9-12

HOW HARD IS HARD WATER?

OBJECTIVES

The student will do the following:

1. Perform chemical analyses for hardness on water samples.
2. Collect data and prepare Data Sheets.
3. Analyze data using various graphing techniques.
4. Determine the importance of water hardness in natural habitats and for human use.

SUBJECTS:
Science (Chemistry, Physical, Biology, Ecology), Math

TIME:
1-2 class periods

MATERIALS:
bottled drinking water
distilled water
milk
soft drink
Epsom salts
fabric softener
deionized salt
lotion
water analysis kit

BACKGROUND INFORMATION

Hard water is the result of the presence of primarily two elements in their ionic form in water. The two elements mainly responsible for hardness are calcium (Ca^{+2}) and magnesium (Mg^{+2}). Iron, aluminum, manganese, and other minerals may also cause hardness, but large amounts of these minerals are not usually found in natural waters. Water hardness is often correlated with the "lathering" capacity of soap in certain water sources by the general public--the harder the water, the less the lather!

The geological makeup of an area usually determines the natural source of hardness. Limestone rock that has been dissolved by slightly acidic water (carbonic acid) is the usual source. Granite isn't easily dissolved by carbonic acid; therefore, areas rich in limestone usually have very hard water whereas those that are mostly granite do not.

Acidic water is formed when water absorbs carbon dioxide. Carbon dioxide (CO_2) makes up 0.03% of air and is a waste product of plant and animal respiration. The decomposition process, in soil and water, also contributes CO_2 to the atmosphere.

When carbon dioxide combines with water, it forms a weak solution of carbonic acid, which is found in carbonated beverages. Carbonic acid reacts with limestone to produce calcium carbonate ($CaCO_3$)--a white compound that leaves a scaly deposit, especially in teakettles.

There's an important relationship between the amount of carbonates in water and the amount of "bicarbonates" that are similar compounds. Bicarbonates function like Alka-Seltzer to buffer water

against acids. If a waterway has a high carbonate content (total alkalinity), it also has a good buffering ability and is less likely to be hurt by acid rain and acid wastes. Some common hardness values are shown in the following chart.

TOTAL HARDNESS (mg/L $CaCO_3$)	DESCRIPTION
0 to 60	Soft water
61 to 120	Moderately hard water
121 to 180	Hard water
181 and up	Very hard water

In the baking industry, very soft water produces sticky bread dough and soggy bread. On the other hand, hard water used for cooking toughens many vegetables and slows fermentation----the process by which cheese, yogurt, and beer are made. Recommended hardness values for industrial use are summarized in the table below.

INDUSTRY	TOTAL HARDNESS (mg/L $CaCO_3$)
Brewing beer	200 to 300
Carbonated beverages	200 to 250
Washing clothes	0 to 50
Steel manufacturing	50

Heavy metals, such as mercury, copper, and lead, and nonmetals, such as ammonia, phenols, and certain acids, are much more toxic to fish in soft water than in hard water because soft water has fewer binding sites for the toxic substances. Research studies have appeared to indicate that drinking soft water over long periods of time may increase one's chances of having a heart attack. To avoid the potential problems, faucets providing drinking water can be disconnected from a water softener.

There are two different testing procedures for hardness. The total hardness test is performed frequently in the water industry. It measures the total amount of calcium and magnesium in water, and the results are expressed in metric units as milligrams per liter (mg/l) of calcium carbonate ($CaCO_3$). The second procedure determines calcium content only.

Both hardness tests, total and calcium only, use EDTA, ethylenediaminetetraacetic acid. It chelates,

or wraps around, any ions in solutions that have multiple positive (multivalent) charges. Calcium and magnesium are the most common multivalent ions in natural waters that contribute to hardness.

Terms

acid rain: 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.

bicarbonate: an acid salt of carbonic acid containing the radical HCO_3^-

calcium carbonate: one of the most stable, common, and widely dispersed materials on Earth; occurs naturally in oyster shells, calcite, limestone, marble, chalk, and other forms; used to express hardness and alkalinity (mg/l of $CaCO_3$)

carbon dioxide: colorless, odorless gas made of carbon and oxygen (CO_2); exhaled by animals and humans, utilized by plants in photosynthesis and contained in automobile exhaust

carbonic acid: substance formed by combining water (H_2O) and carbon dioxide (CO_2); chemical formula H_2CO_3

hard water: water high in mineral content; water containing an abundance of Ca^{+2} and Mg^{+2} ions

hardness: a measure of all the multivalent (primarily calcium and magnesium) ions expressed in mg/l of calcium carbonate ($CaCO_3$)

ion: an atom or molecule that has lost or gained one or more electrons

multivalent (ion): ion that has lost or gained more than one electron (also called a "polyvalent" ion)

toxic: harmful to living organisms

ADVANCE PREPARATION

A. Copy Data Sheets.

B. Discuss Background Information and/or copy and hand out to students.

C. Divide students into small groups.

PROCEDURE

I. Setting the stage

Have the students engage in directed discussion, or have them make a list of places they have lived or visited where they have noticed differences in the water when used for certain activities --- drinking, brushing teeth, shampooing, washing clothes, bathing, etc.

