Acid Rain Study Guide

Introduction

Acid rain is a complex, worldwide environmental problem. This study guide is intended to help you and your students understand what acid rain is, why it is a problem and what possible solutions exist. You are encouraged to use the information and activities in this guide with your students in all disciplines — social studies, language arts, science, mathematics and art.

To augment this guide, we suggest that you obtain **The Acid Test,** a Wisconsin Department of Natural Resources free publication (see Resources). You may also want to consult other publications and organizations listed in Resources and check newspapers and magazines for current articles that address acid rain issues. Many excellent acid rain curriculum materials exist and we encourage you to send for and use them (see Resource Lists, Curriculum Materials, Audio-Visual Materials).

Consider talking with your students before beginning your lessons about acid rain to learn what they already know and think about it. This knowledge can assist you in helping the students connect new concepts with what they already know. As well, it will help you assess how their knowledge changes as a result of your lessons.

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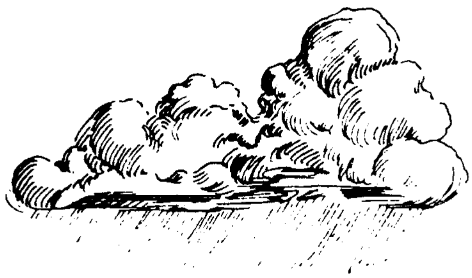
Most of the activities in this guide have been designed for use in grades 4 - 12. With modifications, however, they should be useful to teachers of other grade levels. We encourage you to tailor the activities to meet your students' needs. You are welcome to revise and/or reproduce any part of this guide for distribution to students and other educators.

NOTE: ***Words that appear in italics are defined in rhe glossary.***

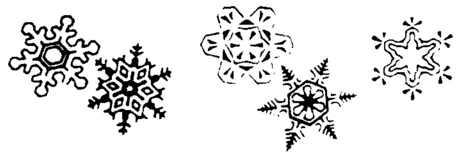


Falling From The Sky...

A cool spring shower splashes off your jacket and soaks into the ground as you dash for home. The rain feels fresh, and you know that it's good for the lawn, farmers' fields and the woods where you like to walk. Or is it? Rain falling in Wisconsin and many other places in the world is unnaturally acidic, and many of us are becoming concerned about its impact on our environment and us.

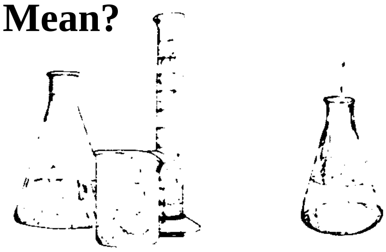
What Is Acid Rain?

The air in our atmosphere — the air that we breathe - contains many forms of pollution produced by people. One form of air pollution is



acid rain. "Acid rain" is the term commonly used to describe those pollutants included under the broader, technical term ***"acid deposition."*** Acid deposition occurs when acid molecules fall from the atmosphere onto land, water and physical objects. Acid rain and other forms of acid precipitation (snow, sleet, hail, fog, dew) are called ***wet deposition.*** But there also is ***dry deposition,*** when acid molecules fall from the atmosphere as gases or attached to particles of soot and dust. In this guide, the term "acid rain" is used to refer collectively to wet and dry deposition.

"Acid" Rain: What Does It Mean?



The acidity of a liquid is determined by its concentration of hydrogen ions (H+). This concentration is described using a ***pH*** scale (Figure 1). The scale ranges from 0.0 (most acidic, highest H+ concentration) to 14.0 (most ***basic,*** lowest H+ concentration). A solution with a pH of 7.0 is neutral. The pH scale is a negative logarithmic scale in

