Hardness Evidence Search

Adapted from: An original Creek Connections activity.

Grade Level: all

Duration: 60 minutes

Setting: lab or classroom and home, possibly school basement

Summary: Students will investigate the consequences of having hard water.

Objectives: To have students understand the source of hardness, and recognize some of the impacts that hardness in our lives and in water ecosystems.

Vocabulary:

Related Module Resources:
- Activity: Hardness Comparisons
- Hardness Hach Test Kit
- Rolaids

Materials (Included in Module):
- Hardness Information Sheet and Fact Sheet
- Sandstone and limestone rocks
- Pipes and other plumbing fixtures with hardness evidence
- Geologic Maps of Pennsylvania
- Ivory Liquid Soap
- Ziploc bags
- Brita Water Filter and information sheets about Brita

Additional Materials (NOT Included in Module):
- Additional hardness evidence (see list within activity write-up)
- Water softening system
- Distilled water
- some water samples

ACADEMIC STANDARDS:

7th Grade

4.1.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 defined as the sum of the polyvalent cations (ions with a charge greater than +1) present in the water. The minerals of 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) 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.

Calcium and magnesium may be added to a natural water system as it passes through soil and rock containing large amounts of these mineral deposits, such as sandstone, limestone, and siltstone. In Western Pennsylvania, if water has had the opportunity to interact with bedrock, rock, and soils for a long time (such as groundwater), it will be hard. Water that has entered waterways directly without soaking into the ground, will be significantly softer.

Drinking water in Pennsylvania is derived from both surface and groundwater sources. Approximately half of Pennsylvania's 12 million residents get at least part of the drinking water directly from groundwater. Pennsylvania has the 2nd most groundwater wells in the country (behind Michigan). Since sandstones and limestones can be found in most parts of Pennsylvania, these groundwater well users are probably drinking hard water. Even the 6 million people that obtain their drinking water from surface water supplies are still drinking hard water. Since groundwater provides approximately 2/3 of the water to streams, rivers, and lakes on average, the surface water has hardness characteristics too.

With hard water in Pennsylvania, there are some consequences that we have to deal with. Hard water is sometimes considered a nuisance. Hardness increases the amount of soap that is needed to produce foam or lather because the calcium and magnesium ions form complexes with soap keeping it from sudsing. The calcium and magnesium deposits from water can cause a film on sinks, bathtubs, hair, skin, fabrics, ice cube trays, glassware, and dishes. This calcium buildup (solid precipitate) from water can also coat the interior of water pipes, boilers, heat exchange equipment, household appliances, and some industrial equipment. Deposits (often called scale) can become so thick that they clog pipes or cause equipment malfunctions, thus becoming an economic burden. These hardness deposits can have a white or greenish color to them. In addition to all of these annoyances, some people do not like the taste of hard water.

Even though hardness can cause plumbing nightmares, hardness is also desirable because it reduces corrosion rates in our pipes. This reduces the amount of lead (from lead sodder), copper, zinc, and other metals from plumbing that may enter our drinking water. Unlike hard water, soft water with few positive ions is more reactive to picking up cations such as metals from pipes or the surrounding environment. The calcium coating on the inside of the pipes can also help reduce corrosion.

Some homeowners actively try to soften their water using a number of different systems. An ion exchange filter/ system exchanges the positive sodium ions from salt (sodium chloride) for calcium and magnesium. The sodium enters the drinking water instead, which can also affect taste in large quantities. Sometimes this system is used only for hot water heaters so extra sodium is not drunk, but expensive pipes and equipment are protected. Another softening method is a lime-soda process, involving the reaction of lime and soda ash reacting with hard water producing a insoluble precipitate with calcium and magnesium ions. These ions no longer interfere with cleaning soaps, but the precipitate can still leave films and be drunk.

Hardness in water can have some biological impacts on waterways. Calcium is an important component of aquatic plant cell walls, and the shells and bones of many aquatic organisms. Magnesium is an essential nutrient for plants and is a component of the chlorophyll molecule. If there is very little calcium in a waterway (less than 10 mg/L), only sparse plant and animal life can be supported because this waterway does not usually contain enough organic matter and nutrients. Hardness is also helpful in limiting metal toxicity for fish because calcium and magnesium keep fish from absorbing metals such as lead, arsenic, and cadmium (which are other polyvalent cations) into their bloodstream through their gills. The greater the hardness, the

harder it is for toxic metals to be absorbed through gills. In addition, hard water is usually also high in alkalinity, which can help maintain pH levels that aquatic life need in order to survive (see Alkalinity and pH Information sheets for more information). Hard water can also affect fish osmoregulation, the process that controls the concentration of internal body fluids. There is a continuous movement of surrounding water into and out of a fish's body. The greater the difference in body fluid concentration and the surrounding water – the greater the osmotic effect. Hard water with more ion concentration is closer to body fluid levels, making the job of osmoregulation a little easier for fish. Soft water or very hard water will disrupt this balance and fish have to adapt their osmoregulation process.

OVERVIEW:

THIS ACTIVITY CAN BE DONE AS A SEPARATE ACTIVITY OR PARTS OF IT CAN BE INCORPORATED INTO AN INTERACTIVE LECTURE.

Students will look for evidence of hardness using a handout that guides them through some of the consequences of having hard water.

