Acid Precipitation Awareness Curriculum Materials in the Life Sciences

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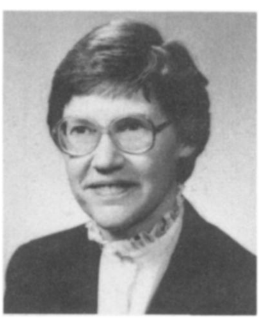


Harriett Stubbs was a secondary school science teacher from 1965 to 1979. She is the Project Director of Acid Precipitation Awareness, a Title IV-C ESEA program funded through the Minnesota Department of Education. In addition, she is Executive Director of The Acid Rain Foundation, Inc. In the past several years Dr. Stubbs has been very active in the development and dissemination of audiovisual, printed, and curricular materials on acid rain. Dr. Stubbs holds a B.A. and an M.S.T. in Biology, and a Ph.D. in Education.

In a *Report to the President's Council on Environmental Quality,* scientists associated with the National Atmospheric Deposition Program in 1978 stated unequivocally that acid precipitation was one of two major environmental problems in the United States (Galloway, *et al.* 1978). President Carter, in August 1979, allocated $10 million per year for ten years for interagency research on the problem. Yet a search of the environmental and science education literature, as well as discussions with scientists and science consultants in state departments of education across the country, revealed no mention of curriculum materials having been developed prior to 1979 which included the topic of acid rain.

The activities in this article were produced as part of Acid Precipitation Awareness, a Title IV-C ESEA Project begun in 1979. This project was funded by ESEA Title IV, Part C, P.L. 95-561, with the Minnesota State Department of Education; the Freshwater Biological Research Foundation; Minnesota Sea Grant - Duluth; and the Minnesota Environmental Education Board, and will continue through the academic year 1982-83. The materials—slide show, transparencies, curriculum activities—developed on the topic of acid precipitation have been focused on certain fundamental concepts necessary to student, teacher, and public understanding of this complex topic of acid rain. We have used the outline on the next page as a general guide to the structure underlying the many different teaching and learning activities.

We have found that introducing the topic of acid rain requires fundamental knowledge concerning pH, neutralization, and the effects of acid precipitation on aquatic ecosystems. For this reason, the following activities were developed and are included here so that you have the essential beginning of a unit on acid precipitation.*

We would like to receive your comments. Please write and let us know how these activities work in YOUR classroom. Another 20 activities are also available, as well as an informational packet containing booklets, pamphlets, and articles pertinent to the topic. The address is: Acid Precipitation Awareness, 1037 Bidwell Street, West St. Paul, MN 55118.

* These activities were produced and reviewed by many people, including Edward Hessler, Editor and Author, Minnesota Environmental Sciences Foundation, Inc.; Eville Gorham, Ecologist, University of Minnesota; Richard Clark, Minnesota State Science Specialist; Eugene Gennaro, Science Educator, University of Minnesota; and James Burke, teacher and author of one activity.

Outline of Course Content For Acid Precipitation

Public Issues at Stake
1. Fisheries
2. Recreation
3. Tourism
4. Parks and wilderness
5. Agriculture and forestry
6. Economic
7. Public health
8. Corrosion of metals, building stone, etc.
9. International

Definition: Acid Precipitation

Historical Viewpoint
1. England
2. Scandinavia
3. U.S.
4. Your state or region

Chemical Changes
1. pH
2. Chemical changes
3. Neutralizing capacity
4. Relation to other environmental problems (SO_X and O_X directly, O_3, hydrocarbons, heavy metals, smoke carcinogens)

Geological Interactions
1. Neutralization
2. Bedrock type
3. Soils

Meteorological Effects
1. Transportation from point source
2. Weather systems in North America
3. Local and regional weather systems

Causes of Acid Precipitation (sources, effluents, products)
1. Plant and animal respiration→ carbon dioxide→ carbonic acid
2. Natural sources (volcanoes, lightning, etc.)
3. Fossil fuel combustion: Smelting and refining→ sulfur dioxide→ sulfuric acid and other sulfates
4. Fossil fuel combustion: Automobile exhaust emissions→ oxides of nitrogen→ nitric acid
5. Industrial plants, petroleum, pulp, flour, paper mills, and high chlorine coals→ hydrochloric acid
6. Industrial plants, steel, aluminum, phosphate, fertilizer plants→ hydrofluoric acid
7. Heavy metals and other trace elements
8. Trace organic molecules

Ecological Concepts
1. Food chain - single energy pathway
2. Food web - a more complex pathway
3. Ecosystem - effects on total system
4. Biosphere - interrelationships among all living things and matter
5. Eutrophic vs. oligotrophic lakes

