MN SEA GRANT EXTENSION

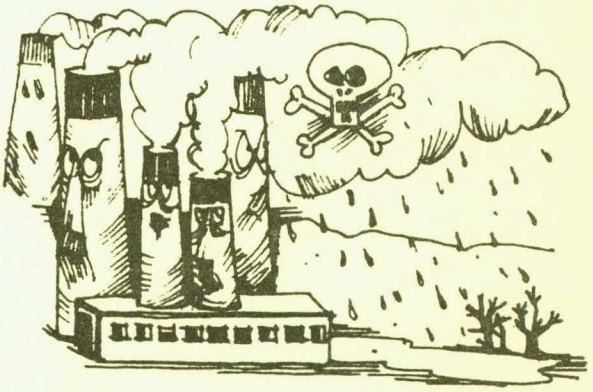
LACUSTRINE LESSONS

University of Minnesota

Aquatic Topics for Grades K-12

MARCH/APRIL 1985

A Source of Acid Rain: Sulfur Oxides*



by Dr. Rodger Bybee, et al.

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.

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

$$SO_{2(g)} + H_2O_{(l)} \rightarrow \underset{\text{sulfurous acid}}{H_2SO_{3(aq)}} \rightarrow 2H^+_{(aq)} + SO2/3_{(aq)}$$

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 ($SO\ 2/3 + 1/2O_2 \rightarrow SO2/4$) 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.

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Vocabulary

acid	fossil fuels
acid rain	sulfur oxides

Materials

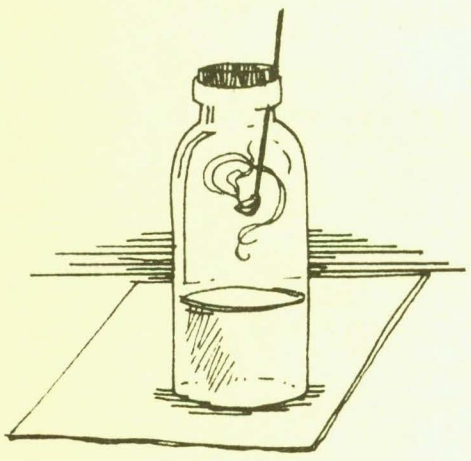
- Sulfur 1-2g
- Ordinary clear glass bottle with cork (1 liter is a convenient size)
- Bromcresol purple indicator solution
- Deflagrating spoon
- Bunsen burner

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:

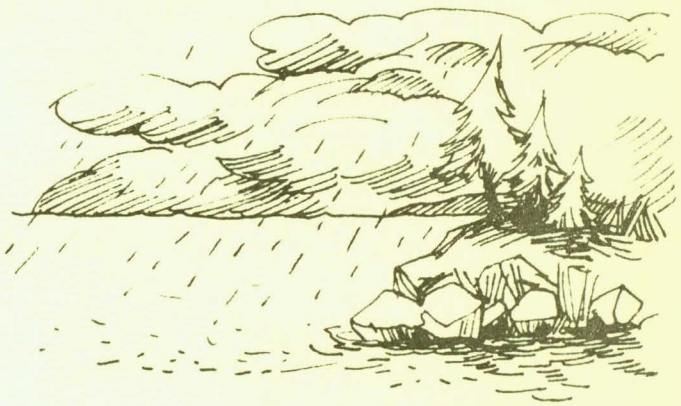
1. Placing white paper under and behind the bottle will make the color change more visible.

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.



Editor's Note :

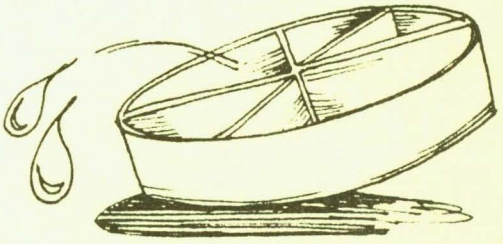
Other pH indicator solutions may be used in place of bromcresol purple if they will indicate pH changes in the pH 4-7 range.

The students may be interested in observing what happens if the sulfur is added directly to the water and indicator solution. This demonstration should offer results which can be used in a discussion of the role oxidation plays in acid formation.

ACID RAIN:

Not a *Trivial Pursuit*

by David Pederson
University of MN-Duluth



There are many popular trivia games that have flooded the market these past few years. A trivia game can be a useful educational tool to help retain and call forth facts and figures. Acid rain is becoming a well known and frequently discussed issue, but many people know only a few facts and figures about the issue. By developing and playing a trivia game based on acid rain, high school students can better understand the history of acid rain, its effects and some possible solutions.