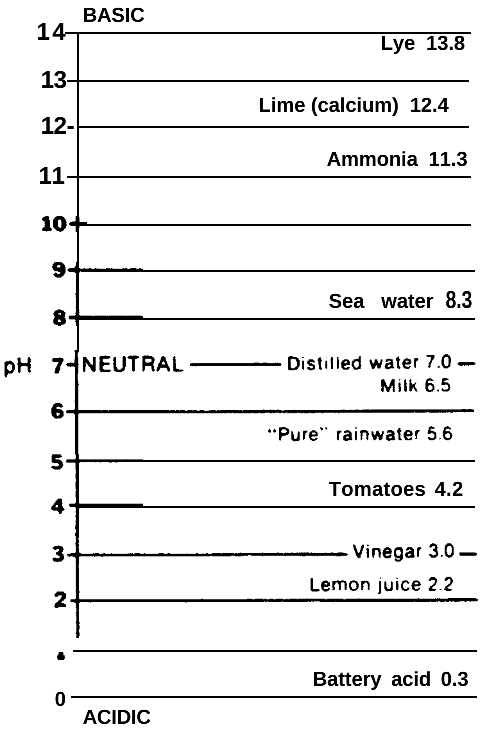
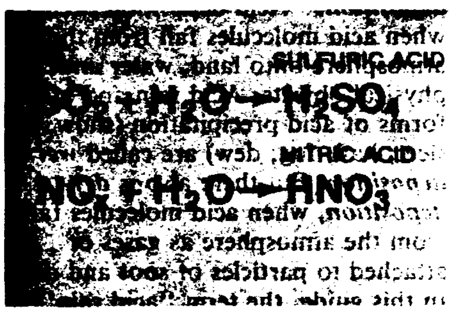
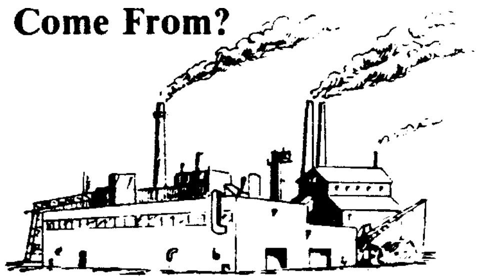


Figure 1. pH scale.



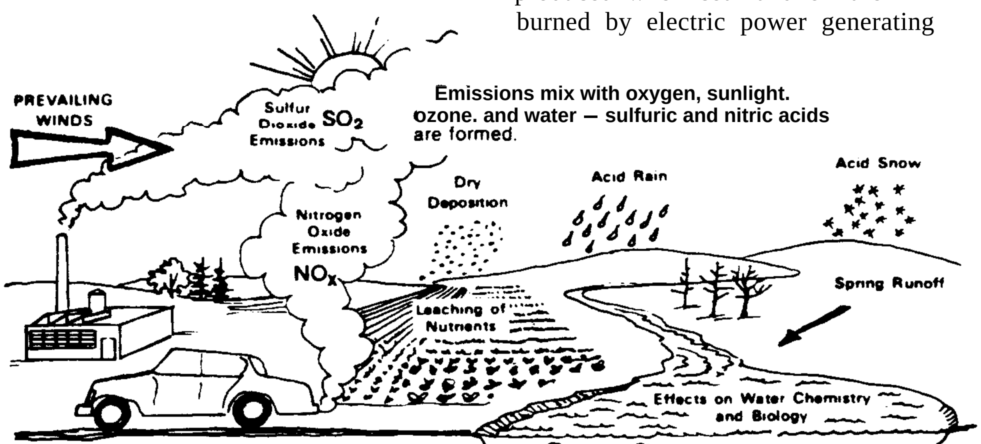
base 10. This means that a solution with a pH of 4.0 is ten times more acidic than a solution with a pH of 5.0, and one hundred times more acidic than a solution with a pH of 6.0. ***Normal precipitation*** (precipitation from clean air) is slightly acidic because carbon dioxide that occurs naturally in the air mixes with water to form a mild solution of carbonic acid. Normal precipitation has a pH of about 5.6. The Wisconsin Department of Natural Resources has defined acid rain as having a pH of 5.0 or less. Rain in Wisconsin currently has a pH of between 4.4 and 4.8.

Where Does Acid Rain Come From?



Acid rain forms when ***sulfur oxides*** (SO_X) and ***nitrogen oxides*** (***NO_X***) in the atmosphere combine with water to make sulfuric acid (H_2SO_4) and nitric acid (HNO_3). The sources of SO_X and NO_X in the atmosphere are both natural (volcanoes, geothermal activity, sea spray, bacteria) and human-made. The major sources, however, are human-made, primarily from the burning of ***fossil fuels.*** Sulfur dioxide (SO_2) and NO_X are produced when coal and oil are burned by electric power generating plants, paper mills and other industries, and by all of us when we heat our homes and businesses. Another major source of NO_X is exhaust emissions from our cars, trucks, airplanes, snowmobiles and other vehicles. Thus, what we all do contributes directly to causing acid rain (Figure 2).

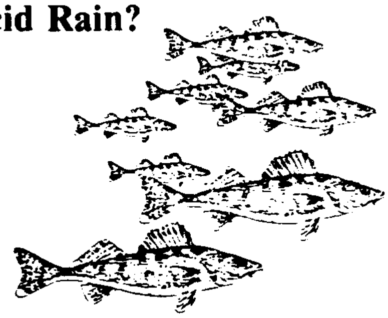
Since air pollution is carried by the wind, it may affect people and places a long distance from its source. In fact, to avoid local pollution, industries often construct tall stacks that release emissions high into the atmosphere, where the wind carries them away. But where is "away?" Where do these emissions end up? Often they are carried in the atmosphere across state and national boundaries, where they eventually fall on our neighbors. Likewise, some acid rain falling in Wisconsin has its origin in other states. Thus, acid rain is a local, regional, national and international problem.



Adapted from- Acid Rain in Minnesota 1984
Minnesota Dept. Of Education, St. Paul. MN

Figure 2. Through a complex chemical process, some emissions of sulfur dioxide and nitrogen oxides are converted into sulfuric and nitric acids, which fall to earth in rain or snow. During the winter, acids accumulate in snow; when the snow melts in the spring. the runoff has a concentrated acidity which can reduce the alkalinity of some lakes and streams.

Why The Concern About Acid Rain?



There is increasing concern that acid rain is causing serious, irreversible changes in our environment. Much research about the impacts of acid rain has concentrated on aquatic ecosystems, and evidence shows that the effects are detrimental. For example, within the past several decades, more than 200 lakes in the Adirondack Mountains of New York have become too acidic to support fish life. Some scientists believe that acid rain also adversely affects ***terrestrial*** ecosystems. As well, air pollutants, including acid rain, erode paint, metals and building materials, resulting in great economic costs.

Since the impacts of acid rain on our environment are complex and develop slowly, they are difficult to study. Scientists are continuing to investigate how ecosystems and individual organisms respond to acid input. Each system may respond differently, depending on its natural resistance to pH changes.

An ecosystem's ability to resist change in pH is called its ***buffering capacity*** **.** For example, when acid rain soaks into the ground, dissolved carbonates in the soil may neutralize the acid and maintain the soil's pH. The concentration of dissolved carbonates is the ***alkalinity*** of the soil. Calcareous rock like ***limestone*** is very alkaline. buffering acid more readily than does noncalcareous rock such as ***granite.***

The buffering materials in soil can influence the chemistry of, for instance, an adjacent lake. Lakes receiving most of their water from groundwater and surface inflow are generally less sensitive to acid rain because the water can be buffered as it flows through or over the soil. Lakes that receive most of their water directly from precipitation are more likely to become acidic because they receive unbuffered acid water (Figure 3). The drainage systems and water chemistry of about 3,500 of Wisconsin's 15,000 lakes make them sensitive to damage from acid rain (Figure 4).

