WATER TREATMENT

Overview

This activity introduces water treatment methods of coagulation, flocculation, sedimentation, filtration, and disinfection, helping students discover that the methods used are dependent upon the water source. Students remove sediments in turbid (cloudy) water, experimenting with alum (aluminum sulfate) as a coagulating variable. They construct a filtration device, removing particles suspended in water samples. Then they learn about water testing for coliform bacteria.

Subjects: Science, Comprehensive Health

Group Size: teams of two to four

Estimated Teaching Time: two hours

Curriculum Framework: IC, IIIA1, IIIA2, IIIA3, IIIA5, IIIA6, IIIB1, IIIB2, IIIB3, IVA, IVB, IVC, IVD, IVE, VA, VB

Environmental Education Framework: Goals IA, IIA, IIIA, IVA, IVB, VA

Vocabulary: alum, CAP water, coagulation, coliform bacteria, disinfection, E. coli, filtration, floc, flocculation, groundwater, imported water, microorganisms, pH, percolation, precipitation, recharge, reservoirs, runoff, SDWA (Safe Drinking Water Act), sedimentation, surface water, suspension, turbidity, water cycle

Objectives

Students will:

- treat sediments in water, experimenting with alum.
- build a filtration system to remove some suspended materials from water, inferring materials similar to soil and rock through which groundwater flows are good filters.
- decide the drinking water safety of a stream where E. coli is present.
- describe treatment methods used to produce safe drinking water.

Background

What is water quality? Water safe for fish may not be safe for drinking. Water suitable for industrial cooling may be toxic to fish or unfit for irrigation. The criteria for judging the quality of water must be based on the intended use of the water. All states and the federal government have established water quality criteria for different classifications of water use.

Many factors affect water quality. **Physical factors** include temperature, color, the limits of light penetration (turbidity), and the amounts of suspended particles. **Chemical factors** include pH, hardness, and the amounts of dissolved oxygen, carbon dioxide, phosphates, and nitrates. **Biological factors** refer to the kinds and numbers of living organisms present. These factors interact. For example, temperature determines the amount of oxygen water can hold. Temperature and oxygen can limit the presence of organisms.

Organisms influence the amount of oxygen and carbon dioxide present in water. Thus, an investigation of water quality is often a search for relationships among physical, chemical, and biological factors.

Changing raw water to safe drinking water is a science. Water in its pure state - two atoms of hydrogen and one of oxygen - is basically nonexistent in nature. Physical, chemical, and biological impurities all contaminate "pure" water. As precipitation falls toward earth, it gathers substances from the atmosphere including dust, smoke, and atmospheric gases like carbon dioxide. When water lands on earth, it is mildly acidic. As it flows over the earth's surface and through the ground, water dissolves minerals such as sodium, calcium, and magnesium. Other substances, from both natural and human sources, also find their way into water. Plants and animals add "impurities" to water through natural processes. Humans add "impurities" through a variety of sources including car emissions, fertilizers, pesticides, leakage from materials deposited in landfills, and industrial processes.

These "impurities" are found in water in two basic ways - suspended or dissolved. Impurities in suspension may include any number of organic materials (such as plant fibers, bacteria and other microorganisms), and inorganic substances (such as silt and asbestos). Impurities in solution are usually inorganic, such as minerals, but may also include natural and synthetic organic molecules.

This activity focuses on suspended impurities that may impact water quality. The WATER IN OUR DESERT COMMUNITY activities in **Properties of Water: The Universal Solvent** focus on dissolved impurities and present a water quality test for hardness.

In **Water Treatment**, students will be introduced to methods of treating water based on water source, and will discover ways water agencies assure a high quality supply of drinking water. Students will experiment with basic water treatment processes used by Phoenix-area municipal water treatment plants. First, alum is used to settle suspended particles in a sample of water. (Students have probably seen alum that has settled from ice cubes made from tap water.) In the second step, students construct a simple water filtration device to remove physical contaminants from a sample of water. Several filtrations, using different samples of liquids, can be performed to show the limits of the filtering device. **It is important students understand that neither of these treatments provides safe drinking water.**

Turbidity refers to the amount of solid material suspended in water. Turbid water contains suspended particles, making water cloudy, interfering with the ability of light to pass through the water, and inhibiting the action of chlorine and other disinfectants. The suspended particles associated with turbidity are due to natural silt, clay, soil, decaying vegetation, microorganisms, and industrial waste discharge. In **Water Treatment**, students will experiment with methods of removing suspended particles from surface water: filtration and chemical addition - coagulation - flocculation - sedimentation. These methods remove most physical and large biological particles.

