Acid Rain Effects

Adapted from: "Where Are the Frogs?" in *Project Wet: Curriculum & Activity Guide*. Bozeman: The Watercourse and the Council for Environmental Education, 1995.

Grade Level: Basic

Duration: 45 minutes

Setting: classroom

Summary: Students will simulate the effect of acid rain on aquatic organisms.

Objectives: Students will be able to describe the characteristics of a healthy lake and one affected by acid rain.

Vocabulary: acid rain, acid deposition, pH scale, neutral, acid, base, nonpoint source, alkalinity, buffering

Related Module Resources:
Additional Module Resources Fact Sheets:
- "Acid Rain in Pennsylvania"
- "Acid Rain"
- "Acid Deposition"
- "USGS Tracks Acid Rain"
- "Canaries and Trout: What's the Connection?"

Materials (Included in Module):
- 32 Organism pH labels with yarn [Acid Rain Effects Module Activity Envelope]
- 4 Limestone signs [Acid Rain Effects Module Activity Envelope]
- 25 Water pH labels with yarn [Acid Rain Effects Module Activity Envelope]
- Game piece originals for Organism pH, Water pH, and Limestone signs

Additional Materials (NOT Included in Module):
- none

ACADEMIC STANDARDS: (ENVIRONMENT AND ECOLOGY)

7th Grade

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.
- Identify residential and industrial sources of pollution and their effects on environmental health.
- Explain how nonpoint source pollution can affect the water supply and air quality.
- Explain how acid deposition can affect water, soil, and air quality.

BACKGROUND:

Acid rain is a form of pollution that is caused primarily by fossil fuel combustion, which releases sulfur dioxide and nitrogen oxides into the air. When these gases react with water and oxygen in the atmosphere, they form a mild mixture of sulfuric acid and nitric acid that falls to the ground with precipitation. Acid rain is the common name for **acid deposition**, which includes both wet (e.g. rain, snow, and fog) and dry (e.g. gas and particulates) forms.

To measure acidity, the **pH scale** is used. The scale runs from 0 to 14, with 7 being **neutral** (neither acidic nor basic). A substance with a pH below 7 is an **acid**, which chemically means that the solution has more hydrogen ions than hydroxide ions. A substance with a pH greater than 7 is a **base**, which chemically means that the solution has more hydroxide ions than hydrogen ions. The pH level is critical to living organisms, especially those living in aquatic environments. Certain pH levels are needed for certain body processes and if the levels change, organisms cannot function.

Rain is naturally acidic; the average pH of rain is 5.6. The pH of rain drops if sulfur oxides and nitrogen oxides mix with atmospheric water vapor forming sulfuric acid and nitric acid. Volcanoes can put these compounds into the air but so can cars and factories that burn fossil fuels. Most forms of transportation depend on some form of petroleum, which creates nitrogen oxides when burned.

Many power plants burn coal to generate energy and coal releases both sulfur dioxide and nitrogen oxides. When the sulfur dioxide and nitrogen oxides reach the upper levels of the atmosphere, they react with water and oxygen to form acid rain. Here, the global winds are able to carry the acidic precipitation far from its source. This means that acid rain is considered a **nonpoint source** of pollution: it is nearly impossible to trace it back to its original source, especially since in the case of acid rain, it has numerous sources from a widespread area.

Because of this phenomenon, acid rain is of special concern here in the northeastern United States. The most acidic rain in the U.S. is in Pennsylvania (average pH of rainfall 4.1), Ohio, and New York. These states are downwind of the big industrial cities in Illinois, Michigan, Indiana, Ohio, and Pennsylvania (including Pittsburgh). The industries found in these cities contribute many of the air pollutants that create acid rain.

Besides eating away at buildings and statues, acid rain yellows and damages plant leaves, and alters soil chemistry making nutrients unavailable to plants. Bodies of water such as streams, lakes, and ponds may have their pH lowered so much that life inside them dies. For most organisms, the lowest tolerable pH is 5.0. Nymphs and larvae of insects along with young fish are especially sensitive to any pH below 5.0. Two major problems may result from a low pH level. First, a low pH causes an imbalance in the sodium and chloride ions found in animals' blood; extra hydrogen ions are taken in while sodium ions are expelled. An animal's body cannot withstand this change in blood chemistry. Secondly, toxic metals like aluminum and copper, become available in the water at low pH levels. These metals clog fish gills, harming the breathing process, and causing deformities in young fish. If the metals settle on the bottom of streams, insects lose habitat and their eggs may be smothered. The following chart lists a few aquatic organisms and their preferred pH range.