Lakes

In lakes that have little buffering capacity, acid rain may change the pH enough to kill sensitive plants and animals (Figure 5). Some animals may survive in water with a lower than normal pH, but their reproductive organs may not develop properly, egg production may decrease and/or eggs may not survive. Lowered pH also increases the solubility of toxic metals, such as aluminum and mercury. Thus, acid rain makes it easier for toxic metals to be leached from the soil into nearby streams and lakes. High levels of aluminum can damage the gills of fish and other aquatic animals. Increased mercury in fish might adversely affect them and fish-eating animals like otters, minks, eagles, ospreys and loons.

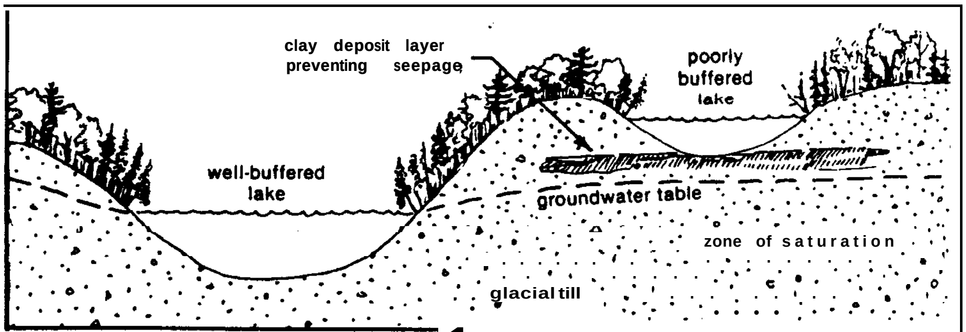


Figure 3. A lake's capacity to buffer or neutralize, acid rain is highly individualized and depends upon many factors. As an example, here is a cross-section of two lakes in a moraine, a landform resulting from glacial activity. The lake on the left is well-buffered because it has contact with the local groundwater system, which contains chemicals' that neutralize acid rain. In contrast, the lake on the right has no groundwater contact causing it to be more poorly-buffered.

Adapted from: Acid Rain in Minnesota 1984. Minnesota Dept. of Education, St. Paul, MN

Forests

Some scientists believe that acid rain is damaging terrestrial organisms and ecosystems. They are studying acidity's effects on natural and agricultural systems – investigating soil chemistry, nutrient availability and uptake by plants, photosynthesis and growth rates, seed germination, soil microbiology and many other biological processes. Researchers are also considering the combined and long-term effects of pollutants on our environment. Combinations of pollutants such as acid rain and ozone may be more damaging than either pollutant alone.

Trees are dying in Central Europe and the Appalachian Mountains of the United States and many scientists believe that air pollution is a primary cause of mortality. For example, pollutants could cause physiological changes in trees that result in their being more susceptible to infection by diseases or to damage from freezing (Figure 6). But scientists do not know specifically what role acid rain might be playing in this air pollution problem.

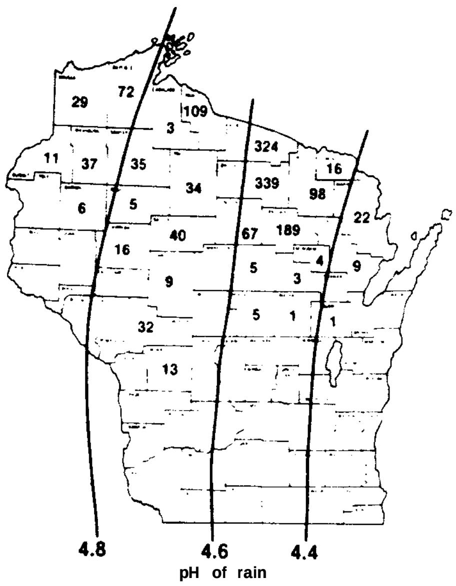
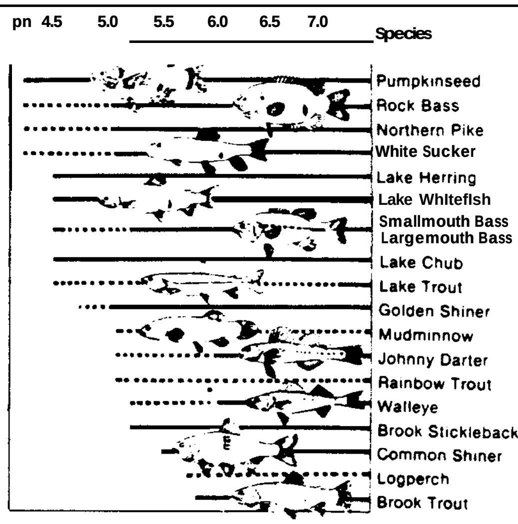