Microorganisms often pass through filters and must be treated by disinfection. Both surface water and groundwater contain many kinds of microorganisms, most of which are harmless. These microorganisms are part of important aquatic food chains.

Some parasites, bacteria, viruses, and other undesirable living microorganisms, however, can cause sickness and even death. Water-borne illnesses include typhoid fever, cholera, and a group of diseases called dysentery. The microbes that cause these diseases enter water supplies with human sewage. Of course, the microbes are excreted only by persons who are infected with the disease.

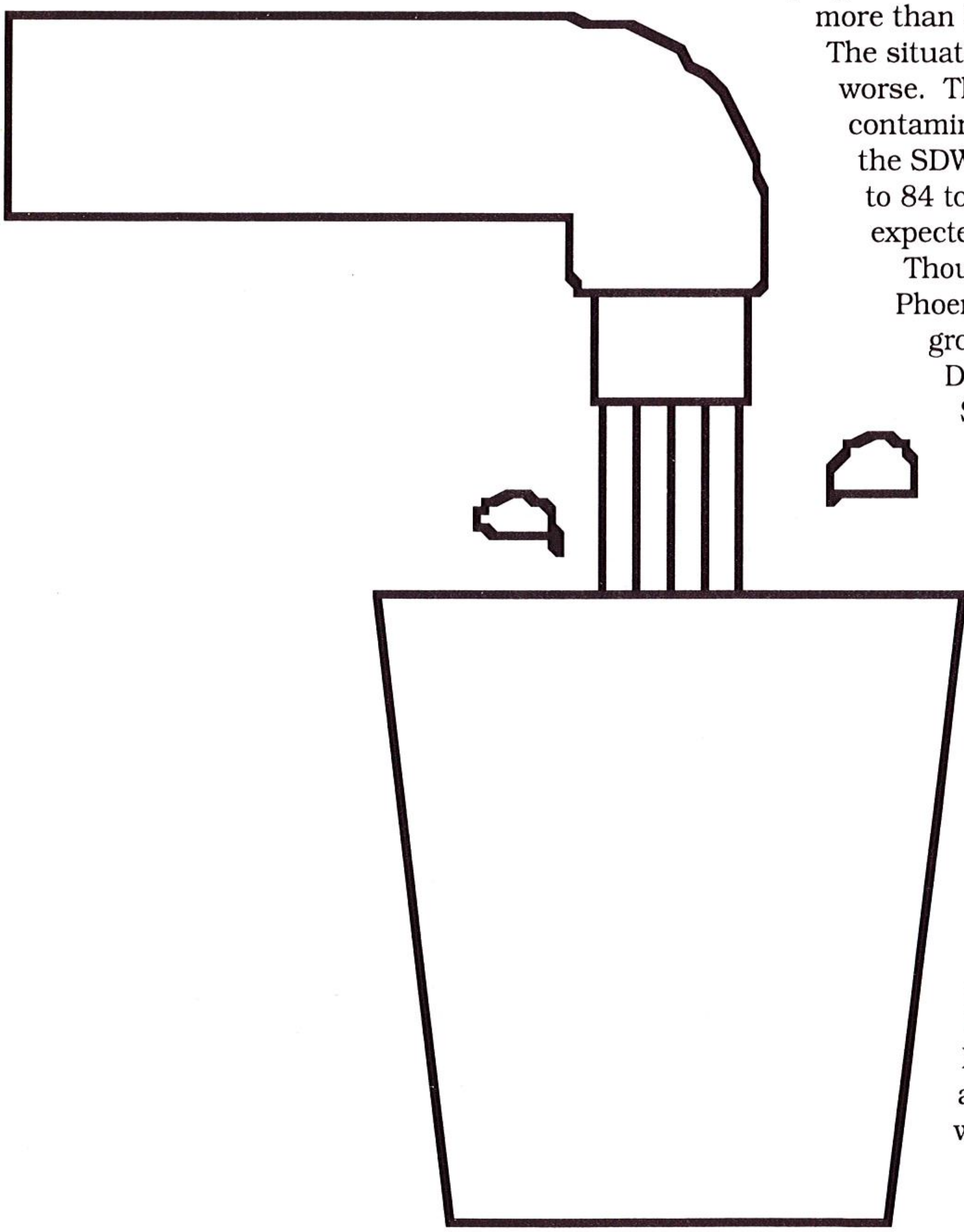
Monitoring for microbiological contamination is essential for assuring safe drinking water. Because the numbers and types of disease-causing organisms are so large and varied, testing for all of them is too costly. The intestinal tracts of humans and other warm-blooded animals, however, contain an abundance of harmless bacteria that are easy to detect. Because a single group of bacteria, called the "coliform" group, live longer in water than the bacteria that cause disease, and because billions of coliform bacteria are excreted by an average person daily, they serve as indicators of sewage pollution. The presence of coliforms is a warning signal. Coliforms indicate that water may also contain dangerous germs excreted by infected persons. Fecal coliforms are tested when total coliform samples are positive, further defining the nature of contamination. If coliform bacteria are not present in the water supply, we can be reasonably sure that no disease-causing bacteria are present either.