Organisms	**Preferred pH Range**
Aquatic plants (algae and rooted)	6.5 to 12.5
Carp, suckers, catfish, some insects	6 to 9.5
Bluegill, crappie	6.5 to 9.5
Snails	7 to 10
Stonefly nymphs, caddisfly larvae	7 to 8.5

Once a lake is affected by acid rain, one method to correct the pH is to add limestone to the lake. Limestone and other rocks and soils containing calcium carbonate and magnesium carbonate increase the **alkalinity**, which is the water's ability to neutralize acid by getting rid of the extra hydrogen ions. The alkalinity, and subsequently pH, of water will increase when it flows over or mixes with limestone. This process is also known as **buffering**. Fortunately, most of Western Pennsylvania's soils and rocks have this buffering capacity naturally which lessens the impact of acid rain. The soils and rocks of the Adirondack Mountains in New York, however, lack limestone and do not have this buffering capacity. They cannot buffer acid rain and, as a result, many streams and lakes there have died.

Although it is possible to reduce the effects of acid rain by adding limestone or other alkaline substances to water bodies, it is more efficient and more prudent to stop the creation of acid rain in the first place. The federal Clean Air Act is in place to stop or lower emissions of sulfur and nitrogen oxides. This legislation requires the installation of scrubbers in smokestacks to clean the emissions on their way to the atmosphere. Scrubbers spray a mixture of water and lime down the smokestack causing the sulfur to solidify; the solid can then be removed. Scrubbers can stop more than 90% of the sulfur from entering the atmosphere. Other methods include prewashing the coal before burning it to reduce its sulfur content or burning coals with a lower sulfur concentration. With less sulfur being emitted during combustion, less acid rain is formed.

OVERVIEW:

This is a three-part simulation. Students will become either an aquatic organism or surface water. First, students will simulate a healthy lake in which organisms are able to find a pH that fits within their range. In the second scenario, acid rain enters the lake, lowering the pH to a level that most aquatic organisms cannot tolerate. The final scenario shows what happens when limestone buffers acid rain, preventing the lake's pH from dropping too much.

PROCEDURE:

Teacher Preparation:

1. If space allows, set up the lake ahead of time. Make a circle of desks or chairs that can contain all of the students.

2. Locate the organism pH labels, the water pH labels, and the limestone signs in the module.

Student Activity:

1. Describe two lakes found in the same general area: Lake A is clear and the bottom is easily seen. Lake B is greenish and the bottom cannot be seen. Which lake would be the best for fishing and observing wildlife?

2. What else would be helpful to know before deciding? Answer the student questions based on the following information:

	Lake A	Lake B
Animal Life	None	Six fish species and variety of amphibians (salamanders and frogs) which eat aquatic insects
Plant Life	None	Lots of plants for shelter and food
pH of rainfall	4.5	4.5
pH of lake	4.2	6.3
Surrounding rock type	Granite	Limestone

3. Divide the students into two groups: one group of aquatic organisms that live in the lake and one group of surface water molecules that filter into the lake. (If you do not have an even number, place the extra student in the water group.) Give each organism a pH label, which tells him/her its name and the pH range it is able to survive in. Distribute water pH labels to the water molecule students.

4. Explain that the circle of desks or chairs is the substrate at the edge of the lake. The organisms may get inside the circle while the surface water should spread out along the perimeter of the lake. When given the signal, they will filter through the soil and enter the lake.

5. SCENARIO 1: In this scenario, there is no acid rain. Have the water molecule students make sure that "pH 6.5 (scenario 1)" is showing. Inform students that it has recently rained and the water should move through the desks or chairs to the lake. Organisms should try to find a pH to match their range. (Every organism should find a partner.) Have the water return to the outside of the circle.

6. SCENARIO 2: This scenario occurs in Lake A (the clear lake) and acid rain hits. The water students should flip their cards over to read pH 4.5 (scenario 2). Ask students what they predict will happen. The water should filter through and organisms should try to find a match for their pH range. (Only the yellow perch and water beetle should survive.) What will happen to the rest of the organisms? Collect the pH labels from the water students and have them return to the outside of the circle.