Figure 4. Estimated number of lakes extremely sensitive to acid rain.

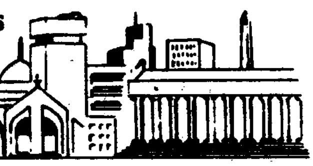
Figure 5.

Some species of fish are better able lo cope with increased acidity than others. To study this variation Dr. Harold Harvey of the University of Toronto collected fish from a number of lakes in the LaCloche Mountain region of Ontario. These lakes received heavy acid loadings and those lacking a good buffering capacity have suffered heavy fish losses. In the graph the solid lines represent fish populations still unaffected by the acidification of their lakes. The broken lines indicate acid levels have had some adverse effect on the population such as the failure to reproduce or a change in growth rates. The end point marks the lowest pH the fish can survive. Beyond this point lies extinction.

From. The Acld Rain Primer 1982. Pollution Probe Toronto. Ont.



Buildings



When acid rain falls on buildings, the acid can dissolve the building materials. Carbonate-rich materials like marble are especially susceptible, and many buildings around the world have been and continue to be damaged. The Acropolis in Greece, the Coliseum in Italy, and the United States Capitol in Washington, DC, as well as buildings, statues and gravestones in Wisconsin, are deteriorating due to the effects of air pollution. In the Northeastern U.S. alone, this damage is an estimated $5 billion annually.

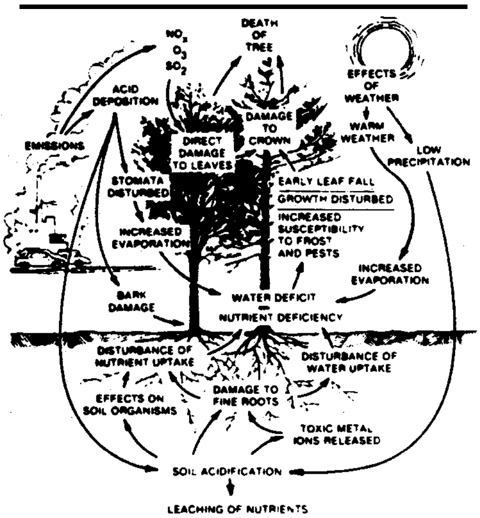
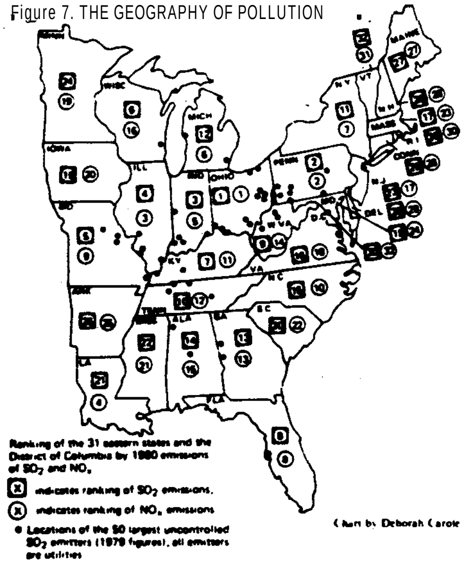


Figure 6. Some current concepts of forest damage caused by air pollution.