Lesson Objectives

1. To make a trivia game based on acid rain.
2. To describe the history, effects and possible solutions of the acid rain issue.

Overview of an Acid Rain Trivia Game

The students will learn many facts and theories about acid rain by doing research to form questions and answers for a trivia game. The acid rain trivia game will use the following six categories (see sample questions at the end of the lesson).

1. Historical - The history of acid rain - names and dates of researchers and discoveries, and major conferences and events.

2. pH - The pH values of different substances.

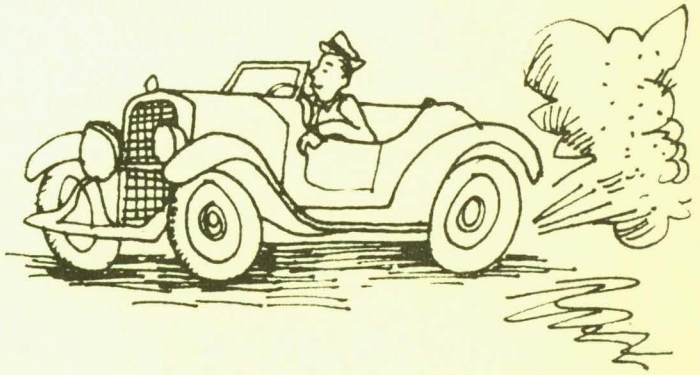
3. Sources - The sources of acid rain - types of fallout, amounts of pollution, man-made and natural sources, the level of emissions of some industrial sources, and prevailing wind patterns.

4. Physical effects - The effects of acid rain on water, soil, rocks and monuments, and which geographical areas are most sensitive. Includes the concepts of teaching and buffering.

5. Biological effects - The effects of acid rain on plants and animals.

6. Solutions - The possible solutions to acid rain - social,political, techological and industrial solutions. Includes possible alternative energy sources.

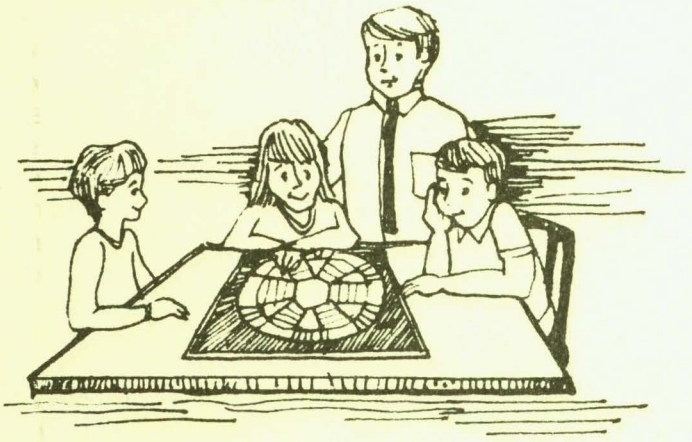
The students will form their own questions and answers for the game and will need to do research to do this. Therefore you need to make sure that the library has the appropriate materials on hand. The references listed at the end of this activity are highly recommended. Also, ten sample questions for each category are provided that you may incorporate into your game.



If you feel that forming questions for any of the categories may be too difficult (the solutions category may be the most difficult) you may drop the category from the game. If you drop a category designate one color as "player's choice," where he/she can choose from any of the five other categories.

Equipment

1. A trivia game board - for example this game could be played using a "Trivial Pursuit" board; or make your own game board.
2. Large blank note cards (4" x 6").
3. A box that the cards will fit in.
4. References.



Procedure

1. Have a general discussion on acid rain with the class to find out their ideas and knowledge about the issue. You could ask questions related to each category.

2. Explain to the class that they are going to make a trivia game about acid rain which they will play after it is finished.

3. Assign each student to one category. Explain that each student will need to research his/her category and form at least ten brief questions, with answers, relating to that category. The student should footnote each question and its answer. It is up to you if you want them to use class time for this project.

4. Collect the questions and answers and consolidate them. Throw out duplicates, rephrase badly worded or long questions, and check dubious or conflicting answers. You have the final say on what questions and answers that will be used. You should have at least 40 questions for each category.

5. Transfer the questions to the note cards.

a. Each category should be color coded so that all historical questions are one color, pH questions are another color, etc.. If you're using a manufactured board the questions should coordinate with the board's color.

b. Each card should have a question from each category on one side and the answer on the other side.

c. The questions and answers should be typed.

d. You could type the questions and answers on a piece of paper and then cut and paste them onto the cards. For longer wear the cards could be plastic coated.

e. Place the cards in a box so the cards stand on edge.