II. Activity

A. Have students bring in samples of water from various sources.

1. bottled water from various geographic areas
2. tap water
3. well or spring water
4. river or creek water
5. lake or pond water

B. Other substances can also be used to test for hardness.

1. carbonated beverages
2. milk
3. solution of Epsom salts
4. liquid fabric softeners diluted with distilled water
5. lotions, creams diluted with distilled water

C. Using a water analysis kit, test each item for hardness. (Directions for using each test kit are included in the kit.)

D. Follow the directions for each testing procedure.

E. Record the data on the Data Sheet.

F. Graph the data from each sample using a bar graph.

G. Write an analysis comparing the test results of each.

III. Follow-up

Explain why groundwater is generally harder than surface water.

IV. Extensions

1. Have students research the geologic areas of the world on the bottled water samples to determine the rock formations. Report on how this correlates with the hardness results.

2. Analyze the hardness results of flowing waters (rivers, creeks) compared to that of standing waters (wells, ponds, swamps, rain barrels). Use bar graphing on poster board, perhaps computer generated, to present results.

3. Obtain hardness data from water quality testing in different states and/or countries and compare to your area. Use a computer to locate databases with this information if there is access to the Internet or a commercial communications network. Hardness data may be obtained from the state Geological Survey and from the U.S. Geological Survey. (See fact sheet pages J-1 to J-6 in the back of this book.)

4. Locate other schools or organizations that do water testing and compare the data collected to that of your area.

RESOURCES

Jacobson, Cliff, Water, Water Everywhere (Student Reading Unit About Water Quality), Hach Company, Loveland, CO, Catalog Number 21975-00. 1-800-227-HACH.

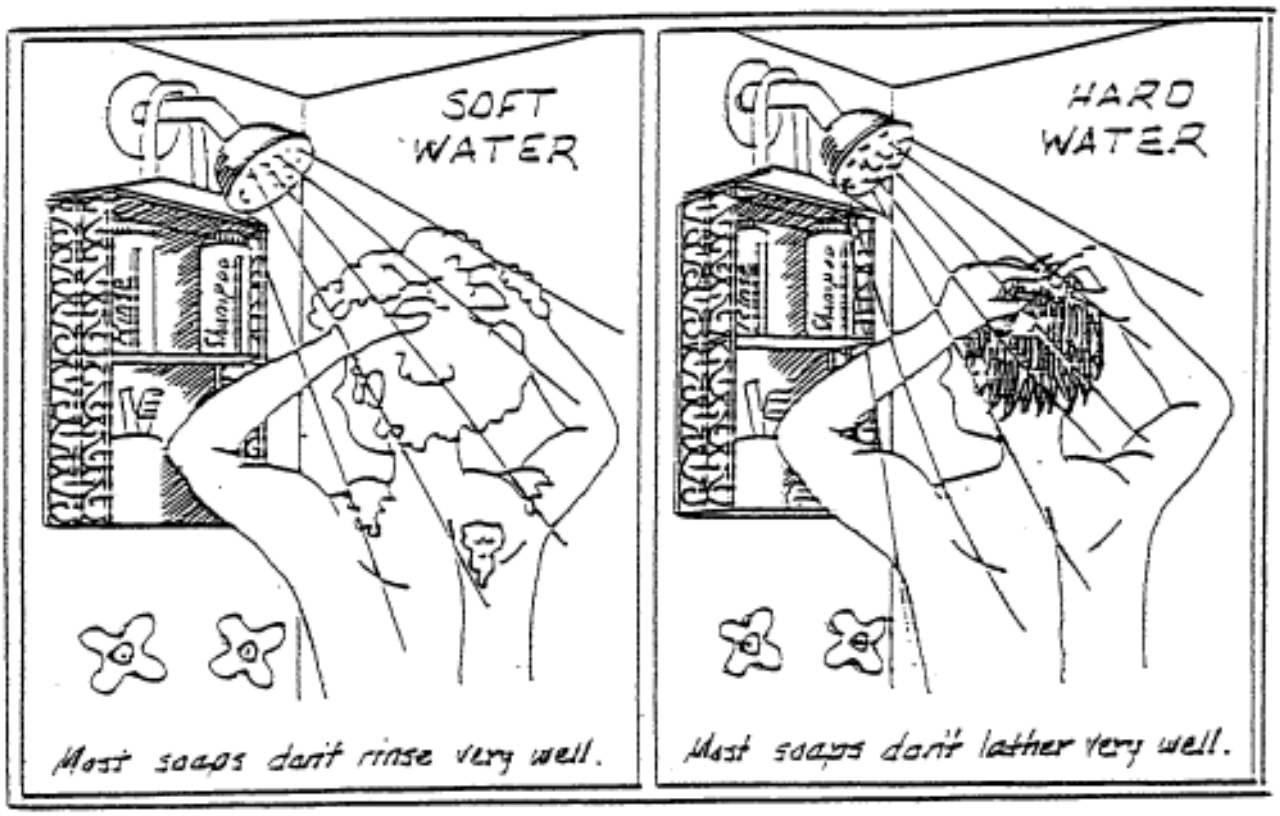
TVA Teacher - Student Water Quality Monitoring Network, March, 1992, Tennessee Valley Authority.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

Water Hardness

Data Sheet

Substance Tested	Hardness ($CaCO_3$, mg/L)


SOFT WATER
Most soaps don't rinse very well.
HARD WATER
Most soaps don't lather very well.