pH Test #3: Rain, Surface, Ground Water (From a series of 5)

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

Grade Level: all

Duration: 30 minutes

Setting: lab, classroom, outdoor field trip to local stream or wetland

Summary: Students test the pH and/or alkalinity and/or hardness of rainwater in their area and compare it to surface water, groundwater, and bottled spring water samples.

Objectives: Students will learn about the pH levels of rain, surface water, groundwater, and bottled spring water, and learn about the relationship between geology and pH.

Related Module Resources:
- "pH Test #1, #2, #4, #5"
- "Acid Buffering Capacity"
- "Hardness Comparisons"
- HANBOOK: p. 57-63; 91-97
- FIELD MANUAL: p.33-35
- pH Information/Fact Sheet
- Interactive pH Scale Poster
- Alkalinity Info./Fact Sheet

Vocabulary: pH, neutral, acidic, basic, acid rain, dissociate, alkalinity, hardness

Materials (Included in Module):
- pH measuring device – pH paper, meter or Hach pH kit (kit will take longer)
- geologic maps

Additional Materials (NOT Included in Module):
- rain water collection container (use anything that is clean)
- distilled water
- water from a local body of water

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.

4.3.7.A Identify environmental health issues.
- Identify various examples of long-term pollution and explain their effects on environmental health

4.3.7.B Describe how human actions affect the health of the environment.
- Explain how acid deposition can affect water, soil and air quality

10th Grade
4.1.10.E. Identify and describe natural and human events on watersheds and wetlands.
- Identify the effects of humans and human events on watersheds.

4.3.10.B Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices.
- Explain how human practices affect the quality of the water and soil

12th Grade
4.1.12.C Analyze the parameters of a watershed.
- Interpret physical, chemical and biological data as a means of assessing the environmental quality of a watershed

4.3.12.A. Analyze the complexity of environmental health issues.
- Identify invisible pollutants and explain their effects on human health.

BACKGROUND: (read other pH activities for more extensive background information).

Water (H_2O) contains both hydrogen ions (H^+) and hydroxyl ions (OH^-). **pH** is a measure of the concentration of free hydrogen ions, which will indicate whether a solution is acidic or basic. The values for pH are arranged on a scale from 0 to 14. A pH of 7 indicates the solution is **neutral** and the concentration of H^+ is equal to the concentration of OH^-. Values of pH less than 7 are considered **acidic** (more H^+ are present, less OH^-). Values of pH greater than 7 are considered **basic** (less H^+ are present, more OH^-).

The pH test is a common test conducted by scientists to help determine if water is being polluted and is healthy enough to sustain aquatic life. The acid levels in rain have been a long time concern by scientists because acid rain can have damaging affects once it reaches land surfaces.

Natural, uncontaminated rain water is generally somewhat acidic, with a pH of about 5.6. This acidity is due to the natural dissolving of carbon dioxide (CO_2)

in precipitation (H_2O) to form carbonic acid (H_2CO_3). The extra hydrogen ions are produced when the carbonic acid **dissociate**s (breaks apart) producing H^+ and bicarbonate HCO_3^-. If the pH of precipitation is lower than normal rainwater (5.6), then it is labeled **acid rain**.

Because of human activity, we have increased the acidity of some precipitation. Fossil fuel burning, industrial processes, and automotive exhausts have added the atmospheric pollutants of sulfur dioxide (SO_2) and nitric oxide (NO_x). Through a reaction with atmospheric water, these chemicals are changed into sulfuric acid (H_2SO_4) and nitric acid (HNO_3), which are the chemicals in acid rain. Both of these acids can dissociate (break apart) to produce extra hydrogen ions and lowering the pH of the rain and any creeks that the rain enters. It can also return to the earth as other forms of wet deposition (sleet, or snow) or dry deposition (dust particles).

The rain that falls in Pennsylvania averages a pH between 4.0 and 4.5. The most acidic precipitation in the United States centers on Pennsylvania, Ohio, and New York. The Pennsylvania Fish and Boat Commission claims the Pennsylvania receives more acid rain than any other U.S. state. Why is this? Pennsylvania is downwind of and is part of the industrial belt of the country – the big cities along the Great Lakes like Chicago, Detroit, Cleveland, and inland cities in Ohio, Illinois, Indiana, and Pennsylvania. Pittsburgh is also part of this industrial belt. These cities emit air pollutants that create acid rain, and Pennsylvania is in the downwind weather patterns containing this rain.

Rainwater can react with more than just the pollutants described above. Sometimes it can react with substances that will reverse or combat the acidity process. This acid buffering capacity is called **alkalinity**, which has an information sheet later in the handbook. The source of alkalinity is usually our geology, so whether or not acid rain is a problem to streams depends on the rocks and soil of a region. The amount of carbonate (CO_3^{-2}) and bicarbonate (HCO_3^-) in water helps to determine its alkalinity. The more of these present, the better chance the water has to resist a change in pH (called alkalinity). Bicarbonate can react with free hydrogen ions to create carbonic acid (H_2CO_3), raising the pH. The carbonic acid can also react with calcium carbonate ($CaCO_3$), which is a component of limestone and sandstone rocks in Pennsylvania, or magnesium carbonate ($MgCO_3$), which makes up dolomite rock. After a few more reactions, additional free hydrogen ions in the water will be used up (raising or maintaining the pH) (see the Alkalinity Information Sheet in the handbook for a much more detailed explanation). Luckily, most of Western Pennsylvania rocks, bedrock, and soil contain calcium carbonate and magnesium carbonate, which can neutralize/buffer the acid (get rid of the extra hydrogen ions).

