer, more-expensive houses.

MARY FOLEY: You and your husband, Peter, own the horse farm across the road from the Tillage Farm. Like the Appletrys, you and Peter would also have tried to buy some of the farm. You are interested in owning the wooded area north and east of Perch Pond. It would give you more land on which to ride your horses. You are hoping that there is still a chance for you and the Appletrys to buy some of the land, especially if the development company is not allowed to build all the houses it has proposed.

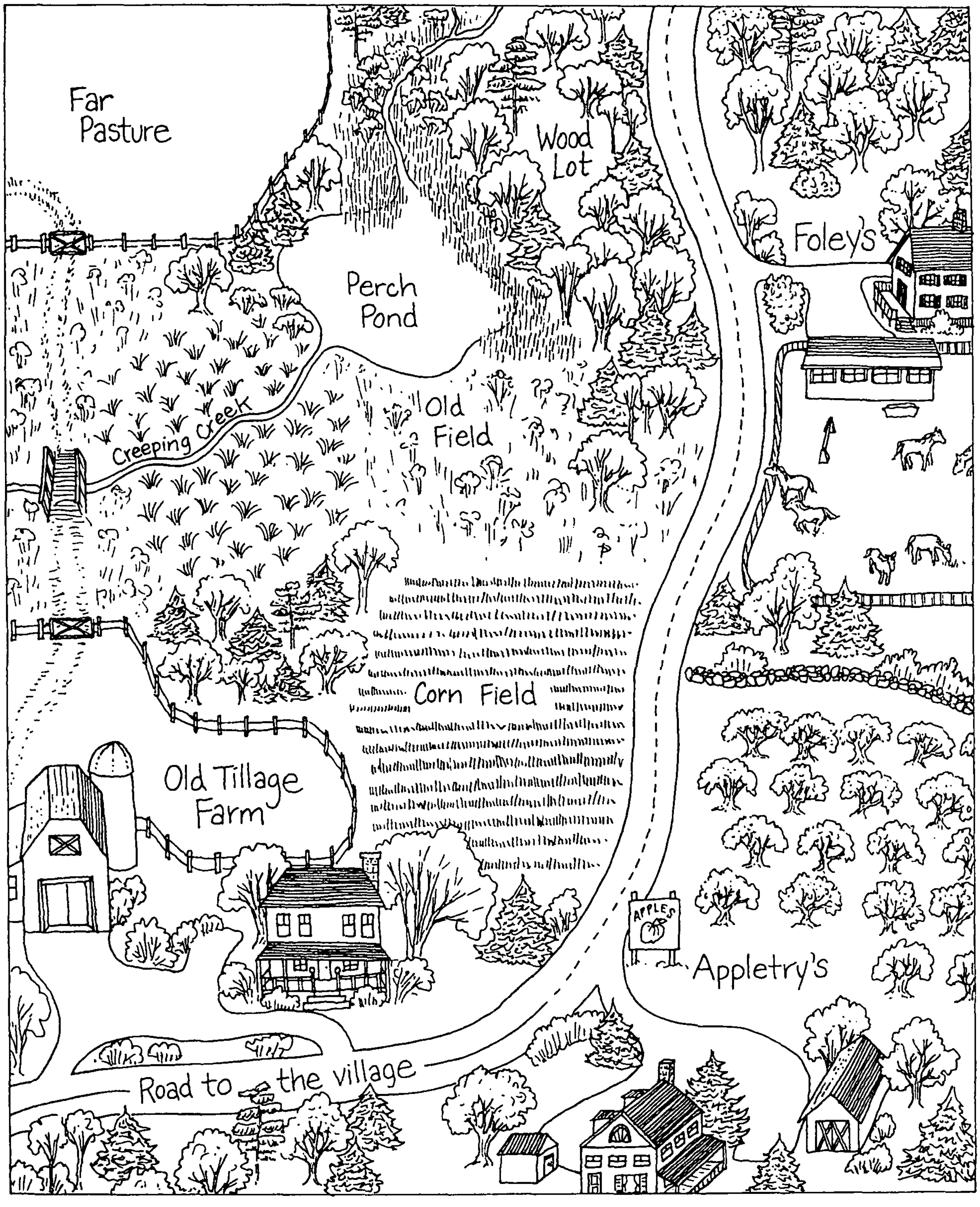
SUSAN BREADLOAF: You own and run the general store in town. You have heard many discussions around the coffee pot at your store about the plans for the Tillage Farm. You know that the Appletrys and Foleys are really upset about the proposed development and are going to fight the project. You aren't sure what to think about it. You don't like to lose farmland or see places like Perch Pond become off-limits to the local kids. Your son used to go to the pond with the Appletry kids when he was younger. But your son will finish high school soon and you haven't saved much money for college, so you would love to have the added business more people would bring.

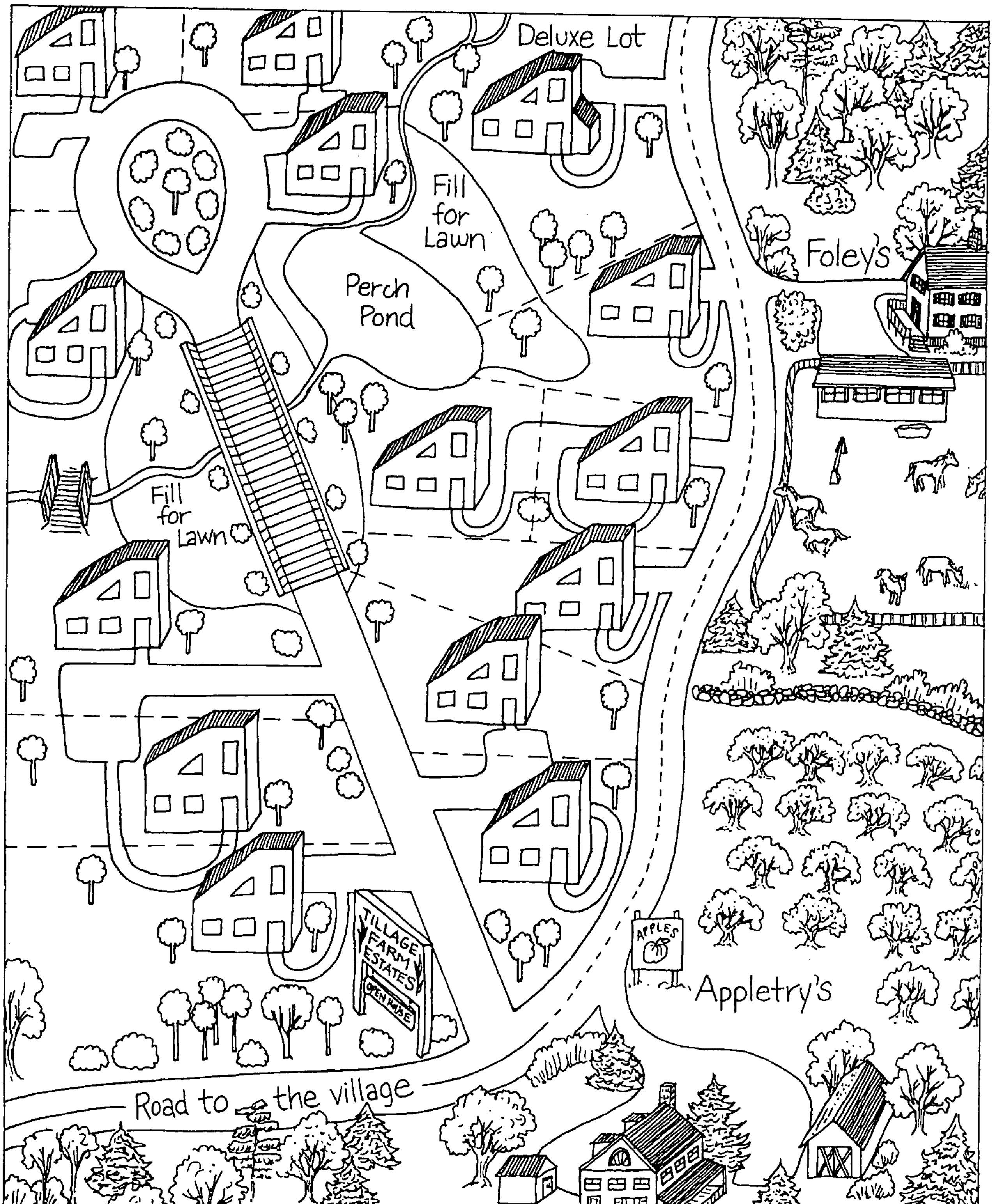
DICK RHODES: You are the road commissioner for Waterton and have lived in the town all your life. You haven't been too involved in the discussions about the proposed development on the old Tillage Farm, but you have heard about the Appletrys and the Foleys being upset. Your friend, Willy Variance, is the chair of the Zoning Board of Adjustment, so you have seen a draft of the site plan. You think it would cost a lot of money to fill in the wetland in order to put a road through it. The cows cross the stream at the wooden bridge below the wetland, and you think that is where a road should be built.

PHOEBE BYRD: You are a member of the area Audubon chapter and a local expert on plants and animals. You were horrified to learn about the development planned for the Old Tillage Farm, especially the amount of wetland to be filled. You haven't been to Perch Pond and the adjacent marsh for a while, but you do know that a marsh wren, a rare bird, has nested in this wetland at least once. You will talk at the planning commission meeting to explain how important wetlands are and to ask that the commission not allow the project as it is planned.

HANK BOARDMAN: You do logging as well as operate a portable sawmill. You are familiar with the Old Tillage Farm because you cut some trees for firewood for Sarah Tillage. You think that the developer ought to be able to do as he chooses with the land although you don't like the idea of so many new people coming into town. Since you might get work clearing land or working on the custom houses, though, it might be good for you.

WILLY VARIANCE: You are the chair of the Waterton Zoning Board of Adjustment, and your group must decide if Alterland Development Company will be allowed to build 14 houses on the Old Tillage Farm. You have heard that many people are coming to the meeting to hear the plans and to make comments about them. You are ready to listen to everyone's comments and try to make a decision that will be the best for your town.


Far Pasture
Wood Lot
Foley's
Perch Pond
Old Field
Creeping Creek
Corn Field
Old Tillage Farm
APPLES
Appletry's
Road to the village


Deluxe Lot
Fill for Lawn
Perch Pond
Foley's
Fill for Lawn
Tillage Farm Estates
Open House
Apples
Appletry's
Road to the village

WATER FILTRATION

6-8

SUBJECTS:
Art, Chemistry, Language Arts

TIME:
2 class periods

MATERIALS:
two 2-liter plastic soda bottles
scissors
1/4 cup topsoil
water
plastic quart container with lid
paper coffee filter
builder's sand
crushed charcoal briquettes
clock
teacher sheet
student sheets

OBJECTIVES

The student will do the following:

1. Define potable and identify water that is potable.
2. Depict an illustration of the water treatment cycle.
3. Identify problems with treating dirty water.

BACKGROUND INFORMATION

Wetlands serve as highly effective surface water purification systems by reducing the effects of sedimentation in rivers, lakes, and estuaries. When turbulent, sediment-laden water encounters masses of wetland plants, it loses its energy and adds its sediments to the wetlands soil. These sediments may carry potentially harmful substances such as excess nutrients, which may lead to eutrophication, as well as pesticide residues and heavy metals with the potential to bioaccumulate.

The real "workhorses" in this natural water purification plant are the microbes. These tiny organisms are able to take many types of toxins and break them down into harmless substances. Those which cannot be broken down are likely to become sequestered within ever-increasing volumes of organic debris. These systems are so effective that they are often utilized by wastewater treatment plants.

How To Purify Water
Boiling is probably the best way to purify water. There is some debate about how long water needs to be boiled before it is safe to drink. Opinions vary from three minutes of a rolling boil to even just a few seconds. There are many water purification devices on the market; all use one or more of the following techniques to clean water:

Micropore filter: tiny holes that big germs can't pass through. This will stop larger microorganisms, such as amoeba and giardia, but bacteria and viruses will pass through.

Iodine: a filter, usually in the form of a membrane, containing a potent form of iodine that latches on to microorganisms as they pass through and kills them. Viruses are killed quickly; the larger germs may require several minutes to be effectively neutralized.

Charcoal: does not have much anti-bacterial effect, but it will remove bad odors and tastes, and some chemical pollutants. It is sometimes provided as an addition to the regular water purification device.

The flashlamp system is a new method still being developed. The high-intensity light generated by the flashlamp system has the ability to actually break DNA strands, and in doing so alter the chemical composition of a substance to render it both harmless and unable to reproduce. Moreover, the sheer intensity of the light produces a kill rate that can effectively decompose viral and microbe contaminants. Treating recirculated water with light is attractive because it does not contribute mineral salts or toxic residues that limit the potential for subsequent reuse of treated water.

Terms

hydrologic (water) cycle: the cycle of the Earth's water supply from the atmosphere to the Earth and back that includes precipitation, transpiration, evaporation, runoff, infiltration, and storage in water bodies and groundwater.

microbe: a microorganism (microbiological organism).

potable: fit or suitable for human consumption, as in potable water.

ADVANCE PREPARATION

A. Prepare an overhead of the attached water treatment cycle.

B. Prepare a water filter using a plastic liter soda bottle with the bottom cut off, the label peeled off, and a one-hole stopper carrying a short length of glass tube inserted into the small end of the soda bottle. Put a little cotton wool in the bottom and then a layer of small clean pebbles. Wash some coarse sand well and place a layer above the pebbles. Next wash some fine sand and make a thicker layer in the filter. Grind up some wood charcoal and make it into a paste with water. Spread the charcoal paste evenly over the surface of the sand. Secure some very muddy water and pour in the top of the filter. Collect the filtrate in a clean glass placed below the filter. (See diagram.)

PROCEDURE

I. Setting the stage

A. Conduct the above experiment and ask for volunteers to drink the potable water.

B. Ask the class to brainstorm ideas of what potable water is. Ask them what word they might confuse with potable.

C. Give the class the correct definition of potable water for their notes. Ask the class to brainstorm ways their school gets potable water.

D. To introduce the water treatment cycle, read <u>The Borrowers A float</u> by Mary Norton.

E. Produce the overhead and compare it to the borrowers' journey and the conducted experiment

F. Have students illustrate cartoons about the borrowers' journey down the drain, thorough a pipe and into a river.

II. Activity

A. Explain to the students how they will recreate the water treatment system for their classroom.

B. Divide the class into cooperative groups.

C. Have each group make muddy water by mixing 1/4 cup of topsoil with water in a quart container. Put the lid on the container and shake.

1. Now make a water filter by cutting the top off a soda bottle about 4 inches below the spout (the teacher should help). Turn the top upside down and rest it in the remainder of the bottle.

2. Wet some sand and put a 1-inch layer in the coffee filter.

3. Put a 1-inch layer of crushed charcoal on top of the sand. Then cover with another 1-inch layer of wet sand.

4. Slowly pour about 1 cup of muddy water into your filter. Be sure to leave some muddy water so you can compare it to the filtered water.

5. Time how long it takes the water to begin filtering. Is the water that passed through the filter cleaner than the water in the other container?

D. Have the groups record their findings and present them on the attached chart.

III. Follow-Up

A. Have the students answer the following questions.

1. Compare the muddy water and the filtered water, explaining how sand can clean the water.
2. What parts of this experiment represent steps used by water treatment plants?
3. Why could or couldn't you use it to make a powdered drink?

IV. Extensions

A. Have groups draw new cartoons that depict the borrowers' journey through the class filter system.

B. Brainstorm problems that could arise in the class's filter system.

RESOURCES

Johnson Cynthia C. Waterways, Division of Public Information St. Johns River Water Management District, 1991.

Norton, Mary. The Borrowers Afloat, ISBN 0-15-2105340-4.

Water Purification Techniques: http://www.achilles.net/~petert/water.html

Polygon Industries Inc., author: Water Purification: http://www.polygon1.com/waterpurification.html

Water Purification Capabilities: http://hermes.ecn.purdue.edu:8001/http_dir/Gopher/agen/agen521/Lessons/Wetlands/purification.html

Directions: Draw a diagram of your filter, then record the data you collect.

Filter Set-Up:

Step 1: Cut the soda bottle off 10 cm below the spout. Turn the top upside down in the rest of the bottle. Put a coffee filter in the bottle.

Step 2: Wet some builder's sand and put a 2.5 cm layer in the coffee filter.

Step 3: Put a 2.5 cm layer of crushed charcoal on top of the sand, then cover with another 2.5 cm layer of wet builder's sand.

Step 4: Slowly pour 250 mL of muddy water into your filter. Save some muddy water to use as a comparison.

Step 5: Time how long it takes the water to begin filtering and record what the water looks like.

Time	What the Water Looked Like
Time 0	
30 seconds	
1 minute	
1 minute, 30 seconds	
2 minutes	
2 minutes, 30 seconds	
3 minutes	
3 minutes, 30 seconds	

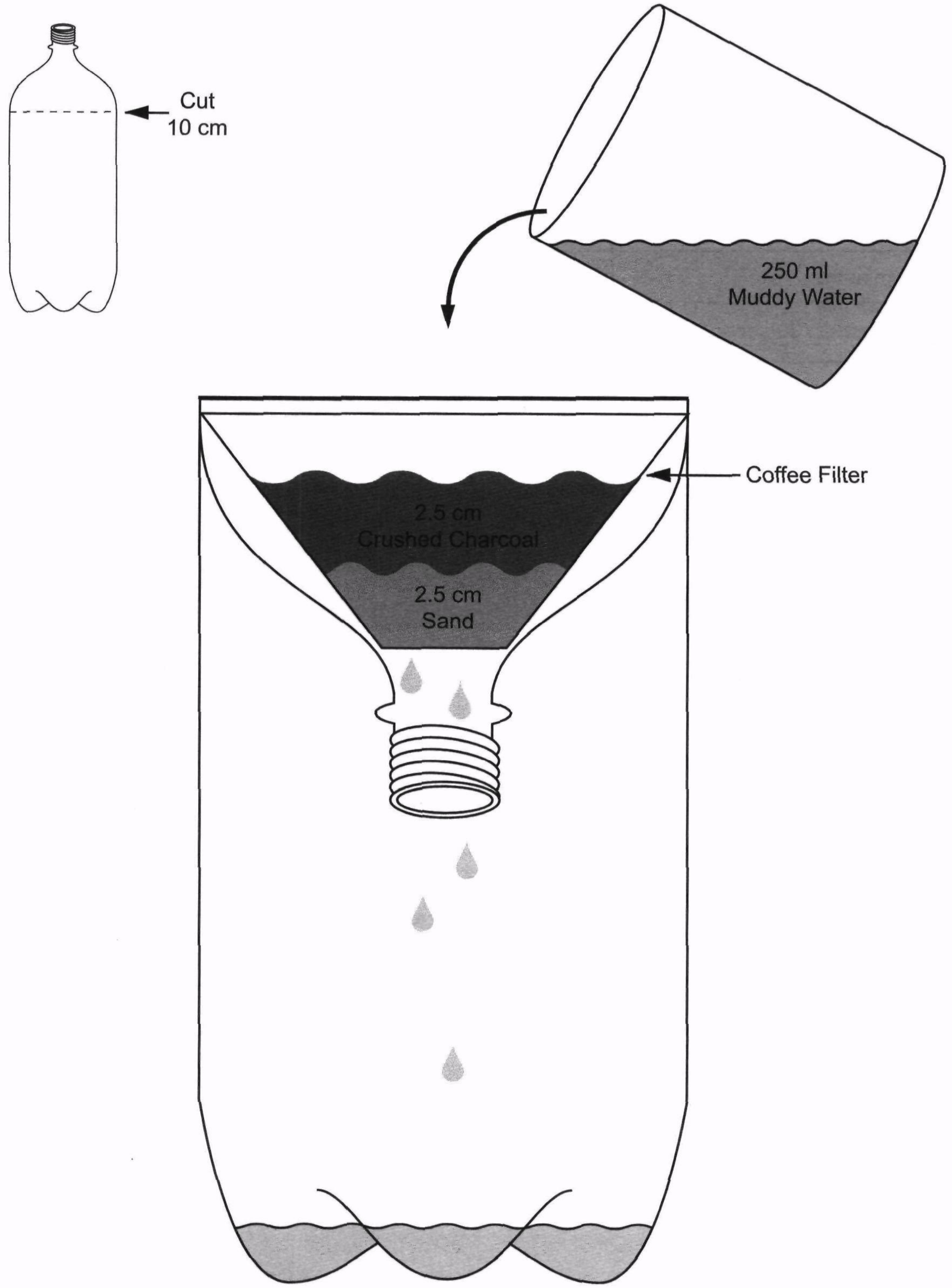
Please answer the following questions:

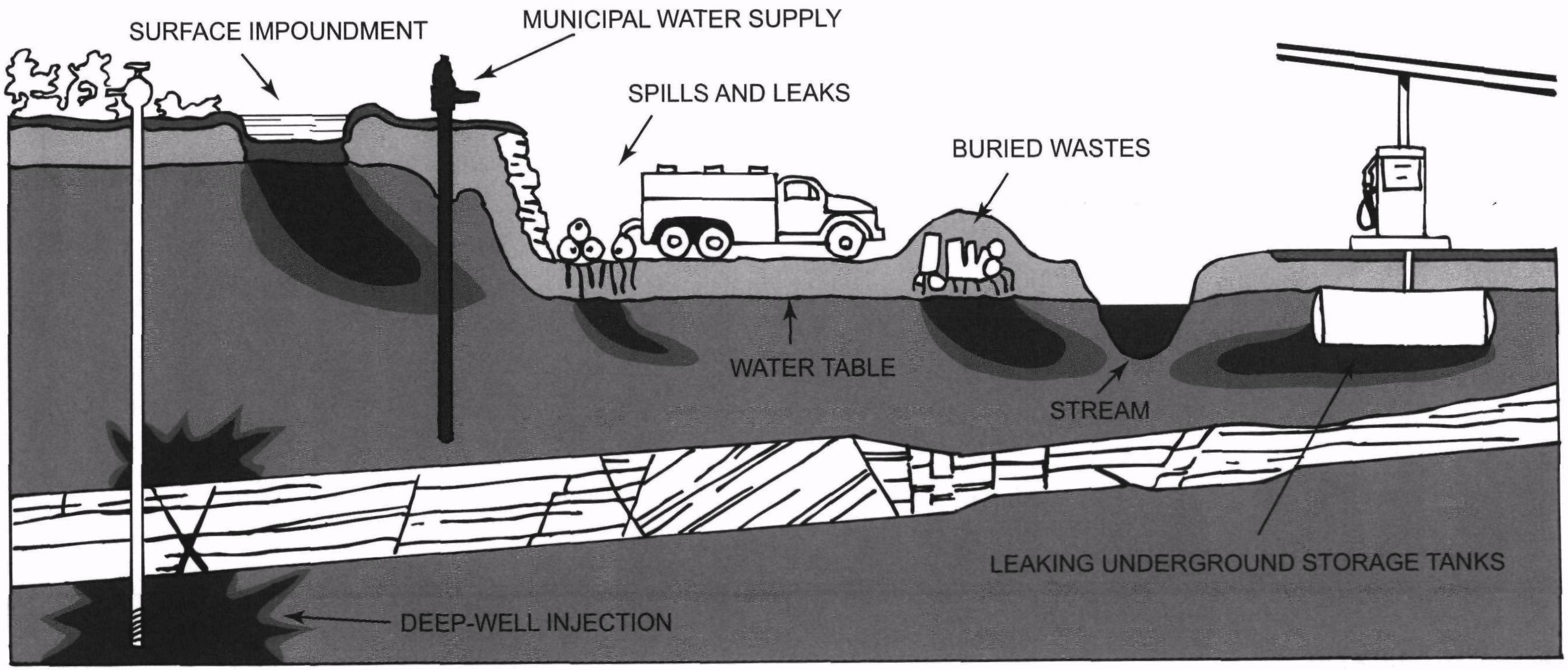
1. How did the filter clean the muddy water?

