

WATER WORKS

SUBJECTS:

Science, Social Studies, Language Arts

TIME:

120 minutes

MATERIALS:

1 gallon (4 L) jug of water
2 1/2 cups (600 mL) soil or mud acetate sheet
four 2-liter plastic bottles
funnel
scissors
2 tablespoons (30 mL) of alum
2 tablespoons (30 mL) of bleach
2 cups (500 mL) fine sand
2 cups (500 mL) coarse sand
1 cup (250 mL) fine gravel
1 cup (250 mL) coarse gravel
1 cup (250 mL) activated charcoal
cotton for plug
tap water
a tablespoon
clock
student sheets (included)

OBJECTIVES

The student will do the following:

1. Demonstrate the process that water treatment plants use to purify water for drinking by conducting a water purification experiment.
2. Describe what happens in the water treatment process by writing a story.

BACKGROUND INFORMATION

Water treatment is the process of cleaning water and making it safe for people to drink. Because water is a good solvent it picks up all kinds of contaminants. In nature, water is not always clean and safe enough for people to drink. Our drinking water comes from both surface and groundwater. Water in lakes, rivers, and swamps contains impurities that may make it look and smell bad. Water that looks clean may contain harmful chemicals or bacteria and other organisms that can cause disease.

In the past, waterborne diseases were a major public health concern but today these diseases are no longer a health threat in the United States because of the improved water treatment. Technicians working in drinking water facility laboratories make thousands of tests each year to insure that our drinking water

supply is free of disease-causing bacteria. These test results are reported to the state and local governments. However new pollution problems caused by failure to enforce the laws and failure to update the laws to limit new chemicals are making water unsafe for wildlife and humans.

It takes the efforts of both federal and state governments as well as local water supply systems to keep our drinking water safe and in good supply. The Safe Drinking Water Act and its amendments set the standards for public drinking water. The Clean Water Acts sets standards for source water. The Environmental Protection Agency administers these standards.

Water treatment plants clean and maintain the quality of drinking water by taking it through the following processes: (1) aeration, (2) coagulation, (3) sedimentation, (4) filtration, and (5) disinfection (see definitions in "Terms" below).

Terms

aeration: to expose to circulating air; adds oxygen to the water and allows gases trapped in the water to escape; the first step in water treatment.

coagulation: the process by which dirt and other suspended solid particles are chemically "stuck together" so they can be removed from the water; the second step in water treatment.

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in the water; the fifth step in water treatment.

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; the fourth step in water treatment.

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.

sedimentation: the process that occurs when gravity pulls particles to the bottom of the tank; the third step in water treatment.

sludge: solid matter that settles to the bottom of septic tanks or wastewater treatment plant sedimentation tanks; must be disposed of by bacterial digestion or other methods or pumped out for land disposal or incineration.

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.

water treatment: a method of cleaning water for a specific purpose, such as drinking.

ADVANCE PREPARATION

A. Make a copy of the diagram of a water treatment plant and water treatment word search puzzle for each student. You may use the diagram of a water treatment plant as a transparency.

B. Gather materials for demonstration of water treatment process.

C. Prepare “dirty water”; add approximately 2 1/2 cups (600 mL) of soil or mud to 1 gallon (4 L) of water.

D. Cut one 2-liter bottle in half, cut the bottom from another bottle, and cut the top from a third bottle.

E. Alum can be found at the grocery store in the spices section. It is commonly used for making pickles.

F. NOTE: You may want to construct the filter before beginning the activity or may choose to let a team of students prepare it. To prepare the filter use the bottle with its bottom cut off to construct the filter. Turn the bottle upside down. Loosely put a cotton plug in the neck of the bottle. Pour the fine sand over the cotton plug followed by activated charcoal, coarse sand, fine gravel, and coarse gravel. Clean the filter by slowly and carefully pouring through 1-2 gallons (4-8 L) of clean tap water.

PROCEDURE

I. Setting the stage

A. Ask the students the following questions.

1. How many of you used water in some way today?
2. How did you use water? (shower, brush teeth, flush toilet, prepare meal)
3. Where does your water come from?
4. How can you be sure your water is safe to drink?

