How-To-Do-It

Acid Rain: Activities for Science Teachers

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The authors of this article were participants in the Science, Technology and Public Policy program of Carleton College, Northfield, Minnesota 55057. The project was developed as part of a course entitled "Science, Technology and Public Education" taught by Rodger Bybee. Eric Johnson, a former biology teacher, coordinated the project and provided technical assistance for the activities. The other authors were students in the class. We wish to acknowledge the Sloan Foundation and Carleton College for support of this project.

When we try to pick out anything by itself we find it hitched to everything else in the universe.

—John Muir

The activities in this article were designed for use individually, as a supplement to an existing curriculum, or as a complete unit on acid rain. Most activities can be used in grades 7-12. In some cases they may be too complicated for middle/junior high school students. In other cases the activities can be used at any level including colleges. In all cases, science teachers will have to make minor adjustments in terms of their curricula, schools, and students. We decided to organize the activities in a way that represented a good introduction to concepts related to acid rain. The following organization is suggested:

1) Sources of Acid Rain: Sulfur Oxides
2) Effects of Acid Rain: Materials
3) Effects of Acid Rain: Soils
4) Effects of Acid Rain: Seeds
5) Effects of Acid Rain: Life Cycle of Fruit Flies
6) Effects of Acid Rain: Ecosystem
7) Effects of Acid Rain: Local Environments.

Each activity begins with an overview followed by scientific background and societal implications. Next we list major concepts, objectives and vocabulary, then materials and procedures for completion of the activity. Finally, there are questions, discussions, and extensions. There is both a structure and a flexibility for the various lessons.

We found the study of acid rain to be an excellent example of John Muir's quotation. Studying acid rain, one soon finds it is connected to everything from the elements to ethics.

ACTIVITY 1: A SOURCE OF ACID RAIN: SULFUR OXIDES

Activity Overview

A demonstration illustrates possible connections between the sulfur found in most fossil fuels and the acid eventually detected in the precipitation over many parts of the world. The demonstration and discussion takes one-half class period.

Science Background and Societal Implications

An important aspect of the acid precipitation problem is the water incorporation of oxides produced by combustion and subsequent acid formation. The basic chemistry of this process is given below.

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

$$SO_{2(g)} + H_2O_{(l)} \rightarrow \underset{\text{sulfurous acid}}{H_2SO_{3(aq)}} \rightarrow 2H^{+}_{(aq)} + SO^{2-}_{3(aq)}$$

One step which occurs in the atmosphere, not represented by the demonstration, is the oxidation of the sulfur from the plus four to a plus six oxidation state. Whether this occurs in the gaseous state ($SO_2 + 1/2O_2 \rightarrow SO_3$) or after dissolution ($SO_3^{2-} + 1/2O_2 \rightarrow SO_4^{2-}$) is not clear. In any case, it should be mentioned that sulfuric (and not sulfurous) acid actually occurs in acid precipitation.

In the discussion, point out the sources of sulfur dioxide as represented here by the burning of sulfur, sources such as volcanoes, power plants, industry, metal smelting, and transportation. Make the point that the gases (SO_2 or SO_3) can travel long distances before and after dissolving in water, i.e., in clouds.

Major Concepts

- Acid rain forms through the chemical combination of sulfur oxides (and nitrogen oxides) and water;
- Burning fossil fuels is the primary source of sulfur oxides.

Student Objectives

After this activity students should be able to:

- Identify the sources of acid rain;
- Describe the chemical process that produces acid rain.

Vocabulary

acid	fossil fuels
acid rain	sulfur oxides

Materials

- Sulfur 1-2g
- Ordinary clear glass bottle with cork (1 liter is a convenient size)
- Bromcresol purple indicator solution
- Deflagrating spoon
- Bunsen burner

Procedures

**It is advised,and in some states required, that the instructor and students wear eye protection during procedures such as this demonstration involving flame or acid.*

1. If a one liter bottle is being used, add about 200ml of distilled water and 5-6 drops of indictor. The solution should be gray in color indicating a pH of about 6. If this is not the case, a few drops of dilute NH_4OH to a yellow solution or dilute acetic acid to a purple solution will adjust the solution to the proper pH.

2. Fill the deflagrating spoon with sulfur (one gram) and heat over a Bunsen burner until it ignites. Insert the spoon with burning sulfur into the bottle and insert the cork (cut a notch in the cork for the deflagrating spoon).

3. After the sulfur has burned out it may be necessary to swirl the solution in order to dissolve sufficient gas. This occurs in much the same way that a swiftly moving stream will dissolve more oxygen than standing water. The indicator will change to yellow at a pH less than six.

