Hardness Comparisons

Adapted from: An original Creek Connections activity.
Creek Connections, Box 10, Allegheny College, Meadville, Pennsylvania 16335.

Grade Level: all

Duration: 50 minutes

Setting: lab or classroom

Summary: Students will conduct hardness tests on various water samples to better understand the connection between geology and water chemistry.

Objectives: To have students understand the source of hardness and how this source influences the level of hardness in different types of water.

Vocabulary: hardness, polyvalent cations, calcareous

Related Module Resources:
- pH measuring device – pH paper, meter [A-1-MB1] or Hach pH kit (kit will take longer)[A-4]
- Hach Alkalinity kit [A-4]
- Books [B-4]

Materials (Included in Module):
- Hardness Information and Fact Sheet
- Hardness Hach Test Kits [A-2]
- Extra glassware [B-1-MB3]
- Sample Bottles [A-4]
- Distilled Water Wash Bottles [A-3,4]
- Rainwater [C-1]
- Spring / Bottled Water [C-1]
- Rolaids [C-1]

Additional Materials (NOT Included in Module):
- Water samples: rain water, tap water, and surface water (from a stream or other waterway), other water if desired (groundwater, distilled water, deionized water, etc.)

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade
4.1.7.B Understand the role of the watershed.
- Explain factors that affect water quality and flow through a watershed

10th Grade
4.1.B Explain the relationship among landforms, vegetation and the amount and speed of water.
- Describe factors that affect the quality of groundwater.

12th Grade
4.1.C Analyze the parameters of a watershed.
- Interpret physical, chemical and biological data as a means of assessing the environmental quality of a watershed
- Apply appropriate techniques in the analysis of a watershed (e.g., water quality, biological diversity, erosion, sedimentation)

BACKGROUND:

Hardness is one of the most commonly tested parameters of drinking water. Because water is a good solvent (able to dissolve substances) and can pick up impurities easily, our water is rarely pure. It usually contains ions and compounds picked up from underground, land surfaces, pollution, and other human impacts. Hardness is one test that helps us determine the amount of certain dissolved minerals.

Hardness is defined as the sum of the **polyvalent cations** (ions with a charge greater than +1) present in the water. The minerals calcium (Ca^{+2}) and magnesium (Mg^{+2}) are usually the predominant cations responsible for hardness levels. Other ions, such as iron (Fe^{+2}), manganese (Mn^{+2}), aluminum (Al^{+3}), may contribute to hardness, but in natural waters these other ions are usually found in insignificant amounts. Hardness is a parameter that somewhat summarizes the amount of various substances that may be in the water. Though methodology for hardness tests can vary to account for different ions, most simple tests focus on just calcium and magnesium. Hardness test kits often express results in parts per million (ppm) or milligrams per liter (mg/L) of $CaCO_3$ (calcium carbonate), which then can be converted directly to calcium and magnesium concentrations. Hardness can also be recorded in grains per gallon (gpg), degrees hardness (dH), or the molar concentration of $CaCO_3$.

Waters with high hardness values are referred to as "hard", while those with low hardness are "soft". Hard water simply has excessive amounts of the polyvalent cations in them. There are *various* verbal categories / levels to classify the numerical results of hardness; they vary depending on the resource or agency. A chart of examples of the classifications follows:

Table 3.3 Water hardness levels

Water Hardness	as ppm $CaCO_3$	as grains per gallon
soft	0 to 20	below 1.0
moderately soft	20 to 60	1.0 to 3.5
moderately hard	61 to 120	3.5 to 7.5
hard	121 to 180	7.5 to 10.5
very hard	>181	10.5 and above

Calcium and magnesium may be added to a natural water system as it passes through soil and rock containing large amounts of these elements in mineral deposits. Hard water is usually derived from the drainage through **calcareous** (calcite-rich) sediments and rock, such as limestones, sandstones, siltstones. Dolomites are rich in magnesium. These rocks are found in Western Pennsylvania, thus affecting the hardness levels in our water. In this area, if water has had the opportunity to interact with bedrock, rock, and soils for a long time (such as groundwater), it will be hard. If the cations responsible for making water hard are not calcium and magnesium, but are iron, sulfate, chloride, manganese, or aluminum, etc. instead, this is considered to be "non-carbonate hardness".

Water that has entered waterways directly without soaking into the ground will be significantly softer. Collected rainwater is usually soft because it has not interacted with any geological sources of the cations. Soft water is also derived from the drainage of igneous rocks, because these rocks don't weather very easily, don't release many cations, and don't always contain calcium and magnesium.

OVERVIEW:

Students will hypothesize the levels of hardness of various water samples and then conduct hardness tests determine their amounts. A comparison will be made between rainwater and groundwater and surface water. Students may elect to harden their soft water samples using various materials containing calcium carbonate.