All public water systems are required by Arizona Law to submit many samples each month. The number is based on the population served by the water system. The samples are to be taken at regular intervals from representative points within the distribution system. For example, systems serving a population of 50,000 are required to submit 50 samples for testing each month; if 200,000 are served, the water provider must submit 120 samples; if 1,000,000, then 300 samples are tested.

WATER QUALITY STANDARDS are established by federal and state regulations. The Arizona Department of Environmental Quality (ADEQ) is responsible for establishing and enforcing standards set by the federal Safe Drinking Water Act (SDWA). The Drinking Water Standards apply to all public and semi-public water systems, that is, those with more than fifteen connections or serving more than twenty-five people.

The Drinking Water Standards reflect the best scientific and technical thinking currently available. Ongoing research constantly revises these standards. Maximum contaminant levels (MCLs) are established for metals and minerals, pesticides and herbicides, radioactive chemicals, volatile organic chemicals (VOCs such as TCE, DCE, Benzene and Carbon tetrachloride), bacteria, cloudiness (turbidity), disinfection by-products, and treatment chemicals. Levels for the taste, color and odor qualities of water, known as Secondary Maximum Contaminant Levels (SMCLs), serve as guidelines only.

Every day, water suppliers conduct tests for the presence of hundreds of potential pollutants: physical, chemical and biological. A large water company may conduct more than 100,000 tests annually to assure high water quality and satisfy regulations (MWD, p. 6). Many of these tests involve the use of equipment found only in highly specialized laboratories. Complying with the requirements of the Safe Drinking Water Act is being jeopardized by resource constraints, however, according to a report by the US General Accounting Office. The lack of resources has made it harder for states to carry out the monitoring and enforcement requirements of the SDWA. The gap between the existing resources of the states and their drinking water program needs is expected to be more than $200 million by 1998. The situation is expected to get worse. The number of contaminants regulated under the SDWA grew from 23 in 1986 to 84 today in 1993, and is expected to be 111 in 1995.



Though it is common in the Phoenix area to pump groundwater that meets Drinking Water Standards, groundwater can become contaminated by materials present in the soil through which it flows. These contaminants may be dissolved in the groundwater or flow freely with the groundwater. In either case, the contaminants must be removed before the water meets Drinking Water Standards and is considered safe for human consumption. It is essential that we do all we can to protect our water sources.

Materials and Preparation

CHEMICAL ADDITION, COAGULATION, FLOCCULATION, SEDIMENTATION EXPERIMENT

For each team of two to four students:

- WATER TREATMENT - THE FIRST PAGE, handout
- two 1-liter clear plastic bottles
- access to measuring spoons and tap water
- two teaspoons of natural clay or silt
- $^3/_4$ teaspoon of alum (aluminum sulfate - from drug or hardware stores)
- white index card or paper

FILTRATION EXPERIMENT

Please caution that students' filters will not make their water samples safe for drinking.