6. Playing suggestions:

a. Split the class into teams; have two people per team and four teams per game board. (If you want to have more than one board playing at the same time you'll need duplicate sets of cards).

b. Set a one to two minute time limit on answering questions.

c. Use the rules from a manufactured trivia game or get class agreement on their own rules.

d. You could devise a system of play-offs to make the game more competitive and add incentive.

7. After everyone has had a chance to play the game have another class discussion on acid rain. Discuss the history, effects, sources, etc., but please, make sure you also discuss the possible solutions of acid rain.

Sample Questions

Historical Category

Q: In 1852 the earliest report of acid rain was in what country? A: England.

Q: In 1939 scientist Bottini recorded hydrochloric acid dominated acid rain by what volcano? A: Vesuvius.

Q: What Swedish scientist reported in the 1960's that many Scandinavian lakes were becoming acidic and fish were dying? A: Svante Oden.

Q: The sulfate deposits in Greenland's icecap have coincidently increased with the beginning of what historical age in Europe? A: The Industrial Age.

Q: The chemist Angus Smith was the first to report the phenomenon of acid rain in what year? A: 1852

Q: What is the title of Angus Smith's 1872 book about his acid rain research? A: Air and Rain.

Q: What two countries established the Bilateral Research Consultation Group on the Long-Range Transport of Air Pollutants? A: Canada and the U.S.

Q: Rain with a pH below 5.6 was detected by the early 1950's in what area of the U.S.? A: Northeastern United States.

Q: Ecologist Dr. Eville Gorham who contributed a major part of our knowledge of acid rain works at what major university? A: University of Minnesota.

Q: What year did the U.S. Congress pass a resolution calling for bilateral discussionwith Canada to preserve and protect mutual air resources. A: 1978

pH Category

Q: The pH value of normal rain is what? A: pH 5.6.

Q: For rain to be called "acid rain" it needs a pH value below what? A: pH 5.6

Q: What is the pH of ammonia? A: pH 11

Q: The pH of blood is what? A: 7

Q: Lemons have what pH value? A: pH 2

Q: What is the pH of stomach acid? A: between pH 1 and 2

Q: The pH of grapes is what? A: pH 4

Q: Baking soda has the pH of what? A: pH 9

Q: A chicken egg has what pH value? A: pH 8

Q: What is the pH of corn? A: pH 6

Sources Category

Q: What are the two ways acids can be deposited? A: Through wet and dry depositions.

Q: Smog is an example of what kind of deposition? A: Wet deposition.

Q: Fly ash is an example of what kind of deposition? A: Dry deposition.

Q: Do most scientists believe that acid rain is primarily a natural or man-made problem? A: Man-made.

Q: Smelters are a primary sources of what acid rain forming pollutant? A: Sulfur dioxide.

Q: What kind of acid rain forming pollutant comes from the family car? A: Nitrogen oxide.

Q: Sulfur released by mudflats can lower the pH of rain, but is it a primary cause of acid rain? A: No

Q: Ohio, Indiana and Illinois produce how much of the U.S. total sulfur oxide emissions? A: About one quarter.

Q: Forest fire can be a source of acid rain, true or false? A: True

Q: On the West Coast what agent appears to be the chief acidifying agent in rain? A: Nitrogen oxides

Biological Effects Category

Q: When the pH reaches 5.0 what changes occur to most zooplankton? A: Lower egg production.

Q: Which European country estimates that 30% of its forests are dead or dying because of acid rain? A: West Germany.

Q: Below what pH is toxic to all fish and most insects? A: Below pH 3.0.

Q: How can acid rain affect the waxy cuticle on leaves? A: Reduces it.

Q: The diversity of flora and fauna diminishes when the pH falls below what level? A: pH 5.6.

Q: When water acidity reaches pH 2.0 what happens to the insects? A: They nearly all disappear.

Q: Walleyed pike spawning is inhibited at what pH? A: pH 6.5.

Q: Deformed leaves, stems, and buds occur on plants at what pH? A: pH 3.0.

Q: Snail populations decline if the pH goes below what? A: pH 6.6.

Q: Tissue damage to birch occur at what pH level? A: pH 4.0.

Physical Effects Category

Q: What is the phenomenon called when accumulated acid precipitation is released is spring snow melt? A: Acid Shock.