2. Is the water potable? Why or why not?

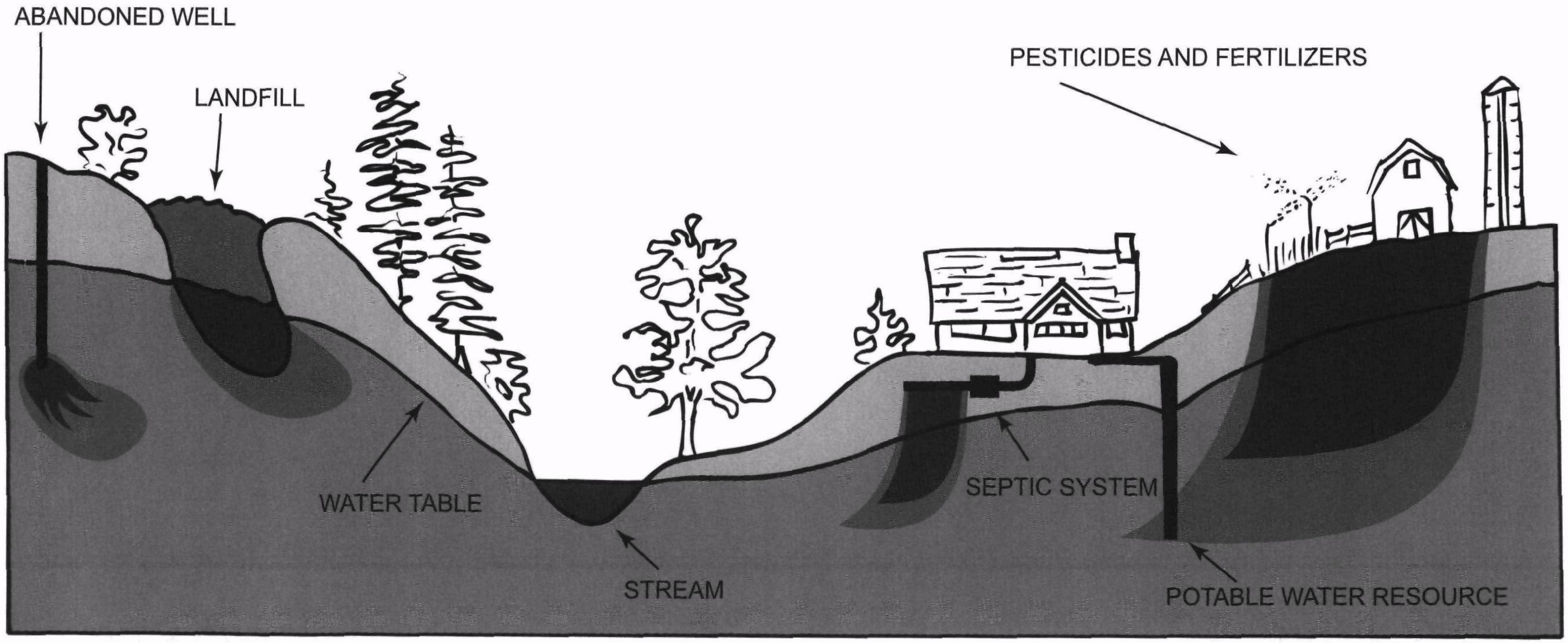
3. What could still be in the water?

4. What parts of your experiment represent steps used by water treatment plants?

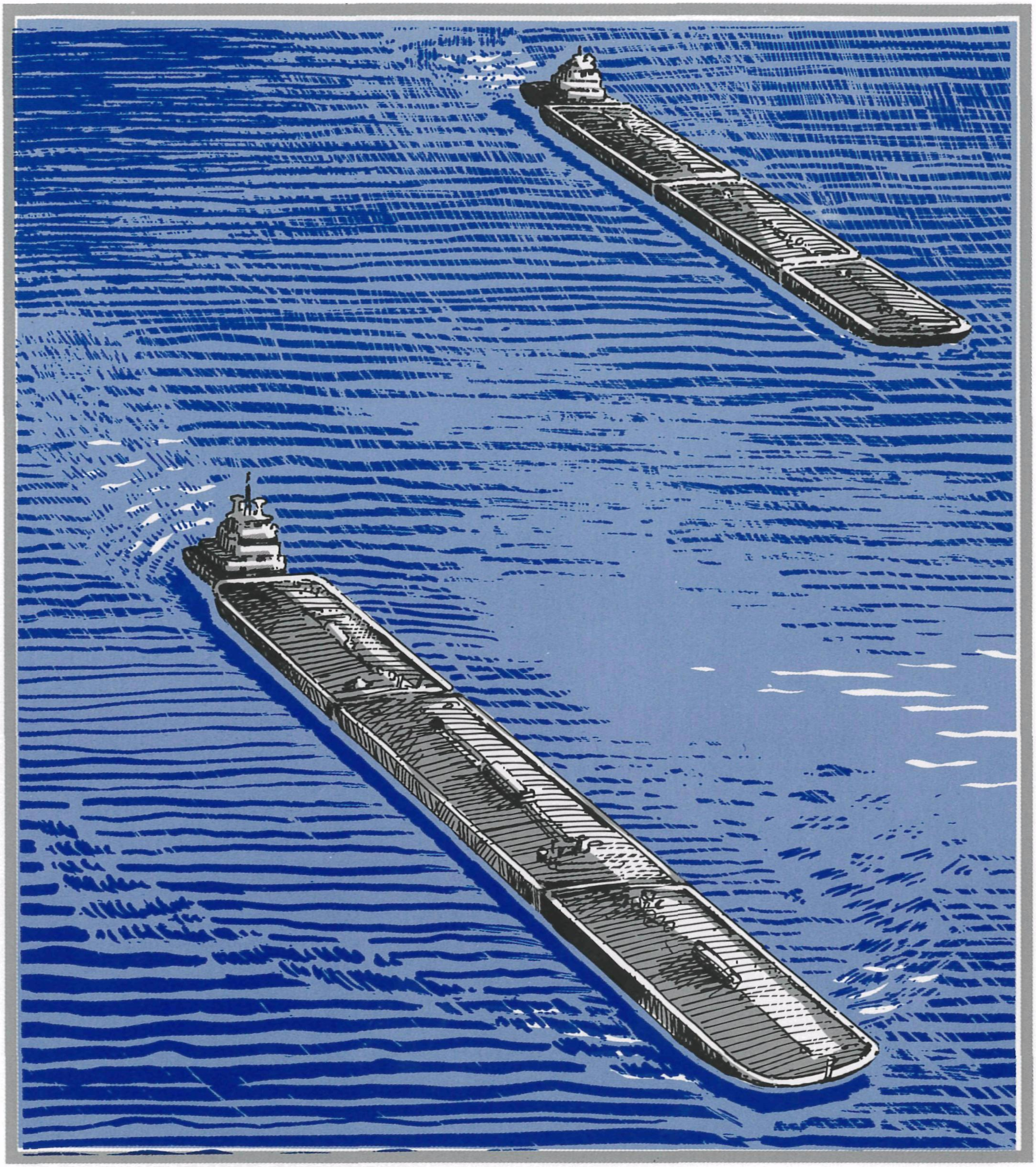

Cut
10 cm
250 ml
Muddy Water
Coffee Filter
2.5 cm
Crushed Charcoal
2.5 cm
Sand



Industrial and Commercial Contamination Sources



Municipal and Rural Contamination Sources



THE WATER SOURCEBOOK

GLOSSARY

GLOSSARY

abandoned well: any well (drinking water, oil and gas, etc.) which is not used for a long period of time, is not maintained properly, and/or is not properly sealed when its useful life is over.

acidity: the strength (concentration of hydrogen [H^+] ions) of an acidic substance; measured as pH.

acid rain (or acid precipitation): rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels or from volcanic activity; may cause damage to buildings, monuments, car finishes, crops, forests, wildlife habitats, and aquatic life.

The Act to Prevent Pollution From Ships: legislation regulating the discharge of oil, noxious liquid substances, or garbage generated during normal operations of vessels.

adhesion: force of attraction between two unlike materials.

aeration: the process of exposing to circulating air.

aerial photography: high altitude pictures taken from an aircraft or satellite.

aerobic: living or occurring in the presence of oxygen.

agricultural sewage: waste produced through the agricultural processes of cultivating the soil, producing crops, or raising livestock..

agriculture: the science, art, and business of cultivating the soil, producing crops, and raising livestock; farming.

airborne pollutants: contaminants borne by air that cause harm to human health or the environment.

algae: any of a large group of simple plants that contain chlorophyll; are not divisible into roots, stems and leaves; do not produce seeds; and include the seaweeds and related freshwater and land plants.

algal bloom: a heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from farm fertilizers and detergents; phosphates also occur naturally under certain conditions.

alternative: a chance to choose between two or more possibilities; one of the two or more possible choices.

alum: as used in drinking water treatment, aluminum sulfate; added to water in drinking water treatment facilities to cause dirt and other particles to clump together and fall to the bottom of settling basins.

amendments: revisions or changes (as to laws).

anaerobic bacteria: any bacteria that can survive in the complete or partial absence of air.

Aqua Lung: a trademark for a self-contained underwater breathing apparatus (scuba).

aquacade: an entertainment spectacle of swimmers and divers, often performing in unison to the accompaniment of music.

aquaculture: the science, art, and business of cultivating marine or freshwater food fish or shellfish, such as oysters, clams, salmon, and trout, under controlled conditions.

aquamarine: a transparent blue-green variety of beryl, used as a gemstone.

aquanaut: a person trained to live in underwater installations and conduct, assist in, or be a subject of scientific research.

aquaplane: a board on which one rides in a standing position while it is pulled over the water by a motorboat.

aquarelle: a drawing done in transparent water colors.

aquarist: one who maintains an aquarium.

aquarium: a tank, bowl, or other water-filled enclosure in which living aquatic animals and, often, plants are kept.

Aquarius: a constellation in the equatorial region of the Southern Hemisphere near Pisces and Aquila.

aquatic life: plants, animals, and microorganisms that spend all or part of their lives in water.

aqueduct: a conduit designed to transport water from a remote source, usually by gravity.

aquifer: an underground layer of unconsolidated rock or soil that is saturated with usable amounts of water (a zone of saturation).

Army Corps of Engineers: Branch of the U.S. Army; responsible for maintaining and regulating inland waterways.

artesian well: a well in which the water comes from a confined aquifer and is under pressure. One type of artesian well is a **free-flowing artesian well** where water just flows or bubbles out of ground without being pumped.

atmospheric transport: the movement of air pollutants from one region to another by wind; may be hundreds of miles.

autotroph: an organism that can make its own food (usually using sunlight).

bacteria: Bacteria are single-cell microbes that grow in nearly every environment on Earth. They are used to study diseases and produce antibiotics, to ferment foods, to make chemical solvents, and in many other applications.

bacterial water pollution: the introduction of unwanted bacteria into a water body.

bag limit: the number of a certain fish that can be caught each day.

bay: a large estuarine system (Example: Chesapeake Bay).

benthic zone: the lower region of a body of water including the bottom.

biocontrol agent: an organism used to control pests Example: lady bugs used to control aphids in a garden).

biodegradable: capable of being decomposed (broken down) by natural biological processes.

biological diversity: a wide variety of plant and animal life.

bioremediation: the use of oil-eating organisms such as bacteria and fungi to remove pollutants.

biosolids: solid materials resulting from wastewater treatment that meet government criteria for beneficial use, such as for fertilizer.

bivalve: a mollusk that has two shells hinged together, such as the oyster, clam, or mussel.

blackwater: *domestic wastewater containing human wastes.*

blue baby syndrome: a pathological condition, called methemoglobinemia, in which blood's capacity for oxygen transport is reduced, resulting in bluish skin discoloration in infants; ingestion of water contaminated with nitrates or certain other substances is a cause.

bog: a poorly drained freshwater wetland that is characterized by a build-up of peat.

bottom lands: low-lying land along a waterway.

brine: water saturated with or containing large amounts of a salt, especially of sodium chloride.

calcium carbonate: a powder occurring in nature in various forms, as calcite, chalk, and limestone, which is used in polishes and the manufacture of lime and cement.

carcinogenic: describing a substance that tends to produce cancer.

catch basin: a sedimentation area designed to remove pollutants from runoff before being discharged into a stream or pond.

caution: a warning against danger.

centrifugal force: the force that causes something to move outward from the center of rotation.

cesspool: a covered hole or pit for receiving untreated sewage.

channelization: the process of channeling or carving a route.

chemical: related to the science of chemistry; a substance characterized by a definite chemical molecular composition.

chemical pollution: introduction of chemical contaminants into a water body.

chlorination: water disinfection by chlorine gas or hypochlorite.

chlorine: a chemical element, symbol Cl, atomic number 17, atomic weight 35.453; used as a disinfectant in drinking and wastewater treatment processes.

cholera: an acute, often fatal, infectious epidemic disease caused by the microorganism *Vibrio comma*, that is characterized by watery diarrhea, vomiting, cramps, suppression of urine, and collapse.

Clean Water Act: water pollution control laws based upon the Federal Water Pollution Control Act of 1972 with amendments passed in 1977, 1981, and 1987; main objective is to restore and maintain the "chemical, physical, and biological integrity of the Nation's waters."

closed season: a time when a certain fish cannot be caught.

closed system: a system that that functions without any materials or processes beyond those it contains and/or produces itself.

cloud: a visible mass of tiny bits of water or ice hanging in the air, usually high above the earth.

cohesion: the force of attraction between two like materials.

coliforms: bacteria found in the intestinal tract of warm-blooded animals; used as indicators of fecal contamination in water.

communities: related groups of plants and animals living in specific regions under relatively similar conditions.

compost: an aerobic mixture of decaying organic matter, such as leaves and manure, used as fertilizer.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund): legislation passed in 1980 and amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA); provides for short-term actions called removal actions in response to accidents and improper handling of hazardous materials which pose an immediate threat to human health and safety. It also provides for long-term actions called remedial actions for cleanups of other sites which pose no immediate threat to public safety.

condensation: the act or process of reducing a gas or vapor to a liquid or solid state.

cone of depression: the cone-shaped area formed when the spaces in the rock or soil are emptied as water is withdrawn from a well.

confined aquifer (artesian aquifer): an aquifer with a dense layer of compacted earth material over it that blocks easy passage of water.

conservation: act of using the resources only when needed for the purpose of protecting from waste or loss of resources.

conservation farming: the management of farm activities and structures to eliminate or reduce adverse environmental effects of pollutants and conserve soil, water, plant, and animal resources.

conserve: to save a natural resource, such as water, through intelligent management and use.

constructed wetlands: wetlands that are designed and built similar to natural wetlands; some are used to treat wastewater. Constructed wetlands for wastewater treatment consist of one or more shallow depressions or cells built into the ground with level bottoms so that the flow of water can be controlled within the cells and from cell to cell. Roots and stems of the wetland plants form a dense mat where biological and physical processes occur to treat the wastewater. Constructed wetlands are being used to treat domestic, agricultural, industrial, and mining wastewaters.

contaminant: an impurity, that causes air, soil, or water to be harmful to human health or the environment.

contaminate: to make impure (not pure) by contact or mixture; to introduce a substance into the air, water, or soil that reduces its usefulness to humans and other organisms in nature.

contamination: the state of being contaminated or impure (not pure) by contact or mixture; the state of having a substance introduced into the air, water, or soil that reduces its usefulness to humans and other organisms in nature.

contour plowing: a system of plowing along the contour lines of the land to prevent soil erosion.

convection current: the transfer of heat by the mass movement of heated particles.

cooling towers: a tower-like device in which atmospheric air circulates and cools warm water, generally by direct contact (evaporation).

corrosivity: ability to dissolve or break down certain substances, particularly metals.

"cradle to grave": phrase used to describe regulations that are part of the Resources Conservation and Recovery Act (RCRA), which requires that hazardous wastes be tracked from their points of origin to their proper disposal; these regulations are designed to protect groundwater, as well as other resources, from contamination by improper treatment, storage, and disposal of solid wastes and are aimed at ending irresponsible "midnight dumping."

crest: something forming the top of something else, such as the crest of a wave.

cubic feet: the volume of a cube whose edge is some number of feet in measure.

cubic meters: the volume of a cube whose edge is some number of meters in measure.

cumulative: increasing or enlarging by successive addition; acquired by or resulting from accumulation.

debris: dead organic material (leaves, twigs, etc.) and sediment.

decompose: to decay or rot; a result of microbial action.

decomposition: the process of rotting and decay which causes the complex organic materials in plants and animals to break down into simple inorganic elements which can be returned to the atmosphere and soil.

defecate: to void excrement or waste through the anus.

de-foaming agents: chemicals that are added to wastewater discharges to prevent the water from foaming when it is discharged into a receiving water body.

degradable: capable of decomposition; chemical or biological.

depression storage: the storage of water in low areas such as puddles, bogs, ponds, and wetlands.

desalination: the purification of salt or brackish water by removing the dissolved salts.

detergent: a synthetic cleansing agent resembling soap; has the ability to emulsify oil and remove dirt; contains surfactants that do not precipitate in hard water.

detritus: loose fragments or grains that have been worn away from rock.

digestion: decomposition of organic waste materials by the action of microbes; the process of sewage treatment by the decomposition of organic matter.

dilution: the act of making thinner or more liquid by adding to the mixture; the act of diminishing the strength, flavor, or brilliance of by adding to the mixture.

discharged: released into a water body.

disinfect (disinfected): to cleanse of harmful microorganisms.

disposal: a disposing of or getting rid of something, as in the disposal of waste material.

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water.

dissolved solids: materials that enter a water body in a solid phase and dissolve in water.

distillation: the process of heating a liquid or solid until it sends off a gas or vapor and then cooling the gas or vapor until it becomes a liquid.

distribution box: a place where one pipe or line enters and exits through several pipes or lines; they are used in municipal drinking water systems to distribute water to homes, in municipal wastewater systems to retrieve wastewater, and by electric companies to distribute power.

divining rod: a forked branch or stick used in an attempt to locate subterranean water or minerals; it is said to bend downward when held over a source.

domestic sewage: waste produced through the functioning of a household.

downstream: in the direction of a stream's current.

dowsing: to use a divining rod in an attempt to find underground water or minerals.

drainage basin: an area drained by a main river and its tributaries.

drainage system: a network formed by a main river and its tributaries.

drainfield: the part of a septic system where the wastewater is released into the soil for absorption and filtration.

dredging: the cleaning, deepening, or widening of a waterway using a machine (dredge) that removes materials using a scoop or suction device.

drought: a lack of rain or water; a long period of dry weather.

duck stamp: required, for a fee, of all duck hunters over age 16 by the U.S. Fish and Wildlife Service; a conservation program aimed at preserving wetlands.

ecology: a branch of science concerned with the interrelationship of organisms and their environments; the totality or pattern of relations between organisms and their environment.

ecosystem: an ecological community together with its physical environment, considered as a unit.

effluent: waste material, such as water from sewage treatment or manufacturing plants, discharged into the environment.

electroplating: to coat or cover with a thin layer of metal using electricity.

elements: substances such as iron, sodium, carbon, nitrogen, and oxygen with distinctly different atoms which serve as some of the 108 basic building blocks of all matter.

The Emergency Planning and Community Right-to-Know Act of 1986 (SARA Title III): law requiring federal, state and local governments and industry which are involved in either emergency planning and/or reporting of hazardous chemicals to allow public access to information about the presence of hazardous chemicals in the community and releases of such substances into the environment.

emission: a substance discharged into the environment.

endangered animal species: a species of animal identified by official federal and/or state agencies as being faced with the danger of extinction.

environment: the sum of all external conditions and influences affecting the development and life of organisms.

Environmental Protection Agency (EPA): the U.S. agency responsible for efforts to control air and water pollution, radiation and pesticide hazards, ecological research, and solid waste disposal.

epidemic diseases: diseases that spread rapidly and extensively by infection among many individuals in an area.

erosion: the wearing away of the earth's surface by running water, wind, ice, or other geological agents; processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is removed from the earth's surface.

estuarine: of an area where a river empties into an ocean; of a bay, influenced by the ocean tides, which has resulted in a mixture of salt water and fresh water.

estuarine intertidal emergents: herbaceous vegetation that grows in saltwater marshes.

estuarine intertidal forested/shrub: a saltwater wetland containing larger woody plants.

estuarine intertidal unconsolidated shores: beaches and sand bars.

estuarine subtidal: a habitat of open water and bay bottoms continuously covered by salt water.

estuarine unconsolidated bottom habitats: sandy bottom area in open water estuaries.

estuary: the area where a river empties into an ocean; a bay, influenced by the ocean tides, resulting in a mixture of salt water and fresh water.

eutrophic: pertaining to a lake containing a high concentration of dissolved nutrients; often shallow, with periods of oxygen deficiency.

eutrophication: a naturally occurring change that take place after a water body receives inputs of nutrients, mostly nitrates and phosphates, from erosion and runoff of surrounding lands; this process can be accelerated by human activities.

evaporate: to convert or change into a vapor with the application of heat.

evaporation: the act or process of converting or changing into a vapor with the application of heat.

evapotranspiration: combination of evaporation and transpiration of water into the atmosphere from living plants and soil.

Federal Water Pollution Control Act (Clean Water Act): the law to restore and maintain the "chemical, physical, and biological integrity of the Nation's waters."

feedlots: confined areas where livestock are quartered and fed, often these are holding areas where animals are fattened-up prior to being shipped to market.

fertilizer: any one of a large number of natural and synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread or worked into the soil to increase its fertility.

fill: material added to a wetland area to make it suitable for building.

filtration: the process of passing a liquid or gas through a porous article or mass (paper, membrane, sand, etc.) to separate out matter in suspension.

fish kill: the sudden death of fish due to the introduction of pollutants or the reduction of the dissolved oxygen concentration in a water body.

fishery: a place engaged in the occupation or industry of catching fish or taking seafood from bodies of water; a place where such an industry is conducted.

FL (fork length): the length of a fish from its mouth to the fork in its tail.

flocculation: the process of forming aggregated or compound masses of particles, such as a cloud or a precipitate.

flood conveyance: the transport of floodwaters downstream with minimal, if any, damage.

floodplain: a low, flat area on either side of a river that can accommodate large amounts of water during a flood, lessening flood damage further downstream.

flooding: an overflowing of water, especially over land not usually submerged.

fluoride: a binary compound of fluorine with another element; added to drinking water to help prevent tooth decay.

food chain: a succession of organisms in a community that constitute a feeding order in which food energy is transferred from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.

food web: the connections among everything organisms in a location eat and are in turn eaten by.

fossil fuel: a hydrocarbon fuel, such as petroleum, derived from living matter of a previous geologic time.

fresh water: water containing an insignificant amount of salts, such as in inland rivers and lakes.

gaining streams: streams that appear from the ground or cracks in rocks because they are flowing directly out of an aquifer.

gallon: a unit of liquid capacity equal to four quarts (about 3.8 liters).

glycerin: a sweet, thick liquid found in various oils and fats and can be used to moisten or dissolve something.

gill: an aquatic respiratory organ (as on fish) for obtaining oxygen dissolved in the water.

grade: the slope of the surface of the earth.

gradient: the degree of inclination , or the rate of ascent or descent, in a highway, road, river, etc.

gravity: the force of attraction, characterized by heaviness or weight, by which terrestrial bodies tend to fall toward the center of the earth.

green zones: areas along river- and streambanks, wetlands, lakes, and ponds where there is high productivity and diversity.

greywater: domestic wastewater that does not contain human wastes such as tub, shower, or washing machine water.

groundwater: water that infiltrates into the earth and is stored in usable amounts in the soil and rock below the earth's surface; water within the zone of saturation.

groundwater discharge: the flow or pumping of water from an aquifer.

groundwater recharge: the addition of water to an aquifer.

gully: a trench worn in the earth by running water.

habitat: the arrangement of food, water, shelter, and space suitable to animal's needs.

halite: a white or colorless mineral, sodium chloride or rock salt.

hardness: the amount of calcium carbonate dissolved in water.

hazardous chemicals: chemical compounds that are dangerous to human health and/or the environment.

hazardous waste: waste containing chemical compounds that are dangerous to human health and/or the environment.

heat capacity: the heat required to raise the temperature of a substance one Celcius degree.

heavy metals: metallic elements Example: cadmium, chromium, copper, lead, mercury, nickel, and zinc) which are used to manufacture products; they are present in some industrial, municipal, and urban runoff.

herbaceous: describes animals that are strictly plant-eating.

heterotroph: an organism that is not capable of making its own food.

holding pond: an animal waste treatment method which uses a shallow pond to temporarily store animal wastes for land application.

holding tanks: a container where wastewater is stored before it is removed for treatment; confined livestock operations have holding tanks to store animal wastes for land application at a later time.

humidity: the degree of wetness, especially of the atmosphere.

hydrocarbons: substances containing only hydrogen and carbon, such as methane, alkane, or ethylene.

hydroelectric: that generation of electricity which converts the energy of running water into electric power.

hydrogen sulfide gas (H_2S): a flammable, toxic, colorless gas with an offensive odor (similar to rotten eggs).

hydrolic: operated, moved, or brought about by means of water.

hydrologic (water) cycle: the cycle of the earth's water supply from the atmosphere to the earth and back which includes precipitation, transpiration, evaporation, runoff, infiltration, and storage in water bodies and groundwater.

hydropower: any means of harnessing power from water.

impermeable: impassable; not permitting the passage of a fluid through it.

impurity: something that, when mixed into something else, makes that mixture unclean or lowers the quality.

induced recharge: replenishing a water body or aquifer by transporting water from somewhere else and putting it into the water body or aquifer.

industrial pollution: pollution caused by industry.

infiltration: the gradual downward flow of water from the surface of the earth into the soil.

injection wells: a well in which fluids (such as wastewater, saltwater, natural gas, or used chemicals) are injected deep in the ground for the purpose of disposal or to force adjacent fluids like oil into the vicinity of oil producing wells.

inorganic material: material derived from nonorganic, or nonliving, sources.

inorganic nitrogen: nitrogen not derived from organic matter.

inorganic phosphorus: phosphorus not derived from organic matter.

irrigation: to supply (dry land) with water by means of ditches, pipes, or streams.

karst: a topography formed over limestone, dolomite, or gypsum and characterized by sinkholes, caves, and underground drainage.

lacustrine: refers to lake or river habitats.

lagoon: as a wastewater treatment method, an animal waste treatment method which uses a deep pond to treat manure and other runoff from a livestock operation, may be aerobic or anaerobic (both use bacteria to break down wastes).

landfill: a large, outdoor area for waste disposal; landfills where waste is exposed to the atmosphere (open dumps) are now illegal; in "sanitary" landfills, waste is layered and covered with soil.

landscaping: improving the natural beauty of a piece of land by planting or altering the contours of the ground.

land use: how a certain area of land is utilized (Examples: forestry, agriculture, urban, industry).

leachate: the liquid formed when water (from precipitation) soaks into and through a landfill, picking up a variety of suspended and dissolved materials from the waste.

leaching: the removal of chemical constituents from rocks and soil by water.

leaking underground storage tank (LUST): an underground container used to store gasoline, diesel fuel, home heating oil, or other chemicals that is damaged in some way and is leaking its contents into the ground; may contaminate groundwater.

legislation: a proposed or enacted law or group of laws.

limiting factor: a factor whose absence exerts influence upon a population and may be responsible for no growth, limited growth (decline), or rapid growth.

liner: a clay or plastic material placed between garbage and soil in a landfill to prevent rotting garbage from coming in contact with groundwater.

litter: rubbish discarded in the environment instead of in trash containers.

littoral zone: region in a body of water that sunlight penetrates.

longshore current: a current that moves parallel to the shore.

losing streams: streams which seem to disappear because they flow into an aquifer.

macroinvertebrates: organisms that are visible to the naked eye and lack a backbone.

mariculture: the cultivation of marine organisms in their natural habitats, usually for commercial purposes.

marine: of or relating to the sea.

marine intertidal: a coastal saltwater wetland flooded by tidewaters.

marine pollution: pollution found in the oceans, bays, or gulfs.

The Marine Protection, Research, and Sanctuaries Act of 1972 (Ocean Dumping Act): legislation regulating the dumping of any material in the ocean that may adversely affect human health, marine environments, or the economic potential of the ocean.

marsh: an area of low-lying wetland.

maximum contaminant levels: the highest content levels of certain substances allowable by law for a water source to be considered safe.

meander: to follow a winding course, such as a brook meandering through the fields.

membrane: a soft pliable sheet or layer, often of plant or animal origin.

mercury: a poisonous metallic element, Hg, atomic number 80, atomic weight 200.59, existing at room temperature as a silvery, dense liquid.

Mesopotamians: people from the ancient country of Mesopotamia located in southwest Asia between the Tigris and Euphrates rivers.

microbe: a microorganism; a very tiny and often harmful plant or animal.

microbial digestion: breakdown and use of a substance by microorganisms.

microbiology: the science and study of microorganisms, including protozoans, algae, fungi, bacteria, and viruses.

microorganisms: organisms too small to be seen with the unaided eye, including bacteria, protozoans, yeasts, viruses, and algae.

midnight dumping: a term used for illegal disposal of hazardous wastes in remote locations often at night, hence the term "midnight."

mill tailings: rock and other materials removed when minerals are mined; usually dumped onto the ground or deposited into ponds.

mineral: a naturally occurring substance (as diamond or quartz) that results from processes other than those of plants and animals; a naturally occurring substance (as ore, petroleum, natural gas, or water) obtained usually from the ground for human use.

miscible: capable of being mixed.

mixture: two or more substances mixed together in such a way that each remains unchanged (sand and sugar form a mixture).

moisture: a small amount of liquid that causes wetness.

molecules: the smallest portions of a substance having the properties of the substance.

monitoring: scrutinizing and checking systematically with a view to collecting data.

monofilament: a single large filament, or threadlike structure, of synthetic fiber, such as a monofilament fishing line.

mulch: a protective covering of various substances, especially organic; placed around plants to prevent evaporation of moisture and freezing of roots and to control weeds.

municipality: a political unit, such as a city or town, incorporated for local self-government.

municipal sewage: sewage originating from urban areas (not industrial).

National Environmental Policy Act of 1969 (NEPA): law that requires environmental impact statements be submitted for any major construction projects that uses U.S. federal money.

National Pollutant Discharge Elimination System (NPDES): part of the Clean Water Act requiring municipal and industrial wastewater treatment facilities to obtain permits which specify the types and amounts of pollutants that may be discharged into water bodies.

national water quality standards: maximum contaminant levels for a variety of chemicals, metals, and bacteria set by the Safe Drinking Water Act.

natural resource: something (as a mineral, forest, or kind of animal) that is found in nature and is valuable to humans.

negative charge: an electrical charge created by having more electrons than protons.

nitrates: used generically for materials containing this ion group made of nitrogen and oxygen (NO_3^-); sources include animal wastes and some fertilizers; can seep into groundwater; linked to human health problems, including "blue baby" syndrome (methemoglobinemia).

nitric acid (HNO_3): a component of acid rain; corrosive; damages buildings, vehicle surfaces, crops, forests, and aquatic life.

nonbiodegradable: materials that cannot be broken down by livings things into simpler chemicals.

non-compliance: not obeying all the federal and state regulations that apply.

non-permeable surfaces: surfaces which will not allow water to penetrate, such as sidewalks and parking lots.

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (Example: outlet or pipe) because it comes from many individual places or a widespread area (typically, urban, rural, and agricultural runoff).

nutrient: an element or compound, such as nitrogen, phosphorus, and potassium, that is necessary for plant growth.

offshore dumping: the disposal or dumping of waste material off or away from the shore.

The Oil Pollution Act: legislation that imposes substantial penalties and liability for oil spills in the ocean; violators are responsible for the cost of the cleanup and restoration of natural resources.

organic material: material derived from organic, or living, things; also, relating to or containing carbon compounds.

oil slick: a smooth area on the surface of water caused by the presence of oil.

organism: any living being; plants and animals.

oxygen depletion: the reduction of the dissolved oxygen level in a water body.

package plants: a small, semi-portable prefabricated wastewater treatment system that services an apartment complex, trailer park, camp, or self-contained business that is not connected to a city sewer system and is not on a site appropriate for a septic system.

palustrine aquatic beds: inland areas which contain floating or submerged aquatic vegetation.

palustrine emergents: plants growing in inland marshes and wet meadows.

palustrine forested: inland areas such as forested swamps or bogs.

palustrine shrub: inland wetland area with shrub growth.

palustrine unconsolidated bottom: muddy bottom of open water ponds.

percolate: to drain or seep through a porous substance.

permeable: passable; allowing fluid to penetrate or pass through it.

permeability: the property of a membrane or other material that permits a substance to pass through it.

pesticide: any chemical or biological agent that kills plant or animal pests; herbicides, insecticides, fungicides, rodenticides, etc. are all pesticides.

petroleum products: products derived from petroleum or natural gas.

pH: a measure of the concentration of hydrogen ions in a solution; the pH scale ranges from 0 to 14, where 7 is neutral and values less than 7 are acidic and values greater than 7 are basic or alkaline; pH is an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

phosphate: used generically for materials containing a phosphate group (PO_4^{3-}); sources include some fertilizers and detergents; when wastewater containing phosphates is discharged into surface waters, these chemicals act as nutrient pollutants (causing overgrowth of aquatic plants).

photodegradable: plastic that will decompose into smaller pieces under certain kinds of radiant energy, especially ultraviolet light.

plankton: minute animal and plant life in a body of water.

point source pollution: pollution that can be traced to a single point source, such as a pipe or culvert (Example: industrial and wastewater treatment plant, and certain storm water discharges).

polar: of or relating to the poles or ends of a magnet.

polarity: having a positive or negative charge.

pollutant: an impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that may be harmful to or affect the health, survival, or activities of humans or other living organisms.

pollution: contaminants in the air, water, or soil that cause harm to human health or the environment.

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials.

pond: a body of water usually smaller than a lake.

population: the organisms inhabiting a particular area or biotope.

porosity: the property of being porous, having pores; the ratio of minute channels or open spaces (pores) to the volume of solid matter.

positive charge: an electrical charge created by having fewer electrons than protons.

potable: fit or suitable for drinking, as in potable water.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the earth's surface, such as rain or snow.

primary treatment: the first process in wastewater treatment which removes settled or floating solids.

pristine: describes a landscape and/or a water body remaining in a pure state.

privy: an outhouse; a latrine.

protozoans: small single-cell microbes; frequently observed as actively moving organisms when impure water is viewed under a microscope; cause a number of widespread human illnesses, such as malaria, and thus can present a threat to public health.

pruning: trimming or cutting off undesired or unnecessary twigs, branches, or roots from a tree, bush, or plant.

purification: the process of making pure, free from anything that debases, pollutes, or contaminates.

quadrillion: the cardinal number represented by 1 followed by 15 zeros.

quota: the number or amount constituting a proportional share.

radioactive: having the property of releasing radiation.

radioactive pollution: the introduction of a radioactive material.

radon: a colorless, radioactive, inert gaseous element (atomic number 86) formed by the radioactive decay of radium; exposure to high levels causes cancer.

recharge: replenish a water body or an aquifer with water.

recharge areas: an area where water flows into the earth to resupply a water body or an aquifer.

reclaim: to return to original condition.

red tide: a reddish discoloration of coastal surface waters due to concentrations of certain toxin-producing algae.

reforestation: replanting trees and establishing a forest after forest harvesting or destruction.

regulation: a governmental order having the force of law.

renewable resource: a resource or substance, such as a forest, that can be replenished through natural or artificial means.

reservoir: a body of water collected and stored in a natural or artificial lake.

Resource Conservation and Recovery Act (RCRA): legislation passed in 1976 aimed at protecting the environment, including waterways, from solid waste contamination either directly, through spills, or indirectly, through groundwater contamination.

restoration: reestablishing the character of an area such as a wetland or forest; cleaning up a contaminated area according to specifications established by the U.S. Environmental Protection Agency.

reverse osmosis: a process where water is cleaned by forcing water through an ultra-fine semi-permeable membrane which allows only the water to pass though and retains the contaminants; these filters are sometimes used in tertiary treatment and to pretreat water in chemical laboratories.

ridge planting: a conservation farming method where seeds are planted in ridges which allows warmer soil temperatures and traps rainwater in the furrows between the ridges.

riparian area: the area along a waterway.

river: a large natural stream emptying into an ocean, lake, or other water body.

riprap: large rocks placed along the bank of a waterway to prevent erosion.

riverine habitats: tidal and non-tidal river systems that feed into wetlands.

The Rivers and Harbors Act of 1899: legislation regulating the discharge of refuse of any kind into navigable waters.

rough (scavenger) fish: non-sport species of fish that tolerate polluted water.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants.

Safe Drinking Water Act: a regulatory program passed by the U.S. Congress in 1974 to help ensure safe drinking water in the United States; sets maximum contaminant levels for a variety of chemicals, metals, and bacteria in public water supplies.

saline intrusion: the saltwater infiltration of freshwater aquifers in coastal areas, when groundwater is withdrawn faster than it is being recharged.

salinity: an indication of the amount of salt dissolved in water.

salt marsh: an area where salt water from an ocean, bay, or gulf meets fresh water from a river.

salt water: water associated with the seas distinguished by high salinity.

sanitary landfill: rehabilitated land in which garbage and trash have been buried.

saturated air: air that contains as much moisture as it is possible to hold under existing conditions.

saturated zone: underground layer in which every available space is filled with water.

saturation: the state of being infused with so much of a substance (Example: water) that no more can be absorbed, dissolved, or retained.

secondary treatment: the wastewater process where bacteria are used to digest organic matter in the wastewater.

sediment: insoluble material suspended in water that consists mainly of particles derived from rocks, soil, and organic materials; a major nonpoint source pollutant to which other pollutants may attach.

sediment pollution: the introduction of sediment into a water body.

sediment pond: a natural or artificial pond for recovering the solids from effluent or runoff.

septic system: a domestic wastewater treatment system (consisting of a septic tank and a soil absorption system) into which wastes are piped directly from the home; bacteria decompose the waste, sludge settles to the bottom of the tank, and the treated effluent flows out into the ground through drainage pipes.

settling: the process of a substance, such as dregs or sediment, sinnking or being deposited.

settling tank: a vessel in which solids settle out of water by gravity during drinking and wastewater treatment processes.

sewage contamination: the introduction of untreated sewage into a water body.

sewage outfall: the point of sewage discharge, often from a pipe into a body of water, in turn called the outfall area.

sewer system: an underground system of pipes used to carry off sewage and surface water runoff.

silage: livestock food prepared by storing and fermenting green forage plants in a silo.

silt: particles of small size left as sediment from water.

sinkhole: a natural depression in a land surface connected to a subterranean passage, generally occurring in limestone regions and formed by solution or by collapse of a cavern roof.

siphon: a bent pipe or tube through which liquid can be drawn by air pressure up and over the edge of a container; to draw off by a siphon.

slope: to take a slanting direction, such as a bank sloping down to a river; a piece of slanting ground, such as a hillside; the upward or downward slant, such as that of a roof.

slough: a stagnant swamp, marsh, bog, or pond, especially as a part of a bayou, inlet, or backwater.

sludge: solid matter that settles to the bottom of septic tanks or wastewater treatment plant sedimentation; must be disposed of by bacterial digestion or other methods or pumped out for land disposal or incineration.

solar radiation: radiation emitted by the sun.

solution: the result of solving a problem; a liquid in which something has been dissolved.

solvent: a liquid capable of dissolving another substance (Examples: paint thinner, mineral spirits, and water).

stormwater runoff: surface water runoff that flows into storm sewers or surface waters.

stream: a body of water flowing in a channel, as a brook, rivulet, or river.

stream use classification: a system for classifying streams according to the intended use of the water (Examples: recreation, industrial cooling, irrigation).

strip mine: an open mineral mine (Examples: coal, copper, zinc, etc.) where the topsoil and overburden is removed to expose and extract the mineral.

subsidence: the compacting and sinking of an area.

substance: a material of a particular kind or constitution.

substrate: the substance acted upon by an enzyme or a fermenter, such as yeast, mold, or bacteria.

suffocate: to die due to the lack of oxygen.

sulfuric acid: the acid (H_2SO_4) formed when sulfur oxides combine with atmospheric moisture; a major component of acid rain.

supersaturation: the state of being infused with more of a substance (Example: water) than is normally possible under given conditions of temperature and pressure.

surface tension: the elastic-like force in a body, especially a liquid, tending to minimize, or constrict, the area of the surface.

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

swamp: land having soils saturated with water for at least part of the year and supporting natural vegetation of mostly trees and shrubs.

taxa: one of the hierarchical categories into which organisms are classified.

temperate climates: climates that are neither hot nor cold; mild.

terrain: the characteristic features of a tract of land's surface; topography.

terrarium: a box, usually made of glass, that is used for keeping and observing small animals or plants.

thermal pollution: the increase in temperature of a body of water due to the discharge of water used as a coolant in industrial processes or power production; can cause serious damage to aquatic life.

TL (total length): the length of a fish from its mouth to the end of its tail.

toilet dam: a device that is placed inside the tank portion of a toilet to reduce the amount of water the tank will hold by partitioning off part of the tank.

topographic map: a map showing the relief features or surface configuration of an area, usually by means of contour lines.

topography: the detailed mapping or description of the features of a relatively small area, district, or locality; the relief features or surface configuration of an area.

topsoil: the rich upper layer of soil in which plants have most of their roots.

toxic: having the characteristic of causing death or damage to humans, animals, or plants; poisonous.

toxic chemical: a chemical with the potential of causing death or damage to humans, animals, or plants;

poison.

toxin: any of various poisonous substances produced by certain plant and animal cells, including bacterial toxins, phytotoxins, and zootoxins.

transpiration: direct transfer of water from the leaves of living plants or the skins of animals into the atmosphere.

treatment: a substance with which to treat water or a method of treating water to clean it.

treatment plant: facility for cleaning and treating fresh water for drinking, or cleaning and treating wastewater before discharging into a water body.

tributary: a stream or river that flows into a larger river or lake.

trough: the lowest point in a wave; also a channel for water; a long channel or hollow.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter.

turbine: a device in which a bladed wheel is turned by the force of moving water or steam; connected by a shaft to a generator to produce electricity.

typhoid (fever): an acute, highly infectious disease caused by the typhoid bacillus, *Salmonella typhosa*, transmitted by contaminated food or water and characterized by bad rashes, high fever, bronchitis, and intestinal hemorrhaging.

ultraviolet light: similar to light produced by the sun; produced by special lamps. As organisms are exposed to this light, they are damaged or killed.

unconfined aquifer: an aquifer without a confining layer above it; the top surface of water in an unconfined aquifer is the water table.

underground storage tanks: large tanks buried underground for storing liquids (Examples: gasoline, heating oil); potential source of groundwater contamination if the tanks leak.

unit: a fixed quantity (as of length, time, or value) used as a standard of measurement; a single thing, person, or group forming part of a whole.

unsaturated zone: an area underground between the ground surface and the water table where the pore spaces are not filled with water, also know as the zone of aeration.

upstream: toward the source of a stream or current.

urban area: an area that is highly populated, such as a city or town.

wastewater: water that has been used for domestic or industrial purposes.

wastewater treatment: physical, chemical, and biological processes used to remove pollutants from wastewater before discharging it into a water body.

waterborne disease: a disease spread by contaminated water.

water conservation: practices which reduce water use.

water cycle: see hydrologic cycle.

water pollution: the act of making water impure or the state of water being impure.

water quality: the condition of water with respect to the amount of impurities in it.

watershed: land area from which water drains to a particular water body.
water system: a river and all its branches.

water table: the upper surface of the zone of saturation of groundwater.

THE WATER SOURCEBOOK
FACTSHEETS

THE WATER CYCLE

Water is perhaps the ultimate example of recycling. Water constantly renews its purity by cycling itself from a liquid (or a solid) into vapor and back again. The change to a vapor removes most impurities and allows water to return to Earth in its clean form. (Exception: **acid rain**, see F-51, Surface Water Issues.)

The study of water, or **hydrology**, starts with the **water cycle**, or the process by which water renews itself. Since the cycle is continuous, it doesn't really have a beginning, but a convenient place to start studying it is with **precipitation** (rain, snow, sleet and hail). When precipitation falls to earth, several things can happen. It can be absorbed into the soil. This is called **infiltration**. This process allows water to seep into the earth and be stored underground as **groundwater**. Precipitation can also become **runoff**, flowing into rivers and streams. Water can **evaporate**, or it can be returned to the atmosphere by **transpiration** through plants. Since it is often difficult to separate these two processes, they are often lumped together and called **evapotranspiration**.

Precipitation can also be **stored**. An ice cap is a form of storage. In temperate climates, water is found in depression storage or surface water—puddles, ditches, and anywhere else that runoff water can gather. This is a temporary form of storage. Water will evaporate from the surface and will infiltrate into the ground below it. It will be absorbed by plants and transpired back into the air. It will flow to other areas. This "cycling" of water is continuous.

A number of factors such as soil type, slope, moisture conditions, and intensity of storm event affect how water travels through this cycle. For example, when rain falls, some of it will infiltrate into the ground, but this rate of infiltration may be fast or slow. If the soil is already wet and saturated, much of the rain will become runoff. If the soil has low moisture content, a large percentage of it may be absorbed. The type of soil will also impact the rate of infiltration. Clay or packed soil allows little water to seep in. Sandy or loose soils allow more infiltration.

The rate of rainfall is a factor to consider. If rain is hitting the ground faster than it can infiltrate, it becomes runoff. The grade or slope can also influence runoff. Water infiltrates very little on steep grades. Human-made structures can reduce infiltration even further. Virtually no water infiltrates through paved roads and parking lots, so almost all of it becomes runoff. This affects the entire water cycle.

WATERSHEDS

Watersheds have a big impact on the water cycle. A watershed, also called a drainage basin, is the area in which all water, sediments, and dissolved materials drain from the land into a common body of water, such as a river, lake or ocean. A watershed encompasses not only the water but the surrounding land from which the water drains. This can be an area as large as the Mississippi River drainage basin or as small as a backyard.

A watershed may be either a large or small area, and its characteristics can greatly affect how water flows through the watershed. For example, the flow in a particular stream may fluctuate dramatically with rainfall because of the characteristics of the watershed. Heavy storms may cause streams to rise rapidly. Human-made features of the watershed like dams or large paved areas can change stream flow and alter the watershed. If the topography is steep, changes in stream flow due to runoff can be significant.

In some watersheds, stream flow may take a long time to respond to rainfall runoff. On heavily vegetated, relatively flat terrain, infiltration is great, or runoff is slowed by vegetation. Eventually, however, runoff will make its way through the watershed and become stream flow. In these areas, stream flow will rise slowly, but also recede slowly.

The stream flow characteristics of a watershed can be a key to evaluating the quality of the water in the watershed. Streams start out in higher elevations, and flow downward, eventually finding their way to the sea. But they don't travel in straight lines. Their paths vary. The terrain may be steep in some areas, causing rapid flow, and flat in other areas, allowing the water to get deeper and spread out. These grade changes create different habitats in the stream which support different forms of life and change the quality of water in the watershed.

Water quality is critically impacted from everything that goes on within the watershed. Mining, forestry, agriculture, and construction practices, urban runoff from streets, parking lots, chemically treated lawns, and gardens, failing septic systems, and improperly treated municipal sewage discharges all affect water quality. Reducing pollution and protecting water quality requires identifying, regulating, monitoring, and controlling potential pollutants. Some examples of control practices include protecting streambanks and shorelines by maintaining vegetated buffer strips, treating all wastes to remove harmful pollutants, or using grass-lined catchment basins in urban areas to trap sediment and pollutants.

THE COMMUNITY WATER ENVIRONMENT

Community water environments, have their own water "cycle within a cycle" based on the factors within the community that affect water uses and flow.

Rainfall, soil composition, terrain, large surface bodies of water, human-made structures, pollution sources, surface water, weather patterns, and other factors can all have an impact on the "community" water environment. For example, a desert community may have a water environment with very little rainfall, while a marine coastal climate like the Northwest will see months of rain. An urban community will have its water environment affected by fast runoff due to paved areas, high water consumption due to large populations, water contaminants from industrial operations, urban runoff, domestic sewage, and construction. A rural area may have its water environment affected by lakes and streams that put large amounts of water into the air through evaporation or forests that contribute water vapor through evapotranspiration. Agriculture often uses large amounts of water for irrigation and watering livestock. Agricultural practices can also pollute the rural water environment with fertilizers and pesticides, if improperly applied, or animal wastes if improperly managed.

In most urban communities, water is withdrawn from either a surface waterbody like a lake, reservoir, or stream, or from a underground aquifer. This water is usually treated at a drinking water treatment plant and distributed to individual homes, businesses, and industries through a vast network of underground pipes. Water is then used by citizens, businesses, and industries. Used water either flows into a drain and travels to a wastewater treatment plant though a network of sewer pipes or is deposited onto the ground. For example, water used to wash the car or water the lawn may either soak into the ground or flow over the earth and run into nearby waterbody or a network of storm drains which flow into a nearby waterbody. Some storm drains are connected to wastewater treatment plants. At the wastewater treatment plant, most pollutants are removed and the treated water is released into a nearby surface waterbody and the cycle begins again.

In rural areas, water is usually withdrawn directly from the ground through a well and piped into the house and other buildings via a network of pipes. Used water is either deposited onto the ground where is soaks in or runs off or it flows through pipes into a septic tank. Wastewater in the septic tank undergoes treatment and flows from the tank into a series of pipes called a drainfield where it percolates into the soil.

In both urban and rural communities the primary source of water is from precipitation which is either stored as surface water or groundwater. In special cases, some communities store water in water towers.

WATER QUALITY

Every time water completes its cycle from vapor to liquid or solid and back to vapor again, its quality is renewed. However, water quality can be damaged by any number of pollutants in the air, on land, or from other water supplies. The amount of water available for use depends on its quality, and the availability of water dictates where we can live, build cities, and create industry.

On the average, every American uses about 150 gallons of water a day. That makes daily water consumption in the United States in 1996, approximately 39 **billion** gallons per day. It's no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies.

Each time we use water, we change its quality by adding substances to it. These materials are such things as municipal sewage, toxic chemicals, solvents, automotive oils, fertilizers, detergents, pesticides, and even extra heat. Some materials, even in small quantities, can damage water quality to the point to make it unusable. A single quart of motor oil, for example, could pollute as much as 250,000 gallons of water.

WATER QUALITY STANDARDS

Water may have different quality "standards," depending on its use. For example, water can be of high enough quality for livestock to drink but not be pure enough for humans to consume. Or, water may provide a fine environment for bass, bluegill and other lake fish while not being cold enough or having enough oxygen content to support trout. Water quality is often in the "eye of the beholder."