Other Suggestions:

1. Placing white paper under and behind the bottle will make the color change more visible.

2. If oxygen is available, for example from a welding shop, filling the bottle with oxygen and leaving it corked until the burning sulfur is inserted will produce a spectacular effect. The sulfur will burn with an impressive blue flame and will burn much longer than under a normal atmosphere.

Questions, Discussion, and Extension

Review the chemistry involved in the demonstration. Be sure to make the connection between the demonstration and the formation of acid precipitation. Discussion should include natural and anthropogenic sources of sulfur oxides.

Repeat the demonstration adding granite chips one time, limestone chips another time. Point out the influence local rock formations can have on the pH surface waters.

ACTIVITY 2: EFFECTS OF ACID RAIN: MATERIALS

Activity Overview

This demonstration shows the effect of a strong acid on selected materials. The demonstration and discussion take one-half class period.

Science Background and Societal Implications

For as many samples as possible describe the reaction through equations.

Examples:

$CaCO_{3(s)} + H_2SO_{4(aq)} \rightarrow CaSO_{4(aq)} + CO_{2(g)} + H_2O$

limestone

marble

$Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$

The reactions of 3M H_2SO_4 are in some cases quite dramatic. Fortunately, it does not rain 3M (pH O), but rather an approximately 1,000 times more dilute solution. It should be discussed that this more dilute solution will have the same effect given a sufficiently long period of acidic precipitation. You might point out to the students that millions of dollars are spent each year for the restoration of materials corroded due to acid rain.

This demonstration shows the direct effects of sulfuric acid on materials. Sulfuric acid also has the ability to dissolve certain naturally occurring compounds of heavy metals. These heavy metals can, in solution, have their own effects on living organisms. These effects are considered by some to be more harmful to aquatic life than acid precipitation itself.

Major Concepts

- Acids (sulfuric and nitric) have pronounced effects on some materials.

- Acid rain corrodes many human materials such as statues and buildings.

Student Objectives

After this study students should be able to:

- Describe the influence of acids on materials.
- Describe the effects of acid rain on human structures.
- Relate concentration and duration to the extent that acid is harmful.

Vocabulary

concentration	heavy metals
duration	metals

Materials

- 1 - 3M H_2SO_4 in dropping bottles
- Watchglasses, petri dishes, or small beakers
- Various materials—some good choices are: concrete, marble, or limestone; metals such as zinc, aluminum, or copper; paper; fabric (colored and white, cotton and synthetic); and leaves. Also ask students to bring materials of their own.

Procedures

Place samples of the materials in different watchglasses. Drop a few drops of the sulfuric acid solution on the samples. Let stand for several minutes and record any observations.

Questions, Discussion, and Extension

Have the students describe the effects of acid on different materials. During the discussion, review the different levels of pH involved in the acid used as compared to acid rain. Point out the variables of time, materials, and pH in the problem. The activity can be extended by examining the effects of different acids, pH, times, and materials. You can also have the students identify any local materials that may have been corroded due to acid rain. Headstones, statues, and building facades are good places to begin this investigation.

ACTIVITY 3: EFFECTS OF ACID RAIN ON SOIL

Activity Overview

The effects of acid rain on soils are examined by simulating natural conditions in the laboratory. The activity demonstrates the relationship between soils and water and the effects of this relationship on other parts of the ecosystem. The estimated time is two class periods.

Science Background and Societal Implications

As the pH of rainwater is lowered, several reactions take place in the soil. The pH of the soil will decrease as it absorbs the acidic rainwater. Important soil nutrients, such as phosphates, become more soluble and are leached from the soil along with some soil minerals, such as iron, aluminum, and calcium.

The consequences of having these substances in the soil or water vary greatly. Aluminum in water is toxic to plants while phosphorus is a fertilizer. A lower pH in the soil will favor some plants and be detrimental to others.

The water which has been altered by the soil leaching then gets into other areas of the environment. Some will enter the groundwater system while some will run off into streams and rivers. As this water travels it will carry with it chemically altered sediments which will become part of the soil downstream. As the water enters wells and drinking water systems it can contaminate them with the leached minerals.

As the composition of the soil changes, new types of plant communities emerge and crops may be affected, probably requiring more fertilizer to keep the same yields. Streams and rivers are already suffering from greater amounts of dissolved materials. Polluted groundwater affects humans directly when it reaches wells used for drinking. Processing may be required to make contaminated water usable.

Major Concepts

Soils are affected by water which runs over and through them. Water can add to the soil or take nutrients from it through leaching. Some soil nutrients are leached more easily when the pH of the water is lowered.

- Water with leached nutrients and minerals affects other areas of the environment.
- Soil which has been leached is different and has different capabilities than it did before.

Student Objectives

After this activity students should be able to:

- Define soil leaching.
- Describe the effects of chemically altered soils.
- Describe the effects of chemically altered water in various parts of the environment.
- Demonstrate acid rain effects on soils in a laboratory simulation.