Effects of Acid Precipitation
1. Aquatic ecosystems
   - A. Phytoplankton and zooplankton
   - B. Insect larvae
   - C. Crustaceans
   - D. Fish
     1. Scandinavia
     2. Adirondacks
     3. Local, regional examples
   - E. Salamanders
   - F. Birds
   - G. Mammals
2. Terrestrial ecosystems
   - A. Soil
   - B. Forest ecosystems
3. Materials
   - A. Weathering of buildings
   - B. Erosion of sculptured works of art
   - C. Corrosion of metal objects
4. Humans
   - A. Effect of heavy metals
   - B. Effect of sulfate aerosols

Possible Solutions
1. Liming of aquatic environments
2. Liming of soil
3. Breeding acid-resistant plant and animal species
4. Emission control
5. Shift in life style
6. Shift in energy sources

The Dilemma—Tradeoffs (Examples of a few)
1. Liming of aquatic ecosystems
   - A. Change of plant and animal populations
2. Liming of soils
   - A. Changes in soil composition
3. Breeding acid-resistant species
   - A. Impossible for all organisms in an ecosystem
   - B. Shall only a few exist? Which ones?
4. Emission control
5. Shift in life style
   - A. Willing to use less?
     1. automobiles
     2. electrical appliances
     3. lower thermostat on furnaces
     4. use air conditioner less
6. Shift in energy sources
   - A. Nuclear
   - B. Solar
   - C. Wind
7. Health
   - A. Effects of heavy metals
   - B. Effects of air pollutants

ACTIVITY 1: AN INTRODUCTION TO pH

Introduction

This activity introduces: 1) the meaning of pH; 2) scale; 3) simple measures of pH; and 4) the pH of some common, household substances. (Grades 7-12.)

Background Information: pH

The pH, a numerical value used to describe the strength of an acid, is determined by a mathematical formula based on a solution's concentration of hydrogen ions (H^+).

The pH scale ranges from a numerical value of 0 to 14. A value of pH 1 is very acid (battery acid), pH 7 is neutral (distilled water), and pH 13 is very alkaline (lye).

pH values are logarithmic: they increase by a factor of 10 between units. This means that a pH 6 solution is 10 times more acid than a pH 7 solution. pH 5 is 100 times more acid than pH 7; pH 4—1,000 times more acid; pH 3—10,000 times; pH 2—100,000 times; and pH 1—1,000,000 times.

Precipitation is defined as being acidic if the pH is less than 5.6, which is the pH of pure rain. It is thought that the slight natural acidity of normal rain is controlled by carbonic acid (H_2CO_3), which is formed by the reaction of atmospheric carbon dioxide (CO_2) with water.

Under unpolluted conditions, the pH of "pure" rain was probably not controlled by carbonic acid alone. Release of sulfur dioxide from volcanoes might have caused a lower natural pH in some areas while the addition of alkaline dusts and ocean spray to the atmosphere caused a higher natural pH in other areas.

Materials

- Hydrion papers - pH range of 2-11
  or
  colorpHast pH paper
  or
  pH water-test kits
- pH color chart
- Jars: baby food jars or beakers
- A variety of common and safe household solutions such as shampoos; fruit juices: lemon, apple; baking soda; vinegar; water: tap, spring, bog, swamp, distilled, snow, rain, pond, colored water; antiseptic solutions; bleaches: powdered, liquid; etc.

Procedures: Pre-lab Discussion

Most students will have heard of pH balanced shampoos and you can ask them what they think pH is and what the advantages of such shampoos are. Decide on the level and depth of the discussion appropriate for your students. Some outcomes of the discussion:

- acids are solutions whose hydrogen ion concentration is greater than that for pure distilled water;
- bases are solutions whose hydrogen ion concentration is less than that for pure distilled water;
- the effects of some common acids and bases on materials such as metals;
- the relative strengths of different acids and bases;
- what ions are;
- measurement of H^+ ion concentration.

This lab can be used to review acid-base laboratory *and* household safety with your students.

Introducing the Laboratory

1. The students should work with 6-10 unknowns. "Mask" the unknowns with food colorings. You will need a set of numbered jars for each group of six students. Make a master list of the solutions and their pH readings.
2. Review the student assignment sheet (see sample). Students can work alone or in groups of two.
3. Emphasize laboratory safety.
4. Pre-cut small pieces of hydrion paper.

Post-lab Discussion

Read the names of the numbered solutions and their pH.

- How accurate were the student findings?
- How much variation is there in the outcomes for each solution? Record this where everyone can see it.
- Are there any patterns in the outcomes, e.g., were errors more common on one (or more) solution(s)? Were some errors "closer" than others?
- What could have caused some of the observed errors? (Ask students what evidence they are using, i.e., just state simply, "What is your evidence?"). It is possible that students made methodological errors, e.g., used pH paper more than once or did not read the color chart immediately after dipping the pH paper or misread the color chart or . . .
- If you were going to repeat the experiment with pH, how would you improve it?
- If you were going to teach this laboratory experiment to grade school students (pick an appropriate grade level) how would you teach it?