PROCEDURE:

Teacher Preparation: Before doing this activity, you will also have to gather as many examples of hardness evidence as possible or arrange to see some evidence in the school. See if you would be able to take the class to see some of the plumbing and heating infrastructures of the school, possibly in the basement or kitchen. Only take them to see this if they present evidence of hard water. If not, you may have to have students investigate their own homes or just use plumbing examples in the classroom. Some examples of hardness are enclosed in the module.

Examples of hardness evidence:

a) piping with scale (calcium deposits) inside or along joints and connections
b) other plumbing fixtures or hot water tank fixtures with deposits
c) hardness film on sinks (especially metal sinks)
d) hardness film on ice cube trays
e) hardness film on glassware, dishes
f) soapy water vs. non soapy water
g) fish in a fish tank
h) aquatic plants in a fish tank

Evidence of how we deal with hardness:

a) Brita filter or other simple water purification system
b) water softener system if school has one
c) empty bag of water softening salts

With Students:

1. Discuss background information as needed. Possibly hand out copies of the Hardness Information Sheet.
2. Hand out worksheet for this activity.
3. Have visual aids showing hardness evidence ready for students to investigate.

4. On the worksheet are instructions for students to conduct a short experiment about water hardness effects on soap.

DISCUSSION:

Make sure students are aware of all the consequences of having hard water. The visual aids and worksheet has helped emphasize these main points.

Are their any benefits to having hard water? *(Yes, calcium and magnesium are needed in the human diet. Calcium deposits on the inside of pipes (scale) can help reduce the corrosion of the pipes, and help limit the amount of toxic metals that might enter the drinking water running through those pipes. Hardness also benefits plumbers and installers / operators of water softening systems – it give them business and makes them money.)*

EVALUATION:

- What are the ions that contribute to hardness levels in water?
- Where is the source of these ions?
- What are the consequences of having hard water?

EXTENSIONS AND MODIFICATIONS:

- Have students take digital camera pictures of hardness evidence to document what they find.
- Ask a plumbing or water service specialist to come to school to discuss hardness with students and discuss methods they use / install to deal with hardness. Discuss water softening systems.
- Do some website surfing to investigate hardness websites and water softening system websites. See if plumbing company websites mention hardness on their websites.

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

Hardness Evidence Search

Name: _____ Date: _____

CHECKLIST OF HARDNESS EVIDENCE

- ❑ Sandstone – a sedimentary rock responsible for hard water
- ❑ Limestone – another sedimentary rock responsible for hard water
- ❑ Pipes with scale (calcium deposits) inside or along joints and connections
- ❑ Other plumbing features with hardness deposits
- ❑ Hot water tank with evidence of hardness
- ❑ Hardness film on a sink, faucet
- ❑ Hardness film on bathtub or shower
- ❑ Hardness film on household appliance
- ❑ Hardness film on glassware or dishes
- ❑ Hardness film in ice cube tray
- ❑ Increased amount of soap needed to create suds and bubbles
- ❑ Water Softening System
- ❑ Water Softening Salts
- ❑ Brita Water Filter
- ❑ A fish (perhaps in an aquarium)
- ❑ An aquatic plant (perhaps in an aquarium)

GEOLOGY

1. Use the Geologic Maps of Pennsylvania to determine what type of rocks can be found in your area. What are the rock types? Do they contribute to hardness in the water? If yes, how do they contribute to hardness?

PIPES AND SCALE (CALCIUM DEPOSITS)

2. What are the negative consequences of having calcium deposits inside the piping? Are there any benefits to having the deposits coating the inside of the pipes? If yes, what are the benefits?

HARDNESS AND SOAP

3. Attempt an experiment to determine if hard water takes more soap in order to create suds and bubbles.
   a) Fill a ziploc bag ¾ full of distilled water – which is not supposed to contain hardness minerals [SOFT WATER]. You may want to mark the bag with a marker.
   b) Fill another ziploc bag with an equal amount (3/4 full) of either tap water (that has NOT gone through a softener) or tap water from a groundwater well (NOT softened) or spring water or small stream water [HARD WATER]
   c) PLEASE NOTE, THIS EXPERIMENT MAY NOT WORK UNLESS THERE IS A BIG DIFFERENCE IN HARDNESS LEVELS BETWEEN THESE TWO SAMPLES.
   d) Using the Ivory Liquid Soap (other soaps may not work – see side note), you are going to add an EQUAL DROP of soap to each ziploc bag. PLEASE NOTE, THE SUCCESS OF THIS EXPERIMENT MAY DEPEND ON THE TYPE OF SOAP AND THE EQUAL AMOUNTS OF SOAP USED.
   e) Doing the same to each bag, shake the bag an equal amount of times to see if there is a difference in amount of bubbles and suds produced from the soap.

A Note About Soaps:
Not all liquid soaps will work with this bubble test. Soap and detergent are not the same thing. Some hand soaps such as Liquid Ivory contain more soap and fewer additives. Additives found in some soaps are designed to overcome the effects of calcium and magnesium. Read labels to see if your soap has these additives. You may want to try different soaps for this experiment.

Was there a difference between your two ziploc bags? If not, why do you think there was no difference? Why would it be a concern to a homeowner using soap to clean something that they have hard water?

HARDNESS FILM ON SURFACES

4. Why would an owner/manager of a fancy restaurant be concerned if their water was hard and left a film of calcium deposits on the glassware, dishes, appliances, sinks, and inside the dishwasher and hot water tank?

WATER SOFTENING SYSTEMS

5. What role does the salt play in common water softening systems for homes and industries?

AQUATIC LIFE AND HARDNESS

6. Explain what impact hardness levels have on fish and aquatic plants?