B. Discuss the water treatment plant and what it does.

1. Hand out the diagram of a water treatment plant.
2. Discuss the process that takes place during each step. Use the definitions given to explain each step:
 - a. Aeration – Vigorously stirring up water to add air to it and drive out other gases that might be dissolved in it; similar to “whipping” it with a mixer (as in cooking).
 - b. Coagulation – Adding chemicals to make dirt and other particles clump together.
 - c. Sedimentation – Letting the clumps settle out (they’re heavier than water, so they sink to the bottom).
 - d. Filtration – Pouring the water through a filtering system that has lots of layers of materials that trap things that did not settle out (including things too small to see).
 - e. Disinfection – Adding chlorine to kill germs that might make people sick (similar to swimming pool methods).
3. Write the letters A, C, S, F, and D on the board. Review with the students the words they stand for. Write simple-to-remember phrases for each one, such as:
 - a. A = Add air
 - b. C = Create clumps
 - c. S = Soil settles out
 - d. F = Fine filters to trap tiny things
 - e. D = Die, germs, die!

Leave these on the board while the class builds the model.

II. Activities

- A. Review the diagram of the water treatment plant. Discuss with the students, checking for understanding. Allow for questions and comments from the students.
- B. Divide the students into teams of four or five students. Each team will perform one step in the process. (Supervise closely.) Give Team I the materials and dirty water to start.
1. Team I should pour about 1.5 quarts (1.6 L) of “dirty water” into the uncut 2-liter bottle with the cap. (Use a funnel) Ask the students to describe the water.
 2. Have a student in Team I put the cap on the bottle and shake for 30 seconds. Continue the aeration process by pouring the water back and forth between two bottles 10 times. Ask the students what part of the water treatment process we have demonstrated. (aeration) Ask the students to describe any changes they observe.
 3. Team II should pour the aerated water into the 2-liter bottle with the top cut off. Add 2 tablespoons (30 mL) of alum to the water. Stir the mixture slowly for 5 minutes. Ask the students what process this group has demonstrated. (coagulation) Ask the students to predict what will happen.
 4. Team III should allow the water to stand undisturbed for 20 minutes. Ask the students to observe the water at 5 minute intervals and record their observations as to changes in the appearance of the water. (NOTE: Other groups may do the student sheet word search during this time frame or Team IV may construct the filter from the bottle with its bottom cut off. If you prefer to construct the filter model yourself, you may do it now if you’d like.) Ask the students what step this is? (sedimentation)
 5. Team IV should carefully, without disturbing the sediment, pour the top two-thirds of the water through the filter. Ask the students what step this is. (filtration) Have them quickly rest the filter model in the 2-liter bottle cut in half to collect the filtered water.
 6. After waiting until you have collected more than half of the water poured through the filter, add 2 tablespoons (30 mL) of bleach to the filtered water. The bleach represents the chlorination process. (CAUTION: Wear eye protection when handling bleach and quickly wash it off your skin if some should splash.) This is disinfection. Ask the students: “Did we recover the same amount of water we started with?” Measure approximately. Discuss that there is a certain loss of usable water in the water treatment process.
- C. Compare the treated and untreated water.
1. Ask the students whether treatment has changed the appearance and smell of the water. How has it changed?
 2. Explain to the students that this is a simulation of the process that a water treatment plant does; therefore, this water is not safe to drink.

III. Follow-Up

A visit to the local water treatment plant is a valuable experience. If this is not possible, ask a representative from the water utility to visit the class.

- A. As you tour the plant, use your A, C, S, F, and D memory devices to review the terms with the 2-13 students.
- B. Assign each student a responsibility to perform during the trip or visit. Develop assignments and questions in advance. You may use the student sheet, “Water Works.”
- C. Send the contact person at the water treatment plant a copy of the assigned questions before the visit so he/she will be prepared for the group.
- D. One student could also tape record the experience and another student could take photos for a visual record.

IV. Extensions

- A. Have the students write a story or draw cartoons about “Betty Bacterium,” “Sediment Sam,” or other fictional characters and describe what happens to these characters as they go through the water treatment process.
1. Share the stories/cartoons with the class.
 2. Use as a bulletin board activity to reproduce the water treatment process.

RESOURCES

“Science Demonstration Projects in Drinking Water: Grades K-12,” U.S. Environmental Protection Agency, Washington, DC, 1990.

“The Official Captain Hydro Water Conservation Workbook,” East Bay Municipal Utility District, Oakland, California, 1982.

“The Story of Drinking Water” (student booklet), American Water Works Association, Denver, Colorado, 1984.

“The Story of Drinking Water: Teachers Guide, Intermediate Level, Grades 4, 5, 6,” 2nd ed., American Water Works Association, Denver, Colorado, 1988.