For each team of two to four students:

- WATER TREATMENT - THE SECOND PAGE, handout
- one 2-liter plastic bottle
- access to scissors and tap water
- A variety of materials for building filters, including but not limited to:

charcoal	rubber bands	kitty litter	sand
cheese cloth	diatomaceous earth	gravel	cotton
screen	panty hose	wool fiber	coffee filters
marbles		felt and other fabric	

- "Water" samples to be treated. At least one gallon of liquid will be needed for 8 teams filtering a cup of untreated water through two designs (16 cups in a gallon). Challenge students with one or all of these samples:
  - Really dirty water, made by adding three tablespoons of topsoil to one quart of tap water and shaking.
  - Alum-treated water sample. This follows the treatment sequence used at water treatment facilities.
  - Kool-Aid, no need to add sugar!
  - Other liquids the students may wish to test in their filters, such as coffee, milk, cola, flavored-waters.
- one cup containers for liquid samples

BACTERIA IN WATER DISCUSSION

- WATER TREATMENT - THE THIRD PAGE, handout

Procedure

OPTIONAL HOMEWORK: Assign each team the task of bringing two clear 1-liter containers, one 2-liter container, and filtering materials for the experiments.

1. Distribute WATER TREATMENT - THE FIRST PAGE and THE SECOND PAGE to each team of two to four students, explaining that students will learn about different ways groundwater and surface water are treated to be safe for drinking. In two experiments students will treat water to remove physical impurities.

2. Have students read about intake and chemical addition, coagulation, flocculation, sedimentation. Mention that in Phoenix, groundwater is not usually treated with these methods.

3. **CHEMICAL ADDITION, COAGULATION, FLOCCULATION, SEDIMENTATION EXPERIMENT**. Clumping and settling of physical impurities are common steps in surface water treatment. Allow students to work as independently as possible. While waiting for sedimentation, encourage students to start the second experiment (on THE SECOND PAGE). Remind students when 15 minutes has passed.

4. Discuss conclusions. Students should discover that the sample with alum was less turbid or clearer than the untreated water sample. Alum bonds with the silt and clay particles suspended in the water, causing them to settle.

5. **FILTRATION EXPERIMENT**. This problem solving exercise can be as open-ended as you want. The filtration materials and even the samples treated in the filters can be decided by the students. Reinforce the **CAUTION: No device you design will make the sample you treat safe to drink. It could still contain harmful bacteria and other microorganisms, and potentially toxic substances.** The federal government has set standards in the Safe Drinking Water Act that require water providers to test for 84 contaminants (and likely 111 contaminants by 1995)!

6. Allow students to work as independently as possible, treating the liquid samples available.

7. Distribute THE THIRD PAGE before students redesign their filters, pointing out the recommendation from other students on the top of THE THIRD PAGE. Remind them that groundwater rarely is filtered because the soils and rocks through which it travels underground filter many physical contaminants.

8. Discuss conclusions. Which filter designs seemed to work best to remove dirt suspended in the liquid

samples? Were all colors and odors removed? Did the filters remove all the contaminants from the samples treated? It is likely many physical contaminants were removed in well-designed filters, but chemical contaminants may still be in solution and biological contaminants may still be in suspension.

9. Both groundwater and surface water are disinfected to treat biological contaminants. Have each team read and discuss **DISINFECTION** on WATER TREATMENT - THE THIRD PAGE.

10. Ask for team responses to the three questions. The presence of coliforms does not necessarily mean water contains disease-causing microorganisms, so sickness from drinking the stream water is not guaranteed. The decision to drink from the stream is a very personal one; there is no right answer. Good advice, however, is to never drink from any stream with which an animal may have had contact.

11. Ask if students can rely on their sight alone to identify a sample of water meeting the federal government's Safe Drinking Water Act (SDWA) standards. Then have students summarize the water treatment methods that are commonly used in the Phoenix area for both groundwater and surface water.