SAMPLE pH ASSIGNMENT SHEET

Your teacher has placed materials of different pH on the lab tables. Determine the pH of each sample and record it on the chart.

		Trial		
Sample	*Jar #*	*1*	*2*	*pH*
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________
4	________	________	________	________
5	________	________	________	________
6	________	________	________	________

Directions

1. Dip a *small* piece of pH paper into the sample. Remove it.
2. Immediately compare the color of the paper against the color chart.
3. Read the pH number and record it.
4. Do this twice for each sample. Use a fresh piece of pH paper each time.

ACTIVITY 2: EFFECTS ON AN ORGANISM

Introduction

Invertebrate organisms are easily obtained, can be readily observed in the classroom, and the biological consequences of acidification can be seen by students. In this activity students become familiar with some of the effects of acid rain on *Gammarus*, a small crustacean of the subclass Malacostraca that is easily observed with the naked eye.

Background Information: *Gammarus*

Gammarus are crustaceans found in ponds and streams. You may know them as amphipods or "scud." *Gammarus* are *very* active: they swim, jump, crawl . . . they are almost always on the move. They are not easy to catch and beginning students will find a fine mesh fish net useful. If you and your students find *Gammarus* clinging to plants, carefully remove the plants from the water and gently scrape the *Gammarus* from the vegetation into collecting jars.

Once you know that and where to look for them (in decaying vegetation, under stones and rocks), scud are easy to collect. *Gammarus* are also easy to raise and maintain in the laboratory. In the event that you have not had experience with *Gammarus*, references are readily accessible which describe the "scud" and their care and feeding. One source for *Gammarus* is Trans-Mississippi Biological Supply, 550 Cardigan Rd., St. Paul, MN 55112.

These freshwater invertebrates are easy to collect and not too expensive to purchase if that is necessary.

You can prepare the acid solutions before class or better, prepare the solutions as a class demonstration. Students can help you stir, add/count drops, and take pH measurements. If *Gammarus* are obtained from a biological supply house, use bottled spring water with a pH of approximately 6. If you and/or your students collect the organisms, use water from the pond or stream. The number of drops suggested in the chart below are estimates. As drops are added, be sure that you stir the solutions. It might be worthwhile letting the acidified solutions stand overnight in order that any released CO_2 could equilibrate. The H_2SO_4 recipe is:

a. 500 ml of spring water — pH 6
b. 500 ml of spring water + approximately 5 drops of 10% H_2SO_4 — pH 5
c. 500 ml of spring water + approximately 15 drops of 10% H_2SO_4 — pH 4
d. 500 ml of spring water + approximately 25 drops of 10% H_2SO_4 — pH 3

Materials (per team of 4)

- *Gammarus* (approximately 15)
- Glass containers - 100 ml (4), 500 ml (1), beakers, baby food jars, battery jars, canning jars, small aquaria
- Spring water - 500 ml for each jar (or lake or stream water from collection site)
- pH paper - range 2-7
- Labels/masking tape
- Culture dishes
- Pipettes - bulbs 2.5 cm diameter, glass tubing with an internal diameter of 3mm
- 10% H_2SO_4
- Dropper bottles
- Stirring rods

Optional Materials Available:

- Monocular microscopes
- Stereomicroscopes
- Hand lenses
- Depression slides

Procedures

The student assignment sheets are divided into two activities. In activity 1, students become familiar with the morphology, physiology, and behavior of *Gammarus*. In activity 2, students determine the effects of an acid environment on *Gammarus* behavior and survival. Review the assignment with the students. Students are asked to design a table for recording the data they are to chart. They may need some help designing it.

Activity 2 cannot be completed in one class period. You should make provisions for some students to return to make observations later in the school day and after school or have subsequent classes continue the observations. You will have to tell your students when the investigation is finished.

After the Activity

Discuss the experiment with emphasis on: 1) variables; 2) what parts of the experiment the investigator controlled; 3) what students could not know (control) until they conducted the experiment; 4) what variable(s) students measured; 5) how students measured the variable(s); 6) the representation of data to discover relationships; and 7) what students can infer about the effects of pH from the data.

