Activity 10

Total Hardness

Part 1

Why is it called HARD water? Hardness is one of the folk terms inherited from the past with origins from "wash day." Water from some locations did not easily make lather or suds with soap, requiring much larger amounts of soap to get a good lather. This water was called "hard" water because cleaning with it was hard (difficult). Conversely, water that easily formed suds with soap was called "soft" water, the opposite of "hard" water. In areas where the water was hard, rainwater collected in a rain barrel or cistern was preferred for laundry.

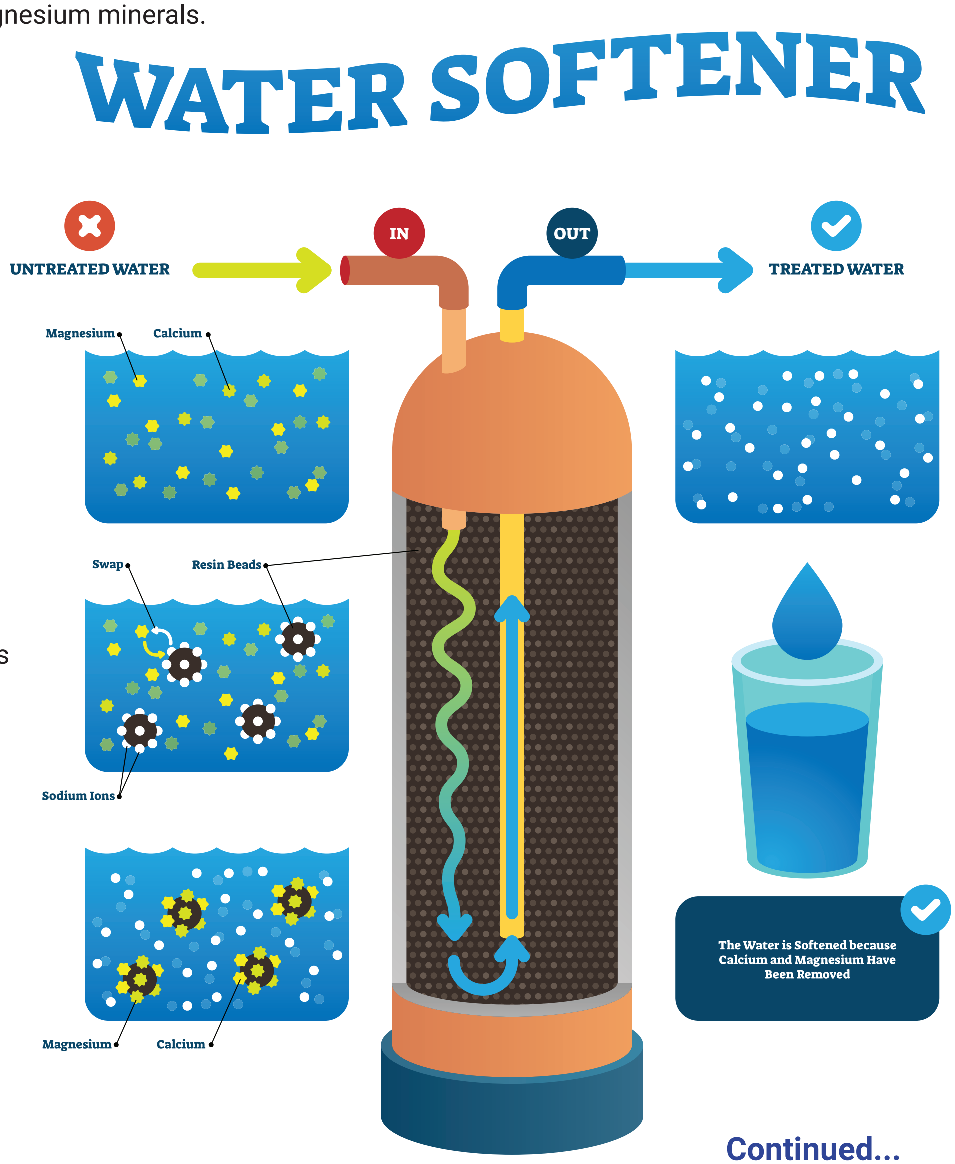
What makes water hard? Hardness of water is a measure of the amount of calcium, magnesium and/or iron salts dissolved in the water. These salts enter the water supply naturally as rainwater runs through rocks and soils containing calcite, dolomite and ferro magnesium minerals.

When these calcium, magnesium or iron salts combine with soaps (water-soluble sodium or potassium salts of fatty acids), they react to form insoluble salts with the fatty acids. These precipitate to form a sticky, gray curd called soap scum. When soap is added to hard water, this process will continue until all the calcium, magnesium and iron ions have precipitated out. Only then will soap that is added to the water form lather.

Hard water causes other problems by forming a scaly deposit inside teakettles, hot water tanks and hot water pipes. Ironically, Many of the dissolved salts that make water hard are LESS soluble in hot water than in cold. This buildup of scale can clog hot water pipes and cause boilers to explode.