Extensions

1. Visit your community's water treatment plant. Investigate methods by which water is tested and treated for chemical, biological and physical impurities to reach drinking water quality. Discover the test findings that require groundwater to be filtered. Learn more about water quality standards depending on different water uses. Analyze waste water treatment methods.

2. Invite a speaker from your water department or Maricopa County's Household Hazardous Waste Program to teach more about protecting groundwater. Have students scan the newspapers for evidence of groundwater contamination. Challenge students to identify the source of contamination, the possible effect of drinking the water, and the treatment methods and costs for cleanup.

3. Research water treatment methods used in industry, public water systems and at home, including: activated alumina, activated carbon, distillation, ion exchange, mineral bed, reverse osmosis, sediment filtration, and ultraviolet illumination. (**Home Water Treatment and Bottled Water: Facts for Consumers** by SAWARA is a good source.)

4. Investigate disinfection tablets, purification pumps, and other devices used by backpackers to treat water.

Evaluation

1. Describe at least four common methods of treating surface water so that it is safe for drinking.

2. How is Phoenix-area groundwater treated?

3. While hiking, you cross a flowing stream. The water looks clear. Give at least three reasons why you should be cautious about drinking the water.

Resources

Alberhasky, J.E., Utility Support Services Assistant, City of Glendale. 1994. Personal correspondence and telephone conversations.

America's Clean Water Foundation (ACWF). 1992. **Water: the Source of Life**. Washington, D.C.: ACWF.

Cole, J. 1986. **The Magic School Bus at the Waterworks**. NY: Scholastic.

Craun, G.F. 1990. "Drinking Water Disinfection: Assessing Health Risks" in **Health & Environment Digest**, a publication of the Freshwater Foundation. Vol. 4, No. 3.

Dale, J., P. Coresentino, R. Brickell. 1992. **The Story of Drinking Water: Teacher's Guide**. Denver: American Water Works Association.

Houk, V.N. 1989. "Carcinogens in Drinking Water and Water Quality Standards" in **Water Review**, a publication of the Water Quality Research Council, Vol. 7, No. 2.

Metropolitan Water District of Southern California (MWD). **Water Quality**. Los Angeles: MWD.

Nevada Science Project, High School Edition. 1991. **Water Unit**.

Peterson, N.J., Chief, Office of Risk Assessment and Investigation, Division of Disease Prevention, Arizona Department of Health Services. 1993. Personal correspondence and telephone conversations.

Salt River Project. **Water . . . in the Valley today**. Phoenix: SRP.

Southern Arizona Water Resources Association. 1989. **Home Water Treatment and Bottled Water: Facts for Consumers**. Tucson: SAWARA.

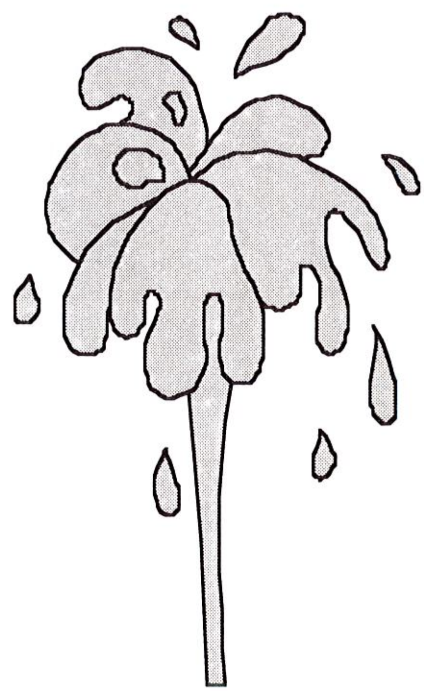
Stewart, J.C. 1990. **Drinking Water Hazards: How to Know if There Are Toxic Chemicals in Your Water and What to Do if There Are**. Hiram, OH: Envirographics.

Symons, J.M. 1992. **Plain Talk About Drinking Water: Answers to 101 Important Questions About the Water You Drink**. Denver: American Water Works Association.

U.S. General Accounting Office. 1993. **Drinking Water Program: States Face Increased Difficulties in Meeting Basic Requirements**. Gaithersburg, MD: GAO/RCED-93-144.