PROCEDURE:

Teacher Preparation:

1. Before doing this experiment, collect rainwater using some clean containers. If you are unable to do this, there is some rainwater in a labeled sample bottle in this module, but for best results, the rainwater should be new. You will also have to have various types of water samples ready in labeled (or numbered – see Extensions

Section) containers for use in this experiment. Only some types are provided in the module. Examples of possible water samples include:

a) rainwater
b) tap water from school (know the source of the water – from ground or surface water).
c) tap water from various locations or students' homes (ask them to find out the source of the water – well or city water, from ground or surface water).
d) groundwater – from a private home well
e) water from a spring or small stream, perennial stream (the source of the water will be mainly groundwater unless it has recently rained)
f) from a larger stream, creek, French Creek
g) bottled water, spring water (make sure you know the geographic source of it)
h) purified bottled water
i) water after it has been filtered through Brita Filter
j) distilled water

2. So the whole class can participate, you will need to create stations of extra glassware (square mixing bottles, eyedroppers), chemicals, and instructions from the Test Kit Instruction Section of the Module Resource Guide. Some materials will need to be shared amongst the entire class.

Student Experiment:

1. Discuss background information as needed. Have student break into lab groups.

2. Tell students that they will be testing various water samples to determine the amount of hardness. Depending on group size, amount of samples, and time, determine how many different samples each student or group is to test. Each group can test a different type of water and then consolidate data.

3. Give students the list of various water samples they will be testing. Possibly have students hypothesize which of the samples they think will have the most hardness. Which will be the softest? (These questions are on the data sheet).

4. Distribute Hardness test kits and instructions, extra glassware and chemicals, and data sheets if not already done. Caution students that the extra eyedroppers should only be used for the Titrant Reagent, Hardness 3 and not any of the other chemicals. For the other chemicals, use the eyedroppers enclosed with each container. This will avoid contamination.

5. Have students conduct the total hardness, calcium hardness and magnesium hardness tests on the samples you have collected. Have them record their data on the data sheet.

DISCUSSION:

Which sample was the hardest? *Probably groundwater – see background information for why.*

Which sample was the softest? *Probably rainwater– see background information for why. It may also be bottled water if the geographic source of the water is from a region that does not contain sedimentary rocks that contribute calcium.*

Find out if students correctly hypothesized which samples would be the most hard and soft. Have the students rank the samples from hardest to softest and discuss why this may be. *See background information, but the more the water has come in contact with our Western Pennsylvania bedrock, rocks, soil – our geology – the harder it will be.*

Have students refer to the color geological maps of Pennsylvania enclosed in the module. If taken from the same location, would a sample of groundwater that has been underground for 1 year be harder than a sample of groundwater that has been underground for only 1 week. *Yes, 1 year is more time for the water to pick up calcium and magnesium cations.*

Ask the students why a sample of groundwater from upper New York State would be significantly softer? *Not all regions in the country contain geology that is rich in calcium and magnesium – upper New York State contains many non-sedimentary rocks such as granite.*

EVALUATION:

- What are the ions that contribute to hardness levels in water?
- What are the sources of these ions and how would these sources influence the samples you tested?
- Correctly performed testing procedures and correctly filled out data sheet.
- Discussion questions above.

EXTENSIONS AND MODIFICATIONS:

- Instead of having labels on the bottles indicating where they came from, just have them numbered and you have an answer key. Have students try to figure out their locations (you give the choices) based on their hardness results. You might want to test the samples first to make sure the results are reflective of expected results.
- Take rainwater (if you have enough of it) ask students how they would make it harder. Have students attempt to do this using any of the following: crushed up rolaids, tums or other acid reduction medicine that contains calcium carbonate; garden lime; baking soda; or sandstones, siltstones, shales, or limestones (whole or crushed). Test this hardened water with the hardness test to see if they have succeeded.
- Conduct pH and/or alkalinity testing along with the hardness testing and have student make the connections between these various parameters. *(low pH = low alkalinity = low hardness; high pH = high alkalinity usually = high hardness).*

NOTES (PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS USING THIS ACTIVITY IN THE FUTURE):

Activity Version: November 2001

DATA SHEET: HARDNESS COMPARISONS

Student Name _____ Date _____

Which of the water samples (if contents are known) do you think will be the hardest?

Which of the water samples (if contents are known) do you think will be the softest?

WATER SOURCE Or SAMPLE #	**TOTAL HARDNESS**		**CALCIUM HARDNESS**		**MAGNESIUM HARDNESS**	
	In grains per gallon	In mg/L	In grains per gallon	In mg/L	In grains per gallon	In mg/L

**** To convert grains per gallon (gpg) to mg/L, multiply by 17.1*** 1 gpg = 17.1 mg/L*

NOTES / OBSERVATIONS: