Acid Rain: Demonstrating the Acid Rain Phenomenon (Teacher’s Guide)
OVERVIEW

Students will study the variation of water acidity due to carbon dioxide dissolution. Using straws, students will blow into a volume of water and visualize their results in real time using the Ward’s DataHub software. After that, they will use tools for graph analysis to document and analyze the results.

MATERIALS NEEDED

Ward’s DataHub
USB Cable Connector*
Beaker
Ward’s DataHub pH Probe
Straw(s)
Distilled Water

* The USB cable connector is not needed if you are using a Bluetooth enabled device.

NUMBER OF USES

This demonstration can be performed repeatedly.
### Dimension 1: Science and Engineering Practices

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Use mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

### Dimension 2: Cross Cutting Concepts

- Patterns
- Cause and effect: Mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: Flows, cycles, and conservation
- Structure and function
- Stability and change

### Dimension 3: Core Concepts

- Earth and Space Science
  - ESS2: Earth’s Systems
  - ESS2.D: Weather and Climate
  - ESS3: Earth and Human Activity
  - ESS3.C: Human Impacts on Earth Systems

### NGS Standards

- Middle School Standards Covered:
  - MS.ESS-WC: Weather and Climate Systems
- High School Standards Covered:
  - HS.ESS-CC: Climate Change
  - HS.ESS-HS: Human Sustainability

### National Science Education Standards © 2002

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and Function

### Earth and Space Science Standards

- Middle School
  - Structure of the Earth System
  - Earth’s History
  - Earth in the Solar System
- High School
  - Energy in the Earth System
  - Geochemical Cycles
  - Origin and Evolution of the Earth System
  - Origin and Evolution of the Universe

 Indicates Standards Covered in Activity
LEARNING OBJECTIVES

Core Objectives (National Standards):

- Develop the ability to refine ill-defined questions and direct to phenomena that can be described, explained, or predicted through scientific means.
- Develop the ability to observe, measure accurately, identify and control variables.
- Decide what evidence can be used to support or refute a hypothesis.
- Gather, store, retrieve, and analyze data.
- Become confident at communicating methods, instructions, observations, and results with others.

Activity Objectives:

The purpose of this activity is to investigate the effects of acid rain as a forerunner to water acidity, create a hypothesis, and test the hypothesis, using the Ward’s DataHub pH-meter sensor.

Time Requirement:

30-45 minutes
VOCABULARY

Acid Deposition: The input of acid from the atmosphere to the Earth's surface. Includes acidic precipitation, clouds, fog, particles, and gases.

Acidic: Any of a class of compounds that form hydrogen ions when dissolved in water, and whose aqueous solutions react with bases and certain metals to form salts.

Acid Rain: Rain with acids that form in the atmosphere when industrial gas emissions (especially sulfur dioxide and nitrogen oxide) combine with water.

Carbon Dioxide: A colorless, odorless gas that is present in the atmosphere and is formed when any fuel containing carbon is burned.

Clouds: A visible body of very fine water droplets or ice particles suspended in the atmosphere at altitudes ranging up to several miles above sea level.

Combustion: The process of burning.

Ion: An atom or molecule with a charge.

Nitric Acid: A type of acid that forms in the atmosphere from oxides of nitrogen.

Nitrogen: A nonmetallic element that makes up about 78 percent of the atmosphere by volume, occurring as a colorless, odorless gas.

Precipitation: A form of water, such as rain, snow, or sleet, that condenses from the atmosphere, becomes too heavy to remain suspended, and falls to the Earth's surface.

Scrubber: A pollution control device that uses water or a solution to purify gases coming from a factory, power plant, etc.

Sulfuric Acid: A type of acid formed in the atmosphere from sulfur dioxide.

Sulfur Dioxide: A colorless, poisonous gas or liquid with a strong odor. It is formed naturally by volcanic activity, and is a waste gas produced by burning coal and oil.