7. SCENARIO 3: The final scenario happens in Lake B (the greenish lake), which also receives acid rain like Lake A. The water students should flip their cards so that they read 4.5 (scenario 3). The same acid rain that hit Lake A hits Lake B. Predict what will happen. Remind students about the differing geologies: Lake A is surrounded by a granite substrate but Lake B is surrounded by a limestone substrate, which acts as a buffer (it reduces the acidity) of acid rain. Place the limestone signs on the desks or chairs. As the water students filter through, they should flip over their pH so that the 6.0 is showing. Aquatic organisms should look for a match. (All organisms should find a partner.)

DISCUSSION:

What caused the death of organisms in this simulation? *The organisms' environment changed when the acid rain occurred. The acid rain lowered to the pH of the lake water to a level below the tolerance range of many organisms. The pH level is important for certain body processes that occur inside organisms.*

Why did most of the organisms die in Lake A but not in Lake B? *The granite surrounding Lake A did not buffer the acid rain so it entered the lake at a low pH of 4.5, too low for most of the organisms to survive in. Lake B was surrounded by limestone, which buffers the acid rain, or makes it less acidic. The pH went from 4.5 to 6.0 as it passed through the limestone.*

What could be done to reduce the effects of acid rain on Lake A? *One solution is to increase the pH by adding limestone to the lake. Limestone contains calcium carbonate, which increases* ***alkalinity.*** *Water mixed with limestone will raise its alkalinity and in turn, its pH*

Explain why a clear, blue lake appears "healthy" but may not be. *A clear blue lake is often appealing to humans; it seems like a good place for a swim, like a swimming pool. Biologically, however, there is probably nothing living in it. When plants are living in the water, it usually gains a greenish tinge. The presence of plants and animals tends to cloud the water due to their activities and body processes.*

How does acid rain affect water quality? *Acid rain lowers the pH of bodies of water with low alkalinity. This can lead to other water quality problems such as toxic metals becoming mobile instead of locked in the sediments as they would at a less acidic pH.*

What are the residential sources of acid rain? *Anything that requires burning fossil fuels such as driving a car and mowing the lawn. If the electricity supply comes from a coal-fired power plant, then any action requiring electricity would also contribute to acid rain formation.*

What are the industrial sources of acid rain? *Anything that requires burning fossil fuels. Transportation of goods usually involves burning some petroleum product. Power plants are a big source as many of them burn coal.*

What do you do in your daily life that contributes to acid rain? What could you do to reduce those contributions? *Answers will vary.*

EVALUATION:

- Discussion questions above.
- On an index card, have students illustrate and/or list the characteristics of a healthy lake. On the other side, do the same for a lake affected by acid rain.
- Students can make a collage that displays the effects of acid rain on living and nonliving (i.e., buildings, statues) things.

EXTENSIONS AND MODIFICATIONS:

- To further investigate buffering, pour liquids with different pH's through calcium carbonate. Measure the pH before and after pouring. This could be contrasted with pouring the same liquids through other types of rocks found in your area.
- Have students research why water beetles and yellow perch survive in Scenario 1 of the activity.

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

MUSSEL pH Range 5.5 to 8
EEL pH Range 5.5 to 8
FROG pH Range 5.5 to 8
BASS pH Range 5.5 to 8

WATER BEETLE pH Range 4.5 to 8
BROOK TROUT pH Range 5.5 to 8
SALAMANDER pH Range 5.5 to 8
CLAM pH Range 5.5 to 8

MAYFLY pH Range 5.5 to 8
SALMON pH Range 5 to 8
CRAYFISH pH Range 5 to 8
YELLOW PERCH pH Range 4.5 to 8

pH 6.5 scenario 1
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pH 6.5 scenario 1

pH 4.5 scenario 2
pH 4.5 scenario 2
pH 4.5 scenario 2
pH 4.5 scenario 2

pH 4.5 scenario 3
pH 4.5 scenario 3
pH 4.5 scenario 3
pH 4.5 scenario 3

pH 6.0 scenario 3
pH 6.0 scenario 3
pH 6.0 scenario 3
pH 6.0 scenario 3

LIMESTONE