Laws involving water quality date back as far as 1914. The first Federal law dealing exclusively with water quality was passed in 1948. Under this law, the states retained primary responsibility for water quality standards and protection. The Federal government supplied money primarily for research. The law provided only weak punishments for offenders. During the 1960s, amendments provided for Federal water quality standards, Federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern resulted in passage of three more very important environmental laws.

The National Environmental Policy Act of 1969 (NEPA) required federal agencies to consider the environmental impacts of their actions. All federal agencies must prepare environmental impact statements to assess the impacts of major federal actions, such as large building or industrial projects. Because of NEPA, federal undertakings have been conducted in a manner to ensure protection of all natural resources, including water.

The Federal Water Pollution Control Act (Clean Water Act) which was passed in 1972 and amended in 1977, 1981, and 1987 provides the basis for water quality standards today. The Clean Water Act (CWA) also established the National Pollutant Discharge Elimination System (NPDES), a permitting program which has assisted in reducing discharges of pollutants to surface waters. The Safe Drinking Water Act (SDWA), passed in 1974 and amended in 1986 and 1996, requires public drinking water systems to protect drinking water sources, provide water treatment, monitor drinking water to ensure proper quality, and notify the public of contamination problems. The Environmental Protection Agency is responsible for implementing or authorizing states to implement the NPDES permitting program, establishing drinking water standards, and enforcing other provisions of the CWA and SDWA.

LAND USE AND WATER QUALITY

Land use can have a tremendous effect on water quality. Farmlands can be the source of sediment, fertilizer, pesticides, and animal waste pollution. When forests are cut down, they can be major sources of sediment pollution. Cities pose numerous water quality problems due to: the demand for clean water, industrial and commercial pollutants, and human and pet wastes, and urban runoff from lawns and paved areas.

So it's important that when we decide to use land for a specific purpose, we take into account water quality, not just in the immediate area but within the whole watershed. This means considering the **amount** of water available as well as how it must be processed before and after use. For example, crops require tremendous amounts of water. If there's not enough rainfall to support their growth, crops must be irrigated, which means transporting water from lakes, streams, or wells. Irrigation may require so much water that aquatic life in lakes and streams may be adversely impacted, or the water table may be lowered, causing wells and wetlands to dry up. Another good example is the case of a computer chip manufacturer in California. The manufacturing plant owner/operator may take great care to avoid discharging dangerous pollutants, but still come under attack by environmentalists for the amount of water it uses in an area where water supplies are severely limited. To avoid such attacks or criticism, the plant owner/operator can make sure that it withdraws water only during periods of high flows after rain and storm events.

Certain land use practices can minimize negative impacts to the environment. For example, planting trees and other vegetation to protect soil and reduce erosion, fencing livestock to prevent access to streams, properly treating animal wastes, minimizing use of fertilizers and pesticides, properly treating all waste products from industries, using less harmful chemicals and other products in homes, businesses, and industries, and reducing, reusing and recycling commercial products can all help reduce water pollution.

WATER POLLUTION

Water has the remarkable ability to renew and cleanse itself. When waste materials are deposited into a receiving stream, they often settle out, break down, or become diluted in the stream. However, pollution can occur if too much of a substance or too many substances are discharged so that it overwhelms the capacity of the stream to assimilate the substance(s) or cleanse itself. Water pollution may also occur if even just a little of a highly toxic substance is discharged into a receiving stream (e.g., dioxin).

Water pollution can be classified into two main categories: **point source** pollution and **nonpoint source** pollution. The difference between the two categories is simple. Point source pollution is any type of pollution that can be identified as coming from a clearly established source. This may be a factory, a previously polluted stream, or other source that is obviously causing pollution. Point source pollution problems are often simpler to control because it's easier to see the cause of the pollution and to do something about it.

Nonpoint source pollution problems are more difficult to resolve because they often cannot be traced to one specific location. Nonpoint source pollution includes sediment from rainwater runoff or fertilizer pollution as storms wash nutrients from fields. Nonpoint source pollution can be runoff from animal wastes, construction sites or mines, and leachate from landfills. Nonpoint source pollution could even be acid rain from atmospheric pollutants that falls to earth in polluted rain or snow and contaminates waterbodies.

There are six major types of water pollutants:

*Biodegradable wastes

*Plant nutrients

*Heat

*Sediments

*Hazardous and toxic chemicals

*Radioactive wastes

Biodegradable wastes include human and animal wastes, food scraps, and other types of organic materials. Biodegradable wastes can cause water pollution by providing nutrients for bacteria. If there are excessive nutrients, aerobic (oxygen-consuming) bacteria multiply too rapidly, consuming the oxygen in a stream and making it uninhabitable for some species of fish and other aquatic life. In fact, if the bacteria grow too fast, they consume enough oxygen so that virtually everything in the water dies, leaving only anaerobic bacteria (bacteria that do not require oxygen to live) that create foul smelling gases.

Biodegradable wastes can also cause water pollution by spreading disease-causing bacteria. This type of pollution was the cause of typhoid fever and cholera epidemics that led to the development of public water treatment systems.

Many of the **nutrients** used to bring the earth to life can "overfeed" a waterway to death. Sources of **nutrient pollution** are sewage and septic runoff, livestock waste, fertilizer runoff, detergents, and industrial wastes. Some of these are point source causes, while others are nonpoint source.

Nutrients like phosphates and nitrates stimulate plant growth, and are primary ingredients in fertilizers. These compounds occur naturally, but in excess quantities they can cause great damage. Approximately 80 percent of nitrates and 75 percent of phosphates added to lakes and streams in the U.S. are the result of human activities.

Natural nitrates and phosphates usually are **limiting factors** in the growth of plant life. In other words, they occur in limited amounts that help govern the growth of different organisms and keep nature in balance. But when excess amounts of these nutrients are introduced into a waterway, some plant species can experience explosive growth, literally choking off other life forms.

When soluble inorganic nitrogen concentrations in water reach just 0.3 parts per million and inorganic phosphorus concentrations reach 0.01 parts per million, algae "blooms," or multiplies rapidly. The algal blooms can become so severe that an entire lake can be fouled with a green, foul-smelling slime. Clear water can become so cloudy that visibility is restricted to a depth of a foot or less, destroying the aesthetics of the lake.

Once a bloom occurs, its negative effects can multiply rapidly. The green slime can foul up boat propellers and make swimming unpleasant. Nutrients can also cause weeds and other undesirable plants to flourish, increasing the problem. The algal bloom impairs water quality, and if the waterway is a source for municipal water supplies, it can be expensive to remove impurities and odors. Masses of algae can wash up on shore, decaying and producing hydrogen sulfide gas, which smells like rotten eggs. Certain marine algae can also release toxics that concentrate in fish and shellfish which cause human digestive problems. In fact, in some areas it is dangerous to eat foods like oysters at certain times of the year because of "red tide," a phenomenon caused by a marine algal bloom.

When an algal bloom clouds water, it can block sunlight from other plants and aquatic life, killing them or limiting their growth. And as the algae die, the bacteria which feed on them can deplete oxygen levels in the water to the point where it cannot support other life forms. This condition leads to **eutrophication.** Eutrophication is a naturally-occurring process of changes that take place after a waterbody receives inputs of nutrients, mostly nitrates and phosphates from erosion and runoff of surrounding lands. Usually this process occurs slowly over millions of years. Human activities can accelerate this process and the results can be very serious. Eutrophication caused Lake Erie to "age" nearly 15,000 years between 1950 and 1975.

Heat, or **thermal pollution**, can be a deadly water pollutant. An important relationship exists between the amount of dissolved oxygen in water and its temperature. The warmer the water, the less dissolved oxygen. Thermal pollution can be natural, such as in hot springs or shallow ponds during summer months, or it can be human-made, when water used to cool power plants or other industrial equipment is discharged back into streams. The amount of oxygen in water affects the life it can support. Some sport fish, such as trout, need cold water with high levels of dissolved oxygen and cannot live in warm water. Other nongame fish like carp and suckers thrive in warm water and can take over habitats from other fish if waters become too warm. This can result in greatly reduced diversity of fish species important for the environmental health of the stream.

Thermal pollution has been such a problem that most states have passed laws requiring power plants and industries to cool water before releasing it back into streams.

Sediment is one of our most destructive water pollutants. America's water is polluted by more than one **billion** tons of sediment annually. Every day, Americans lose about one million dollars because of sediment pollution. Sediment is mineral or organic solid matter that is washed or blown from land into lakes, rivers, or streams. It can be point source or nonpoint source pollution. Typically, it comes from nonpoint source causes. Sources of sediment pollution include construction, row cropping, livestock operations, logging, flooding, and runoff from city streets, parking lots, and buildings. Sediment by itself can be a dangerous pollutant, but it is also considered serious because other contaminants such as heavy metals and toxic chemicals can be transported with it.

The effects of sediment pollution can be devastating. It can clog municipal water systems. Lakes or reservoirs can receive so much sediment that they actually fill in. Sediment can turn a deep lake into a shallow wetland area over time. Fine sediment can blanket the bottoms of lakes and rivers, smothering aquatic life such as fish eggs and insects and damaging fish gills. This can disrupt the entire food chain, and cause great damage to an ecosystem. Sediment can also be detrimental before it settles, while it is still suspended in water. It can make water cloudy, or turbid. High turbidity makes water aesthetically unpleasant and can destroy recreational opportunities. Some species of fish, such as smallmouth bass, will not thrive in a highly turbid aquatic environment, and studies indicate that high turbidity decreases fishing success.

Sediment in water can also create thermal pollution problems. Sediment darkens water, and allows it to absorb more solar radiation. This raises water temperatures to the point where it may not support some forms of life. At the same time, sediment blocks light from reaching aquatic plant life, slowing or stopping plant growth. And since plants add oxygen to water, oxygen levels can be reduced to the point that fish kills can occur.

This type of damage to the ecosystem is cumulative. As plants and fish die, the waterway loses its ability to break down wastes and materials that are naturally washed into it. These materials begin to accumulate and form another source of pollution.

Chemical pollution is usually human-made. Modern nations rely on thousands of organic and inorganic chemicals in industry, agriculture, and the home. These materials provide many benefits, and new chemical compounds are constantly being developed to improve existing processes.

But with modern chemicals come modern pollution problems. Improperly used or disposed of, reasonably safe chemical compounds cause toxic reactions. The effects of such toxics can be short term or long term and are regarded as a major national and international health concern.

Toxic water pollution is most often linked to point source causes, such as improperly treated industrial discharges or accidents in transportation (such as oil spills). But it can also come from nonpoint source causes. These include runoff from both urban and rural areas, and atmospheric transport.

Hard-surfaced roads and parking lots and urban areas collect toxics such as lead, oil, cadmium (from tires) and other pollutants, which can be washed into streams through storm drains. These materials can cause immediate toxic effects as well as long-term effects by accumulating in sediment or in living organisms. In the 1970s, many people suffered severe health problems from eating swordfish and tuna containing high levels of mercury, which accumulated in the fish over a long period of time. In agricultural areas, pesticides containing toxic compounds are applied to crops to improve crop quality and increase yields. Their proper use has helped eliminate hunger in many parts of the world. But improper application of pesticides can create serious water pollution problems, because runoff from fields can introduce large amounts of toxics into waterways. Pesticides can also cause groundwater contamination. Techniques of integrated pest management that involve a combination of biological control (natural predators) and reduced application of pesticides can help eliminate some of the potential problems of excessive pesticide application.

The cost of disposing of toxic chemicals created by industry is high. Federal and state laws require careful monitoring of industrial processes and specific storage and disposal procedures of these materials. This cost has caused some unscrupulous people to illegally dispose of toxic chemicals, a process called "midnight dumping." Pollution from this source may go undetected for years, and when discovered, it can be very difficult to determine the source. Legislation adopted since the late 1970s has imposed large fines and jail sentences for people caught illegally dumping toxic wastes.

Another, perhaps surprising, source of toxic water pollution comes from individuals. Household chemicals such as cleaners, dyes, paints, pesticides, and solvents are a large source of toxic water pollution, particularly in urban areas. Many of these materials are simply poured down drains or flushed down toilets with no regard to their consequences. And while the toxic chemicals from one household may not seem like much, they can cause problems. In fact, a single quart of used motor oil can pollute a quarter of a million gallons of water. And homeowners may use ten times the amount of pesticides per acre as farmers do. The amount of toxics released by an entire city—one person at a time—can be staggering. EPA and other agencies have published educational materials to explain ways to properly apply and dispose of pesticides. (See "A Citizen's Guide to Pesticides," U.S. EPA, Office of Pesticides and Toxic Substances, 3rd Edition, OPA 008-89, Washington, D.C., 1989.)

Radioactive pollution can be human-made or natural. It can come from wastewater discharges from factories, hospitals or uranium mines, or it can come from naturally-occurring radioactive isotopes in water like radon. Radiation accumulates in the body, and children are more sensitive to the effects of radiation than adults. Radiation can cause cancer, and in high concentrations, death.

Facilities that use radioactive materials are highly regulated and carefully monitored to prevent pollution. However, one of the potential problems of radiation pollution is stored radioactive wastes. Tons of waste have accumulated over the years, and the waste will remain dangerous for centuries. Unless suitable storage methods are found, these wastes could pollute groundwater or streams through improper storage. Work continues to create ways to safely dispose of radioactive wastes.

WATER CONTAMINATION (NATURAL DISASTERS)

Water pollution can also come from natural occurrences. Storms can create large amounts of runoff that carry pollutants into water supplies. Fires destroy ground cover and cause sediment pollution. Earthquakes can break sewer lines and cause pollution from human-made sources, or they can even change river courses, destroying some aquatic habitats while creating others. Naturally occurring elements in soils can cause water pollution when they leach into water in concentrations that exceed water quality standards or criteria. For example, desert soils are naturally high in concentrations of salt, boron, and other trace elements. Irrigation can cause these elements to wind up in high concentrations in the water supply, causing pollution that is a danger to crops and wildlife.

WATER POLLUTION PREVENTION

Different pollution sources have different methods of prevention. The fight against **biodegradable wastes and bacterial water pollution** is almost as old as human beings. Epidemic diseases such as cholera killed hundreds of thousands of people before the link to polluted water supplies was established. In third world countries, the lack of clean water still results in critical health problems.

Proper sewage treatment is key to stopping bacterial pollution. Modern municipal sewage treatment plants typically are capable of controlling bacterial pollution, unless storm water loads overwhelm the treatment systems. Private septic systems, however, can be a significant problem. Well-designed and properly operating septic systems will safely treat wastewater, but a failing system can lead to pollution of both ground and surface water. The Environmental Protection Agency reports that many waterborne diseases are caused by old or poorly operating septic systems. Systems should be periodically pumped out and cleaned, with the removed material disposed of properly.

Proper management of livestock and domestic animal wastes can eliminate bacterial pollution problems affecting both humans and animals. Well designed and properly managed animal waste management systems prevent water pollution and use the wastes to fertilize crops and condition soil. Special devices like "pooper-scoopers" are now required in larger cities to collect and dispose of pet waste before it washes into nearby water bodies.

Since many sources of **nutrient pollution** are human-made, they have the potential to be controlled. It has been estimated that fertilizer use has increased more than 15 times since 1945. There is discussion of reducing the use of high phosphate and nitrate fertilizers in areas where nutrient pollution is a problem, even though crop yields would be reduced. Land management practices, such as crop rotation to reduce fertilizer requirements, and biological pest control, are other options.

Homeowners can also adopt more environmentally sound lawn and garden practices. In many places, chemical tests indicate that individuals use 10 to 50 times more fertilizer than necessary for good plant health. Substituting compost as a mulch and fertilizer for gardens and landscaping can eliminate this potential pollution source. Care should also be taken when using fertilizer. (Composting also reduces waste going into landfills.)

Good sewage treatment plants only remove about 50 percent of the nitrogen and 30 percent of the phosphorus from domestic sewage. This still allows an estimated 200 to 500 million pounds of phosphates into waterways every year. The use of lower phosphate detergents has been encouraged to reduce this, along with providing more advanced sewage treatment systems to remove more nutrients before water is released.

Proper management of livestock can reduce nutrient pollution from animal wastes. Catch basins in feedlots can trap nutrient pollution. Federal and local wastewater release regulations govern industrial releases of many materials that could contribute to nutrient pollution.

Heat or thermal pollution from human-made sources can be controlled by requiring power plants and industry to have cooling towers, holding ponds, and other facilities that allow water to cool before being released back into lakes or streams.

Because many causes of **sediment pollution** are nonpoint source, finding solutions to the problem can be difficult. In some cases, solutions are ongoing activities like dredging sediment deposits and water filtration. Over 2 trillion gallons of drinking water are filtered annually to remove silt.

Many causes of sediment water pollution can be reduced or eliminated through proper land management, particularly for activities that create erosion, such as agriculture, construction, mining, or logging. Farming accounts for the largest amounts of sediment pollution. However, careful land management can cut erosion and sediment problems dramatically.

Bare earth erodes quickly, since there is no plant cover to protect soil from rainfall or wind. Construction sites and strip mined areas can lose soil to erosion at a rate up to 70 tons per acre per year—fifteen times higher than the normal rate from croplands. Many federal and local laws require construction and mining companies to reclaim land instead of leaving it bare to the ravages of erosion—and subsequent sediment pollution. In some cases, certain harmful land use practices have been eliminated completely.

Since sediment pollution is often caused by nonpoint sources, new ways of identifying sources have been created. Aerial photography is now being used to determine land use in specific areas, identify drainage patterns, and erosion rates. Information can be quickly gathered in this manner and steps taken to reduce problems.

Better livestock management practices have also been used to reduce sediment pollution from livestock runoff. Runoff is channeled into lagoons, where sediment settles before water is released into streams. The nutrient-rich sediment is then used to fertilize croplands. And proper management of croplands and logging areas can reduce runoff, improving crop yields and making reforestation easier.

Increased concerns over **chemical pollution** have created strict regulations for most companies, ranging from large plants to small businesses such as dry cleaners, which use potentially toxic solvents. Since the effects of some toxics have not yet been determined, it is expected that even more regulations will be created in the future to limit the material that can be released into the nation's waterways. The introduction of many new chemicals for industrial, mechanical, and other uses presents difficult challenges in determining their safety and impact on the environment. This creates a major challenge for industry to keep up with changing regulations and develop ways to meet new requirements.

Control of air emissions that cause acid precipitation are critical to eliminating this pollution problem. Burning of fossil fuels like coal, oil, and gasoline are prime contributors. The use of non-polluting methods of electric generation, such as hydroelectric, thermal, and solar, can help, as can making sure automobiles are adequately tuned, tires are properly inflated, and pollution control devices are working. Reformulated gasoline is also designed to reduce these emissions.

Solid wastes buried in landfills can cause pollution problems if harmful leachate percolates into aquifers and contaminates groundwater supplies. Newer landfills are being constructed with double liners and monitoring wells to prevent leachate from reaching groundwater supplies and detect leaks before they become a problem. Solving past problems will take research and work. One way to reduce this dilemma is to reduce the amount of waste going into landfills through recycling and by using products with less packaging and discardable materials.

RIPARIAN AREAS

Riparian areas are the green zones along the banks of rivers and streams. These are some of the most productive ecosystems in nature, and display a wide diversity of plant and animal life. In the south, "bottom lands" are an example of riparian areas. These areas are important for flood storage, water quality, cover and shade for plants and animals.

Because of their value, rights to riparian lands are a subject of great interest, especially on public lands. Federal and state agencies have created a variety of land management programs designed to protect public riparian lands. These include leaving vegetation strips along fish bearing streams to prevent stream erosion and maintain habitats. Livestock may be prohibited from riparian lands during summer months to keep them from "camping" at the water's edge and destroying vegetation or causing animal waste pollution. In some areas, beavers have been introduced into ecosystems to provide "natural engineering" to rehabilitate eroding streams. Land uses around riparian areas must be taken into account.

BEST MANAGEMENT PRACTICES

Not all water pollution can be avoided. Some manufacturing processes, farming, and other activities create pollutants that can contaminate water. In cases where water pollution is expected to happen, companies and individuals can use **best management practices** to control pollutants and keep them from causing damage to water supplies.

Examples of best management practices include the agricultural practice of collecting animal wastes in a lagoon to settle before discharging wastewater into streams. It may also mean waiting until certain times to spray pesticides or apply fertilizers to prevent runoff. Best management practices can mean taking water quality into account when planning a housing development or new factory, or it may mean controlling wastewater discharges and storm water discharges in conjunction with stream flow. Best management practices may mean planning wastewater treatment for a mine in advance of mining operations. Operators of saw mills can reduce pollution by storing their materials and processing their products indoors so they do not come in contact with storm water runoff. Airport employees can reduce storm water runoff pollution by using deicing chemicals only in designated collection areas and by cleaning oil and grease spills from pavement immediately. Best management practices are designed to keep any unavoidable water pollution in as much control as possible.

INDIVIDUAL ACTIONS

Individual actions can also have a big impact on pollution problems. One very effective way to reduce water pollution is to simply reduce water consumption. This can be done by changing a few habits. For example, put a bottle of water in the refrigerator rather than letting water run from the tap until it gets cold. Wash full loads. Turn off the water while brushing your teeth. Take shorter showers. Install low flow showerheads and toilets, faucet aerators, and/or toilet dams. Wash the car using buckets of water instead of a hose. And finally, water plants in early morning or late evening only when they really need it. Better yet, choose plants which require less watering. Other ways to reduce water pollution are to keep litter, pet wastes, and debris out of street gutters and storm drains as they flow directly to waterbodies. Apply lawn and garden chemicals sparingly according to package directions. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds. The use of herbicides should also be avoided.

Virtually every liquid in an automobile is a serious pollutant, and care should be taken to avoid spilling oil, antifreeze, or other fluids from automobiles. In some cases, it may be more ecologically sound to have repairs done by a reputable garage than to attempt messy do-it-yourself work (especially if a community does not have proper disposal centers). Dispose of used oil and antifreeze properly by taking them to a local service station or recycling center.

Household cleaners can add toxics or nutrients to water. In most cases, harsh chemicals are not necessary to do an effective cleaning job, and less damaging substances can be substituted. Baking soda can be used as a scouring powder and water softener to increase the cleaning power of soap. Soap biodegrades safely without adding phosphates or dyes to water like many detergents. Borax cleans, deodorizes, and disinfects. An all-purpose cleaner made of a teaspoon of liquid soap, two teaspoons of borax and a teaspoon of vinegar in a quart of water is an effective grease cutter. A quarter cup of baking soda followed by a half cup of vinegar makes a good drain cleaner. Consumers should also take care in disposing of potentially dangerous household chemicals like batteries, nail polish, drain cleaner, and paint. Do not dispose of any unused portions of these items down drains, toilets, or storm sewers. Many communities offer regular hazardous waste pickups to collect these items. If your community doesn't have one, ask your local government to establish one. The EPA Resource Conservation and Recovery Act hotline (1-800-424-9346) can supply more information.

Citizens can also become more politically involved. For example, encourage local government officials to enforce construction/sediment ordinances in your community or encourage city officials to use sand instead of salt to deice roads. Participate in public meetings to plan water policy. Organize litter clean-up campaigns and hold local fairs to educate your community about water resource issues.

WATER QUALITY LEGISLATION

Laws involving water quality date back as far as 1914. The first Federal law dealing exclusively with water quality was the Water Pollution Control Act, passed in 1948. Under this law, the states retained primary responsibility for water quality standards and maintenance. The Federal government supplied money primarily for research. There were no water quality standards established, and the law provided only weak punishments for offenders. During the 1960s, amendments provided for water quality standards for interstate waterways, Federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern resulted in passage of two more very important environmental laws.

The National Environmental Policy Act of 1969 (NEPA) required federal agencies to consider the environmental impacts of their actions. All federal agencies must prepare environmental impact statements to assess the impacts of major federal actions, such as large building or industrial projects. Because of NEPA, federal undertakings have been conducted in a manner to ensure protection of all natural resources, including water.

The Federal Water Pollution Control Act (Clean Water Act) which was passed in 1972 and amended in 1977, 1981, and 1987, provides the basis for water quality standards today. The Clean Water Act allowed the Federal government to assume a lead role in cleaning up the nation's waterways. National goals for pollution elimination were set, and the National Pollution Discharge Elimination System (NPDES) was established. The NPDES permitting system made pollution discharge without a permit illegal. Generators of pollution to surface waters (sources) must apply for NPDES permits, which are issued by EPA or EPA-approved state agencies. The limits on what the generators may release vary from small amounts (for suspended biodegradable organic material and solids) to none allowed (for some toxics). The stringency of the requirement is greatest for the most dangerous water pollutants. The public is invited to participate in the permit issuance process through public notice of proposed permits, and opportunity to comment or request a public hearing.

The Clean Water Act also established four national policies for water quality:

1. Prohibit the discharge of toxic pollutants in toxic amounts

2. Assist publicly owned treatment works with Federal grants and loans

3. Support area-wide waste treatment planning at Federal expense

4. Create a major research and development program for treatment technology

Future amendments to the Clean Water Act are likely to make ecosystem protection as important as providing potable water for human use. Amendments are also likely to establish water quality standards for lakes and to focus more specifically on preventing storm water nonpoint source pollution.