Watershed: An area or ridge of land from which runoff drains into a given river, river system, lake, etc.
INTRODUCTION

In our modern society, fossil fuels are used in numerous aspects of our daily life, including operating vehicles, producing electricity, heating, and industry. A large amount of particulate pollutants are released into the atmosphere because of the combustion of these types of fuels. This contamination can be transported long distances by wind and/or it can become concentrated in defined spaces.

Ask students:

- Have you ever seen or heard about smog, the gray layer above some cities?
- What environmental effects are produced from emissions from fossil fuel combustion?

After completing this activity, students should be able to answer the following question:

- What directly determines the pH of acid rain?
BACKGROUND

The gases (nitrogen oxides, sulfur dioxide and carbon dioxide) produced by fossil fuels burning mainly react in the atmosphere with water and oxygen. The result is an acid solution that, when it falls as water, is called acid rain. Deposition of these compounds also occurs in wet environments where fog is present. The majority of lakes and streams have a pH between six and eight, a range essential to sustain an appropriate habitat for plants and animals.

Acid rain mainly affects watershed ecosystems, because the basin soils are unable to neutralize new loads of acidity. The addition of acidic compounds to the ground and water supply has a direct impact on plants and animals. Many forests are highly sensitive to acid variation from soil to air humidity, resulting in detrimental effects such as the direct destruction of leaf tissue and reduced growth of roots. Animals, fish and amphibians are affected mainly at the primary and juvenile stages, with data showing that at pH 5, the majority of fish eggs cannot hatch, and at lower pH levels, adult fish die.

Acid rain also accelerates the decay of buildings of all types, which is of particular loss to mankind when culturally relevant sculptures and architectural monuments are affected.

At this point, encourage students to formulate a hypothesis to test as part of this activity. Students may find it helpful to formulate their hypothesis as an answer to the following question.

- How will the water pH change by direct CO$_2$ exposure?

Then have students begin the activity.
CONNECTING THE WARD’S DATAHUB TO A COMPUTER

If you are using a Bluetooth communication device:
Right click on the Bluetooth icon in the lower right corner of the screen and select the Ward’s DataHub you are using. The icon will change from gray to blue, as shown at right, indicating that the Ward’s DataHub and the computer are now connected.

If you are using a USB communication device:
In order to use USB communication, connect the Ward’s DataHub and the computer with the USB cable supplied. Click on the USB icon at the lower right corner of the screen. This icon will change from gray to blue, as shown at right, indicating that the Ward’s DataHub is connected to the computer via USB.

USING THE WARD’S DATAHUB

= Select key  = On/Off and Escape key  = Scroll key

To collect measurements with the Ward’s DataHub, it must first be configured as follows:

1. Turn on the Ward’s DataHub by pressing the On/Off/Esc key.

2. Go to setup by using the Scroll key; then select Setup by pressing the Select key.

3. Select the Set Sensors option by pressing the Select key.

4. If any sensor(s) appear on the screen, press the key representing that sensor to deactivate it. Once you have a blank window, press the pH Sensor key once.

5. Press the On/Off/Esc key once to return to the setup menu.

6. Press the Scroll key to highlight the Sampling Rate and then press the Select Key.

7. Use the Scroll key until “1/Sec” is highlighted, then press the Select key.

8. Press the On/Off/Esc key to return to the setup menu.

9. Press the Scroll key to highlight the Number of Samples and then press the Select Key.

10. Press the Scroll key until “1000” is highlighted, then press the Select key.

11. Press the On/Off/Esc key three times to return to the main operating screen.

12. Press the Select key to start measuring. (You are collecting data when there is an icon of a runner in the upper left hand corner of the screen.)