Q: What can acid rain leach out of the soil? A: Heavy metals.

Q: Approximately how many of Minnesota's lakes are sensitive to acid rain? A: More than 2000

Q: What is the effect of acid rain on buildings, monuments and art objects? A: Deterioration.

Q: Does weather play a major or minor role in the severity of acid rain? A: A major role.

Q: Calcium carbonate and other materials which help prevent a lake from acidifying are referred to as what? A: Buffers.

Q: How many billions of dollars are estimated to be spent annually in the U.S. to repair materials damaged by acid rain? A: $5 billion.

Q: What can calcium carbonate do to acid rain? A: Neutralize it.

Q: Which area is the most sensitive to acid rain: New Foundland, Nebraska, Western Texas or New Mexico? A: New Foundland.

Q: Acidification can be an exceptionally severe problem during what time of the year in the northern states? A: During spring snowmelt.

Solutions Category

Q: What can be added, in massive amounts, to acid damage lakes to neutralize them? A: Lime.

Q: Is liming acid damaged lakes a permanent or temporary solution? A: Temporary.

Q: The first legislation of its kind, the Acid Deposition Control Act, was passed in 1982 by what U.S. state government? A: Minnesota.

Q: What may have the biggest effect in reducing acid rain? A: Reducing emissions.

Q: Using low sulfur coal from what region

in the U.S. could improve the amount of sulfates put into the air? A: The Western U.S.

Q: One of the processes used in scrubber is to spray what kind of water into the gases as the move up the stack? A: Lime water.

Q: It's estimated that scrubbing will add at least what percent to the cost of electricity? A: 10%.

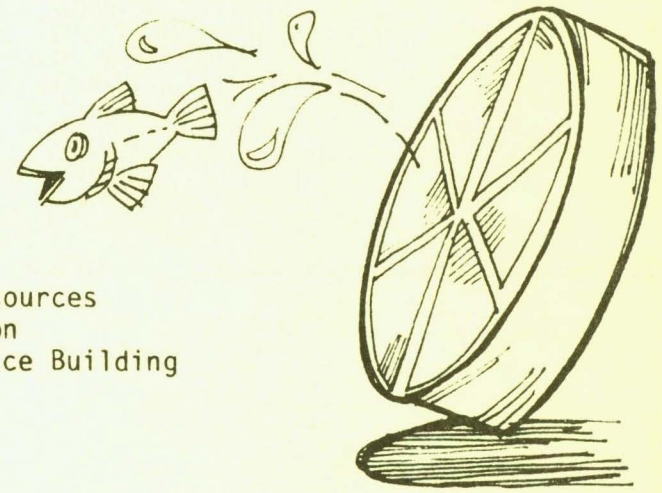
Q: The Canadian government has proposed to the U.S. that both countries should reduce their sulfur dioxide emissions by what percent? A: 50%.

Q: What U.S. Governmental agency enforces emission standards? A: Environmental Protection Agency.

Q: In 1981, the Nation Research Council recommended that the precipitation's average acidity should not exceed what pH level. A: pH 4.6 to 4.7.

To obtain free information contact:
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113
(612) 296-7373

Department of Natural Resources
Fish and Wildlife Division
3rd Floor Centennial Office Building
658 Cedar Street
St. Paul, MN 55155
(612) 296-3325



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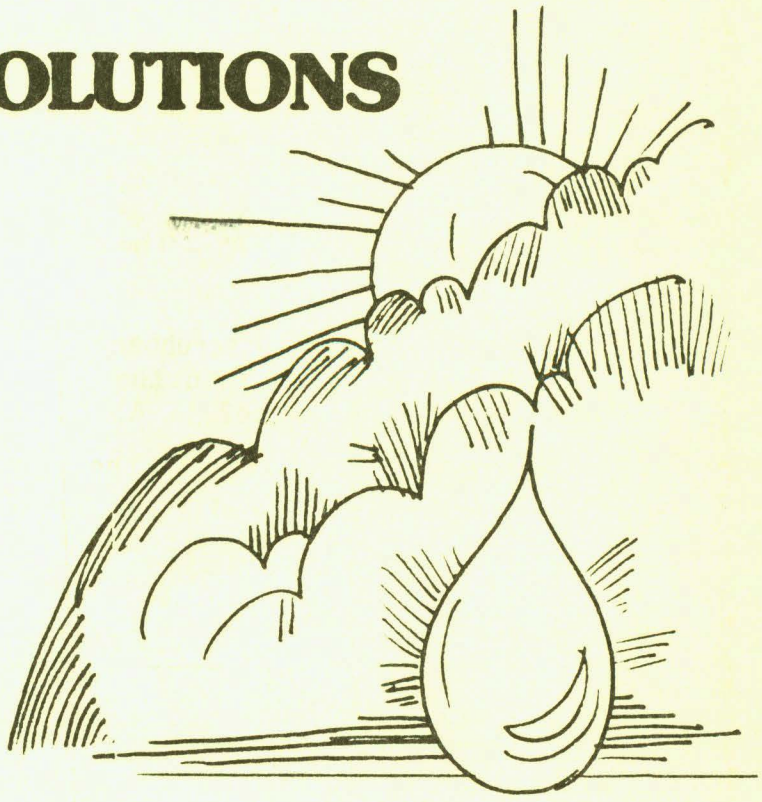
ACID RAIN: SOLUTIONS