Other federal laws that deal with water quality are the Safe Drinking Water Act & Amendments of 1986 and 1996, the Toxic Substances Control Act of 1976, the Resource Conservation and Recovery Act of 1976, the Surface Mining Control and Reclamation Act of 1977, and the Rivers and Harbors Act of 1899.

WASTEWATER TREATMENT

Wastewater is water that has been spent or used in a domestic waste, agricultural, or industrial process. After water is used, it must often be treated to avoid polluting another body of water. Almost any use adds contaminants to water that must be removed before it can be returned to the environment.

WASTEWATER TREATMENT PROCESS

Wastewater treatment is designed to kill dangerous bacteria and reduce or remove chemicals and solids before water is returned to lakes and streams or groundwater.

Wastewater treatment may be a simple process or it may be complex, depending on how many pollutants are added to water during use. Water from a household may require minimal treatment before it can be returned to natural bodies of water, while industrial wastewater may need several processes before it is safe to release. Municipal and home treatment systems have been in use for years to prevent health risks from wastewater. Laws enacted in the 1960s, 70s, and 80s began placing more stringent controls on water released from industrial plants to reduce pollution from these wastewater sources. Since this water quality "wake-up call," anti-pollution laws have progressively become more strict about protecting water quality.

Most municipalities with wastewater treatment systems are required to have two stages of treatment. In the primary treatment stage, screens and settling tanks remove most of the solids in the water. Solids make up about 35 percent of the pollutants in wastewater. In the secondary treatment stage, bacteria are used to digest the remaining pollutants in the water. The activated sludge process mixes microorganisms and oxygen with wastewater to speed up the digestion process. A trickling filter process allows the wastewater to trickle down through a layer of rock and gravel covered with bacteria that break down pollutants. Large settling tanks then allow most of the remaining solid material to settle out, and some systems will run the water through sand filters to further cleanse it. Finally, the water is disinfected with chlorine, ozone, or ultraviolet light and discharged. By the time it is discharged, about 85 percent of the biochemical oxygen demand (BOD) and total suspended solids (TSS) should be removed from the wastewater. The solids remaining in the treatment plant are rich in nutrients and can often be used on farm and forest lands as fertilizer.

In some cases, tertiary (advanced) treatment of wastewater is done. This is a third stage of treatment that is designed to remove more of the impurities from wastewater. This step may involve filtering the wastewater through carbon or sand filters to remove solids or even allowing the water to flow into a natural or constructed wetland area to purify it further.

In 1988, the wastewater from more than 144 million people received secondary or more advanced levels of wastewater treatment. More than 23 million households had on-site disposal systems such as septic tanks.

MICROBIAL DIGESTION OF WASTES IN WASTEWATER

Microorganisms need nutrients to survive, and they can process the nutrients in wastewater, providing a very effective method of treatment. Anaerobic bacteria break down waste materials without oxygen or aeration. Aerobic bacteria break down waste material with oxygen. Both types reduce concentration of nutrients, making it safe to dispose of wastewater. Aerobic bacteria break down wastes without as much odor, but require more surface area (for aeration) than do processes using anaerobic bacteria. Both types of bacteria are usually present in wastewater treatment systems.

BIOSOLIDS

The solids recovered during wastewater treatment are not worthless; in fact, they can be used as high quality fertilizers in many cases. Wastewater solids, or sludge, meeting strict criteria for beneficial use are called biosolids. The nutrient rich biosolids can be spread on croplands.

Biosolids must be treated before disposal or use. Primary sludge is combined with microorganisms for partial digestion, and then it is thickened by using centrifugal force, gravity, or pressure to remove water. It is then collected and transported to the site of disposal or spreading.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

The single most important provision of the Clean Water Act is the National Pollutant Discharge Elimination System (NPDES). The Clean Water Act requires that each source of water pollution—cities, factories, power plants, animal feedlots, and so on—treat their wastewater as necessary to meet effluent discharge limits and performance standards set by the EPA or EPA before releasing the wastewater to streams or lakes. Generators of pollution (sources) must apply for NPDES permits, which are issued by EPA or EPA-approved state agencies. The limits on what the generators may release vary from small amounts (for suspended solids) to none allowed (for some toxics). The stringency of the requirement is greatest for the most dangerous water pollutants. Each pollution source is evaluated separately, and it may take a number of years for a permit to be issued, depending on what is to be discharged.

NPDES also makes it illegal to discharge pollutants without a permit, and sets civil and criminal penalties for violations. Criminal penalties can include fines of up to $100,000 per day of violation and imprisonment of up to 30 years for repeat offenders. Civil fines can be up to $25,000 per day per violation.

ALTERNATIVE WASTEWATER TREATMENT METHODS

Smaller communities may have different approaches to wastewater treatment. Some communities, hotel complexes, or apartment buildings use package plants to process wastes. These prefabricated units utilize procedures similar to those used by as full-scale plants. Lagoons are another form of treatment. Lagoons allow solid wastes to settle, and then rely on a biological interaction of sunlight, algae, and oxygen to clean wastewater.

CONSTRUCTED WETLANDS TO TREAT WASTEWATER

In some cases, constructed wetlands can be used to treat wastewater. They can be used to treat domestic, agricultural, industrial and mining wastewaters. They generally cost less than conventional wastewater treatment systems and operating costs are very low. They are also more aesthetically pleasing than wastewater plants and attract desirable wildlife.

Wastewater to be treated flows into a constructed cell that has been lined to prevent leaks and assure adequate water for wetland plants. Flow is distributed evenly across the cell. Plants such as cattails, phragmites, and bulrushes are planted in the cell, and their roots produce a dense mat of materials through which the wastewater circulates. Chemical, biological, and physical processes filter out contaminants from the wastewater. A second cell may be added for more treatment. It may be unlined to allow water to filter and can contain attractive wetland plants like irises, elephant ears, and arrowheads. Plants transpire water into the atmosphere and provide oxygen for bacteria and other organisms to break down biodegradable wastes.

Wetlands may or may not discharge treated waters into surface waters, depending on their size, design, and local site conditions.

RAPID INFILTRATION

Rapid infiltration is a wastewater treatment method that can be used in areas where solid permeability is moderate to high. A basin area can be flooded with appropriately pre-treated wastewater and allowed to infiltrate into the ground. The ground then filters the wastewater as it infiltrates into the groundwater or into the local surface waters. After a basin is filled, it is allowed to drain and dry, which restores aerobic soil conditions and helps treat the wastewater as it infiltrates.

OVERLAND FLOW

Overland flow is a process where water is allowed to flow down a sloped surface, usually planted with thick grasses. Soils are nearly impermeable, which forces the water to flow through the vegetation, where physical, chemical, and biological processes treat it. It is then collected into runoff channels and discharged.

SLOW RATE IRRIGATION/SILVICULTURE

These two processes are related in that in both, wastewater is used to irrigate land and is used to treat wastewater. Slow rate irrigation allows wastewater to flow onto land parcels at a rate that doesn't overburden the land's ability to allow the water to infiltrate and process impurities. Silviculture is the practice of using large areas of land as a treatment site for wastewater and planting the land with crops or trees that will flourish during the treatment. Both processes are based on ancient ideas and practices of wastewater treatment that have proven themselves for centuries.

AQUACULTURE

Aquaculture is the practice of using aquatic plant and animal species to treat wastewater, similar to the use of wetlands for this purpose. An aquaculture area might be constructed with a number of ponds for different levels of wastewater treatment. Each pond contains specific plant and animal life for wastewater treatment, and wastewater may be allowed to flow from one pond to another as it is being treated. Plant life may be harvested or maintained in the ponds to maximize system performance. Aquaculture systems have been able to remove impurities such as heavy metals from wastewater.

SEPTIC TANKS AND SEPTIC SYSTEM ALTERNATIVES

Septic systems are the wastewater treatment method for most Americans in rural areas. Septic systems typically consist of an underground **septic tank** that collects wastewater from a home. Solids from wastewater are allowed to settle in the tank, and bacteria in the tank digest some of the heavier solids and household grease and oils. During the decomposition, gas is produced and usually vented through a pipe in the roof of the home. The partially treated water, or effluent, flows out of the tank into a **distribution box** where it is channeled into a series of perforated pipes or open tile. Water percolates out of the pipes into the system's **drainfield**, where it is filtered and treated by organisms in the soil. Eventually, treated wastewater returns to the groundwater supply.

Well operating septic systems will safely treat wastewater, but a failing system can lead to pollution of both ground and surface water. The Environmental Protection Agency reports that many waterborne diseases are caused by old or poorly designed septic systems. Systems should be periodically pumped out and cleaned, with the removed material disposed of properly. To avoid septic system problems, systems should be regularly inspected and solids pumped out when necessary. Avoid putting solids such as coffee grounds, disposable diapers, cigarette butts, plastics, and other bulky wastes into the septic system. Pouring liquid fats and grease down the kitchen sink can cause problems as these wastes solidify and block the system's operation. Use of a kitchen sink garbage disposal should also be avoided unless the septic system has been designed to accommodate extra wastes. A garbage disposal can increase loads on the system by as much as 50 percent. Keep toxic and hazardous chemicals like paint thinner, petroleum products, and pesticides out of the septic system. Systems don't break down these materials, and pouring them into a septic system is like pouring them directly into the groundwater supply.

Alternatives to septic systems may be used when soil does not readily allow systems to work or there are too many households in an area to provide adequate septic fields. Alternatives to septic fields are also used as ways to conserve water. Some systems separate **blackwater** (water predominantly from toilets or associated with human waste) from **graywater** (water from showers, dishwashers, etc.). Blackwater requires more treatment, while graywater may need only minimal treatment before it can be used for other household purposes, such as watering the lawn. Other alternatives to septic systems include devices such as incinerating, chemical, or composting toilets, which process wastes before they are released; and holding tanks that are regularly pumped out instead of processed on site. Water conservation methods like low-flow faucets and shower heads, energy efficient appliances, and other products also reduce septic system loads.

COMMERCIAL/INDUSTRIAL WASTEWATER TREATMENT

Wastewater treatment for industrial plants may be more complex than that for residential areas due to hazardous pollutants added to wastewater during manufacturing. Many plants have invested millions of dollars into their own wastewater treatment facilities. Even small businesses such as dry cleaners, gas stations, restaurants, and photo labs may have specialized treatment processes to clean wastewater. For example, a photo lab may have an electroplating system to remove silver from wastewater. The silver can then be processed and sold back to photographic film companies for use in making new film.

INDUSTRIAL WASTEWATER TREATMENT METHODS

Public wastewater treatment plants were not designed for industrial wastes, especially toxic substances. Toxic wastes from industrial plants can actually damage public systems by killing useful bacteria. So modern industrial plants separate their wastewater into several categories for treatment:

*Wastewater that can be treated and reused within the plant

*Wastewater that can be treated in a wastewater treatment plant designed to accommodate the needs of industry

*Wastewater that can be sent to public treatment facilities, either directly or after treatment at the industrial site

*Wastewater that is so toxic that it must be treated on site or disposed of as hazardous waste

New techniques for treating industrial wastewater are continually being developed. These can include chemical reactions to remove hazardous materials from the wastewater. New processes even use ultraviolet radiation to kill microorganisms or break down chemicals into more common biodegradables.

MINING WASTEWATER TREATMENT METHODS

Mining is an industry that can create severe water pollution problems from sediment, chemicals, metals, and acids. Federal law now requires mines to treat wastewater before releasing it into waterways. Since most mine sites are remote, lagoons are a common form of treatment. Lagoons (which must be lined to prevent groundwater pollution) allow sediment to settle out, eliminating a major water contaminant, and depending on the type of mining, other water treatment processes can be applied as necessary. These may include adding lime to reduce acidity, removing heavy metals, or skimming off oils or petroleum wastes. Constructed wetlands have also been used to treat mining wastewater.

OTHER WASTEWATER TREATMENT ISSUES

RECLAMATION AND REUSE OF WASTEWATER

For industry and municipalities, water use efficiency means cost efficiency. Wastewater treatment is expensive, so most industries analyze water use as carefully as they do any other raw material. Many industrial plants have wastewater treatment plants to treat wastes that can't be handled by public treatment plants, but they may also treat wastewater for reuse instead of paying for additional water or discharge. Efficient uses of reclaimed water in industry can be for heating or cooling, irrigation, or materials processing. Many municipalities also reclaim wastewater with calcium, fluoride, and argon for other uses.

STORM WATER TREATMENT

Storm water runoff can be a serious wastewater treatment problem because large amounts of runoff can overload wastewater treatment systems and cause untreated water to be released into streams. Another problem with storm water runoff is chemical contamination from industrial sources or simply from the greases and oils it picks up when flowing across parking lots and roadways. The debris, chemicals, and other pollutants in the storm water runoff may be deposited, untreated, into our waterways. The result can be the closing of beaches; no swimming, fishing, or boating; and injury to the plants and animals that live in or use the water.

Provisions of the Clean Water Act Amendments of 1987 are designed to reduce pollution from storm water. These amendments require certain industries and municipalities, with populations exceeding 100,000, to have permits for storm water runoff and to prepare and implement storm water pollution prevention plans. Such plans describe how they will prevent storm water from becoming polluted in the first place. Making sure that potential pollutants are not left outside uncovered, cleaning up spills right away, and planting grass and other vegetation as quickly as possible after soils are disturbed can all be part of a storm water pollution prevention plan.

DRINKING WATER

WATER SUPPLY

The world's supply of water is 326 million cubic miles. If it were poured on the United States, it would submerge the country to a depth of 90 miles. But only a small portion of the world's water supply is usable fresh water. In fact, of the Earth's total water supply, less than one-half of one percent is usable fresh water. Only 0.03 percent is surface water. Of every 10,000 gallons of water on Earth, fewer than 50 are potentially usable fresh water; only 3 gallons are found in surface water bodies such as rivers, lakes, and streams.

The United States is water "rich." We have 39,400,000 acres of lakes and reservoirs, and over 35,000 square miles of estuaries. The Great Lakes cover 98,000 square miles and contain about 1/5th of the world's fresh water supply. About four percent of the U.S. land mass is covered by surface water.

The United States has nearly 60,000 community water supply systems, but only 20 percent of these systems use surface water as their primary source. Groundwater is the primary source of water for 80 percent of U.S. communities—nearly half of the entire U.S. population.

INTRODUCTION TO DRINKING WATER

Water is vital for life. Our bodies are approximately 75 percent water. Water makes up 83 percent of our blood, transports body wastes, lubricates body joints, keeps our temperature stable, and is a part of every living cell in our bodies. On the average, every American uses about 150 gallons of water a day. With a 1996 U.S. population of approximately 260 million, that makes daily water consumption in the United States over 39 **billion** gallons per day. It's no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies. One aqueduct in California is over 450 miles long and transports water from its source to Los Angeles where it is needed.

DRINKING WATER STANDARDS

In 1974, Congress passed the Safe Drinking Water Act (SDWA), setting up a regulatory program among local, state, and federal agencies to help ensure safe drinking water in the United States. The Safe Drinking Water Act states that public water systems must provide water treatment, monitor drinking water to ensure proper quality, and provide public notification of contaminant problems. Regulations implementing the act established drinking water standards (maximum contaminant levels and treatment technique requirements) for a variety of chemicals, metals, and pathogens. Amendments continue to strengthen the act and enhance drinking water quality. Significant penalties are imposed for non-compliance.

The SDWA applies to all public water systems, defined as having at least 15 service connections or "regularly" serving at least 25 individuals. States are required to enact their own drinking water regulations that are at least as stringent as Federal standards. SDWA protects drinking water supplies through required treatment, testing, and reporting. The SDWA established a permitting program for underground injection wells. It also requires protection of aquifers and groundwater and surface water sources for drinking water supplies.
The SDWA requires that **maximum contaminant levels** or **treatment technique requirements** be established for specific inorganic chemical, organic chemicals, bacteria, and radioactive elements. SDWA also sets **secondary (non-enforceable) standards** for parameters that affect aesthetic qualities relating to public acceptance of drinking water. These include color, corrosivity, foaming agents, odor, and metals. EPA is continually in the process of selecting new contaminants for which to establish **drinking water standards.**

RESERVOIRS FOR SUPPLY/DAM CONSTRUCTION ON STREAMS - TVA

Reservoirs from dams serve a variety of water needs. They provide ways of storing large supplies of water for industrial and residential use. They control floods and other natural disasters that can cause water pollution.

They generate power and provide sources for recreation. While creating dams removes certain types of habitats, it also creates new habitats which support thousands of species of wildlife.

Since 1933, the Tennessee Valley Authority has been charged with developing and managing water resources in the Tennessee Valley. This has meant constructing more than 30 dams, including the largest dams east of the Mississippi River. TVA has also assumed management of a number of dams already constructed in the area before the agency came into existence.

TVA's role in protecting and improving water quality differs from that of any other federal, state, or local water quality program. TVA monitors water quality to identify problems and detect changes. TVA research programs study the relationships among water quality and land use, wastewater treatment, stream flow, and other factors. Reservoir water quality management plans identify better ways to protect and use the Valley's water resources. Monitoring for problems and changes, working with others to correct identified problems, demonstrating new solutions, and planning to prevent pollution are cornerstones of TVA's approach to water quality management.

DRINKING WATER TREATMENT

Water is in its purest form the moment it condenses from vapor into a liquid, but it quickly picks up impurities. Rain or snow can pick up dust, smoke, and other particles in the air. Runoff water dissolves minerals and carries small particles of soil. Streams can carry sediment, human-made pollutants and other materials. Once water is used by humans, it picks up even more pollutants and impurities before it is returned to nature. The need for a supply of clean water required water treatment methods to be developed, so that it can be safely used.

Since very early times, people have created ways to remove debris from drinking water to make it look and taste better. Ancient Egyptian inscriptions describe water purification by boiling, exposure to sunlight, charcoal filtration, and settling in an earthen jar. The Chinese were the first to discover the purifying effect of boiling water, and as early as 400 B.C., Hippocrates, the father of medicine, recommended boiling water and straining it through cloth to remove particles.

However, it wasn't until the 1850s that scientists suspected that disease could be spread through water. The rise of microbiology identified a number of diseases that were transmitted by water supplies, and the first attempts were made to disinfect drinking water by using chlorine. Around the turn of the century, Middlekerke, Belgium became the first city to install a permanent chlorine disinfection system. Chlorination was first used in the United States in 1908 to destroy bacteria in drinking water. The widespread use of chlorination wiped out waterborne diseases such as typhoid and cholera.

Obviously, water used for drinking requires more treatment than wastewater, which is returned to a lake or stream. But the two can have an impact on each other. The extent to which drinking water must be treated depends on the quality of the raw water supply, so a community downstream from other cities may find its water quality affected by the wastewater released by those cities.

Drinking water from a well may require little or no treatment before it is used. Water from a lake exposed to recreational activities or sewage contamination may need significant treatment before it can be used as drinking water. The Safe Drinking Water Act requires EPA to establish national drinking water standards and implement source water protection to help ensure water quality.

Conventional water treatment for drinking water consists of the following steps:

*Water is pumped from the water source, such as a lake, river, or reservoir and is strained to keep fish and large objects out of the system.

*Alum or other materials are added to the water to cause the dirt and other particles to coagulate, or clump together and fall to the bottom of settling basins.

*The then-clear water is filtered through layers of sand, charcoal/anthracite, and gravel to remove more impurities.

*Chlorine is added to kill bacteria remaining in the water. Most water systems add fluoride to help prevent tooth decay. Other chemicals (lime or phosphate) may be added to adjust the pH of the water.

*Finally, the treated water is pumped through pipelines to homes and businesses or it is stored for future use. At various points in the process, water is monitored to make sure it meets the requirements of the Safe Drinking Water Act, which measures some contaminants in concentrations as low as parts per quadrillion.
Public water supply systems in the United States produce more than 34 **billion** gallons of drinking water per day. The United States' more than 60,000 community water supply systems are valued at over $175 billion. The price in a 1990 survey of water in North America was $1.66 per 1000 gallons; however, the average price, in 1996, increased to approximately $2.00 per 1000 gallons.

DRINKING WATER CONTAMINATION

Drinking water can be contaminated from a variety of sources and by a variety of contaminants. Contaminants can come from runoff from precipitation, spills of hazardous chemicals, leaking underground storage tanks, animal wastes, leachate from landfills, excess fertilization of farmland and other sources. Groundwater protection from pollution is especially important since groundwater is a major source of drinking water. Individuals can pollute their own drinking water from wells if they overuse pesticides on their lawns, dump even small amounts of petroleum products, flush household chemicals into a septic field, or fail to keep their septic systems functioning properly.

WELLHEAD CONTAMINATION

Wellhead contamination is the contamination of a well from pollutants that come from around the well itself. Wellhead pollution protection requires the protection of the area around the well from pollutants that could affect the groundwater and therefore, the well water supply. A wellhead protection area (WHPA) can be established for any type of aquifer and can include the well's cone of depression, recharge area, and surrounding aquifer. A growing number of states and communities are starting to create wellhead protection areas to guard against contamination of well water. These areas may be large or small, depending on the characteristics of the aquifer and the potential hazards that could threaten groundwater. States and communities can apply for wellhead protection grants from EPA and other organizations to protect groundwater supplies.

OTHER ISSUES: DRINKING WATER

DESALINATION

Since seawater makes up over 97 percent of the Earth's water supply, it is a readily available and plentiful water source. However, because of its salinity, seawater is unsuitable for drinking, and it must be treated before it can be used. Desalination is a relatively expensive process that is principally used in arid and coastal areas where water is so scarce that the process becomes cost effective. One desalination process is simple evaporation, where water vapor from saltwater is collected and allowed to recondense as fresh water. Another process is reverse osmosis, in which water is filtered through membranes with holes large enough to allow water molecules to pass through, but small enough to the keep the larger salt molecules from following. The salt can then be collected and used for other purposes.

As water supplies become tighter, desalination becomes more cost effective and more practical to use. Some desalination plants are operating in Southern California to meet the area's tremendous water demand.

WELLHEAD PROTECTION

Amendments in 1986 to the Safe Drinking Water Act (SDWA) called for wellhead protection programs to identify the land area around wells and wellfields that need protection and to set up measures to protect these areas from contaminants. The SDWA also calls for contingency plans to locate alternate drinking water supplies in the event that a well or wellfield does become contaminated. Under the 1996 Amendments to the SDWA, the wellhead protection concept, was extended to address surface water intakes in what is called **source water protection.**

SDWA applies to public water sources, but individuals who use private wells need to have their own groundwater protection strategies. Such strategies include not dumping household wastes that could pollute groundwater, making sure septic systems are in proper working condition, and avoiding overfertilization of lawns or excessive accumulation of livestock wastes that could damage groundwater supplies.

Federal and state laws protect groundwater supplies. SDWA sets specific goals for implementation of groundwater protection. SDWA requires states to prohibit the use of underground injection wells for waste disposal except by permit. Permit applicants are required to satisfy the state that underground injection would not endanger drinking water sources, and permit holders are required to inspect, monitor, and keep records on injection well use.

LEAD IN PIPES

Lead is a cumulative poison and can interfere with the formation of red blood cells, reduce birth weight, cause premature birth, delay physical and mental development in babies and young children and impair mental abilities in children in general. In adults, lead can increase blood pressure and interfere with hearing. At high levels of exposure, lead can cause anemia, kidney damage, and mental retardation. Health effects from lead generally depend upon total exposure to all sources. Pregnant women are also at risk if exposed to high concentrations of lead. Since lead is a very soft, easy to work with metal, it was often used in pipes before it was determined that lead in pipes could poison human beings. Lead solder was also used to help seal pipes to prevent leaks.

The SDWA amendments of 1986 ban future use of lead pipe and solder in all public drinking water systems because of the possibility of leaching. This provision of the SDWA requires the use of "lead-free" pipe, solder, and flux in the installation or repair of any public water system or any plumbing in a residential or non-residential facility connected to a public water system. Solders and flux are considered to be lead-free when they contain less than 0.2 percent lead. (Before this ban took effect in 1986, solders used to join water pipes typically contained about 50 percent lead.) The Lead Ban requires that any lead solders carry a warning label indicating that they are not to be used in connection with potable water plumbing. Pipes, pipe fittings, faucets, and other fixtures are considered lead-free under the Lead Ban when they contain less then 8 percent lead. In 1988, SDWA was amended by the Lead Contamination Control Act (LCCA) requiring that a number of activities be conducted by Federal and other parties to identify and correct lead-in-drinking-water problems at schools and day care facilities. One principal activity to be conducted by EPA was the development of a guidance document and testing protocol that could be used by schools to determine the source and degree of lead contamination problems and how to remedy such contamination if found.

At the time the LCCA was passed, considerable attention was being given to water coolers with lead-linked tanks. The law defined these sources as "imminently hazardous consumer products." As a result, the legislation specifically stated requirements to result in the repair, replacement, or recall and refund of these water coolers and attached civil and criminal penalties to the manufacture and sale of any drinking water cooler containing lead.