Vocabulary

groundwater	nutrients
leaching	soils

Materials

Each student or group of students should have:

- 20 g of sodium phosphate or potassium phosphate
- Stand with dropping pipets or other containers for measuring titration amounts
- Beakers
- Cans with metal screen bottoms which will hold soil, but allow water to pass through
- Ring stand support for cans
- Several liters of water of pH 5.5 and pH 4.0
- Bucket for catching water drained from cans
- Soil samples
- Soil acidity test kit

Procedures

1. In one beaker dissolve about 10 g of phosphate in water of pH 5.5 which is approximately equal to normal rainwater. Record exactly how much water is required to dissolve the sample by reading the pipets.
2. Repeat the procedure from step 1 using water of pH 4.0 instead of pH 5.5 in order to simulate acid rain. Record the amount of water required to dissolve the phosphate.
3. Fill the screen-bottomed can with 5-8 cm of soil. Test the soil acidity.
4. Run water of pH 4.0 through the soil sample until there is a change in the acidity of the soil. The amount of water necessary to effect a change will vary depending on where the soil sample was taken. Soils which have

developed beneath pine trees, for example, will be more acidic than those developed beneath deciduous trees.

5. Note the visible changes in the water which has been run through the soil sample.

Questions, Discussion, and Extensions

After the activity, have the students consider the effects of soil leaching on all parts of the environment including forests, croplands, groundwater, streams and rivers, and areas through which these streams and rivers run. Remember that water which initially affects one area will eventually affect other areas too.

You might discuss how much time would be required to create a change in the soil acidity of your area. Use your data from the experiment and the value for average rainfall in your area.

The activity could be extended in the following ways: The soil sample tests lack a control for the experiment. Differences between normal rainfall and acid rain can be tested by running water of pH 5.5 and water of pH 4.0 through separate samples. Have students gather soils from different areas and compare test results. Soils from forests, lawns, drainage ditches, and various fields of crops may all be different.

Determine phosphate changes over time by first testing to see how much phosphate is in your soil sample with a soil test kit. Then relate that information to your experimental results and your rainfall values.

Perform solubility tests on nitrates or other soil nutrients.

Use the altered soils from your tests in a terrarium and examine changes in plant growth.

ACTIVITY 4: EFFECTS OF ACID RAIN: SEED GERMINATION

Activity Overview

Students investigate the effects of acid rain on seed germination by conducting an experiment with bean seeds, or locally available seed, under varying pH conditions. The estimated time for this activity is one class period to organize groups and set up the experiment. Then, take a few minutes at the start of every other class (for approximately two weeks) to water and measure seed growth, and to record data on individual and class groups. Finally, there should be a class period to summarize results and prepare reports.

Science Background and Societal Implications

The ability of a plant to germinate depends on breaking dormancy which includes: the softening of the protective seed coat, the chemical change of starch to usable sugars, and the stimulation of growth of the young plant. Just like people, plant seeds depend on proper conditions such as temperature, light, and moisture to germinate, grow, and reproduce. Acid rain, however, has the potential to bring about an imbalance of these conditions necessary for seed germination.

Major Concepts

- Seed germination is dependent upon proper conditions of pH.
- Increases of acidity due to acid rain may inhibit seed germination and plant growth.

Student Objectives

After the activity students should be able to:

- Measure the growth of bean seed.
- Record data on an individual graph and on a class graph.
- Draw the bean seed before seed germination and each day that growth measurements are taken.
- Make a bulletin boad display (summary graph) of individual graphs once completed including their final drawing of seed germination.
- Compare data to establish the optimum pH for the germination of a bean seed.

Materials

- Petri dish
- 4 bean seeds (preferably seeds grown locally: alfalfa, pea, bean, etc.)
- Water solutions ranging in pH from 2-7 (boiling will be necessary to drive off CO_2 and raise pH to 7).
- Rainwater (optional)
- Absorbent paper towels
- Transparent metric ruler
- Graph paper
- Colored chalk or magic markers

Procedures

Preparation of bean seed:

1. Assign each student a pH solution to "water" their bean seeds. A couple of students should be assigned distilled or rainwater for a control. The class as a whole should represent increments on a pH scale ranging from 2-7.
2. Cut four paper discs the size of a petri dish from the absorbent paper towel.
3. Dampen the paper discs with appropriate pH or rainwater solution.
4. Place two discs at the bottom of the petri dish.
5. Measure the seeds and average them.
6. Arrange seeds in the petri dish and cover with the two remaining paper discs.
7. Replace lids on petri dish and label with student name.
8. Each student should hypothesize in writing what they believe will be the ideal pH.

Preparation of Graph:

1. Obtain a piece of 8" x 11" graph paper.
2. Set up graph as follows: Horizontal axis, age of seed in days; Vertical axis, length of seed in mm.

Procedures for Alternate Days:

The students will be taking measurements of seed growth and recording data on individual and class graphs.

1. Taking measurements and plotting data on individual graphs:
   a. Remove lid from petri dish.
   b. Sketch the shapes of the four seeds. Note the color of the seeds.
   c. Use transparent ruler to measure the straight length of seeds.
   d. Take the average straight line length increase and plot it on

your graph. (It is important to plot the increase of seed growth because seeds are different lengths before germination takes place.)

e. Make sure paper towel is still moist. If not, add more pH solution (be sure pH solutions are not mixed).

f. Replace lid on petri dish.

2. Class graph: Constructed on chalk board or large piece of white construction paper on visible wall or board and saved throughout experiment.

The graph should use same layout as individual graphs.

a. Assign each pH a particular color (chalk or magic marker).

b. More than one student may be experimenting with the same pH solution. These students should average their results of seed length.

c. Have one student representing each pH record data on the board using code color that represents pH used. (example: a pH of 3 is represented by the color green; a pH of 7 is represented by the color purple).

d. After a few recordings have been plotted, students should draw a line connecting points of the same pH.

Questions, Discussion, and Extension

Have class gather around the completed glass graph. What appears to be the optimal pH solution for successful seed germination and growth? The least ideal? How does the local rainwater used compare to the other pH solutions used? From the data expressed on the class graph, what pH do you think the rainwater has? (Test it!) What impact on local crops might an increased rain acidity have? Do you think there is a reason for concern?

Each student should prepare a report which includes:

a) Brief description and purpose of experiment;

b) Data collected, individual graphs, and seed drawings;

c) Analysis of individual class results:

1) Ideal pH
2) Least favorable pH
3) Comparison of rainwater to other pH solutions.

d) Discussion questions: What impact on local crops might an increased acidity have? Do you think there is a reason for concern?

e) A concrete example of how acid rain and its effect on seed germination could have an effect on food crops grown in the nearest agricultural area.

ACTIVITY 5: EFFECTS OF ACID RAIN: LIFE CYCLE OF FRUIT FLIES

Activity Overview

In this activity the students investigate the effects of varying levels of acid mist on egg, larval, and pupal stages in the life cycle of *Drosophila melanogaster.* The teacher coordinates a research project for which different teams of students accumulate data on aspects of the problem. All the student teams report their results at a scientific meeting. Students are then confronted with the task of summarizing the results across the entire research effort. Finally, there is a discussion of recommendations for other experiments and recommendations based on accumulated data. Estimated time for the project is two weeks.

Science Background and Societal Implications

Concepts relative to acid rain should have been developed prior to this activity. The design of the activity is such that students gain some understanding of scientific investigation using the life cycle of a simple organism and the problem of acid rain.

Some of the problems related to scientific inquiry are modeled in the activity. Design of experiments, separation and control of variables, observing, graphing, and reporting data are all aspects of the activity. There is another dimension that teachers can introduce. Science is an enterprise that accumulates and evaluates new knowledge. And, this is often done at scientific meetings. Having each group of students study one small part of the problem and share their results can help the students gain a better understanding of science.

We have extended the activity beyond the mere reporting of results. Citizens are required to act on the best information available on a given problem. Often the information is not clear, and seldom does it provide all the answers. Students are asked to make recommendations for the control of acid rain based on the available information. Essentially, they are asked to determine harmful levels of acid precipitation for one organism. The lack of clarity of data, the fact that lower phyla organisms were studied, and the weight or strength of evidence in decisionmaking will become evident in the final stages of the activity. The need, ways, and means to monitor problems such as acid rain in order to avoid a large-scale crisis is an important societal implication of the activity.

Major Concepts

- The effects of logarithmic differences in acidity.
- Susceptibility of different stages in the life cycle of fruit flies to acid precipitation.
- Separation and control of variables in scientific experiments.
- The influence of chronic low-intensity changes in the environment.
- Limiting factors in the life cycle.
- Effects of lethal and sublethal doses of a pollutant.
- Science progresses through the accumulation of information.

Student Objectives

After this activity students should be able to:

- Use the processes of scientific investigation, specifically to:
  - —Design an experiment with a suitable control and single variable;
  - —Observe changes;
  - —Record data;
  - —Report data to fellow students;
  - —Analyze significance and limitations of class results;
  - —Suggest the next logical experiment.

SAMPLE STUDENT DATA TABLE-Activity 5

pH = __________

		Egg			Larva				Pupa			Adult—
Day	1	2	3	4	5	6	7	8	9	10	11	12

Egg#				Adult #	% Surviving
_____	Petri Dish	1		_______	_______
_____		2		_______	_______
_____		3	Use X to indicate spraying schedule	_______	_______
_____		4		_______	_______
_____		5		_______	_______

- Use data analysis in making a recommendation on what standards should be set as tolerable limits on acid precipitation.
- Use the *Drosophila* life cycle to represent organisms generally that have varying sensitivity to acid precipitation during their lives.
- Describe observable effects of acid rain on organisms.
- Calculate logarithmic differences in pH scale.
- Identify difficulties in making decisions based on scientific information.

Vocabulary

pH	lethal dose
life cycle stages	control
egg	variable
larva	quantitative data
pupa	lethal
adult	sublethal
viability	scientific meeting

Materials

- Petri dishes—5 per lab group designated as follows:
  Control with no added water;
  Control with pH 7 water (boiled and cooled) sprayed;
  Experimental with assigned pH sprayed during the egg stage;
  Experimental with assigned pH sprayed during the larval stage;
  Experimental with assigned pH sprayed during the pupal stage.
- Nutrient agar prepared with standard materials
- Simple grid to simplify counting
- Stock acid solutions (sulfuric or nitric) of pH 2.6, 3.6, 4.6, 5.6, and 7.0 in plastic spray bottles
- Data tables and graphs drawn by students prior to collecting data

Procedures

(Note: A step-by-step *and* daily sequence are indicated.) We recommend beginning on a Monday, spraying containers through the 13-day life cycle.

Day 0

1. Gather five nutrient-filled petri dishes and label each appropriately (see materials).
2. Introduce a fertilized female *Drosophila* to provide eggs. Leave female in dish for 24 hours.
3. Prepare stock solutions and adjust sprayers to give uniform amounts of mist.

Day 1

4. Remove female *Drosophila* and use grid to help count the number of eggs in each petri dish. Record numbers.
5. Spray appropriate solutions into one control and first experimental petri dish to simulate a light rain.

Days 2, 3

6. Repeat step 5.

Days 4-7

7. Spray appropriate solution into the 2nd experimental petri dish to simulate a light rain.

Days 8-11

8. Spray appropriate solution into the third experimental petri dish to simulate a light rain.

Day 12

9. Count and record the number of adult *Drosophila* in each of the five petri dishes.
10. Divide the number of adult *Drosophila* survivors by the original (day 0) number of eggs to obtain a percentage of survivors under your pH conditions.
11. Have the class simulate a scientific meeting at which each group will report its data and learn about the research of fellow scientists. Report data to class indicating which stage was most affected by your simulated acid rain.
12. Suggest what experiments should be done next to learn more about the effects of acid rain on organisms.

Questions, Discussion, and Extension

The discussion of student work can be based on:

1. A standard lab report.
2. Participation in the scientific meeting.
3. Suggestions on the next steps needed to further study acid precipitation.
4. Participation in an optional second set of experiments based on 3.
5. Extension and elaboration of this study to the scale of a science fair project.

This experimental approach could be expanded in many ways including:

SAMPLE CLASS DATA TABLE-Activity 5

pH	% Egg Survival	% Larval Survival	% Pupal Survival
7			
6.6			
5.6			
4.6			
3.6			
2.6			

1. Use of other species of flora and fauna.
2. Changing a second factor such as temperature or light to test for synergistic effects.
3. Vary the amount or frequency of simulated acid precipitation.
4. Use different acids but the same pH range.
5. Observe organisms daily to note sublethal effects such as differences in activity patterns or levels.
6. Expand the number of acid solutions in the range this experiment shows to be harmful. Try to more specifically pinpoint a critical or lethal concentration for each stage.

Reference

DEMEREC, M., and KAUFMANN. 1965. *Drosophila guide.* Washington, D.C.: Carnegie Institute of Washington.

ACTIVITY 6: EFFECTS OF ACID RAIN: ECOSYSTEMS

Activity Overview

A simplified version of a freshwater pond ecosystem simulates the effects of acid precipitation on the interrelationships among organisms. The students experience the interaction between abiotic (nonliving) and biotic (living) factors, and the biological magnification of ecosystem stress. The concepts of this activity relate to human pollution or natural catastrophic events that change the abiotic environment, the general interrelationships that make up the food web, and energy flow through an ecosystem. The ecosystem should be set up one week in advance for populations to grow and stabilize. The experiments take half an hour for observations and addition of acid, and should be repeated each class period for about two weeks.

Science Background and Societal Implications

Acid rain stresses and eventually may change ecosystems in various ways. This activity investigates the effects on the ecosystem as a whole.

The abiotic changes in the ecosystem, such as lowering of the pH level, depend on the buffering capacity of the soils and rocks. Carbonate rocks and soils have buffering capacity great enough to offset acid inputs, whereas noncarbonate rocks, such as granite, have no buffering capacity. If pH level decreases, many abundant nutrients and minerals essential to the biota are released from soils and rocks. Acidification rates may differ depending on the season. For example, acidified snow collects all winter with little effect on the environment. Spring runoff, however, can multiply acidity in streams and ponds by 100 times within a few days to pH values lethal to aquatic organisms.

The biotic portion of ecosystems evolves toward a dynamic equilibrium with its abiotic portion. The biotic portion can be viewed as a self-regulating system based on dynamic feedback with cycles of producers, herbivores, carnivores, and decomposers. pH changes that exceed the threshold level for organisms to function, grow, and reproduce normally lead to severe imbalances and possible death of an ecosystem.

Metals and other essential micronutrients, most notably aluminum and magnesium, can be stored within organisms. As usable energy is lost in each step of the food web, or energy pyramid, the metals become further concentrated in the organisms. For example, the release of aluminum from the soil and rock inhibits the growth of plant roots and affects plant productivity. The herbivores in turn feed off the producers, concentrating the aluminum in their tissues which results in abnormally low reproductive rates and increases birth defects. The carnivores further concentrate the metal with even more severe effects. Aluminum can clog gills and gradually smother fish. Alternately, increases in nitrogen caused by acid rain can lead to explosive growth of some plant species, especially green and blue green algae. This plant growth decreases ecosystem diversity and multiplies the number of dead organisms consumed by aerobic bacteria, thereby increasing biological oxygen demand. Consequently, some fish will not be able to live in the oxygen-depleted water and the chemical cycling of the ecosystem will be seriously impaired or collapse. Subtle changes in the acidity of an ecosystem can be biologically magnified to have great repercussions on the biotic community.

Society must recognize the synergistic effects of acid rain on an ecosystem. In making political and economic decisions concerning sulfur and nitrogen producers, it is not enough simply to study the effects of increased acidity on fish. Rather it is necessary to study the resulting effects on population and health of both the plants the fish consume and the birds which consume the fish. Therefore the holistic approach presented in this activity is needed for a realistic view of the outcome of acidification.

Major Concepts

- Acid rain stresses the relationships among organisms and the interaction between abiotic and biotic factors. Buffering capacity of the abiotic portion of the ecosystem and the organisms' level on the energy pyramid help determine the effects from acid rain.
- Micronutrients released in excess from rocks and soil due to acid rain can be toxic and increase in concentration as they follow up the energy pyramid.
- Episodic inputs of acid solutions, termed acid shock, have more dramatic effects than chronic low concentration inputs.

Student Objectives

After this activity students should be able to:

- Define ecosystem, biotic, abiotic.
- Describe the biological manfication of acidity.
- Describe the changes due to acid rain on organisms and the subsequent effects on the food web and ecosystem balance.
- Describe the interaction between abiotic and biotic factors.

Vocabulary

abiotic	ecosystem
acid shock	dynamic equilibrium
biological	energy pyramid
magnification	food web
biotic	herbivores
buffering	micronutrients
capacity	producers
carnivores	

Materials

- 4 lighted terraria covered with wire screen.
- Washed granite pebbles or quartz sand to line the bottoms of 3 terraria.
- Washed limestone gravel to line the bottom of 1 terrarium.
- 1 lb. plant fertilizer, should contain nitrogen, phosphorus, and other micronutrients. (Available locally at garden/hardware stores)
- Aluminum Sulfate
- Distilled water
- 50 pieces pH paper
- Sulfuric acid
- Nitric acid
- Ice cube trays
- Stirring rod
- 2 L beaker
- 100 ml graduated cylinder
- One of the following producers: herbivore, carnivore
- Combinations for all 4 terraria:

1. green algae and/or tape grass	mayfly and pond snail	waterboatman and/or musk turtle
2. same as above	water sow bugs midges (larvae)	fish (a quickly reproducing species such as guppies)
3. same as above	mayfly dermestid	damselfly praying mantis

Procedures

Set up a week in advance:

1. Set up 4 terraria with an appropriate amount of gravel (3 with granite or quartz and 1 with limestone) and water. Add the fertilizer and aluminum sulfate and check for normal lake pH acidity (7.0 - 6.0 pH), since some fertilizing chemicals can make water acidic. If pH has become acidic, crush and powder some limestone gravel and add it to the terrarium. Introduce the species to their appropriate microenvironment. Label the terraria "#1-Control," "#2-Low Buffering Capacity," "#3-High Buffering Capacity," and "#4-Low Buffering Capacity and Acid Shock."

2. First class preparation:

Make a 2 L solution of sulfuric and nitric acid to a pH of approximately 4.2 (pH of rainwater in the Ohio Valley and parts of the Appalachian Mountains). Freeze 200 ml of the acid solution in ice cube trays. Group students for each terrarium #2-#4. Inform the students about the prepared acid solution and about the terraria's different abiotic environments. Have them make a table in their lab notebooks similar to the one illustrated below:

Make 4 posterboard-sized tables and post them near the terrarium they represent.