Student Sheet - DRINKING WATER TREATMENT PLANT

Student Sheet - FILTER MODEL

Student Sheet - Answer the following questions

WATER WORKS (questions students can ask their local drinking water treatment plants)

Answer the following questions.

1. Where does our water come from?
2. How much clean water is produced every day?
3. How is the water tested?
4. What is used to destroy the bacteria in the water?
5. How are other pollutants like PPCPs kept out of the water?
6. What are the future plans for the water treatment system? As our community grows, will it be enlarged?
7. Who is in charge of or who owns the water utility?
8. How much water does the water source hold?
9. Do you use pumps or gravity to move the water?
10. How many people does this plant serve?
11. Is there anything unusual about this system?
12. How often is the system upgraded?
13. Who pays for the upgrades?

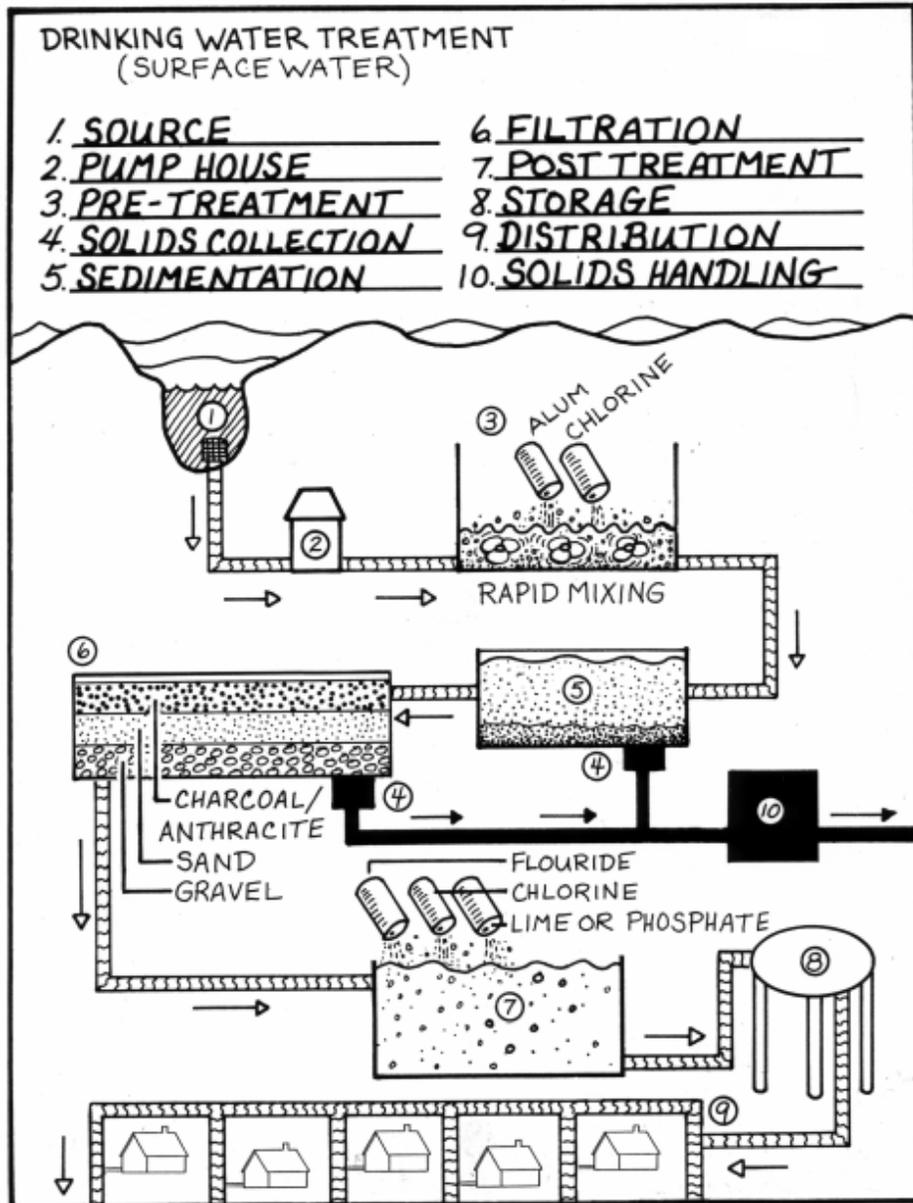
Student Sheet

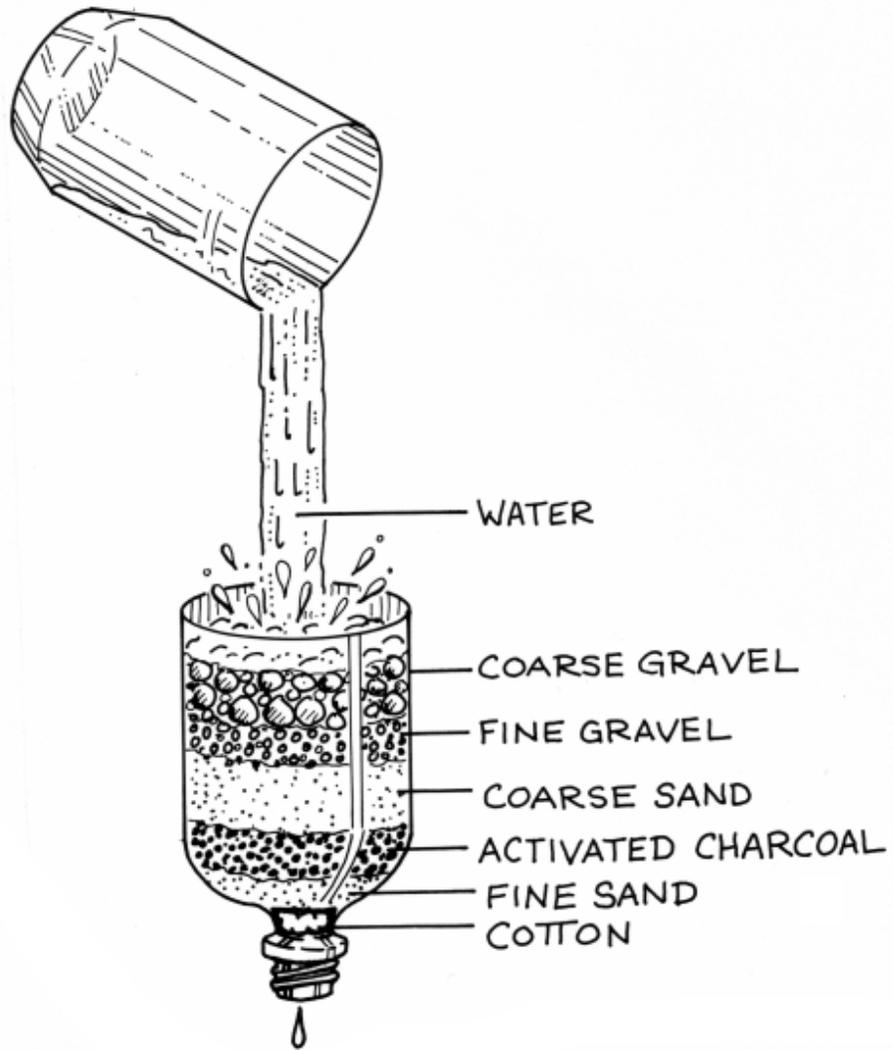
Answer the following questions.

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2. How much clean water is produced each day?
3. How is the water tested?
4. What is used to destroy bacteria in the water?
5. What are the future plans for the water treatment system?

DRINKING WATER TREATMENT PLANT

Student Sheet





WATER PATROL

SUBJECTS:

Science, Social Studies, Health, Language Arts

TIME:

45-90 minutes

MATERIALS:

hat or badge to represent police or fireman

poster board or construction paper

markers

stapler

student sheet (included)

www.epa.gov/learn-issues/learn-about-water

OBJECTIVES

The student will do the following:

1. Become aware that there are laws enacted and enforced to protect people's health and safety.
2. Become aware of the failure of these laws.
3. Demonstrate, through role play, different laws or acts that protect the health and safety of citizens.

BACKGROUND INFORMATION

Most of us take safe, clean drinking water for granted. Prior to the passage of the Safe Drinking Water Act in 1974, the protection of public water supplies in the United States was guided by drinking water standards developed by the United States Public Health Service. Congress enacted the Safe Drinking Water Act in 1974 to ensure safe public drinking water. This law was amended in 1986 to expand the Environmental Protection Agency's role in protecting public health from contaminated drinking water. The amendments require the Environmental Protection Agency to:

1. Control specific disease-causing organisms and indicators of their presence in drinking water.
2. Require public water supply systems that use surface water sources such as lakes to filter their water unless it is established that their sources are very clean and well protected.
3. Require public systems to disinfect their water, unless the water comes from sources that are not at risk from microbiological contamination.