Because of this geology influence on our water and because water readily dissolves substances, much of Western Pennsylvania's surface and groundwater tends to have a characteristic called **hardness**. 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. They can be found in the water because the buffering reactions described above will yield these ions as a by-product. So water that has been in contact with Western Pennsylvania rocks and deeper bedrock will often have hardness. Water that has not been in contact with the geology (such as rain) will be much lower in hardness.

OVERVIEW: Students test the pH and/or alkalinity and/or hardness of rainwater in their area and compare it to surface water, groundwater, and bottled spring water samples.

PROCEDURE:

Teacher Preparation:

1. Rinse a rainwater collection container with distilled water (any empty jar, bucket, plastic container, or cake pan will do). Leave it outside to collect rainwater. Keep it from under a roof or away from any roof edges.

2. Obtain the following other water samples: surface water (creek, lake, wetland, small stream), groundwater (this could be well water from a private well or municipal tap water if obtained from groundwater sources), and bottled spring water (from module or store). It makes it interesting if you have different kinds / locations of the above.

Student Experiment:

1. There are two options. You can place all kinds of water samples out in labeled containers/cups and have students just do chemical tests on them and record and compare results. Or you can put them out in unlabeled, numbered containers and have an answer key correlating to the numbers. If they are unlabeled, the students have to try to figure out what the mystery samples are based on the chemical test results. They try to determine which sample is rainwater and where the other samples may be from based on options you give them. (ie. one is normal rainwater, one is acid rain, one is groundwater, one is French Creek, one is a small spring).

2. Divide students into groups. Depending on time and the focus you want to take, have students conduct pH tests, and/or alkalinity and/or hardness tests on the water samples. Feel free to keep them focused strictly on pH parameter. Use the instruction sheets for these tests found in the Instruction Sheets Section of the Module Resource Guide. Groups can either test all the samples or test just one and then consolidate data as a class.

3. Have students record their data for each labeled sample or mystery sample. They can make educated guesses on the source of each mystery sample after all data has been collected. You may want to review geologic maps of Pennsylvania to facilitate the decision-making.

4. EXTRA NOTE: If you use bottled spring water from New York or New England states or Quebec, you may get some very different results. Because these regions have more igneous rocks and less sedimentary rocks, they are lower in pH, alkalinity, and hardness than Western Pennsylvania water. Having water from one of these locations may make it difficult for students to explain results, but it is a very good discussion opportunity pertaining to the influence of geology on water.

DISCUSSION:

Have students research what the pH of "normal rain" is? *(pH around 5.6)* Ask them to explain why the pH of normal rain is acidic. *See background section.*

What was the pH of the collected rainwater? Was it acidic? More acidic than normal rain? What might be causing this acid rain? *See background section*

Is all of our rain in the Western Pennsylvania always acidic (below 5.6)? *No. Pollution levels always change and acid rain may not always be produced. In addition, area near Lake Erie may receive "lake effect" precipitation drawn mainly from more local lake waters and not having mixed with as much pollution from the country's entire industrial belt region.*

Relate the pH of your local body of water to the rainwater. How might the rainwater be affecting the pH of the water in the stream or wetland? *It could increase the acidity of the waterway (adding extra hydrogens) unless the stream has good alkalinity (buffering capacity). Waterways may not be affected by this acidic rain if the geology in the watershed contains a lot of acid-neutralizing rocks containing* $CaCO_3$. *This type of region has high alkalinity (ability to resist changes in pH). However, a region void of this type of rock and low alkalinity can have streams that are damaged by acid rain. For example, the Adirondack region in New York has rocks and streams that are unable to neutralize the acid rain; as a result, widespread fish kills have occurred because the streams are acidic.*

Which types of waterways would be most affected by an acid rain event - a small headwater stream or a large river, etc.? Why? *A small stream could be more affected from a precipitation event causing an acid spike – where the acid rain washes directly into the stream without being buffered any. In a large water body, the rain event would be more diluted and have less impact. However, small streams often have more alkalinity (buffering capacity) then large rivers – read to Alkalinity Information Sheet to find out why.*

Why did rainwater not have high hardness and alkalinity values? *The source of alkalinity and hardness is usually our geology, so if water, such as rain, has not been in contact with rocks and soil, then it will not have dissolved substances in it that provide alkalinity and hardness.*

Why would a sample of spring water or groundwater from upper New York State be low in alkalinity and hardness? *It is a region that has more igneous rocks and less sedimentary rocks, so there is less calcium carbonate and magnesium carbonate available to react with acid inputs.*

EVALUATION:

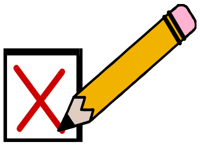
- Recognize that normal rain is slightly acidic and why that is.
- Give some of the expected pH, alkalinity, and hardness levels of rainwater, surface water, and groundwater for Western Pennsylvania.
- Explain why groundwater or water from a small spring contain higher pH and alkalinity levels than rainwater.

EXTENSIONS AND MODIFICATIONS:

- Test the pH of the water in a local stream or wetland both before and after it rains to see if it has changed.
- Have student research the geology of the area and learn more about how it interacts with/affects acid rain and surface water.
- Monitor rain for its pH levels throughout the school year.

NOTES (TEACHERS, PLEASE WRITE ANY COMMENTS ABOUT THIS ACTIVITY BELOW):

Activity Version: October 2001



DATA SHEET: pH TEST #3 - Rain, Surface, Ground Water

Student Name____________________________________ Date______________

SAMPLE	**pH**	**Alkalinity (mg/L)**	**Total Hardness (mg/L)**	**Calcium Hardness (mg/L)**	**Magnesium Hardness (mg/L)**
			To convert grains per gallons (gpg) to mg/L, multiply by 17.1. 1 grain per gallon (gpg) = 17.1 mg/L		

NOTES: