Experiment
12

PRELIMINARY ACTIVITY FOR Soil and Acid Precipitation

Acid precipitation can be very harmful to the environment. It can kill fish by lowering the pH of lakes and rivers. It can harm trees and plants by burning their leaves and depriving them of nutrients. In addition, it can weather away stone buildings and monuments.

Carbon dioxide, CO_2, is a gas found naturally in the air. When CO_2 dissolves into water, it produces a weak acid called carbonic acid, H_2CO_3. This makes precipitation slightly acidic naturally. Precipitation of pH 5 to 6 is common and does not generally cause any problems. Oxides of sulfur and nitrogen released into the air by fossil fuel burning power plants, various industries, and automobiles dissolve into atmospheric water to form acids such as H_2SO_3 (sulfurous acid), H_2SO_4 (sulfuric acid), HNO_2 (nitrous acid), and HNO_3 (nitric acid). The resulting precipitation can be as acidic as pH 4, precipitation with a pH below 5.6 is generally considered to be “acid precipitation.” Figure 1 shows precipitation pH in the United States in a typical year. Notice that the most acidic precipitation occurs over and downwind of heavily populated and industrialized areas.

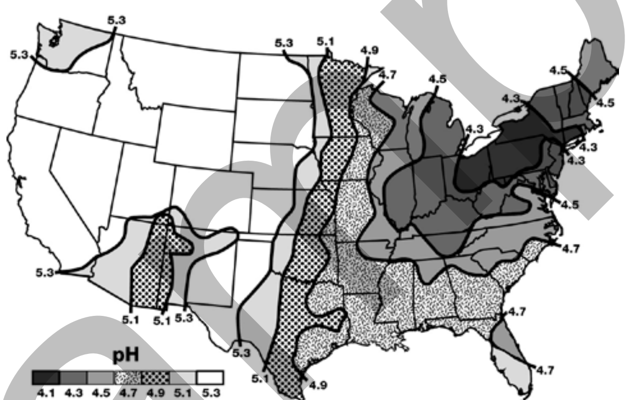

Figure 1

Acid precipitation is not problematic in all locations. Some soils contain substances that will help neutralize acid precipitation. These substances, called *buffers*, are commonly composed of limestone, calcium carbonate, or calcium bicarbonate. The buffers help stabilize soil pH and, because they dissolve into water runoff, they help stabilize the pH values of surrounding lake, stream, and pond waters as well.

In the Preliminary Activity, you will use a pH Sensor to measure the pH of acid rainwater. You will then filter the acid rainwater through soil, collect the resulting filtrate, and measure the filtrate pH as you determine the soil’s influence on acid rainwater pH.

After completing the Preliminary Activity, you will first use reference sources to find out more about acid precipitation, soil pH, and soil buffering capacity before you choose and investigate a researchable question. Some topics to consider in your reference search are:

- acid precipitation (acid deposition)
- soil pH
- buffers
- soil buffering capacity

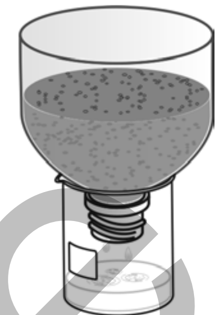

Figure 2

PROCEDURE

1. Connect the pH Sensor and the data-collection interface.
2. Thoroughly rinse the pH Sensor with distilled water.
3. Obtain 100 mL of acid rainwater in a beaker.
4. Measure the pH of the acid rainwater.
   a. Place the tip of the pH Sensor into the acid rainwater. Make sure the glass bulb at the tip of the sensor is covered by the water. Stir gently.
   b. Note and record the pH value when the reading stabilizes.
5. Prepare the soil.
   a. Set the funnel (top half of milk jug) on top of the beaker as shown in Figure 2.
   b. Place a coffee filter in the funnel.
   c. Add 50 g of soil to the filter. Make sure the soil is covering the bottom of the filter but do not pack it down.
6. Slowly pour the 100 mL of acid rainwater you just tested over the soil in the filter.
7. When the rainwater has filtered into the beaker, measure and record the pH of the filtrate.

QUESTIONS

1. What was the pH of the acid rainwater before it was filtered through soil in the Preliminary Activity? What was its pH after filtering?
2. Calculate the pH change.
3. List three or more factors that affect the ability of soil to buffer acid precipitation.
4. List at least one researchable question for this experiment.

Soil and Acid Precipitation

Experiment 12

OVERVIEW

In the Preliminary Activity, your students will use a pH Sensor to measure the pH of simulated acid rainwater sample. They will then filter the acid rainwater through soil, collect the resulting filtrate, and measure the filtrate pH as they determine the soil's influence on acid rainwater pH.

During the subsequent Inquiry Process, your students will first learn more about acid precipitation, soil pH, and soil buffering capacity using the course textbook, other available books, and the Internet. They will then generate and investigate researchable questions.

LEARNING OUTCOMES

In this inquiry experiment, students will

- Identify variables, design and perform the experiment, collect data, analyze data, draw a conclusion, and formulate a knowledge claim based on evidence from the experiment.
- Use a pH Sensor to measure the pH of simulated acid rainwater.
- Identify problems caused by acid precipitation.

CORRELATIONS

AP Environmental Science Topic Outline Correlation

For the most up-to-date AP correlations, see www.vernier.com/ap

IB Environmental Systems and Societies Syllabus Correlation

For the most up-to-date IB correlations, see www.vernier.com/ib

THE INQUIRY PROCESS

Suggested time to complete the experiment

See the section in the introduction, Doing Inquiry Experiments, for more information on carrying out each phase of an inquiry experiment.

I	Preliminary Activity	35 minutes
II	Generating Researchable Questions	15 minutes
III	Planning	15 minutes
IV	Carrying out the Plan	60 minutes
V	Organizing the Data	10 minutes
VI	Communicating the Results	15 minutes
VII	Conclusion	10 minutes

MATERIALS

Make the following materials available for students to use. Items in bold are needed for the preliminary activity.

data-collection interface
data-collection program
Vernier pH Sensor
wash bottle and distilled water
acid rainwater
100 mL graduated cylinder
two 250 mL beakers
soil sample
balance
coffee filter
funnel (top half of milk jug)
others as requested by students

I Preliminary Activity

This inquiry begins with an activity to reinforce prior knowledge of the use of Vernier data-collection technology and to introduce a method for collecting pH data. Students should use the auto-ID data-collection settings that are loaded when an auto-ID pH Sensor is connected to a data-collection interface. If you are using non-auto-ID pH Sensor, you may need to tell the students how to set up the data-collection program.

Sample Results

Table 1: Preliminary Activity Results	
pH of rainwater before filtering through soil	4.2
pH of rainwater after filtering through soil	7.1
Change in pH of rainwater	2.9

Answers to the Questions

1. Answers will vary. In the Sample Results shown above, the pH of the acid rainwater was 4.2 before it was filtered through the soil sample. After filtering its pH was 7.1.

2. Answers will vary. In the Sample Results shown above, the pH change was 2.9.

3. Some factors that affect the ability of soil to buffer acid precipitation are:
    - the soil's organic and mineral content
    - the soil's physical properties such as density and particle size
    - the pH of the acid precipitation events
    - the duration and frequency of acid precipitation events
4. Answers will vary. See the Researchable Questions list below for some possible answers.

II Generating Researchable Questions

See page xiii in the Doing Inquiry Experiments section for a list of suggestions for generating researchable questions. Some possible researchable questions for this experiment are:

- How is the ability of soil to buffer acid precipitation affected by soil type?
- How is the ability of soil to buffer acid precipitation affected by repeated exposure to acid precipitation?
- How is the ability of soil to buffer acid precipitation affected by duration of exposure to acid precipitation?
- How is the ability of soil to buffer acid precipitation affected by the pH of acid precipitation?
- How is the ability of soil to buffer acid precipitation related to soil pH?
- How is the ability of soil to buffer acid precipitation related to soil depth?
- Can the ability of soil to buffer acid precipitation be depleted?
- How does the addition of lime affect the ability of soil to buffer acid precipitation?
- How does fertilizer affect the ability of soil to buffer acid precipitation?

There are many more possible researchable questions. Students should choose a researchable question that addresses the learning outcomes of your specific standards.

III Planning

During this phase students should formulate a hypothesis, determine the experimental design and setup, and write a method they will use to collect data. Circulate among the student groups asking questions and making helpful suggestions.

IV Carrying out the Plan

During this phase, students use their plan to carry out the experiment and collect data. Circulate among the student groups asking questions and making helpful suggestions.

V Organizing the Data

See page xiv in the Doing Inquiry Experiments section for suggestions concerning how students can organize their data for their inquiry presentations.

VI Communicating the Results

See page xv in the Doing Inquiry Experiments section for a list of inquiry-presentation strategies.

VII Conclusion

See page xv in the Doing Inquiry Experiments section for a list of suggestions concerning assessment and ways to utilize the results in subsequent instruction.

SAMPLE RESULTS

Student results will vary depending on experimental design.

Table 2: The Effect of Soil pH			
Soil pH	Filtrate pH	Rainwater pH	Δ pH
7.9	7.9	4.2	3.7
7.4	7.1	4.2	2.9
7.0	6.8	4.2	2.6
6.4	6.5	4.2	2.3
5.0	5.9	4.2	1.7
4.0	5.3	4.2	1.1
3.3	4.5	4.2	0.3

This investigation addresses the question, "How is the ability of soil to buffer acid precipitation related to soil pH?" In this study, pH change upon the addition of acid rainwater increased as soil pH increased. Soil pH was determined using techniques presented in Experiment 10, Soil pH.

Table 3: Effects of Repeated Exposure to Acid Precipitation				
	Clay rich soil with soil pH 7.0		Mountain meadow soil with soil pH 4.0	
100 mL portion of pH 4.2 rainwater added	Filtrate Conductivity (µS/cm)	Filtrate pH	Filtrate Conductivity (µS/cm)	Filtrate pH
1	164	6.8	44	5.3
2	108	7.1	21	5.3
3	59	7.1	19	5.3
4	47	7.0	12	5.4
5	51	7.0	11	5.4
6	42	6.9	12	5.4
7	39	6.8	11	5.4
8	37	6.8	10	5.4
9	40	6.8	10	5.4
10	40	6.6	10	5.4

This investigation addresses the question, "How is the ability of soil to buffer acid precipitation affected by repeated exposure to acid precipitation?" Ten successive 100 mL portions of simulated acid rainwater, with a pH of 4.2, were filtered through a 50 gram sample of clay loam soil, with soil pH of 7.0, and a 50 gram sample of an organic matter rich mountain meadow soil, with a soil pH of 4.0. The pH values of the filtrates were then measured.

The successive pH values of the clay loam soil filtrates decreased slightly, whereas the successive pH values of organic matter rich mountain meadow soil filtrates stayed essentially constant.

Table 4: Buffering Ability *vs*. Soil Depth

Depth (cm)	Soil pH	Filtrate pH	Rainwater pH	Δ pH
2	7.5	7.0	4.2	2.8
15	7.8	7.7	4.2	3.5
30	7.9	7.9	4.2	3.7
75	7.7	7.5	4.2	3.3
200	7.9	7.5	4.2	3.3

This investigation addresses the question, "How is the ability of soil to buffer acid precipitation related to soil depth?" The site chosen had slightly or moderately alkaline soil at the various depths. The soil samples taken at depths of 15, 30, 75, and 200 cm had similar buffering abilities, and the sample from a depth of 2 cm had less buffering ability.

TIPS

Experiment Information

1. You can provide the soil samples for the Preliminary Activity, students can bring samples from home, or they can get samples from the campus grounds.

2. The funnel for this experiment can be made of the top of a gallon milk jug. Alternatively, the top of a 2 L soda bottle can be used.

3. Acid rainwater can be made by adding dilute sulfuric acid to distilled water drop wise until the pH is between 4.0 and 4.5. A dilute sulfuric acid solution (0.10 M H_2SO_4) can be purchased from Flinn Scientific (Order code S0419 for 500 mL of 0.10 M H_2SO_4). To prepare the sulfuric acid solution yourself, dilute 5.6 mL of concentrated sulfuric acid into distilled water to make a total volume of 1.0 L. It should be made available in small dropper bottles. **HAZARD ALERT:** Severely corrosive to eyes, skin and other tissue; considerable heat of dilution with water; mixing with water may cause spraying and spattering. Solutions might best be made by immersing the mixing vessel in an ice bath. **Always add the acid to water, never the reverse**; extremely hazardous in contact with finely divided materials, carbides, chlorates, nitrates and other combustible materials. Hazard Code: A—Extremely hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual,* (800) 452-1261, www.flinnsci.com. See *Appendix H* of this book for more information.

4. Coffee filters work well for this experiment. Fine filter paper tends to clog up too fast.

5. See Experiment 10, Soil pH, for details on determining soil pH.

Sensor Information

1. The stored calibration for the pH Sensor works well for this experiment.
2. The pH Sensor can be stored short term (up to 24 hours) in pH 4 or pH 7 buffer solution. For long-term storage (more that 24 hours) the pH Sensor should be stored in buffer pH 4/KCl storage solution in the storage bottle. The pH Sensor is shipped in this solution. You can prepare additional storage solution by adding 10 g of solid potassium chloride, KCl, in 100 mL of buffer pH 4 solution.
3. A pH 7 buffer solution can be used as a "pH soaking solution" for pH electrodes between trials during this experiment. It can be purchased from chemical supply companies. Vernier Software & Technology sells a package of capsules for preparing buffer solutions of pH 4, 7, and 10 (Order Code PHB). We recommend that you remove the pH Sensor from its storage bottle before class. If the pH Sensor is socking in a beaker pH soaking solution, students will have an easier time taking pH measurements.
4. It is difficult to obtain accurate pH values for distilled water, deionized water, rainwater, soft water, and other low ion strength waters using a pH electrode. These waters do not have enough ions present for pH electrodes to function properly. In these circumstances, pH electrodes respond slowly and readings drift. Better results can be obtained with the use of a pH ionic strength adjuster (pHisa) which adjusts the ion strength of the water without changing the pH. A 7% KCl solution works well as a pHisa adjuster for use with the Vernier pH Sensor. Use five mL of the 7% KCl solution per 100 mL of sample. Hazard Code: D—Relatively non-hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, (800) 452-1261, www.flinnsci.com. See *Appendix H* of this book for more information.

Sensor Check

Here is an easy way to tell if your pH Sensor is working correctly.

1. Remove the sensor from the storage solution and rinse with distilled water.
2. Place the pH Sensor in a pH buffer of known strength and check the pH reading. If no buffers are available, try it in vinegar (~ pH 2.5–3.5) and ammonia (~ pH 10.5–11.5).

We are grateful to Robyn Johnson for her contributions to this experiment.