The Safe Drinking Water Act is primarily enforced by the states. Therefore, it is the responsibility of the local water supply system, the states, and the federal government to provide clean, safe drinking water to the public.

However the Safe Drinking Water Act has not been updated and there are no provisions to protect drinking water from pollutants like those in pharmaceuticals and personal care products and thousands of other chemicals. The EPA has not set a new, enforceable drinking water standard since 2001, even though the Safe Drinking Water Act requires EPA to assess the need for standards for at least five new chemicals every five years. Three-fourths of the current standards were set in 1991 and 1992 and have not been updated since. Since 1996, EPA has reviewed data on toxicity and water pollution for 138 chemicals, but in every case it declined to set a safety standard.

Other [environmental laws](#) help to protect drinking water, including the [Clean Water Act](#). The Clean Water Act recommends states to designate surface waters used for drinking water and to establish water quality standards for those waters. The Act also establishes programs to prevent the release of pollution to these waters. Each state is responsible for creating the legislation and infrastructure to fulfill the EPA's federal Clean Water Act but many have never created state-level regulations to enforce the law. Budgets to enforce the laws that do exist have been cut and some in government have continued to try to weaken existing laws.

The chemical pollutants come from various sources, including: factory farm waste, pesticides, fertilizer and sediment; sewage and urban runoff; industrial chemicals; water treatment and distribution byproducts; and natural processes that produce more contamination as a result of development and deforestation.

By failing to clean up rivers and reservoirs that provide drinking water for hundreds of millions of Americans, EPA and the Congress force water utilities to spend heavily to make contaminated water drinkable. According to industry market studies, drinking water utilities spend more than \$4 billion a year on water treatment chemicals alone. Less than one-twentieth that amount is invested in source water protection and pollution prevention, an average of \$207 million per year (data for 1997-2008). This includes funds allocated for the management of non-point water pollution sources under the Clean Water State Revolving Fund and for source water protection under the Drinking Water State Revolving Fund (EPA 2009l; EPA 2009m; EPA 2009n).

The result of lack of government policies, oversight and funding to protect water resources is playing out in cities and others all over the country. Furthermore nationally, there's been a lack of investment in water infrastructure. The country's water infrastructure—the million miles of pipes, treatment facilities, and pumping stations that comprise municipal water systems—is old, dating in some cases back to the mid to late-19th century. This lack of investment in the nation's infrastructure and the high cost of repairing or rebuilding is challenging communities that are struggling economically in other ways.

Millions of Americans buy bottled water in the mistaken belief that it's safer than tap water, but this is not the answer. Many popular brands are nothing more than bottled tap water, tainted with the same pollutants, and the enormous growth of the bottled water market has bloated the nation's solid waste stream with vast amounts of plastic.

The list of water disasters is long and getting longer.

On the same day that the chemical leak that poisoned the water supply of 300,000 people was discovered in Charleston West Virginia in 2014, U.S. House of Representatives lawmakers voted to limit the EPA's ability to regulate companies that dispose of toxic waste.

Ohio lawmakers have been slow in enforcing the Clean Water Act in Lake Erie so that nutrients that are causing harmful algal blooms are controlled. In Aug 2014 Toledo's water supply was unfit for nearly half a million people because water coming out of the taps was not safe for drinking or even for bathing.

In Flint, Michigan, researchers uncovered evidence that a switch in the city's drinking water source is likely behind a spike in lead levels in the city's children. The finding prompted a federal investigation of Michigan's safe drinking water program. And in Wisconsin, a group of citizens asked the U.S. Environmental Protection Agency to intervene after years of what they see as a systematic failure and dismantling of state water protection programs.

The best case scenario is that this attention will result in legislative changes both at the state and federal level because one of the key lessons learned from these Water Crises is that federal laws like the Clean Water Act and the Safe Drinking Water Act were not being enforced at the state level.

Terms

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.

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

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.

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters.

waterborne disease: a disease spread by contaminated water.

ADVANCE PREPARATION

A. Gather materials for the role playing. You may make hats or badges from poster board and/or construction paper to represent different people who enforce rules or laws (policemen, fireman, principal, mayor, governor, etc.).

B. You may also use toy badges or hats that represent these persons if they are available.

C. Make photocopies of the student sheet, "Cause and Effect," for each student.

PROCEDURE

I. Setting the stage

A. Ask the students the following questions:

1. What are laws? (any rule or principle that must be obeyed; relate to school rules that must be followed in the school environment)

2. Why do we have laws or rules that we must obey? (to protect people)

3. Give an example of a law or rule being broken. (e.g., exceeding the speed limit) Is this dangerous? (yes) Why? (It affects the safety of the driver and others.)

4. Who enforces the law?

a. On the local level, the mayor and those persons acting under his orders.

b. On the state level, the governor and those agencies that are under his jurisdiction.

c. On the federal level, the president and those agencies that are established for specific laws.

B. Share with the students the following information:

We only have to look around us to see the effects of rules or laws. We can see rules or laws being observed in our schools, in our community, and throughout our environment.

1. What do you think would happen if we had no rules in our school? (We would not be able to do our work, and/or it would not be safe.)

2. What do you think would happen if we had no rules or laws in our community? (People might not respect others' rights and our environment would not be a very safe or happy place to live; accept any answer.)

II. Activities

A. Have the students demonstrate laws being broken by role-playing "cops and robbers."

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1. Have the students prepare a list of rules or laws that would protect their health or safety.

2. Have each student act out or role play (using props such as hats) one of the law breaking situations they have listed.

3. Ask the classmates to try to guess what rule or law is being portrayed. The first student to guess the rule or law being acted out, will role play the person who enforces that law and "arrest or reprimand" that person who has broken a law or rule.

4. Continue this process until all students have participated. (You may want to set a time limit for each student.)

B. Discuss with the students what laws or rules are being represented in each situation. Tell the students that they have a responsibility as a citizen to help to see that laws and rules are followed. Ask what they might do as citizens to help enforce the laws. (report wrongdoing they observe to the proper person who enforces the laws or rules)

C. Share the background information with the students. Emphasize that drinking water must be very clean or people could get sick. Ask the students to apply what they have learned about protecting water supplies and enforcing laws to ensure their water is safe to drink. Ask them these questions:

1. What can you do? (never pollute water in streams; report to proper authorities if you observe anyone dumping pollutants into drains, streams, and other bodies of water; accept any reasonable answer)

2. What law protects your drinking water? (the Safe Drinking Water Act) (Clean Water Act protects source water.)

3. Who enforces these Acts? (the Environmental Protection Agency and the states)

4. What should you do if you suspect your water supply is contaminated? (You can contact your local water treatment plant or water utility to find out what steps you should take to have your water tested for contaminants. The address of your local facility will be on your bill.)

5. For detailed information, contact your local water treatment facility or health department. Ask them how they comply with the Safe Drinking Water Act and the Clean Water Act.

III. Follow-Up

A. Have the students complete the student sheet, "Cause and Effect." (Answers: 1-c; 2-a; 3-f; 4-b; 5-c; 6-d.)

B. Have the students write a paragraph explaining why we have laws and why those laws should be enforced.

IV. Extensions

A. Have the students choose one of the following topics, look up its danger to drinking water, and write a report on how each could contaminate drinking water. Younger students might depict these on "mini-murals" (large construction paper sheets).

1. Landfills

2. Underground storage tanks

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3. Hazardous waste

4. Pharmaceuticals and personal care products (PPCPs)

5. Harmful algal blooms (HABs) caused by too many nutrients in the water. (Toledo, Ohio 2014)

B. Find articles about water quality problems. Use websites to learn more about water problems in Flint, Toledo and Charleston. Think about how your life would be different if you did not have access to clean water.

B. Contact your senator, congressman, or local state representative and ask what bills have been offered in the legislature to protect drinking water standards and groundwater in your state.

RESOURCES

Jorgensen, E. P., ed., *The Poisoned Well: New Strategies for Groundwater Protection*, Island Press, Washington, DC, 1989.

"Protecting Our Drinking Water from Microbes," U.S. Environmental Protection Agency, Washington, DC, 1989.

Student Sheet CAUSE AND EFFECT

Match the causes and effects.

Causes

1. Pour oil in drainage ditch
2. High concentration of lead in drinking water
3. Contaminated surface and groundwater
4. Safe Drinking Water Act
5. Adding fluoride to drinking water
6. Environmental Protection Agency

Effects

- a. Serious damage to brain, kidneys, and nervous system
- b. Ensures clean drinking water to protect public health
- c. Stronger, healthier teeth
- d. Sets national standards and monitors water supply operators
- e. Groundwater contamination
- f. Waterborne diseases

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