Must acid rain destroy the fish, trees and waters of northern Minnesota and other areas of the world?

The answer is no. There is hope, but there are no quick fixes. Solutions require public interest, motivation and funds; they won't just happen.

To keep a diversity of plants, animals and their environments that will assure a high quality of life for humans on our planet, it's important for students to learn about acid rain and how the problem can be solved.

The problem has been widely discussed by both the research community and the general public. The problem stems from our use of fossil fuels and the resultant emissions of sulfur dioxide and nitrogen oxides.

Solutions have not been as widely discussed.

Solutions fall into four major areas: technology, biology, social and political.

TECHNOLOGY Some technology to combat acid rain already exists, and the future looks bright. Success will depend on how much money and motivation is available for developing and applying technology.

Coal switching and blending are now used by some coal burning power plants and industries to decrease final smokestack emissions of sulfur dioxide (SO_2), a known source of acid rain.

Depending on the blend, this method can reduce sulfur dioxide emissions by 30% to 80%.

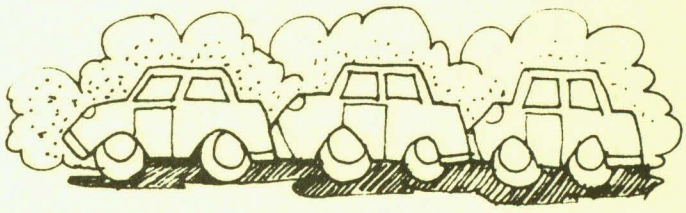
High sulfur can also be mechanically and chemically cleaned before it's used, to reduce by up to 30% the amount of sulfur dioxide emitted.

Scrubbers using lime or limestone spray, usually with water, added to the flue gases may reduce sulfur dioxide emissions by 90%.

Researchers have also looked at reducing sulfur dioxide emissions by injecting limestone into the furnace. Results show a 20% to 50% reduction, and a reduced nitrogen oxide (NO_x) emission rate as well.

Fluidized-bed combustion, another developing technology, uses a special furnace configuration and a mixture of fuel and limestone to reduce sulfur dioxide by 90% or more. This method also removes some nitrogen oxides.

Sulphur dioxide emissions are the most immediate concern of scientists who want to stop acid rain. But nitrogen oxides are also major contributors to the problem. Some technological solutions specifically address the problem of nitrogen oxide emissions.

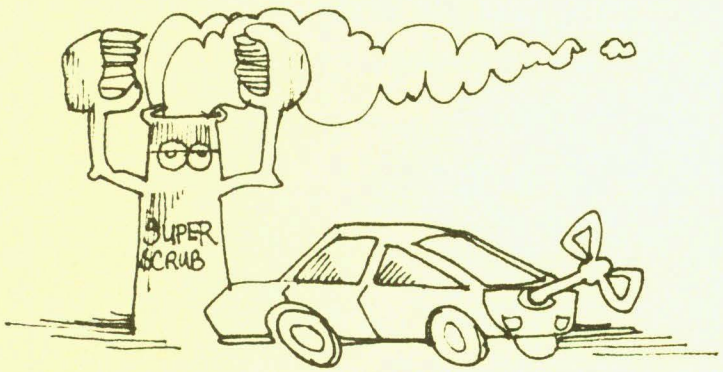


The rate of fuel and air mixing and resulting temperatures are the basis of three combustion modifications that have been developed to reduce nitrogen oxide emissions of coal-fired boilers. They are: Low-excess air combustion, overfire air ports and low nitrogen oxide burners.

Selective catalytic reduction is an effective but costly technology that can remove nitrogen oxide from flue gases rather than treating the problem at the point of combustion.