3. Repeat the following every class period until observable results are obtained (about 1-2 weeks): Have the students:
   a) observe their terrarium and terrarium #1;
   b) test for pH with pH paper;
   c) record their observations into the table in their notebooks. Also have them fill out their classroom table each day so other groups can share observations in developing their hypotheses.

Terrarium #1: Sprinkle 40 ml of distilled water over the terrarium. Record the data in the classroom table.

Terraria #2 and #3: Have the students measure out 40 ml of the prepared acid solution and sprinkle it over their terraria.

Terrarium #4: Have the students measure out 40 ml distilled water, and sprinkle it over their terrarium for three class periods. Have the students add the ice cubes to the screen on the fourth class period. For the remaining class periods have the students again measure out 40 ml of the distilled water and sprinkle it over their terraria.

Questions, Discussion, and Extension

Have the students construct graphs of 1) pH; 2) acid added to their terrarium; and 3) producer, herbivore, and carnivore populations, all with time on the horizontal axis. Ask the students: What similarities and interactions, if any, do the graphs have with each other? What changes, if any, occurred in the interrelationships among producers, herbivores, and carnivores? Did terrarium #1 respond differently from your terrarium? (Remember the differences in the abiotic environment of the two terraria.) What real-life ecosystems does your terrarium represent? Make a general statement about the effects of acid rain on the ecosystem.

Lead a class discussion to further develop students' hypotheses and to share results of the different groups.

As an extension of the activity, the students can do a report on the actual ecosystem such as one near their home. In the report, identify any energy pyramids or elements of the food web. Find out the buffering capacity of the abiotic environment. Use the local library, teacher, and local Agricultural Extension Service as resources. From all they know, predict the results of acid rain with the acidity amounts used in your experiments.

Set up additional terraria representing different abiotic environments. One model of a typical environment would use limestone gravel and acid ice cubes. Or, increase daily the acidity of the acid water added to the terrarium. Or even filter a gas engine's exhaust, empty a measured amount of the filtered particulates to the terrarium daily, and use only distilled water for watering the ecosystem. Have the students try to design other models. Incorporate these additional terraria in the activity.

SAMPLE TABLE—Activity 6

Day	1	2	3	4	5	6	7
1_____ 2_____							
1_____ 2_____ 3_____							
1_____ 2_____							
Interrelationships among producers, herbivores, and carnivores							
Comparison with terrarium #1							
pH of water							
Volume of acid added							

ACTIVITY 7: EFFECTS OF ACID RAIN: LOCAL ENVIRONMENTS

Activity Overview

Students investigate their immediate surroundings for possible influences and evidence of acid precipitation. Materials are collected from local environments such as soil, lake water, rainwater, or snow. Students become aware of possible acid precipitation problems in their area and, at the end of the lesson, they write a letter to their Congressional representatives. The estimated time for the activity is two class periods.

Science Background and Societal Implications

The degree to which acid precipitation is destructive differs in various areas of the world. Among many factors which influence acid precipitation probability and vulnerability are the type and extent of industrial production in the region and the neutralizing capacity of the soil or bedrock. One can test the extent of acid precipitation in one's own area starting with a map of the United States which displays general areas of greatest vulnerability. After determining the degree of vulnerability in the area, several actual tests of the surroundings can be performed. These tests synthesize the activities of the previous lessons and aid the student in understanding that significant or measurable acid precipitation could currently or in the near future be present in the local environment.

Effects of acid precipitation threaten our environment. Classroom education is one means of increasing public awareness. Preventive action is necessary immediately if we are to save our local lakes, forests, crops, and wildlife from subtle effects or, in some cases, destruction by acid precipitation. Through acid precipitation activities, individuals can become more aware of their immediate surroundings and begin to develop a concern for their environment. This type of education is a good start toward universal environmental awareness and appreciation.

Major Concepts

- Acid precipitation is an important current environmental problem.
- Certain areas of the country are more susceptible to acid precipitation than are other areas.
- Differences in susceptibility are due mainly to the amount of industry in the area and the neutralizing capacity of the bedrock.

Student Objectives

After this activity students should be able to:

- Describe areas in the United States with greatest and least acid precipitation susceptibility.
- Discuss reasons why areas of the United States vary in their degree of susceptibility.
- State four possible problems of acid precipitation in the local area.
- State factors influencing the degree of acid precipitation in the local area.
- Discuss reasons why the public should be better informed of the acid precipitation problem.
- Communicate with their representatives in Congress.

