TESTING WATER FOR HARDNESS

A SEMI-QUANTITATIVE APPROACH USING SOAP BUBBLES

Developers:

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Grade level:

Grades 3 to 5

Discipline :

Physical Science

Goals:

1. To broaden the student's knowledge and understanding of water
2. To determine what materials cause water to become hard.
3. To understand the function and limitations of soap in mineralized water.
4. To determine the hardness of a mystery sample of water.

Specific Objectives:

1. Students will discuss water quality and usefulness to various industries.
2. Students will observe that soap reacts differently with different water samples.
3. Students will conclude that while all water samples look the same to the naked eye, there is something different in each one that prevents soap from working the same in each sample.
4. Students will discuss the nature, cause and effect of hard water.
5. Each student will conduct a soap test on a sample of hard water where the hardness is known, measuring the height of the bubbles produced.
6. Students will conduct a soap test on an unknown sample of tap and attempt to ascertain its approximate hardness.

Background:

Not all water is created equal.

Water has the unique ability to dissolve a wide variety of materials. Some industries cannot use water with materials that may be present naturally because they would cause adverse effects to the machinery of the facility, the product, or the environment. A power plant is an example in point. The presence of such dissolved solids as salts of magnesium, iron, calcium and others require the power company to expend more energy than normal to raise water to its boiling point. In addition to energy waste these materials can quickly lead to a mechanical hardening of the arteries as they precipitate out inside steam tubes.

People are also affected by this problem. When using soaps in water with a high mineral content, it will be difficult to raise a lather because the compounds in the water must be precipitated from the solution before sudsing can occur. In addition, mineralized water will leave a film or "soap scum" around the washing surface that will be difficult to remove.

Water that contains large amounts of calcium and magnesium salts is said to be "hard water." Hard water usually occurs in areas where limestone rock can be dissolved by water that is slightly acidic. The acid in water comes from carbon dioxide. A waste product of animal respiration, CO_2 makes up 0.03 percent of the air we breathe. When combined with water, carbon dioxide forms a weak acid. This *carbonic acid* eats away at limestone- or magnesium- rich earth and produces calcium or magnesium carbonate. These are the compounds that are most frequently associated with the production of hard water. Iron and aluminum salts and other minerals may cause hardness if enough of them are present in a given quantity of water. However, large amount of these minerals usually are not found in natural waters.

Hardness tests are frequently performed in industries that rely on pure water. These tests measure the total amount of calcium and magnesium salts in a water sample and express the results in metric units such as milligrams per liter (mg/L) of calcium carbonate ($CaCO_3$) or the English units of grains per gallon (gpg) of calcium carbonate. To convert from metric units to the customary English unit simply apply the formula :

$$mg/L = gpg \times 17.1$$

Water is said to be hard when its total hardness exceeds 121 milligrams per liter of calcium carbonate.

This background is condensed from *Water,Water Everywhere, Teacher's Guide and Experiments* by Cliff Jacobson.

Not all materials dissolved in water are necessarily harmful. Some elements in small amounts can be quite beneficial. Small amounts of fluoride can help prevent tooth decay, and water companies frequently add chlorine to cut down on the number of micro-organisms that that would reproduce in our drinking water and make us sick.

Advance Preparation:

Teachers will need to make up a stock solution of hard water and prepare several dilutions of the stock in specific concentrations for the students to test. Students should bring in samples of tap water from home, rain water or other sources to check for hardness.

TO PREPARE THE STOCK SOLUTION

1. Obtain several 1- and 2-liter containers. If none is available, 2-liter soda bottles will work. Make a mark on a full bottle of each to use as a measuring container.
2. Place 1/4 tablespoon or 1.4 grams of calcium chloride in to a 2-liter container and fill to the mark with distilledwater. This is your stock solution and should have a total hardness of 391.8 parts per million as calcium carbonate. Label this container A.
3. To make a 0.1 dilution, take 100ml of A and place in another 2-liter container. Add one liter of distilled water. Label this container B (to make a 0.2 dilution use 200ml). If you do not have 100-mL graduated cylinders available, a 4-oz baby food jar will hold just about 100 mL.
4. Take 100 mL of B and add it to 1 liter of distilled water labeling this C. This is a 0.01 dilution of the stock.

Materials:

Distilled water, can be purchased at the grocery store.
Magnesium chloride crystal or Epsom Salts to make a 1.0 stock solution.
Calcium chloride or calcium chloride-based ice removal material to make a 1.0 stock solution.
Liquid hand soap (*detergent will not work*)
Medicine Droppers
Felt marking pens
Test tubes, at least 4 per group
Metric ruler
Stoppers for test tubes

Procedure:

Part A: Does all water behave the same way when soap is added?

1. Arrange test tubes, label each A,B,C, and so on.
2. Place equal amounts of the appropriate solution in each test tube, filling each about 1/3 full.
3. Place a line on each tube at the height of the sample; this becomes the base line.
4. Add one drop of liquid hand soap to each tube.
5. Stopper and shake each tube 10 times, recording the height of suds from the base line to the top of the suds. Record this number.
6. Compare group results.

Part B: Finding the relative hardness of a mystery sample of water

1. Arrange the test tubes in order from the one with the most bubbles to the one with the least amount of bubbles.
2. Compare the results from each student group.
3. On the board, write the concentrations of each dilution and their appropriate total hardness.
4. Prepare a test tube as described above and fill to 1/3 with the mystery sample.
5. Add one drop of liquid soap solution.
6. Shake 10 times and measure the height of bubbles formed.
7. Compare the results of the mystery sample with those of the known dilutions from part A.
8. Determine which test dilution is closest to the mystery solution.

Extensions:

Different soap brands may give different results.
The amount of soap used can be increased.
A soap solution could be made from shavings of solid bars of soap.

Suggested Questions:

A control of distilled water could be used to demonstrate that when the test solutions are diluted there is a relationship between concentration and bubbles produced.

1. Which test solution, A,B,C, or the control, produced the most suds?
2. Did anything precipitate from solution in any of the dilutions tested?
3. Was there any variation between the results of the different groups?
4. About how hard was the mystery sample?