Cars are a major contributor of nitrogen oxide to the environment, and technological solutions, such as catalytic converters, continue to be refined and developed for this source.

Combustion and emissions are just two approaches to technological solutions of the acid rain problems. Only public interest, motivation and funds will limit what can be done in the future.



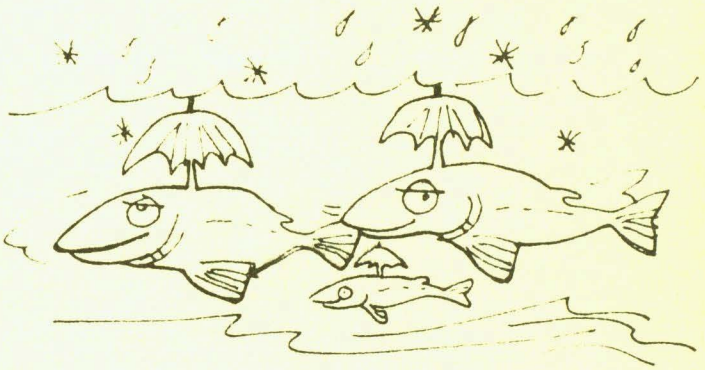
BIOLOGY Scientists have begun efforts to breed and culture acid tolerant plants and animals.

Strains of brook trout, for example, have been identified which have an increased acid tolerance.

High tech genetic manipulations and cloning are possibilities.

Liming of acidified waters may, in some situations, recreate an environment suitable for natural plant and animal populations.

The only limits to biological solutions, too, are public interest, motivation and funds.



SOCIAL Social solutions fall into two broad and sometimes overlapping areas: conservation and alternative energy sources.

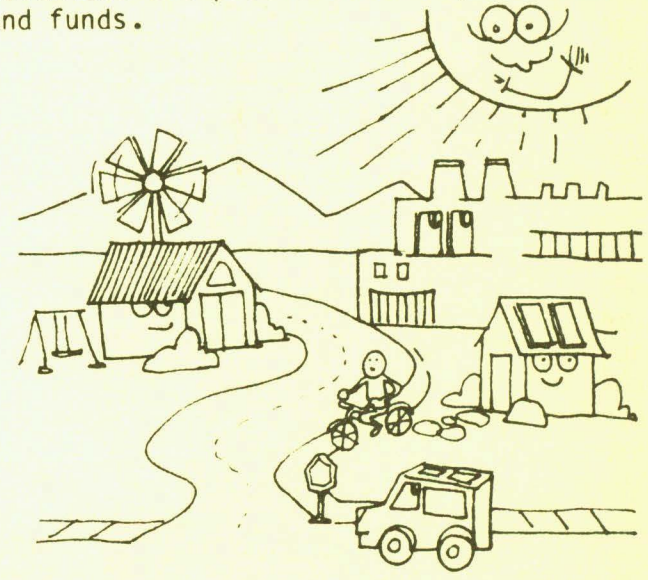
Conservation, on both an individual and collective basis, will mean fewer emissions of acid rain producing pollutants.

Conservation measures include efficiently using and/or consuming fewer items that require fossil fuels to be produced.

Use of alternative energy sources may really be a form of conservation.

But in a larger sense it is a social solution because it involves changing the way people think about energy sources. Individuals and groups must weigh whether to use more hydroelectric, solar, wind and nuclear power. Those decisions can reduce sulfur dioxide and nitrogen oxide emissions.

Again, the only limitations to social solutions are public interest, motivation and funds.



POLITICAL Political and social solutions overlap. Political action is usually taken as a result of changes in social thought.

Some people think political solutions are the easiest solutions. All that needs to be done, they say, is to pass legislation regulating emissions of acid rain producing substances, and regulations that would ban deposits of those substances.

Canada, West Germany, Sweden and Norway already have such laws.

But laws will not solve the problems. Technological, social and perhaps even biological solutions must be applied to meet the standards set by legislation. Applying those solutions would cost billions of dollars annually. The costs would undoubtedly affect us as individuals.

No one answer is likely to solve this global problem. Perhaps the words "solved" and "solution" imply a final correct answer. What we're really talking about here is mitigation of the problem. Although a "solution" is unlikely, the situation can be improved.

All that is needed is public interest, motivation, and money!

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"lacustrine/la-'kas-trən/adj (prob. from French or Italian lacustre, from Latin lacus lake): of, relating to, or growing in lakes." *Webster's New Collegiate Dictionary*

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