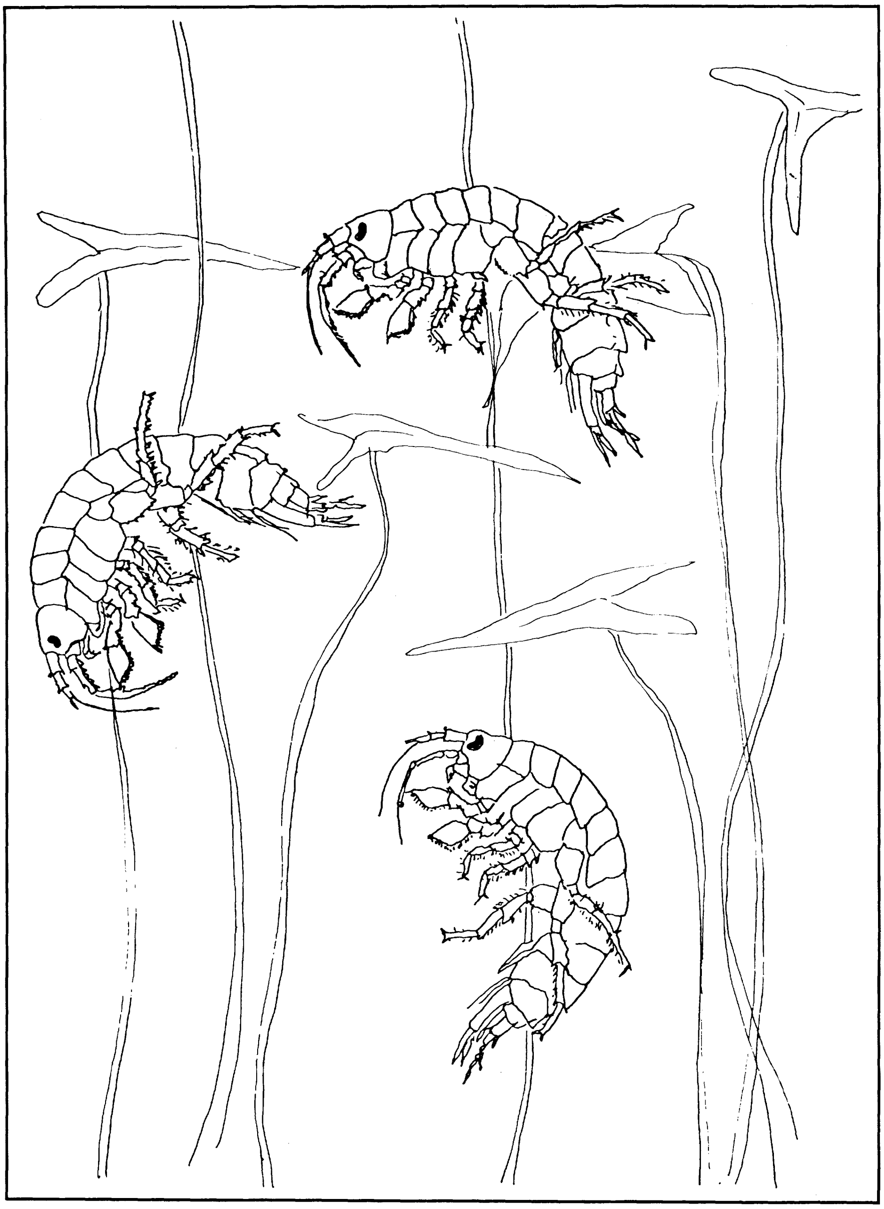
Activity 2-1

Add 500 ml of spring water to a container. Measure the pH of the spring water which should be approximately 6. Add four *Gammarus* to the container. If you have green algae available add them to the container.

A. General Anatomy
Make as detailed a sketch of *Gammarus* as you can and label the parts: eyes, feelers, legs (label the swimmer, jumper, and crawler legs).

B. General Behavior
Observe and record the behavior of *Gammarus* for 10-15 minutes. Where does it spend its time in the container? What percent of its time is spent moving? How does it spend its time? Does it use all of its legs in swimming? Which ones are used in jumping and climbing? Do *Gammarus* avoid each other? What do they do when they "bump" into each other?

If there is time try to learn more about *Gammarus* by touching it (gently) with a glass rod or toothpick. How sensitive is *Gammarus* to touch?



Scud (*Gammarus*). *Gammarus* length ranges from 5-8 mm to 12-15 mm. (Drawing by Kristine A. Kohn.)

Activity 2-2

Experiment

1. Carefully read the laboratory instructions.
2. Label four, 100 ml containers, pH 3 to pH 6.
3. Add 100 ml of the pH solutions to the containers as follows:
   a. Container 3 = 100 ml pH 3 solution.
   b. Container 4 = 100 ml pH 4 solution.
   c. Container 5 = 100 ml pH 5 solution.
   d. Container 6 = 100 ml pH 6 solution.
4. Check and record the pH in each container. The pH *must* be accurate. Your teacher can help you adjust it, if it is necessary.
5. Place two *Gammarus* in the pH 6 container. Record the time.
6. Place two *Gammarus* in the pH 3 solution. Record the time and your observations. You are familiar with *Gammarus* behavior. Is the behavior "normal" or is it new and different? Does *Gammarus* survive in this pH? If any organisms die, record the time.
7. Place two *Gammarus* in each of the pH 4, and 5 solutions and record the time.