Water Education Foundation. 1991. **Layperson's Guide to Drinking Water**. Sacramento: Water Education Foundation.

Water Environment Federation. **Clean Water for Today: What is Wastewater Treatment?** Alexandria, VA: Water Environment Federation, formerly Water Pollution Control Federation.

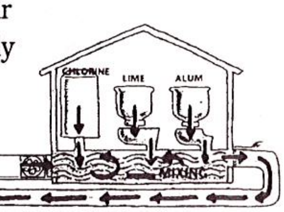


WATER TREATMENT - STUDENT PAGE
THE FIRST PAGE

adapted from ***THE STORY OF DRINKING WATER***

Water is treated to make it safe for people to drink. There are many methods used to treat water. Treatment methods depend on the source and quality of water. Water goes through a treatment plant where it is also sampled and tested after each treatment method. Drinking water must meet standards set by the local, state, and federal governments. The following methods are used to get clean water to your home and school.

INTAKE. First water is taken from the source that could be **groundwater** or **surface water** (either local runoff or CAP water). Screens remove large pieces of debris such as fish, logs and other plants from **surface water** that may be stored in a reservoir before processing. If the source is **groundwater**, the screening has already been done by soil as the water travels under the earth's surface.



WATER ENTERS THE TREATMENT PLANT. **Surface water** may go through chemical addition, coagulation, flocculation, and sedimentation. In the Phoenix area, **groundwater** is rarely treated with these processes.

GROUND WATER

CHEMICAL ADDITION, COAGULATION, FLOCCULATION, AND SEDIMENTATION. Because the water is turbid or cloudy, alum (aluminum sulfate) and synthetic polymers are added to increase the stickiness of dirt and other particles. The particles coagulate when they collide during mixing, and clump together. The heavy particles, called floc, fall to the bottom as sediments. Lime or caustic soda may be added to adjust the pH of the water to ranges between 7 and 8.

Experiment with alum to see how it affects sediments suspended in a water sample.

1. **Hypothesis.** How will the turbidity (clarity) of a water sample with alum compare with that of an untreated water sample?

2. **Apply Experimental Treatment**
   - Fill two 1-liter bottles with about 750 ml of tap water.
   - To both bottles, add one teaspoon of natural clay or silt.
   - Replace the lids and shake both bottles vigorously to suspend the soil particles.
   - To one bottle only, add 3/4 teaspoon of alum. Label that bottle.
   - Wait fifteen minutes. (Note: while waiting for sedimentation to occur, learn about other treatment methods.)

SURFACE WATER

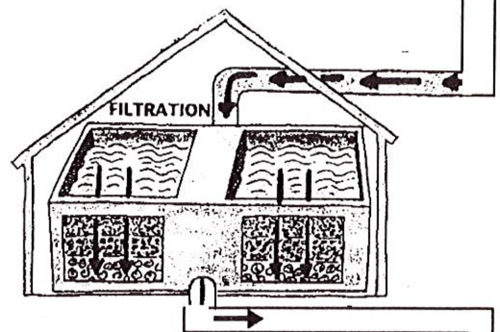
3. **Gather and record data.** While scientists use expensive instruments called turbidimeters to measure **turbidity** or the ability of light to pass through water, you can gather data about turbidity using a visual comparison. Place a white card behind both bottles, comparing the clarity of the water. Record your observations.

Bottle With Alum	**Bottle Without Alum**

4. **Draw conclusions.** Which water is more turbid (cloudier), the one with the alum or the one without alum? Which is less turbid (clearer)? Use your own words to describe how alum affected the suspended particles.

THE SECOND PAGE

SURFACE WATER FILTRATION. Surface water flows through layers of sand and gravel to remove remaining suspended particles from the water.



Experiment with water filtration. Build a water purification filter using layers of common materials. **CAUTION: No device you design will make the sample you treat safe to drink. It could still contain harmful bacteria and other microorganisms, and potentially toxic substances.**

1. **Hypothesis.** Which materials in which order will work best and why? Sketch and label the layers.