What is soft water? Water containing few calcium, magnesium or iron salts is called "soft water." This does not mean that the water is "salt-free," but that the salts do not react with soap or cause scale buildup. Some water softeners for home use replace calcium ions with sodium ions. Water that is too soft may also be too acidic (because of the alkaline and buffering characteristics of the calcium salts.) This may cause lead and copper to leach from the pipes into the drinking water. Some water suppliers add zinc orthophosphates to the water to reduce its softness and balance the pH to near 7.0.

Soaps versus detergents - Although the term detergent means, "cleansing agent" and includes soap, it is now used commonly to refer to soap substitutes. The problem with soaps is that they form insoluble precipitates in hard water. Detergents are resistant to the action of hard water minerals and most will not form a scum. Therefore they are more effective cleaners under a variety of conditions. Detergents are also preferred in situations where sudsing could cause problems, such as in dishwashers and washing machines.



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Part 2

USING THE TEST STRIPS

Dip one test strip into the sample for 10 seconds, with no motion. Immediately (within the first 15 seconds,) remove the strip from the water sample and match the pH (end pad) color to the pH color chart. Match the total alkalinity pad color to the total alkalinity color chart before 30 seconds have passed. Note: The pH strip may read low if the Total Alkalinity is less than 80 ppm. It may read high in highly buffered solutions with high ionic content.

The EPA does not regulate the levels of hardness in the water supply. However, water with hardness less than 60 is considered soft water. Hardness of 61-120 is considered moderately hard and may reduce the effectiveness of soaps. Hardness greater than 120 is considered moderately hard and will cause scale formation in hot water. Above 180 is very hard, and dishwasher use will produce a film on dishes. In a pond or aquarium, high levels of hardness may affect the health and breeding habits of the fish.

MATERIALS:

School Test Kit Materials:
Total Hardness test strips
Plastic droppers
School Kit Color Chart and Instruction card
Data collections sheet, copied for number of students

Equipment:
Identical small glass jars with lids (baby food jars or screw top test tubes)
Ruler
Tablespoon
Watch or clock with second hand

Shopping list:
Epsom salts (magnesium sulfate)
Borax (sodium borate)
Ivory liquid
Distilled water
Distilled Water
Tap Water
Creek, pond or lake water
Rainwater

SAMPLE PREPARATION:

Label jars with sample # and contents.

Hard water – Combine 0.2 g Epsom salt in 250 ml distilled water X volume needed

Borax Solution – combine 0.2 g Borax in 250 ml distilled water X volume needed (Note to teacher: Borax is a laundry additive that acts as a natural water softener by replacing calcium and magnesium with sodium.)

Ivory Soap Liquid – Use plastic dropper to combine 1 ml Ivory Liquid Ultra in 100 ml tap water. (Note to teacher: Commercial soap products may contain glycerin, perfumes, detergents, sanitizers and other chemicals, all of which may affect the results of this experiment. Ivory is recommended for this activity because it is pure soap.)

PROCEDURE:

1. Take 6 clean jars with lids, labeled 1-6. In #1, put 50 ml distilled water. In the second jar, put 50 ml hard water. In #3 put 50 ml rainwater. In #4 put 50 ml tap water. In #5 put 50 ml creek or lake water. In #6, put 50 ml borax solution.
2. Measure the total hardness of each sample. Dip one total hardness test strip into each water sample for 3 seconds; remove and immediately match the colors to the color chart. Record the results on the data sheet.
3. With the plastic dropper, add 5 drops of the soap solution to each sample. Secure the lid on each jar. Shake vigorously for 30 seconds. Allow the jar to stand for 15 seconds. Measure the height of the suds above the water level in each jar. Record results on the data table.
4. Compare how the distilled water and the baking soda solutions respond to the addition of an acid. Use the same distilled water and baking soda samples from steps 2 and 3. Fill a dropper with the vinegar solution. Drop 5 drops of the vinegar solution into the distilled water sample. Using a clean test strip, test for pH and total alkalinity; record the results on the data sheet. Repeat with the baking soda solution.

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Activity 10

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Part 3

ANALYSIS AND APPLICATION

1. Describe the difference in appearance of the suds in samples #1 and #2. Predict the results of using sample # 2 (hard water) to wash hair or clothes.
2. Using the test strip results from step 2 as recorded in the data table, rank the water samples from hardest to softest. Create a bar graph comparing the hardness of each sample in parts per million.
3. Construct a bar graph comparing the height of the suds above the water level in the different samples. Use the results recorded in the data table from step 3. Compare the suds graph with the hardness in ppm graph from step 2.

EXTENSION

1. Soap must first remove the minerals in hard water before it can form suds.
2. Testing one water sample at a time, record in the data table how many drops of soap are needed to produce the same amount of suds as the distilled water. Repeat the procedure for each water sample.
3. Repeat the experiment (steps 1-3) using detergent solution instead of soap. Compare the results. Construct a bar graph showing the number of additional drops of soap it took to create suds equal to distilled water for each sample. Use the results as recorded in the data table for the extension activity (step 1).
4. Compare the three graphs.
5. Compare the sudsing abilities of soap and detergent in the different water samples. Which would you prefer to use for general household cleaning?
6. Test the assumption that more suds mean better cleaning. Design an experiment to measure cleaning ability (as opposed to sudsing ability) in hard and soft water.

Total Dissolved Solids (TDS) in parts per million (ppm)