13. Once you have finished measuring, stop the Ward’s DataHub by pressing the Select key, followed by the Scroll key.
ACTIVITY

1. Pour 50 mL of distilled water in a beaker.
2. Place the pH sensor into the beaker so that it does not touch the sides or the bottom of the beaker.
3. Begin taking measurements; after a few seconds, record the initial pH of the water.
4. Using a straw, blow into the water for one minute, while continuing to take measurements of the pH.
5. After you have finished blowing into the water for a minute, continue to measure the pH of the water for another minute; then stop the Ward’s DataHub.

RESULTS AND ANALYSIS

Note: A sample graph is shown below.

1. Select the line graph from the Ward’s DataHub menu to show the experimental results.
2. Using the tool, label part of the curve to indicate each stage of the experiment.
3. Using the markers, show pH values from the initial and final stages.
4. Analyze your graph.
   - Was your hypothesis proved? Explain.
   - What effect was caused by blowing air into the water?
   - What happened to the pH of the water when you stopped blowing into it?

DID YOU KNOW?

In 1971 the EPA set new limits on the amount of sulfur dioxide emissions, the main contributor to acid rain. To help meet these new limits, the Clean Air Act of 1977 required that all new factories and power plants install smokestack scrubbers to remove sulfur dioxide from the exhaust before it entered the atmosphere. In 1990 further revisions were made to the Clean Air Act under the acid rain program. According to the EPA, sulfur dioxide emissions in 2001 were 33% lower than in 1990, and 5% lower than in 2000.
CONCLUSIONS AND ASSESSMENTS

1. Based on this experiment, what factor(s) affect the decrease in the pH of the water? **Defend** your answer, using **evidence** from the experiment.

   Students should point out that the pH decreases due to dissolution of carbon dioxide in water. The decreases in pH are directly related to available CO₂ (affected by how much air was blown into the water, either by time and/or volume.)

2. Why didn't the pH reach the original value after the experiment? **Explain** your answer.

   Students should infer from the experiment that the dissolved carbon dioxide reacts with water and oxygen which comes from the blown air, producing a carbonic acid solution.

3. How does this experiment relate to what happens on Earth with respect to acid rain? Cite **examples**.

   Students should indicate that the acidification of water due to dissolved CO₂ as a result of the experiment is similar to atmospheric dissolution of industrial gases. It is important to relate the acidity degree to the concentration of this kind of pollution.

4. Write a **concluding** paragraph describing what you observed during the experiment.
DID YOU KNOW?

Aside from the effects that acid rain has on lakes and streams, it also damages forests, especially those in higher elevations. The soil becomes depleted of essential nutrients and aluminum builds up. This prevents trees from taking up the required amount of water, causing the leaves and needles to fall off the trees.

ACTIVITIES FOR FURTHER APPLICATION

The aim of this section is for students to extrapolate the knowledge acquired during this class and apply it to different contexts and situations. Additionally, it is hoped that students will question and present possible explanations for the experimentally observed phenomena.

1. How would you evaluate the atmospheric contamination level in your city?

   Students could propose collecting some samples of rain over a period of time in their city and measure the water acidity. They could plan to compare the pH values of samples taken right after it rains and also after a long dry period, and the periods between a rainfall and a dry period.

2. What actions could help prevent and/or reduce acid rain?

   Students could suggest limiting the amount of industrial emissions and promoting alternative energy sources. Other suggestions might include, cleaning smokestacks and pipes, turning devices off when they are not in use, better insulating homes to avoid excessive heating or cooling system use, etc.
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What environmental effects are produced from emissions from fossil fuel combustion?

After carrying out this experiment, you should be able to answer the following question:

What directly determines the pH of acid rain?
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13. Once you have finished measuring, stop the Ward’s DataHub by pressing the Select key, followed by the Scroll key.

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ACTIVITY

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Was your hypothesis proved? Explain.

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What effect was caused by blowing air into the water?

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3. How does this experiment relate to what happens on Earth with respect to acid rain? **Cite examples.**

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4. Write a **concluding** paragraph describing what you observed during the experiment.

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