Lead contamination of tap water is also regulated by EPA's Lead and Copper Rule. This drinking water regulation requires that: certain **action levels** be met as calculated via measurements taken at customer's taps; treatment technique requirements be met; and if necessary, public education materials be distributed to customers. EPA also requires that public notification be given to customers of water systems which exceed EPA action levels, to inform them of the harmful effects of lead.

NITRATE CONTAMINATION

Nitrate contamination can make water taste and smell bad and cause algal growth, but except in excessive concentrations, is not dangerous for adults and older children. However, in infants, stomach acids are not strong enough to prevent some forms of bacterial growth. Bacteria can convert benign nitrates into harmful forms that bind with hemoglobin in the blood to prevent oxygen from getting to the rest of the body. The result is methemoglobinemia, which can cause "blue baby" symptoms and can be fetal.

Nitrates get into drinking water from fertilizers, animal wastes, malfunctioning septic systems, air deposition to surface water, and normal vegetation decay. The nitrates may reach drinking water by runoff air deposition into surface water, runoff into sinkholes, soil leaching into groundwater, and improperly protected wellhead areas.

WATER CONSERVATION

On the average, every American uses about 150 gallons of water a day. That makes daily water consumption in the United States in 1996, approximately 39 **billion** gallons per day. It's no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies.

Of the 150 gallons each of us uses every day only, one half-gallon is used for drinking. The other 149 and a half gallons go for cleaning, cooking, flushing, watering the lawn, washing cars, and other uses. One very effective way to reduce water pollution is to simply reduce water consumption. Wastewater treatment plant operators report that they treat millions of gallons of water that shouldn't have been used in the first place.

Effective personal water conservation can be done by changing a few habits. A bottle of water in the refrigerator for drinking saves water over letting water run into the sink until it gets cold. Peel fruits and vegetables and **then** rinse them. That can save two gallons every minute. A dishwasher uses less water than washing by hand—about six gallons a load. And washing an entire load of dishes—or clothes—saves water over washing several partial loads.

New washing machines can reduce water consumption by one third, or more than 400 gallons monthly for a family of four. But the most water use occurs in the bathroom. Simply turning off the water while brushing your teeth could save as much as ten gallons per person per day. Taking a shower instead of a bath can save about 25 gallons, and new low-flow shower heads can reduce consumption even more.

A large percentage of the water used every day is flushed down the toilet. New toilets use less than one-third the water of old models, and older toilets can still work effectively with less water. Devices like toilet dams block part of the water in the tank and reduce the amount used with each flush. If installing a toilet dam sounds too difficult, the same effect can be achieved simply by putting a water-filled plastic bottle in the toilet tank. This displaces water and means that less is used. Don't use a brick; it can break apart and clog pipes.

Repair leaks immediately. Even a small drip can waste hundreds of gallons of water a day—and add to the treatment loads of the sewer or septic system. Watering the lawn or garden is more efficient in the early morning or at night when the sun won't cause as much evaporation. It is best to water lawns and plants early in the morning. Washing the car with a running hose will use more than 100 gallons of water. Using a bucket and sponge cuts that by 90 percent.

XERISCAPE

Xeriscape is a water conservation approach to landscaping design, installation, and maintenance. It was developed in 1981 in Colorado in response to prolonged drought. Xeriscape landscaping is a package of seven common-sense steps for making a landscape more water-efficient. These are:

Step 1 - Planning and design. In the planning stage, begin with a basic map and analyze the site characteristics. Incorporate shade into the design and plan for different uses of the area such as public and private areas. Note the water-use zones and estimate the amount of water needed for each one. Once a design scheme and a water management arrangement are in place, develop a master plan and fit plants into the design. This will include selecting new plants and possible renovation of the existing landscape for improved water conservation.

Step 2 - Soil analysis. Evaluate the planting soil, including its structure, texture, water holding capacity, and drainage. Let the physical and chemical characteristics of the existing soil be your guide in determining the type of soil improvement needed.

Step 3 - Appropriate plant selection. Select plants appropriate to the site and the imposed stresses of the environment. Drought tolerance is important in a Xeriscape-type landscape, but it should not be the only criteria. Some plants are drought tolerant but cannot tolerate wet soil or heavy shade. Additional important criteria to consider inclue (a) mature size and form, (b) growth rate, (c) texture, (d) color, and (e) functional use.

Step 4 - Practical turf areas. Use turf for a function or aesthetic benefit, such as in a recreational area, an erodible slope, or as a welcome mat to the home. Select a turfgrass that is adapted to the site and has good drought resistence.

Step 5 - Efficient irrigation. When irrigation is required, make every drop count by watering efficiently to prevent run-off or evaporative loss. Let your plants tell you when they need water, and avoid watering according to a set schedule or habit. Hand watering individual plants and drip irrigation on ornamentals requires 30% - 50% less water than sprinkler irrigation. Water plants between 9 p.m. and 9 a. m. to avoid evaporative loss of water.

Step 6 - Use of mulches. Use fine-textured, organic non-matting mulches when possbile. Fall leaves, pine straw, pine bark nuggets, and shredded hardwood bark are excellent choices. Mulch as large an area as possible under trees and shrubs. Islands of unplanted mulch require no water and little routine maintenance.

Step 7 - Appropriate maintenance. Keep plants healthy, but do not encourage water-demanding growth. Once plants are established, reduce the amount of nitrogen applied as well as the application rate and frequency of application. Avoid plant stress by mowing properly, by thinning shrubs instead of shearing, and by controlling weeds and pests before they affect plant health.

For more information on xeriscape, please call the American Water Works Association at 800-559-9855, web site at http:\\www.waterwiser.org, or e:mail bewiser@waterwiser.org.

SURFACE WATER

When runoff from precipitation occurs, it goes downhill, eventually winding up at a point where it gathers, such as a stream, lake, river, pond, wetland, ocean, or reservoir. This is **surface water**, or water you can see.

Surface waters are a major source of the usable water on the planet. Surface waters supply water for drinking, recreation, transportation, crop irrigation, and power generation. Most of our major cities have grown up around large bodies of surface water. More than 80 percent of the Earth's surface is covered by water, but less than 0.03 percent of all water is found in surface water bodies other than oceans.

The world's supply of fresh water is 326 million cubic miles. If it were poured on the United States, it would submerge the country to a depth of 90 miles. The United States is water "rich." We have 39,400,000 acres of lakes and reservoirs, and over 35,000 square miles of estuaries. The Great Lakes cover 98,000 square miles and contain about 1/5th of the world's fresh water supply. About four percent of the U.S. land mass is covered by surface water.

Even though the U.S. is water rich this water is not distributed evenly across the country. For example, the western parts of the country contain large desert areas and limited fresh water supplies.

AQUATIC ECOSYSTEMS

Surface water can be broken down into five major categories:

- Oceans
- Lakes
- Rivers and Streams
- Estuaries
- Wetlands

Oceans cover two-thirds of the earth's surface. These saltwater bodies also contain much of the world's plant and animal life. The resources of the world's oceans are vast, and although ocean water is too salty to drink, the plant and animal resources of the ocean are harvested for food and hundreds of other uses.

Lakes are bodies of fresh water contained within a larger land mass. Lakes can be natural or human- made. Lakes are used by humans for many purposes, such as water storage, flood control, recreation, and fisheries. The number of lakes has increased as humans have created them to provide clean, fresh water resources.

Rivers and Streams are created from runoff water and water that previously infiltrated and is now coming up out of the ground and entering the stream as well. Streams, therefore, are made up of two distinct water sources—runoff and groundwater. The fast-moving action of rivers and streams causes the mixing of water and air, which allows oxygen to be dissolved into the water. This process, **aeration**, gives rivers and streams the oxygen levels they need to support wide varieties of life. If oxygen levels drop, then streams can lose their ability to be habitats for many life forms. Rivers are often used to dilute pollution, such as water released from wastewater treatment plants.

Estuaries form where rivers meet oceans. This unique environment serves as a spawning ground or nursery for many animal species. Shellfish are a good example of creatures who thrive in estuaries. Estuaries are rich in commercial fishing and recreational opportunities, but because of their complexity and their location at the end of rivers, they can be seriously affected by deposits of sediment and pollutants. They can also be adversely affected when channel dredging changes the salt/freshwater balance in the estuary. Some estuaries, such as the Chesapeake Bay and Puget Sound, have become seriously polluted.

Wetlands are lands that are periodically covered with water. They may be known as swamps, marshes, bogs, and sloughs. They can be coastal (saltwater) or freshwater. The true importance of wetlands is just being realized. Wetlands keep surface waters clean by filtering out sediment and trapping pollutants. Coastal wetlands cushion drier lands from the full impact of storms. They help control floods by temporarily storing runoff waters. They also provide breeding grounds for many of the fish species that make up a $9 billion or more food market.

Wetlands have traditionally been regarded as wastelands, and since colonial times, over half the wetlands in the United States have been destroyed. But new Federal and state regulations are protecting wetlands and regulating the way they are used.

TYPES OF AQUATIC HABITATS

Aquatic habitats are as diverse as the types of surface water. A single stream or body of water may be home to a number of habitats, and during the life of the body of water, habitats may change, due to natural processes or human-made pollution.

The major determinant of aquatic habitats is the amount of dissolved oxygen in water. Cold, fast-running mountain streams that run over rocks and splash down slopes dissolve high amounts of oxygen, making them perfect habitats for fish like trout, which require high levels of oxygen. As waters level out and become more still, they absorb heat from the sun and lose oxygen content. Trout may not be able to survive in them, but other fish like bass and sunfish like crappie and bluegill thrive. If water gets too warm and oxygen content gets lower, then"rough" fish like carp and suckers move in.

Plant life also thrives around lakes and streams. The immediate area around a waterbody is known as a **riparian** area because it supports so much plant life. Like almost everything else in nature, riparian areas also benefit wildlife and fish populations, providing cover and shade to keep water from getting too warm and losing oxygen content. On public waterways, riparian areas are carefully managed to keep water ecosystems balanced.

Wetland areas have their own unique habitats. They are such complex areas that hundreds of species of plants and animals live there. They are nurseries for many species of animals and provide food to nourish our most productive fishing beds. Over half of all rare and endangered animal species are either located in wetland areas or are dependent on them. About 66 percent of the commercial fish catch taken along the Atlantic and Gulf coasts depend on wetlands for survival.

SURFACE WATER QUALITY STANDARDS

Under the Clean Water Act, water quality standards are based on three key components: an antidegradation statement (stating under what conditions water quality may be lowered), stream use classifications, and water quality criteria, or the degree of water quality needed to support a designated use for a stream. Water quality criteria can include dissolved oxygen content, turbidity, chemical and nutrient contents, and other factors.

Stream use classifications can include:

- Domestic water supply
- Industrial water supply
- Fish and aquatic life
- Recreation
- Irrigation
- Livestock watering
- Wildlife
- Navigation

Streams may be divided into segments with a different set of uses established for each segment. Different uses dictate different levels of water quality.

Criteria used in assessing water quality include:

- Dissolved oxygen
- pH
- Hardness, or mineral content
- Total dissolved solids
- Solids, floating materials and deposits
- Turbidity or color
- Temperature
- Coliforms
- Taste and odor
- Toxic substances
- Other pollutants

Depending on the designated stream use, only certain criteria may be used. To evaluate drinking water quality, all eleven criteria are taken into account, but fewer are used to protect livestock watering and wildlife uses. Individual criterion requirements may also vary with different uses. A trout stream requires 6 mg/l dissolved oxygen on content. For other fisheries, 5 mg/l is sufficient. Allowances may be made down to 3 mg/l based on site-specific conditions and according to designated uses (e.g., for irrigation or livestock watering).

WATER QUALITY MONITORING

Water quality monitoring depends on stream use, land management, and state and federal regulators. Under the Clean Water Act, the owner or operator of a facility covered by a National Pollutant Discharge Elimination System (NPDES) permit is required to monitor effluent or wastewater quality at regular intervals, maintain complete and accurate records, and report the results. Regulators can also monitor water quality at such sites to determine compliance with permit requirements and notify the operator of any violations. Industrial plant operators or land managers may also choose to monitor water quality frequently if changes in quality have an adverse affect on operations or on plant and animal life.

Water quality monitoring measurements can include on-site chemical tests to detect pollutants, laboratory water analysis, observations of plant and animal life in the area, and even catching fish for field or laboratory analysis.

Even if other indicators show no problems, changes in fish health may signal a pollutant or ecosystem imbalance that needs to be corrected.

LAND USE AND WATER QUALITY

Land use can have a tremendous effect on water quality. Farmlands can be the source of sediment, fertilizer and animal waste pollution. Forests may not be the source of pollutants, but they can be damaged severely by water pollution. Human activities affecting forests (forestry practices such as clear cutting and road construction that cause erosion and sedimentation) can impact water quality. Cities pose numerous water quality problems due to high water demand, industrial pollutants, nonpoint source pollution, and human wastes.

So it's important that when we decide to use land for a specific purpose, we take into account water quality, not just in the immediate area, but downstream and upstream as well. This means considering the **amount** of water available as well as how it must be processed before and after use.

For example, crops require tremendous amounts of water. If there's not enough rainfall to support crop growth, they must be irrigated, which means transporting water from lakes, streams, or wells. Irrigation may require so much water that aquatic life in lakes and streams may be affected, or the water table may be lowered, causing wells to dry up. The complete water cycle must be considered for irrigation. Irrigation drainwater must be properly discharged or recycled to avoid causing pollution as well.

Another good example is the case of a paper mill on a small mountain river. Paper production requires lots of water, and the wastewater discharged back into the stream contains a large number of pollutants, including some toxic chemicals. A paper company might come under attack from environmental groups for this mill but receive praise for how mills are operated in other areas on larger rivers. One reason is the **amount** of water available for use. The small mountain river doesn't have enough flow to support the operation of the paper mill.

AGRICULTURAL IMPACTS

Agriculture can create serious demands on water supplies and cause several serious types of pollution, as salts and trace elements are leached from the soil. Runoff and seepage of agricultural chemicals like fertilizer, herbicides, and pesticides introduce nutrients, toxics, and sometimes bacteria into waterways and groundwater. Sediment, however, is the major pollution source from this land use.

Animal wastes can enter streams, ponds, or lakes in pasture lands in which animals have direct access to water, or wastes can be washed into streams by rain or enter groundwater through the soil. Animals produce large amounts of waste (cattle create about ten tons of manure per head yearly, swine about two tons), so pollution problems can be severe around large livestock farms. Nutrients, sediment, bacteria, and organic toxics can all come from these "natural" sources of pollution.

One practice for reducing erosion and sediment pollution from agriculture is conservation tillage. Instead of plowing under the residue from a previous crop and exposing bare soil, conservation tillage uses a disc or other device to cut through the residue so seeds can be planted. This process allows a protective layer of vegetation to remain on top of the soil to retard erosion and to retain more water in the soil. One negative is that this process may require increased use of herbicides. Another process, called ridge planting, puts seeds in ridges of plowed soil. This method allows warmer soil temperatures for planting and traps rainwater in the furrows between the ridges. Biological pest control or integrated pest management (IPM) can be used to reduce the amount of pesticides needed to protect crops. In IPM, predators like ladybugs or praying mantises are introduced to control the pest that is causing crop damage.

Agricultural extension services also provide soil testing to farmers so that fertilizers can be properly used. The tests indicate which nutrients may be needed for the type of soil and the crop being used so that excess fertilization does not occur. Not only does this practice reduce pollution, it can reduce the cost of producing a crop.

Other best management practices include crop rotation, which may replace a row crop with a grain or other plant that covers more ground and reduces erosion. Planning field layouts can also reduce erosion and sediment pollution by changing the direction of rows or creating runoff channels that allow sediment to settle before the runoff water is released into streams.

There are several best management practices that can be applied to reduce pollution. Examples are diversion channels to direct runoff to a safe outlet, grassed waterways to prevent erosion by small channels, and sediment basins to collect runoff and sediment. These are called structural best management practices.

Management practices are often used. This type of best management practice involves making management decisions that will reduce the potential for pollution. For example, integrated pest management is used to scout for pests and pesticides are applied only when the number of pests reaches a threshold beyond which it is economical for pesticide use. This requires less pesticides and permits natural predators to assist with pest control.

Waste management systems can be used to convert animal wastes to reusable resources such as fertilizer or methane for energy. A ton of animal manure can be equal to about 100 pounds of high quality chemical fertilizer.

There is no one single system that is best for animal waste operations. Depending on the size and type of livestock and the potential for pollution, systems may need to be customized to a particular location. Considerations for system design include local environmental regulations, the number of animals, type of confinement, fertilizer needs, location of water sources, and the location of residences around the livestock operation.

A waste management system has four basic components: collection, transportation, storage, and disposal. For some farms, a system may provide collection and transportation functions, with the wastes delivered to another location for storage, and disposal. Collection methods vary, ranging from scraping to washing and flushing. Transportation methods include conveyors, pumps, wagons or manure spreaders.

Collection and storage methods are based on the principles of either keeping wastes for later use or providing a safe method for their treatment and disposal. Proper storage facilities are important because wastes can lose nutrients and fertilizer value. A common treatment facility is a lagoon. Aerobic lagoons break down waste materials without oxygen or aeration. Aerobic lagoons break down waste material with oxygen. Aerobic lagoons create less odor than anaerobic lagoons, but require more surface area. Both types reduce the concentration of nutrients, making it safe to dispose of wastes by irrigation. Disposal or land application should be done at the time and in a manner that reduces the potential for runoff.

Other alternatives include collection of wastes and drying them for use as household fertilizers or even additions to silage for animal feeds, or as alternative fuel for energy. Dead animals may be composted or processed and used for soil amendments or fertilizer and animal food.

URBAN IMPACTS

Densely populated urban areas, which are covered by non-permeable surfaces like streets, sidewalks and buildings, create a great deal of runoff. The high concentrations of people in these areas tend to produce greater quantities and varieties of pollutants, including nutrients, bacteria, and toxic chemicals. Automobiles and manufacturing are two primary sources of toxics.

Less densely populated suburban areas have three primary water contamination problems. The first is runoff and seepage of lawn and garden chemicals. These chemicals are often used in much higher concentrations than in agriculture, and they can wash off into storm sewer systems or percolate through soil into groundwater. Faulty septic systems are another source of pollution, which can produce nutrient, bacteria, and even toxic contamination. Many household chemicals like pesticides, herbicides, solvents, paints, and cleaners are so toxic that they would require specialized disposal in industrial situations. A third source of pollution is runoff from streets, driveways, and parking lots. This runoff contains large amounts of petroleum contaminants, as well as bacteria and nutrients.

Control of both point source and nonpoint source pollution in urban and suburban areas is increasing. Tremendous investment by government and industry has helped control pollution problems immensely. Municipal sewage treatment facilities have grown faster than the nation's population. However, more improvements are still needed to make sure that wastewater treatment systems can keep up with needs. Federal and state laws, beginning with the landmark 1972 Clean Water Act, are continually being developed that limit what types of contaminants can be released into wastewater systems. These controls have stopped many of the fish kills and other problems associated with pollution in the 1970s. Many urban area lakes that were considered "dead" are now healthy enough to support many fish species and other aquatic life. Phosphate based detergents are banned by some communities.

Prior to 1992, urban runoff was controlled primarily by voluntary means. Federal regulations now require cities with a population of greater than 100,000 and certain types of industries to develop and implement plans to control storm water pollution. Cities have adopted new practices like leaf collection and street cleaning at critical times, that can reduce the flow of sediment and other contaminants into waterways. City planning places new emphasis on water conservation and source control, particularly in areas where water supplies may be limited. Detention-retention ponds have been incorporated into some water control systems to allow contaminants to settle, and to feed rainwater into runoff channels at a controlled rate.

In some cases, building codes limit construction based on water demand. A single new household consumes more than a hundred thousand gallons of water each year, placing more demand on water supplies and on wastewater and sewage treatment systems.

Education programs designed to teach people proper use of water and disposal of potential pollutants are also having a positive impact. These programs show people the staggering amounts of water they consume each day, and steps they can take to reduce consumption. Less consumption means less wastewater that has the ability to carry pollutants.

INDUSTRIAL IMPACTS

Industrial impacts on water can be severe. Industry can introduce toxic chemicals into a stream or lake, either through manufacturing or through an accidental spill. Thermal pollution from power plants or factories can raise water temperatures and change the ability of the water to support life. Nutrients from detergents or other organic chemicals can cause nutrient pollution that chokes the life out of waterways.

Since most industrial pollution is point source pollution, cleanup efforts can be focused and effective. NPDES point source pollution control requires any industry that discharges a pollutant into a water supply to have a permit specifically to do so. Severe penalties are established for failure to have a permit or exceeding permit limits. Many industries are required to treat wastewater before releasing it back into streams.

Construction is an industry that can create nonpoint source pollution as well as point source pollution. Construction contaminates water in two ways. Sediment pollution can be created when plant cover is removed, with erosion occurring at much greater rates than for undisturbed land. Toxics from construction materials, such as paint, solvents, acids, and glues can also pollute water.

Construction must take into account both short term and long term water pollution management practices. Construction removes vegetation from the ground, inviting erosion and sediment pollution. Practices to reduce this include temporary measures such as diverting water flow through trenches or sediment ponds that allow silt and other materials to settle before water runs off into streams. Hay bales, mulch, and other materials may also be used as temporary controls, as well as the planting of temporary grasses to control erosion before more permanent landscaping can be done. Perennials or other long lasting vegetation can be used to provide more permanent ground cover for sites that won't be landscaped.

One key to success in best management practices for construction is proper site planning. The type of soil, the location of streams, and the topography of the area must all be considered before the construction process begins. Permanent measures may have to be taken to ensure that slow erosion doesn't create problems several years in the future. These measures may include: storm drains, "riprap," a permanent layer of stone that retards water flow and enhances infiltration, or even construction of grassed or lined waterways that convey excess storm water away from developing areas or critical slopes. The construction process itself may be modified to include a stone "pad" at the construction entrance to reduce the transportation of mud off the building site by vehicles or runoff.

FORESTRY IMPACTS

Forests are one of the least-polluting land uses. However, chemicals like insecticides used on tree farms can soak into groundwater or wash into streams. Logging can cause erosion and sediment pollution, particularly if care is not taken in cutting logging roads and planning loading and stacking areas. Forestry has different environmental impacts in different parts of the country.

Forestry practices have been modified voluntarily and by law to reduce their pollution potential. To reduce soil erosion, many logging companies now employ buffer zones and streambank protection procedure which reduce erosion and other impacts on the land. Many forest product companies have found that proper land management can actually increase their profits by increasing forest yields.

For softwoods like pine, which are used for paper production and lumber, forest product companies manage their own "plantations" of timber, replanting several trees for every one cut down. This has increased the amount of usable timber available in the U.S., and has reduced the potential of pollution. Site planning is now an important consideration. Logging road paths may wind around hills to reduce erosion and allow natural growth to quickly "retake" the land after cutting is finished.

MINING IMPACTS

Improper mining can threaten ground and surface water supplies. Sediment, toxics, and rubble from mines are water contaminants. Rainwater running through discarded mine material (tailings) can become acidic, poisoning aquatic plant and animal life.
Mining is one activity that is specifically regulated as a potential source of pollution. Since 1965, more than three million acres of land have been disturbed by strip mining activities. Severe problems have been created by erosion and acidity. However, mined lands must now be "reclaimed," or restored to acceptable condition after operations are complete.

The practices included in this process are preplanning to determine how the site will be used after operations are finished, stabilization of the site while work is in progress so that it does not create an immediate source of pollution, creation of storm water control and storage, and re-creation of natural beauty by replanting the site. Since mining can destroy topsoil, new soil or nutrients may need to be added before plants can thrive, or different vegetation requiring less nutrients may be used to start growth.

Underground mines can be pollution sources, particularly for groundwater. These are also subject to reclamation, and laws require that steps be taken to keep sediment or toxics from entering waterways.

COMMERCIAL BUSINESS IMPACTS

We normally think of major industries as creating the most pollution, but small businesses can also be pollution sources. In fact, many small businesses pollute, but do not realize it. Local garages that dump waste oil and anti-freeze instead of collecting it can be serious contributors to water pollution. A single quart of oil can pollute as much as 250,000 gallons of water. Photo labs can be sources of heavy metal pollution, such as silver. Dry cleaners use a variety of solvents that can be toxic. And trash created by businesses that goes into landfills can ultimately result in water pollution.

Many smaller businesses have voluntarily adopted approaches to prevent or reduce pollution. Recycling of automotive wastes is becoming standard practice for many garages, and other businesses regularly practice recycling a variety of materials to reduce cost and waste. Businesses such as photo labs that have installed systems that recover silver used in electroplating and thereby reduce potential water pollution. Laws regarding toxic substances also apply to small businesses, and many wastes that used to be dumped into water supplies are now collected for proper disposal.

RECREATION IMPACTS

Recreation can impact surface water in a number of ways. The improper use of our waterways or overuse by too many people can impair surface waters, destroy habitats, and cause injury or death to wildlife. Litter dumped in and around our waterways can not only cause pollution, but can be mistakenly eaten by wildlife.

Boats cause water pollution through leakage or spilling of petroleum products. Boaters can also damage habitats or hurt endangered species, such as the West Indian Manatee, which lives primarily in warm waters around the coast of Florida. As of 1996, approximately 2000 of these notoriously gentle mammals remain. Yet, each year, many die or suffer injuries at the hands of boaters.

To stem the tide of deaths and injuries to manatees and other aquatic wildlife, state regulations often require safeguards to be implemented, such as boater education and strict speed limits in certain areas. For it is only through the proper management of recreation areas, education to help people protect these areas, and laws that require appropriate human behavior in these areas, that we can begin to protect our aquatic resources from human recreational impacts.

OTHER SURFACE WATER ISSUES

ACID RAIN

The water cycle helps renew water as a pure resource. But the flow and cycling of water can also help spread pollution sources.

Acid precipitation is a prime example. Air pollution from industrial sources and automobiles releases sulphur oxides and nitrogen oxides into the air. When mixed with water vapor, they form sulfuric and nitric acids, which fall to the ground in the form of acid rain, snow, fog, or dew. Acid precipitation, commonly called "acid rain," can cause damage to buildings, car finishes, crops, forests, wildlife habitats, and aquatic life.

This acid precipitation can also pollute clean waterways through runoff. Increased acidity of water can negatively affect fish and other aquatic life. The effects of acid precipitation may not be felt for many months or years. Acidic snowmelt may create acid "shock" in a stream and cause serious fish kills in the spring.

NONPOINT SOURCE POLLUTION

Water pollution is identified in two categories. **Point source pollution** is contamination that comes from a single, clearly identifiable source, such as a pipe which discharges material from a factory into a lake, stream, river, bay, or other body of water. Point source pollution could also include stormwater runoff that is channeled from a drain directly into a waterway, or even a polluted tributary that regularly adds contaminants to a body of water. Point source pollution is relatively easy to identify.

Nonpoint source pollution is more difficult to identify. This is pollution which originates over a broad area from a variety of causes. Examples of nonpoint source pollution include: improper application of pesticides and fertilizers; sediment from construction and logging; leachate from landfills and septic tanks; petroleum-based products from streets and parking lots; and atmospheric fallout. Because of its dispersed sources, nonpoint source pollution can be difficult to control.

GROUNDWATER

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place, depending on the slope of the land, amount and intensity of rainfall, and type of land surface. Porous, or permeable, land containing lots of sand or gravel will allow as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable areas, as little as five percent may seep in. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater.

As water seeps through permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table. The water table can rise or fall according to the season of the year and the amount of precipitation that occurs. The water table is typically higher in early spring and lower in late summer. The porous area between the land surface and the water table is known as the unsaturated zone.

AQUIFERS

Water-bearing rock, sand, gravel, or soil that is capable of yielding usable amounts of groundwater is called an aquifer. The water yield from an aquifer depends greatly on the materials that make it up. Mixtures of clay, sand, and fine particles yield small amounts of water because the spaces between the particles don't allow water absorption and flow. Materials sorted into distinct layers will yield high amounts of water from coarse-grained materials like large sand grains and gravel, but low amounts from fine-grained sand, silt, or clay. Bedrock aquifers will yield substantial amounts of water if there are large openings or cracks in the rock. The capacity of soil or rock to hold water is called its porosity; the capacity for water to move through the aquifer is called permeability.

There are two types of aquifers: confined, or artesian aquifers, and unconfined, or water table aquifers. Artesian aquifers contain groundwater that is trapped under impermeable soil or rock and may be under pressure. Artesian wells are wells that pierce artesian aquifers. The water in these wells usually rises toward the surface under its own pressure. If the water level in the well is higher than the land surface, it may be a flowing artesian well. A well in an unconfined aquifer has the same water level as the water table around it.

GROUNDWATER RECHARGE

Water that seeps into an aquifer is known as recharge. Recharge comes from a variety of sources, including seepage from rain and snow melt, streams, and groundwater flow from other areas. Recharge occurs where permeable soil allows water to seep into the ground. Areas in which this occurs are called recharge areas. They may be small or quite large. A small recharge area may supply all the water to a large aquifer. Streams that recharge groundwater are called losing streams because they lose water to the surrounding soil or rock.

GROUNDWATER DISCHARGE

Groundwater can leave the ground at **discharge points**. Discharge happens continuously as long as enough water is present above the discharge point. Discharge points include springs, stream and lake beds, wells, ocean shorelines, and wetlands. Streams that receive groundwater are called **gaining streams** because they gain water from the surrounding soil or rock. In times of drought, most of the surface water flow can come from groundwater. Plants can also contribute to groundwater discharge, because if the water table is close enough to the ground, groundwater can be discharged by plants through transpiration.

GROUNDWATER MOVEMENT

Groundwater usually moves slowly from recharge areas to discharge points. Flow rates within most aquifers can be measured in feet per day, though in karst bedrock the rate of flow can be measured in miles per hour. Flow rates are faster when cracks in rocks or very loose soil allow water to move freely. However, in dense soil,

groundwater may move very slowly or not at all.
Groundwater typically moves in **parallel paths**, or layers. Since groundwater movement is slow, it doesn't create enough turbulence to cause mixing the way surface waters mix when a river or stream empties into another waterbody. That is, layers of groundwater remain relatively intact. This can be an important factor in locating and determining the movements of contaminants that might enter the groundwater supply. But eventually contaminants will disperse through part or all of an aquifer.

Wells affect groundwater flow by taking water out of an aquifer and lowering the nearby water table. Removed water is recharged from the water table, and the lowered water table caused by the well is called a **cone of depression**. The cone of depression from a well may extend to nearby lakes and streams, causing the stream to lose water to the aquifer. This is known as **induced recharge**. Streams and wetlands have been completely dried up by induced recharge from well pumping.

GROUNDWATER PROBLEMS

SOURCES OF GROUNDWATER CONTAMINATION

Groundwater contamination can come from a number of natural and human-made sources. These can include:

***Leaks and spills at factories and commercial facilities**

Spills and leaks can result from accidents, lack of employee training, improper planning, and inadequate maintenance. They are especially problematic if proper procedures are not in place to clean them up once they occur. Materials which can cause problems if spilled, include gasoline, other petroleum products, hazardous chemicals, and a variety of other materials.

It's difficult to eliminate accidental spills, but they can be reduced and the damage they cause can be minimized by proper design and maintenance of facilities and proper employee training. The Emergency Planning and Community Right-to-Know Act of 1986 (SARA Title III) requires states, communities, and businesses to have plans for responding quickly in the event of an accidental spill. Workers must be informed as to what hazardous chemicals they may be working with, and what to do in case of an accident. This act has prevented or reduced many instances of groundwater contamination.

***Improper hazardous waste disposal**

Improper industrial waste disposal can come from a variety of sources, including major industrial plants and small businesses. The local dry cleaner uses a number of solvents and hazardous chemicals for cleaning clothes, and these must be handled as carefully as any other hazardous waste to prevent groundwater contamination. Industrial wastes can create groundwater pollution problems that take years to resolve.

The disposal of hazardous industrial wastes is now carefully regulated under the Resource Conservation and Recovery Act (RCRA), which requires industry to have a "cradle to grave" system of tracking hazardous wastes. This system is designed to prevent inadvertent (and sometimes purposeful) release of hazardous materials into the environment by requiring businesses to report hazardous wastes and account for their proper disposal (except for some small quantity generators). The law establishes severe penalties for noncompliance. Another Federal law, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) responds to environmental threats from improper disposal of hazardous wastes and sets standards for cleanup—even for sites that were contaminated years ago where the source of contamination may not be easily identifiable.

Individuals can also be sources of hazardous waste pollution. If you dump oil in your driveway, pour paint thinner in the toilet, or dispose of wastewater with hazardous cleaners in the bathtub, you could be a source of hazardous pollution. Ways to avoid this are to recycle oil and other petroleum based chemicals at service stations or recycling centers. Avoid using hazardous chemicals when possible and substitute more environmentally friendly materials. Many communities sponsor household chemical disposal days so that individuals can take solvents and other hazardous wastes to a site for proper disposal.

***Improper use and disposal of pesticides**

Pesticides used on farms and even on individual lawns can create serious groundwater pollution. Improper pesticide use can cause people and animals to become ill, kill plants, and have adverse effects on aquatic life in nearby streams. Improper pesticide use can include excessive or ill-timed application, improper storage, or improper disposal of excess pesticides. If you overuse pesticides on your yard, you could be polluting your own groundwater. It's been estimated that individuals use over 100 times as much pesticides and fertilizer on their yards as farmers use on the same amount of land.

Avoiding pesticide pollution of groundwater is relatively easy. Follow instructions carefully. Reduce pesticide use in areas known to be recharge areas for groundwater. Use natural pest control methods rather than chemicals. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds.

***Leachate from landfills**

If landfills are not properly constructed, liquid from decomposition of materials, or **leachate**, can leak out of the landfill into an aquifer. Leachate can contain high levels of bacteria, hazardous chemicals, metals, and ammonia. Runoff water from landfills after rains can also carry pollution to groundwater recharge areas—and hence into groundwater.

New landfill construction methods are designed to prevent pollution of groundwater. Landfills are now built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

***Septic systems**

Septic systems can be a source of groundwater pollution if too many systems are located in an area, if a system is overloaded or not working properly, or if a system is improperly used for disposal of chemicals or other materials. If a septic system is not working properly, it can contaminate groundwater with bacteria, viruses, and hazardous cleaning materials or household chemicals. Even properly working well-maintained septic systems can contribute nitrates to groundwater. These can show up in well water around the septic system.

Methods of preventing groundwater pollution from septic systems include proper system installation and maintenance. If the concentration of households in an area is too great, then a public sewer and waste treatment system may be necessary. Dumping hazardous chemicals into septic systems should also be avoided.

***Saline Intrusion**

In coastal areas, too much demand on potable groundwater can create induced recharge from ocean waters, resulting in saline intrusion into groundwater supplies. This can also happen in times of severe drought. (Induced recharge can not only contaminate groundwater, but enough induced recharge has been known to dry up wetland areas and destroy habitats for wildlife.)

Careful planning of coastal communities and water conservation are ways to avoid saline intrusion into groundwater supplies.

***Salts and chemicals used to deice roads**

In northern climates, tons of salt and other chemicals are used for deicing roads, and these can create groundwater contamination problems. Runoff from storage areas and highways can seep into the ground and cause high levels of chlorides in well water. Prevention of pollution from this source can be through protection of storage areas, minimal salt use, and substitution of other materials, such as sand or gravel.

***Liquid waste storage lagoons**

Storage lagoons are used by industries, farms, cities, and mines as a way of preventing pollution by allowing solid wastes to settle before wastewater is released. However, storage lagoons can cause groundwater pollution if they leak or overflow. They can be sources of bacterial or chemical groundwater pollution.

Groundwater contamination from lagoons can be avoided through proper installation and maintenance and by locating lagoons away from sensitive groundwater areas.

***Fertilizers**

Like pesticides, misuse of fertilizers can cause groundwater pollution. Overuse can allow nitrates from fertilizer to seep into the water table. In sensitive groundwater areas, rainfall seepage can cause fertilizer to migrate and contaminate an aquifer.

Careful use can avoid or minimize these problems.

***Animal wastes**

Animal wastes are sources of bacteria and nitrates. They can contaminate groundwater if too many animals are located in too small a lot, or if the lot has improper drainage. Lagoons used to trap animal wastes can be a source of groundwater pollution if they leak or if the water table is too close to the land surface. *Proper siting of animal lots, along with regular cleaning and avoiding overloading, can prevent animal waste pollution. Wastes can be recovered and used as fertilizer.*

***Leaking underground storage tanks**

Leaking underground tanks are a potentially large groundwater pollution problem. And no one is really sure how large the problem will be. It's been estimated that the locations of only **half** of all the underground storage tanks are known in the U.S. Many of these are old, corroded, and beginning to leak and cause problems. Underground storage tanks are commonly found at service stations, where gasoline pollution is a potential problem. Many stations have replaced old steel tanks and piping, with fiberglass tanks and piping that don't corrode.

Federal law now requires that owners/operators of USTs prevent the release of product into the environment. This may require the owner/operator to install storage tanks that have a secondary containment system should the primary tank fail. Careful monitoring of tank inventories can be used to detect leaks and correct them, and tanks that are no longer in use must be closed by either removing them or filling them with inert materials.

***Pipeline breaks**

Pipeline breaks can be sources of localized groundwater pollution. Breaks can be severe enough so that they are immediately detected, or they may be small and cause significant groundwater contamination before they are noticed. Pipeline breaks can cause pollution from sewage, petroleum products, or other chemicals. They can occur around roadways due to vibration from vehicles, or they can even be caused by plant roots, which slowly crack pipes and cause leaks. Careful inspection of pipelines and regular maintenance can reduce pollution problems from this source.

****Inadequately sealed wells or abandoned wells***

It's sometimes difficult to imagine wells, our chief way of tapping into groundwater supplies, as a source of groundwater pollution, but they can be pathways for pollutants to enter the groundwater system. If a well isn't sealed or cased properly, polluted water from runoff can enter at the well cover or along its walls and be channeled directly into groundwater. Open abandoned wells can be a significant source of groundwater pollution. And if a well is deep enough to reach a layer of groundwater that is otherwise protected by impermeable soil from pollution from surface seepage, it can create severe contamination of an otherwise pure water source.

Groundwater pollution from wells can be prevented by properly sealing wells which will no longer be used with concrete or earth. Well covers and tight casings are used as temporary measures. Procedures have also been developed to properly seal and plug abandoned wells.

***Underground injection wells**

Underground injection wells are a method of waste disposal. Wastes disposed by this method include industrial chemicals, sewage effluent, cooling water, storm water, and saltwater. Typically, injection wells inject wastes below sources of drinking water, but if injection wells have leaks or are used improperly, they can inject wastes directly into a usable groundwater supply.

Injection wells are carefully monitored by state and federal regulations to prevent pollution. Businesses using injection wells are required to have permits for their use and to comply with permit conditions.

***Radon contamination**

Radon is a naturally occurring radioactive element that has been linked to cancer in humans. It occurs in certain geologic areas, and can be an air or water pollutant. Radon can collect as a gas in a basement, or it can contaminate well water. Test kits for radon detection are available for individual use. Once detected, radon can be removed from a home or a water well.

COASTAL WETLANDS

IMPORTANCE OF COASTAL WETLANDS

Coastal wetlands provide a wide variety of important functions, including:

Water quality. Some wetlands contribute to improving water quality by removing excess nutrients and many chemical contaminants. These improvements occur due to uptake by the plants and binding with soil particles.

Barriers to waves and erosion. Coastal wetlands reduce the impact of storm tides and waves before they reach upland areas.

Flood storage. Coastal wetlands can store floodwater and release it slowly, lowering flood peaks.

Sediment control. Reduced flood flow provided by coastal wetlands allows floodwater to deposit sediment, instead of transporting sediment into waterways where it can pose a water quality problem.

Wildlife habitat. Coastal wetlands can support wide varieties of wildlife (i.e., provide nesting areas, produce food, provide spawning areas).

Fish and shellfish. Coastal wetlands are important spawning and nursery areas for fish and shellfish, and provide sources for commercial fishing.

Sanctuary for rare and endangered species. Protection of wetlands often means providing survival habitats for endangered animals. Nearly half of the threatened and endangered species in the U.S. rely directly or indirectly on wetlands for their survival.

Aesthetic value. The natural beauty of wetlands is a source of visual enjoyment, and can be appreciated through observation, art, and poetry.

Education and research. The rich ecosystems of wetlands are natural locations for biological research and observation.

Recreation. Wetlands provide sites for hunting, fishing, canoeing, and observing wildlife.

Food production. Wetlands have potential for the production of plant products, including marsh vegetation, and for aquaculture. Wetlands also produce great volumes of food in the form of decaying plant and animal matter or detritus. Detritus is consumed by many aquatic invertebrates and fish which are food for game fish, waterfowl, and mammals.

Water supply. With the growth of urban areas, wetlands are becoming more valuable as sources for water supply.

COASTAL HABITATS

Coastal saltwater wetlands contain a number of habitats. **Marine intertidal** habitats are near the shoreline and are flooded by tidewaters. **Estuarine sub-tidal** habitats are open water and bay bottoms that are continuously covered by saltwater. **Estuarine intertidal emergents** are salt marsh areas that are covered by herbaceous vegetation during the growing season. **Estuarine intertidal forested/shrub** habitats contain larger woody plants. **Estuarine intertidal unconsolidated shores** are beaches and sand bars, and **estuarine unconsolidated bottom** habitats are open water estuaries. **Riverine** habitats are tidal or non-tidal river systems that feed into wetlands.

ESTUARIES

Estuaries form where rivers meet oceans. Estuaries are deep water tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open or at least some access to the open ocean. Ocean water in estuaries is partly diluted by freshwater runoff from rivers, but the salinity of still waters in estuary wetlands may be occasionally higher than that of the ocean due to evaporation.

BAYS

Bays are large estuarine systems. The Chesapeake Bay is the largest estuary in the United States and one of the most productive biological systems in the world. The bay is approximately 200 miles long and ranges from 4 to 30 miles wide, but averages a depth of only about 28 feet. This makes it ideal for shellfish and other productive fish species, but it also makes it sensitive to natural changes in temperature and wind and human-made pollution. Other key bays in the United States include Puget Sound in Washington, Long Island Sound in New York, Albemarle Sound and Pamlico Sound in North Carolina, and San Francisco Bay in California.

A WETLAND BENEFIT- FOOD SUPPLY

Coastal wetlands are critical to human food supplies. About 66 percent of the commercial fish catch taken along the Atlantic and Gulf coasts depends on wetlands for survival. Coastal wetlands produce millions of tons of organic matter that provide food for invertebrates, shellfish, and small fish that are in turn food for larger commercial fish such as bluefish and striped bass. Most freshwater fish feed upon wetland-produced food and use wetlands as nurseries for their young. Waterfowl hunters spend hundreds of millions of dollars annually to harvest wetland-dependent birds. Wetlands also provide blueberries, cranberries, and wild rice. And wetlands have further potential for contributing to the food supply, through the harvesting of marsh vegetation and aquaculture.

FRESHWATER WETLANDS

Like saltwater coastal waters, freshwater wetlands offer a variety of benefits, including:

Water quality. Some wetlands contribute to improving water quality by removing excess nutrients and many chemical contaminants. These improvements occur due to uptake by the plants and binding with soil particles.

Flood conveyance. Wetlands can form natural floodways that allow floodwater to move downstream without causing damage (i.e., contains flood flows within a corridor that should not be developed).

Flood storage. Freshwater wetlands can store floodwater and release it slowly, lowering flood peaks.

Wildlife habitat. Inland wetlands can support wide varieties of wildlife (i.e., provide nesting areas, produce food, provide spawning areas).

Sanctuary for rare and endangered species. Protection of wetlands often means providing survival habitats for endangered animals. Nearly half of the threatened and endangered species in the U.S. rely either directly or indirectly on wetlands for their survival.

Aesthetic value. The natural beauty of wetlands is a source of visual enjoyment, and can be appreciated through observation, art, and poetry.

Recreation. Wetlands provide sites for hunting, fishing, canoeing, and observing wildlife.

Education and research. The rich ecosystems of wetlands are natural locations for biological research and observation.

Water supply. With the growth of urban areas, wetlands are becoming more valuable as sources for water supply. Some wetlands help recharge groundwater supplies.

Food production. Wetlands have potential for the production of marsh vegetation and aquaculture for humans; they provide detritus, plants, and insects as food for animals.

Timber production. Properly managed, wetlands can provide good sources of timber.

Historical value. Some wetlands were locations for Indian settlements and provide significant historical and archeological value.

WETLAND HABITATS

Freshwater wetland habitats include **palustrine forested**, or forested swamps and bogs; **palustrine shrub**, or shrub wetlands; **palustrine emergents**, or inland marshes and wet meadows; **palustrine unconsolidated shores**, or freshwater shores and sand bars; **palustrine unconsolidated bottom**, or open water ponds; **palustrine aquatic beds**, or floating aquatic or submerged vegetation; **lacustrine** (lake) habitats; and **riverine** (river) habitats.

DESTRUCTION OF WETLANDS

It is estimated that over 200 million acres of wetlands existed in the United States, at the time of European settlement. In 1975, wetlands were estimated to be 99 million acres. Iowa, for example, has lost 99 percent of its wetland areas. Many wetlands have been converted to agricultural areas, and wetlands have also been lost to real estate development, mining, and drained for timber production. Laws used to encourage wetlands destruction for "useful purposes."

Wetlands are still being destroyed at an alarming rate, but there is a new awareness of wetlands value, and an increased interest in preserving wetland areas. Some wetlands have been restored, and governments and private groups have begun purchasing wetland areas for conservation and preservation.

PROTECTION OF WETLANDS

Because so many acres of wetlands have been lost, Federal and state governments have worked hard to establish ways to protect and revitalize remaining coastal areas and wetlands. Private concerns have also worked toward wetland preservation.

Approaches toward wetlands protection have included acquisition of wetland areas, both by governments and private groups such as The Conservation Foundation and The Nature Conservancy. Buying duck stamps at the post office also raises money for wetlands conservation. Economic incentives for wetland preservation have included tax reductions and deductions for wetland donation; economic **disincentives** to wetland destruction have also been put in place. A provision of the Food Security Act eliminates farm program benefits for farmers using wetlands converted into farmlands.

Specific regulation of wetlands comes with Section 404 of the Clean Water Act, amended in 1987. Under this law, the discharge of dredged or fill materials into the waters of the U.S. requires a permit from the Army Corps of Engineers. This has prevented the loss of many wetlands, but it is not a comprehensive program for protection. For example, some isolated yet ecologically valuable wetlands are not regulated.

Most coastal states have laws in place to protect coastal wetlands, but fewer than 20 states have enacted provisions to protect inland wetland areas. The National Estuary Program (NEP) was established in 1985, to address problems affecting the estuaries, such as loss of habitat, contamination of sediments by toxic materials, depletion of oxygen, and bacterial contamination. As of 1996, 28 of the nation's largest estuaries were listed under the NEP. Management plans for each estuary are due to be completed and steps taken to restore their environmental—and economic—benefits. Another important planning effort is the advanced identification (ADID) of wetlands in the United States.

RESTORED WETLANDS FOR HABITAT

Close to half of all rare and endangered animal species are either located in wetland areas or dependent on them. Government agencies have recently undertaken restoration of wetlands in large-scale projects. One example is the restoration of thousands of acres of floodplain marsh along Florida's Kissimmee River. Some wetland habitats, such as freshwater marshes can be relatively easy to reproduce and regenerate, while others, such as high salt marshes and forested wetlands, may be more difficult and take generations to recreate.

The restoration of wetland habitats is a young and very complex science that will take years to understand fully. Wetland restoration must overcome a variety of problems, such as financial considerations, invasion of unwanted vegetation, proper water recharge and sediment control, and interaction of wetlands with adjacent waterways.

COASTAL AND COASTAL WETLANDS ISSUES

EROSION

Erosion poses a problem for shorelands by removing soils and sediment that support plant and animal life. Erosion can strip away important sediment layers and change the habitat's ability to support life. Extreme erosion can create stream flows that drain coastal wetland areas.

DREDGING AND COASTAL WETLAND LOSS

Dredging, filling, and draining of wetlands have destroyed hundreds of thousands of acres of coastal habitat. Also, dredged materials from navigation channels are often deposited alongside streams in wetland areas. For many years, it was thought good land practice to improve wetland "wastelands" by filing them in or draining them for mosquito control.

Wetlands are now protected by Section 404 of the Clean Water Act. Under this law, the discharge of dredged or fill materials into the waters of the U.S. requires a permit from the Army Corps of Engineers. In order to receive permit authorization, the activity must comply with 40 C.F.R. Section 404 (b)(1) guidelines which stipulate that no discharge can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if significant degradation would occur. This has prevented the loss of many wetlands; however, wetland loss and degradation continue to be a significant environmental concern.

RED TIDE

Red tide is a natural phenomenon brought on by too many nutrients in the water which can cause uncontrolled growth of microscopic organisms or type of plankton called dinoflagellates. These organisms can multiply to the point where water actually looks red. The organisms contaminate shellfish, making them unsafe for human consumption. Red tide also causes fish kills, can damage vegetation, and as of the mid 1990s, has become a toxic threat to endangered aquatic species such as Florida's West Indian Manatee.

NONPOINT SOURCE POLLUTION IN BAYS

Nonpoint source pollution is a problem for bays and other waterways, but in bays, its consequences can be more severe. Since bays are typically shallow, nonpoint source sediment pollution can quickly fill and clog waterways and wetland areas. Sediment can also bring about conditions that can reduce oxygen levels and kill marine life. Nutrient pollution from farmlands can also create havoc in bays. Algal blooms from nonpoint source pollution can have similar effects of reducing oxygen levels and killing existing life. Toxic pollution can quickly settle into shallow bay waters and infiltrate productive fishing and spawning beds, killing or contaminating fish and plant life.