Vocabulary

neutralizing capacity
susceptibility
vulnerability

Materials

If accessible, students should collect the following near their homes:

- Rainwater
- Lake or pond water
- Soil
- Snow
- Other wet or dry desposition (student's choice depending on area.)
- pH paper
- Acid solution (pH = 4)

Procedures

1. Place a map of U.S. on an overhead projector (see p. 239) and distribute a worksheet with the map and questions for this activity on it. (Questions appear periodically throughout this activity. They should be written up and given to the students to fill in as classroom discussion takes place.)

2. Place overlay with areas of highest susceptibility in the U.S. colored on top of the map. Have the students color in these blocked-out areas on their own maps.

3. Discuss the following questions from the worksheet:
   a. According to the map, which parts of the country are most susceptible to acid precipitation?
   b. According to the map, is acid precipitation currently destructive in your area?
   c. Why might one area of the country be more susceptible to acid precipitation than another area?

4. The following activities are designed for the student to test for the possibility of acid precipitation in the local area. Have the students perform whatever tests are appropriate for the area. All students should do the concluding discussion worksheet.

First Investigation: What is the pH of your rainwater? Is your rainwater more acidic than ''normal'' rainwater (which is slightly acidic due to natural causes)?

1. Use pH paper to test your rainwater.
2. What is the pH of your rainwater?
3. How does your rainwater pH compare to that of ''normal'' rainwater?
4. Compare the pH of your rainwater to that of three other students who live in different neighborhoods. Do you find a difference in pH? Describe these differences.
6. Why do you think your rainwater is or is not very acidic?

Second Investigation: Is the soil in your area acid? Does it have a neutralizing capacity?

1. Determine the pH of your soil:
   Materials:
   - ½ cup boiled distilled water (pH = 7)
   - Soil from area

   a. Place soil in a plastic column with small netting on the bottom to allow water through. Place a container under the column to catch the water.
   b. Pour ½ cup boiled distilled water through the column with soil; dirty water should collect in the bottom container.
   c. Use pH paper to determine pH of the collected water. This is the pH of your soil.

   Questions:
   a. What is the pH of your soil?
   b. How does this number compare to that of three classmates. Is there a difference? If so, to what extent?
   d. State two reasons why your soil pH might differ from that of your classmates.
   e. Consider the first investigation on the pH for the rainwater of your area. In what way, if any, is this rainwater affecting the acidity of your soil?
2. Test the neutralizing capacity of your soil:
   a. Measure ¼ cup of acid solution and confirm that pH is 4.0.
   b. Pour the acid solution through a column of soil set up in the same way as above.
3. Determine, with pH paper, the pH of the solution in the bottom container.

   Questions:
   a. What is the pH of the acid solution before washed through soil?
   b. What is the pH of the washed-through solution in the bottom container?
   c. If the pH increases, the solution has become less acidic and therefore the soil does have a neutralizing capacity. If the pH remains the same or decreases, the soil does not have a neutralizing capacity.
   d. Does your soil have a neutralizing capacity?
   e. What might cause a soil to have a neutralizing capacity?
   f. What might be some harmful effects of acid soil (no neutralizing capacity) in your area?
   g. Considering the pH of your rainwater, could your soil be healthy without a neutralizing capacity?

Third Investigation: Is the lake or pond water in your area acidic? Does it have a neutralizing capacity?

1. Use pH paper to determine the pH of lake or pond water in your community.

   Questions:
   a. What is the pH of the lake or pond water?
   b. How does the pH of this water compare with that of a healthy lake or pond?

c. Do you think that this lake or pond is too acidic?
d. If the water is not too acidic and the rainwater is known to be acid, what might be some factors influencing acid in the water.
e. Consider characteristics of the area around the lake or pond, (e.g., forest, farmland, bedrock). How might these factors influence the acidity of the lake or pond water?

Fourth Investigation: Does acid snow occur locally?

1. Melt your snow in a container.
2. Determine the pH of the meltwater.

Questions:

a. What is the pH of your melted snow?
b. How does the pH of your meltwater compare with that of your rainwater from the first investigation?
c. Discuss reasons why snow meltwater might be more or less acid than rainwater.
d. From your data, what conclusions can you make about what time of the year you might find your lakes and soils the most acid?

Fifth Investigation: Write a letter to your Congressional Representative explaining the possibilities for a problem with acid precipitation in your areas. Include in your letter some suggestions for what we as a nation can do to lessen the threat of acid precipitation.

Questions, Discussion, and Extension

1. Discuss causes and effects of acid precipitation in your area.
2. Based on what we have discussed and observed, what can you say about possible future environmental problems due to acid precipitation in your area?
3. If you were to choose an area of the country you wished to farm, where would you life? Why?
4. Answer question 3 for a good fishing location. Why?
5. What can you as an individual do to help lessen the problem of acid precipitation in your area?
6. Discuss reasons why and how the public should be better informed of the acid precipitation problem.