2. **Apply Experimental Treatment**
   - Cut the bottom from a 2-liter bottle just above the black base. Use the top as the structure for your filtering system and place the base under the mouth of the bottle to catch the filtered water.
   - Layer the materials according to your hypothesis.
   - Pour water sample with particles in suspension through your filter.

3. **Gather and record data.** Compare the filtered water with the original sample of dirty water. Record your observations. You may filter it more than once if you wish.

4. **Revise hypothesis.** After you have obtained more information about systems being used to purify water, redesign and retest your filtration system.
   New hypothesis, new observations:

5. **Draw conclusions.** Which materials in which order work best as a water filter, and why?

GROUND WATER

SURFACE WATER

THE THIRD PAGE

RECOMMENDATIONS FOR THE DESIGN OF A PRETTY GOOD FILTER

- Place folded cheese cloth over the mouth of the bottle, securing it with a rubber band.
- Place the following in the inverted bottle in this order, taking care to not mix the various layers:
  - 3 inches of charcoal
  - 3 inches of sand
  - 2 inches of gravel
- Rinse the filtration device with clean tap water until the filtered water runs clear.
- Then pour the water sample to be treated into the top of the device.

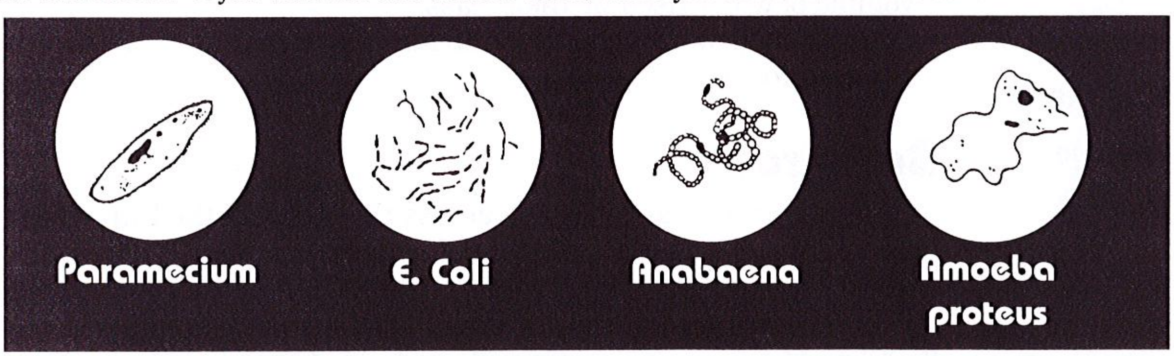
DISINFECTION. Water can look perfectly clear, be free of bad tastes and smells, and yet be unsafe for drinking because of bacteria. Both groundwater and surface water are disinfected. A small amount of chlorine or other disinfecting chemical is added to kill bacteria, parasites, viruses, and other potentially harmful microorganisms. Untreated water also contains harmless microorganisms such as the blue-green algae, **Anabaena**; the protozoan, **Paramecium**; and **Amoeba proteus**.

Several serious diseases can be traced to polluted drinking water, including typhoid fever, cholera, and a group of diseases called dysentery. The microbes that cause these diseases enter water supplies with human sewage. Of course, the microbes only come from people who are infected with the disease.

Scientists test water for coliform bacteria because many harmful microorganisms are difficult and expensive to identify. Although generally harmless, billions of coliform bacteria are found in the intestines of healthy people and other animals. **E. coli** is the most abundant of many coliform bacteria associated with human and animal wastes. Because coliform bacteria live longer in water than disease-causing bacteria, and because they are excreted in such large numbers, they are used as indicators of sewage pollution. The presence of coliforms indicates that the water may also contain dangerous germs excreted by infected people and animals. If no coliform bacteria are present, it is likely no disease-causing bacteria are present.

Discuss bacteria in water. Imagine your team uses a microscope to discover these four microorganisms in stream water.

Would you definitely get sick if you drank this water? If you were hiking and thirsty, would you drink from this stream? If you were lost and without water, would you drink from this stream?



STORAGE AND DISTRIBUTION. When the water meets Safe Drinking Water Act (SDWA) standards as set by the federal government, it is stored to be delivered as needed for drinking at your home or school.