DEVELOPMENT OF COASTAL AREAS

Coastal development has been and continues to be a major threat to wetlands. Coastal property has high real estate value, and developers find it difficult to preserve wetland areas when faced with profit potential from private wetland areas. And even if wetlands aren't destroyed during development, the additional pollution from development can disrupt the delicate environmental balance of wetlands, changing habitats forever. The nation's largest estuary, the Chesapeake Bay, suffers many environmental problems as a result of extensive development within its watershed.

OCEAN DUMPING AND SPILLS

Ocean dumping and accidental spills pose a severe pollution problem, and many coastal areas have received significant environmental damage. A number of federal laws are now in place to protect the coastal environment.

Some of these laws are described below.

*The Rivers and Harbors Act of 1899, was the beginning of laws protecting the oceans. This act was established to prohibit throwing, discharging, or depositing any matter, other than matter flowing in streets and sewers and passing in a liquid state, into navigable waters.

*The Water Pollution Control Act (WPCA) of 1948, was passed by Congress because there was evidence of health dangers that damaged beaches and shellfish beds, and could cause typhoid fever, diarrhea, and dysentery.

*The Federal Water Pollution Control Act (FWPCA) of 1956, amended the WPCA. It authorized grant monies to communities to build sewage treatment plants.

* The 1969 National Environmental Policy Act's main goal was "to create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements to present and future generations of Americans." (Covering the Coasts: A Reporter's Guide to Coastal and Marine Resources, page 81) One requirement under this act is for applicable federal agencies to prepare an environmental impact statement (EIS). An EIS is a detailed statement which describes how a project may significantly affect the environment and living things' habitats.

*London Dumping Convention Act of 1972, placed limits on the amount of industrial and municipal waste dumped into international waters. The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, (also called the Ocean Dumping Act), implements the London Dumping Convention Act, in United States' waters.

*The Clean Water Act of 1972, amended the FWPCA. It established the National Pollutant Discharge Elimination System (NPDES). Under the national permitting program, EPA or EPA authorized states issue permits limiting the pollutants from industrial and municipal discharges into United States' waters.

*Coastal Zone Management Act of 1972, provided establishment of the National Estuary Research Reserves for research and environmental education. The goal of this act is to "preserve, protect, develop, enhance, and restore where possible, the coastal resources." (Covering the Coasts: A Reporter's Guide to Coastal and Marine Resources, page 96)

*Marine Mammal Protection Act of 1972, imposes a moratorium that protects marine mammals and their products for any purpose other than for scientific research or education. This means that no person has the right to "take" (harass, hunt, capture, or kill) or import any marine mammal.

*International Convention for the Prevention of Pollution From Ships of 1973 and 1978, known as MARPOL was not effective until 1983, after several modifications. MARPOL's intent was to end "the deliberate, negligent, or accidental release of ...harmful substances from ships" and to "achieve the complete elimination of international pollution of the marine environment...of harmful substances." (Covering the Coasts: A Reporter's Guide to Coastal and Marine Resources, page 100)

*Fisheries Conservation and Management Act of 1976 (also called Magnuson Act), was established for the conservation and management of all fishery resources within the United States.

*Endangered Species Act of 1973, was established to protect endangered or threatened species. This is accomplished by federal agencies ensuring that their actions do not jeopardize endangered or threatened species or do not adversely affect critical habitats.

*Ocean Dumping Ban Act of 1988, amended the MPRSA. It was established to prohibit ocean dumping of sewage sludge and industrial wastes into waters, effective after December 31, 1991. No sludge or sewage dumping after August 18, 1989, without a MPRSA permit and an enforcement or compliance agreement is allowed. This act enforces that no new dumping of industrial and municipal waste is allowed .

*The Oil Pollution Act of 1990, was established in response to the Exxon Valdez spill off Alaska's coast in 1989. This act addresses all oil discharges into navigable waters and shorelines, imposing liability limits for vessels where gross negligence or misconduct has been demonstrated.

WATER TESTING

Water quality tests are performed on various types of water or wastewater for a variety of reasons. Surface water quality testing is typically performed by states, who are required by the Clean Water Act Amendments of 1987 to assess their waters every two years. Citizens may also conduct stream or other surface water monitoring programs. Wastewater that is discharged from industrial facilities, wastewater treatment plants, and some municipal storm sewers must be tested and meet certain requirements, as spelled out in National Pollutant Discharge Elimination System (NPDES) permits.

The Safe Drinking Water Act and corresponding regulations are designed to protect groundwater and sources of drinking water supplies. Groundwater monitoring is often performed to determine impacts from activities conducted in the surrounding area. For example, groundwater monitoring may be required in the aquifer(s) above deep injection wells or in the aquifer beneath a landfill to determine if injected or leachate is migrating into the aquifer(s). More intensive groundwater monitoring can be required if aquifers are designated as underground sources of drinking water. As well, monitoring programs for either groundwater or surface waters often form an important part of source water protection programs.

To ensure public health, the Environmental Protection Agency (EPA) and state environmental (or public health) agencies require rigorous testing of water supplies by public water systems. Tests for various parameters are conducted on water samples from different points in the drinking water treatment process: (1) on raw, untreated source water, (2) during treatment processes, (3) on finished water exiting the treatment plant, (4) within the distribution system, and (5) at the tap (for some parameters, such as lead and copper). Citizens may also want to conduct in-home tap testing for particular drinking water contaminants. To protect citizens against waterborne diseases, local health departments test water in community pools and spas.

As consumer and environmental awareness increases, citizens want to know more and more about their water quality. Many resources are available to assist in performing tests on water and wastewater samples. The Code of Federal Regulations (CFR) specifies that certain methods be used in conducting water and wastewater testing. However, these regulations are written in complex terms and can prove difficult for non-technical persons to understand. Also, a book titled Standard Methods for the Examination of Water and Wastewater is used as an industry-wide, comprehensive guide for conducting water quality testing.

Water testing companies have responded to the quest for consumer knowledge by designing simple, inexpensive, ready-to-use test kits (containing necessary materials and instructions). These kits can be mail-ordered by individuals, schools, or other organizations and allow affordable testing for many water quality parameters. Only a few companies are listed on this sheet; there are many more nationally-known water quality testing companies. Also, many smaller companies exist, who may provide excellent technical service (perhaps, on-site) to local customers. Check the Yellow Pages of the telephone directory under Environmental or Ecological Services, Water Purification Equipment, or Water Testing. State environmental agencies, local health departments, and public water suppliers may also provide technical assistance and direction in the area of water quality testing. The following resources may be used to assist in conducting water quality testing:

References:

Code of Federal Regulations, 40 CFR Part 136, Appendix A and Part 141, Subpart (C). Available at cost from the Government Printing Office, Washington, D.C., 202-512-1800.

Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 1015 Fifteen Street, NW, Washington, D.C. 20005.

Water Testing Companies: Carolina Biological Supply Company, 2700 York Road, Burlington, NC 27215, 800-334-5551.

Hack Company, P.O. Box 389, Loveland, Colorado 80539-0389, 800-227-HACK.

LaMotte Chemical Products Company, P.O. Box 329, Chestertown, MD 21620, 800-344-3100.

WATER RELATED CAREERS

Water related careers offer rewarding and challenging work. Water related careers include:

***Chemistry**. Chemists analyze water and determine contaminants that affect its quality. This may involve testing at water treatment plants or analysis of groundwater to see if pollutants have moved through groundwater supplies. Chemistry requires a college education, and quite often, post-graduate work to qualify for more advanced jobs.

***Engineering.** Water can be a focus of engineering studies. Major engineering projects require environmental impact studies and city development may be based on the ability to engineer around available water supplies. Engineers also control surface water flow for navigation, recreation, and power generation.

***Utilities.** Wastewater treatment and management is a field growing in importance and complexity as we work to clean water even more before returning it to nature. Water specialists for utilities become involved with plant operations, planning, emergency procedures, and maintenance of the nation's drinking water and wastewater plants.

***Forestry.** Forests and wetlands contain many water resources. How we manage them will govern the quality of our water supplies in the future. Forestry activities related to water can include timber harvest planning to avoid pollution problems, watershed protection, and water analysis to identify and control pollution problems. Forestry experts may work at the Forest Service, State Forester's Offices, colleges or universities, or other private organizations.

***Agriculture.** Water is essential for agriculture, and as water supplies dwindle, their management in agriculture becomes more important for irrigation purposes and to prevent pollution from agricultural sources. Agricultural activities could include genetically engineering crops that require less water to produce and control of nonpoint source pollution. Careers related to agriculture may include farming, or employment at a local agricultural extension service or soil conservation service.

***Biology.** Since water is necessary for all life, biologists must consider water supplies and water quality in determining the health of ecosystems and humans. For example, biologists can be involved in drinking water and wastewater treatment, land management, and aquatic resource management careers. Specialized jobs include fisheries biologists, limnologists, aquatic entomologists, or malacologists.

There are many other water-related jobs and careers. These include service in the Coast Guard, Marines, Army Corps of Engineers, or Navy; working for the U.S. Environmental Protection Agency, the U.S. Geological Survey, state environmental agencies, state or local health departments, state geological surveys, as well as other environmental agencies or private environmental protection organizations; commercial fishing, wastewater treatment plant technician, construction (such as plumbing or septic system installation), service in the merchant marines, meteorologist or weather person, lifeguard; fishing or rafting guide, and others. Many jobs and careers have either a direct or indirect relationship to water or water supplies.

1996 U.S. EPA NATIONAL PRIMARY DRINKING WATER REGULATIONS

National Primary Drinking Water Regulations are enforceable drinking water standards expressed as Maximum Contaminant Levels (MCLs) or treatment technique requirements. The MCL is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. A treatment technique is a drinking water treatment requirement established in lieu of an MCL, typically used when setting an MCL would be too difficult or when compliance with an MCL would be too costly.

An action level is not an MCL, it is simply a level that triggers additional action. If a certain contaminant is measured at or above the action level for that contaminant, treatment may be required or recommended by EPA.

Volatile Organic Chemicals (VOCs)	MCL, in mg/l
Benzene	0.005
Carbon Tetrachloride	0.005
1, 2-Dichloroethane	0.005
Trichloroethylene	0.005
p-Dichlorobenzene	0.075
1, 1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.2
Vinyl Chloride	0.002
cis-1, 2-Dichloroethylene	0.07
1, 2-Dichloropropane	0.005
Ethylbenzene	0.7
Chlorobenzene	0.1
o-Dichlorobenzene	0.6
Styrene	0.1
Tetrachloroethylene	0.005
Toluene	1.0
trans-1, 2-Dichloroethylene	0.1
Xylenes (Total)	10.0
Dichloromethane	0.005
1, 2, 4-Trichlorobenzene	0.07
1, 1, 2-Trichloroethane	0.005

Synthetic Organic Chemicals (SOCs)	MCL, in mg/l
Alachlor	0.002
Atrazine	0.003
Carbofuran	0.04
Chlordane	0.002
Dibromochloropropane	0.0002
2, 4-D	0.07
Endrin	.002
Ethylene dibromide	0.00005
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.04
Polychlorinated biphenyls (PCBs)	0.0005
Pentachlorophenol	0.001
Toxaphene	0.003
2, 4, 5-TP	0.05
Benzo (a) pyrene	0.0002
Dalapon	0.2
Di (2-ethylhexyl) adipate	0.4
Di (2-ethylhexyl) phthalate	0.006
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Glyphosate	0.7
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Oxamyl (Vydate)	0.2
Picloram	0.5
Simazine	0.004
2, 3, 7, 8-TCDD (Dioxin)	$3x10^{-8}$

(Aldicarb, Aldicarb Sulfone, and Aldicarb Sulfoxide have been remanded back to EPA for further regulation.)

Inorganic Chemicals	MCL, in mg/l
Antimony	0.006
Arsenic	0.05
Asbestos*	7 Million Fibers/Liter
Barium	2
Beryllium	0.004
Cadmium	0.005
Chromium	0.1
Cyanide	0.2
Fluoride	4.0
Mercury	0.002
Nitrate (as N)	10
Nitrite (as N)	1
Total Nitrate/Nitrite (as N)	10
Selenium	0.05
Thallium	
0.002	

*Fibers longer than 10 micrometers
(Nickel has been remanded back to EPA for further regulation.)

Radionuclides

	MCL
Gross alpha particle activity	15 pCi/L
Combined radium-226 and radium-228	5 pCi/L
Tritium	20,000 pCi/L
Strontium	8 pCi/L
Beta particle and photon radioactivity	4 millirem/year
Radioactivity (Total, for 2 or more radionuclides)	4 millirem/year

Radon (proposed for regulation in drinking water; action level for indoor air is 4 pCi/l)

Other Contaminants

	MCL
Total Coliform Bacteria (depends on system size; includes repeat requirements for fecal coliform bacteria)	No more than 1 sample or 5% sampling of monthly samples containing coliforms
Total Trihalomethanes, annual average of four quarterly samples (only for systems serving $\geq$ 10,000 people)	0.10 mg/l

Alternate Requirements

Lead and Copper Rule - for all public water systems, treatment requirements depend on system size.

Contaminant	Treatment Technique or Other Requirements
Lead	Below action level of 0.15 mg/l or treatment techniques and/or public education
Copper	Below action level of 1.3 mg/l or treatment techniques and/or public education
Acrylamide 0.05%	Based on 1 ppm (or equivalent)
Epichlorohydrin 0.01%	Based on 20 ppm (or equivalent)

Surface Water Treatment Rule - requires filtration for all surface water systems and groundwater systems under the direct influence of surface water.

Contaminant	Treatment Technique or Other Requirements
Giardia lamblia	Filtration/Disinfection
Legionella	Filtration/Disinfection
Turbidity	Filtration or other requirements
Viruses	Filtration/Disinfection

Unregulated Volatile Organic Chemicals (VOCs) - Monitoring Requirements

Chloroform
Bromodichloromethane
Chlorodibromomethane
1, 1-Dichloropropene
1, 1-Dichloroethane
1, 1, 2, 2-Tetrachloroethane
1, 3-Dichloropropane
Chloromethane
Bromomethane
n-Propylbenzene
tert-Butylbenzene
Bromochloromethane
Naphthalene
1, 3, 5-Trimethylbenzene
2, 2-Dichloropropane
1, 2, 3-Trichlorobenzene
Fluorotrichloromethane
1, 2, 3-Trichloropropane
1, 1, 1, 2-Tetrachloroethane
Chloroethane
m-Dichlorobenzene
o-Chlorotoluene
p-Chlorotoluene
Bromobenzene
1, 3-Dichloropropene
1, 2, 3-Trichlorobenzene
Isopropylbenzene
sec-Butylbenzene
Dichlorodifluoromethane
n-Butylbenzene
Hexachlorobutadiene
1, 2, 4-Trimethylbenzene
p-Isopropyltoluene

Unregulated Synthetic Organic Chemicals (SOCs) - Monitoring Requirements

Aldrin
Carbaryl
Dieldrin
Methomyl
Metribuzin
Butachlor
Dicamba
3-Hydroxycarbofuran
Metolachlor
Propachlor

1996 U.S. EPA NATIONAL SECONDARY DRINKING WATER STANDARDS

Secondary Drinking Water Standards are not MCLs, but unenforceable federal guidelines regarding taste, odor, color and certain other non-aesthetic effects of drinking water. EPA recommends them to the States as reasonable goals, but federal law does not require water systems to comply with them. States may, however, adopt their own enforceable regulations governing these contaminants. To be safe, check your State's drinking water rules.

Contaminants	Suggested Level
Aluminum	0.05 - 0.2 mg/l
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non-corrosive
Fluoride	2.0 mg/l
Foaming agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor number
pH	6.5 - 8.5
Silver	0.1 mg/l
Sulfate	250 mg/l
Total dissolved solids (TDS)	500 mg/l
Zinc	5 mg/l

WATER SOURCEBOOK REFERENCES AND GENERAL PUBLICATIONS

(for definitions, terms and other information)

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Mitch , William J. and James G. Gosselink, Wetlands, 2nd Edition, Van Nostrand Reinhold, New York, NY, 1993.

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American Water Resources Association web site: www.uwin.siu.edu/awra
American Water Works Association web site: www.awwa.org
Farm*A*Syst/Home*A*Syst web site: www.wisc.edu/farmasyst
Freshwater Foundation web site: www.freshwater.org
National Wildlife Federation web site: www.nwf.org
Sierra Club web site: www.sierraclub.org
U.S. EPA web site: www.epa.gov
U.S. EPA Office of Water web site: www.epa.gov/OW or e:mail at OW-GENERAL@epamail.epa.gov
Water Education Foundation web site: www.water-ed.org
Water Environment Federation web site: www.wef.org

Pollution Prevention Clearinghouse: 202-260-1023

Acid Rain Hotline: 617-674-7377

Radon Hotline: 800-767-RADON

Water Resources Center: 202-260-7786

EPA National Center for Environmental Publications and Information: 800-490-9198

National Technical Information Service: 800-553-6847 or 703-487-4650

U.S. Geological Survey: 800-USA-MAPS

U.S. Department of Agriculture, Soil Conservation Service: 800-THE-SOIL

National Lead Information Center: 800-LEAD-FYI

Government Printing Office, Superintendent of Documents, Washington, D.C. 20402, 202-512-1800.

American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD, 20814-2192. (Provides posters and booklets on water use at nominal cost).

Earthfax - USGS news releases, project and product information: 703-648-4888

American Water Works Association, 6666 West Quincy Avenue, Denver, CO, 80235-3098. (Operates Blue Thumb campaign to preserve water resources.)

America's Clean Water Foundation, 750 First Street, N.E., Suite 911, Washington, D.C., 20002-4241. (Develops and distributes educational materials.)

National Water Information Clearinghouse, U.S. Geological Survey, 423 National Center, Reston, VA, 22092-0001. (Supplies federal water data.)

Nebraska Groundwater Foundation, P.O. Box 22558, Lincoln, NE, 68542-2558. (Clearinghouse for general groundwater information and produces Children's Groundwater Festival.)

Water Education Foundation, 717 K Street, Suite 517, Sacramento, CA, 95814-3408. (Focuses on water use in western states; provides information to teachers and others.)

Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994. (Publications, slides, videos, available for rent or purchase.)

Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314, (703) 684-2400. (Produces The Water Quality Catalog: A Source Book of Public Information Materials.)

National Estuary Program Directors and Coordinators list

State Forestry Agencies list

MOTE Marine Laboratory list: 1600 Ken Thompson Parkway, Sarasota, FL 34236, (941) 388-4441.

Camp McDowell Environmental Center, Route 1, Box 330, Nauvoo, AL 35578

Articles, Books, Publications, Videos & Computer Courseware

Executive Summary of the National Water Quality Inventory: Report to Congress, (a.k.a. "the 305(b) Report"), published every 2 years, EPA.

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National Geographic, "Our Most Precious Resource: Water," August 1980.

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National Geographic, "Man and Manatee," September 1984, (endangered aquatic mammalian species).

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National Geographic Video, "Water: A Precious Resource," general audience, 23 min., 1980.

Water Poster Series, USGS, Box 25286, Denver Federal Center, Denver, CO 80225, 800-USA-MAPS

"Environmental Product Catalog: Books, Posters, Pamphlets, Resource Kits, and More", Terrene Institute, 4 Herbert Street, Alexandria, VA 22305. 703-548-5473 (phone) or 703-548-6299 (fax). (This institute offers various water-related information for teachers and students. Call and request a catalog.)

Water, Water Everywhere (an environmental science curriculum), Hack Company, P.O. Box 389, Loveland, CO, 80539-0389. 1-800-227-HACK; Literature No. 9274.

Radio Expeditions: Water - Thirsting for Tomorrow, National Geographic Society and National Public Radio, Soundelux Audio Publishing, Novato, CA, ISBN 1-55935-233-7. (Audiocassettes, CDS, and Teacher's Kit available). 800-555-2875.

DRINKING WATER RESOURCES

Safe Drinking Water Hotline: 800-426-4791

National Drinking Water Clearinghouse: 800-624-8301

Articles, Books, Publications, Videos & Computer Courseware

Drinking Water Fact Sheets (Series on Drinking Water Regulations) - available from the Safe Drinking Water Hotline.

EPA Bottled Water: Helpful Facts and Information, Office of Water, EPA 570/9-90-GGG, September 1990.

Liquid Assets: A Summertime Perspective on the Importance of Clean Water to the Nation's Economy, U.S. Environmental Protection Agency, Office of Water, 800-R-96-002, Washington, D.C., May 1996.

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SURFACE WATER RESOURCES

National Small Water Flows Clearinghouse: 800-624-8301

Adopt-A-Stream, P.O. Box 435, Pittsford, NY, 14534-0435. (Organizes volunteer programs to clean up and monitor water quality.)

American Rivers, 801 Pennsylvania Avenue, S.E., Suite 400G, Washington, D.C., 20003-2167. (Seeks to preserve and restore America's river systems.)

Freshwater Foundation, 725 County Road 6, Wayzata, MN 55391-9611. (Provides educational programs and freshwater research.)

Izaak Walton League of America, 1401 Wilson Boulevard, Level B, Arlington, VA 22209-2318. (Operates Save Our Streams program and provides publications.)

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Wetzel, Robert G. and Gene E. Likens, Limnological Analyses, W. B. Saunders, Company, Philadelphia, PA, 1979.

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National Geographic, "The Amazon," February 1995.

National Geographic, "The Imperiled Nile Delta," January 1997.

"Nonpoint Source NEWS-NOTES", c/o Terrene Institute, 4 Herbert Street, Alexandria, VA 22305, or www.epa.gov

GROUNDWATER RESOURCES

American Groundwater Trust: 800-423-7748

The Groundwater Foundation 402-434-2740 (phone) or 402-434-2742 (fax); P.O. Box 22558, Lincoln, Nebraska 68542; www.groundwater.org.

Groundwater Protection Council: www.site.org

National Groundwater Association: www.h2o-ngwa.org

EPA Office of Groundwater and Drinking Water: www.epa.gov/owow/ogwdw

Safe Drinking Water Hotline: 800-426-4791 (also has groundwater publications)

Articles, Books, Publications, Videos & Computer Courseware

EPA: Office of Groundwater and Drinking Water, EPA 800-F-93-005, September 1993.

National Geographic, "Ogallala Aquifer: Wellspring of the High Plains," March 1993.

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Case Studies in Wellhead Protection: Ten Examples of Innovative Wellhead Protection Programs, EPA: Office of Water, EPA 813-R-92-002, December 1992.

Wellhead Protection: A Guide for Small Communities, EPA: Office of Research and Development, Office of Water, EPA 625-R-93-002, February 1993.

"Protecting Our Groundwater", Office of Water, EPA 813-F-95-002, May 1995 (color pamphlet and mini-poster).

Groundwater Protection: Saving the Unseen Resource. The Final Report of the National Groundwater Policy Forum and A Guide to Groundwater Pollution: Problems, Causes, and Government Responses by the Conservation Foundation, The Conservation Foundation, Washington, D.C., 1987.

COASTAL RESOURCES

Coastal Encounters Nature Center: 912-638-0221 or e:mail coastalkids@www.technonet.com

See appendix pages S-1 thru S-6

Articles, Books, Publications, Videos & Computer Courseware

National Geographic, "Tide Pools: Windows Between the Land and Sea," February, 1986.

National Geographic, "The Coral Reefs of Florida are Imperiled," July 1990.

National Geographic, "Chesapeake Bay: Hanging in the Balance," June 1993.

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- The Beaches are Moving: The Drowning of America's Shoreline
- Living with the West Florida Shore
- Living with the Alabama-Mississippi Shore
- Living with the Louisiana Shore
- Living with the Texas Shore

WETLANDS RESOURCES

EPA Wetlands Hotline: 800-832-7828

See appendix pages T-1 thru T-6

Wetlands Posters are available through Wetlands Hotline or by contacting EPA Region 4, Wetlands Section, 100 Alabama Street, Atlanta, GA 30303-3104.

Articles, Books, Publications, Videos & Computer Courseware

"Stream of Conscience...Natural Solutions for Clean Water" (videotape), The Georgia Conservancy, 1776 Peachtree Street, NW, Suite 400 South, Atlanta, GA 30309.

"Wetlands, Georgia's Vanishing Treasure" (videotape), The Georgia Conservancy, 1776 Peachtree Street, NW, Suite 400 South, Atlanta, GA 30309.

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Why Develop A State Wetland Conservation Plan?, contact Wetlands Hotline

Private Landowner's Assistance Guide, contact Wetlands Hotline

"Teacher's Guide to the Study of Wetlands," contact Wetlands Hotline

Wetlands and Agriculture: Section 404 of the Clean Water Act, contact the Wetlands Hotline

U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, 601-634-4217.

Recognizing Wetlands, U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, 703-487-4650.

Animal Waste Treatment by Constructed Wetlands, Tennessee Valley Authority, Water Quality Department, Haney Building 2C, 1101 Market Street, Chattanooga, TN 37402-2801,
615-751-3164.

Mitch, William J. and James G. Gosselink, Wetlands, 2nd Edition, Van Nostrand Reinhold, New York, NY, 1993.