Adapted from: Proc. U.S. - Canadian Cont. on Forest Responses to Acidic Deposition. 1984. Univ. of Maine, Orono. ME

Figure 7. THE GEOGRAPHY OF POLLUTION



The 31-state area in the map is the focus of regulatory attention. It accounts for the vast majority of total SO_2 emissions in the country and a large share of NO_x emissions as well. The main sources are coal-fired power plants (which emit 74% of the SO_2 in the area), while in the West and Canada, automobiles and smelters contribute a larger share to overall emissions. If Ontario were included in the above state rankings for SO_2, it would be number 15.

From: Conservation Foundation Letter. Dec. 1982. The Conservation Foundation, Washington, D.C.

What About People?

There is concern about how acid rain affects our health, but little is known. However, we are a part of our ecosystem, dependent for our health and survival on the health of our environment. If we pollute it and disrupt ecological processes, we are harming ourselves.

Acid Rain-What Can Be Done?

Air pollution, like the wind thar carries it, is not confined by political boundaries (Figure 7). Solving the acid rain problem will involve cooperative action among governments at all levels. Wisconsin is taking action to curb acid rain, recognizing that our citizens and many of our major industries depend on a healthy environment. Tourism, fishing, forestry, agriculture and recreation all are critical to Wisconsin's economy and could be affected adversely if acid rain goes unchecked.

In 1979, the Wisconsin Department of Natural Resources began an intensive acid rain research effort. This research includes measuring the pH of acid rain in the state, tracking weather patterns to determine acid rain's origin and determining what effects acid rain is having on Wisconsin ecosystems. Wisconsin legislators passed a "cap law" (SB 398 Act 414) in 1983 that placed limits on SO, emissions at the five largest electric utilities in the state. The legislature also passed a bill (SB 354 Act 413) that instructed the Department of Natural Resources to study the economics of reducing SO, emissions within the state. Wisconsin legislative activities in 1985 focused on ways to ensure that the pH of rain falling in Wisconsin did not go below 4.7. Scientists believe that rain must be at or above a pH of 4.7 to prevent Wisconsin's most sensitive lakes from becoming acidic.

Wisconsin must comply with the national Clean Air Act (Public Law 88-206). While the Act sets air quality standards for the nation, it does not set specific standards about acid rain. The Wisconsin government supports strengthening the Clean Air Act to include requirements for reducing acid-forming emissions nationwide.

Nationally, legislators are recommending more research and modification of the Clean Air Act to make it effective in controlling pollutants. Legislators are challenged with deciding just how much reduction of emissions is needed, how to finance these reductions and how to avoid hurting state economies.

Internationally, acid rain problems are increasing. Canada receives about 50% of its acid rain from the United States, while about 15% of the United States' acid rain comes from Canada. The two countries entered into diplomatic negotiations in 1978 to address the problem of transboundary airborne pollution, but as of early 1986, no agreement had been signed. The Canadian Parliament has passed acid rain control bills and Canadian environmental groups have launched lobbying campaigns to encourage similar legislation in the United States. The United States, however, continues to lag behind Canada in controlling emissions.

What Can We Do?

In addition to writing to our legislators to support state and national legislation that places controls on emissions, each of us can think about our daily activities and ways we can reduce pollution. See the section, "More Activity Ideas," which suggests how each of us can reduce our use of energy that is produced by the burning of fossil fuels – the major source of pollutants that cause acid rain and deteriorate our environment.

Conclusion

That cool spring shower that splashes off your jacket may contain more than just beneficial fresh water. Acid rain threatens our environment. Because of the complex, long-term effects of acid rain we need cooperative, long-range action to reduce acid forming emissions, action involving each of us. While protecting our environment will involve economic cost and possible changes in lifestyle, the benefits of maintaining a healthy environment are priceless and worth the effort.

Glossary:

Acid deposition: The transfer of acidic compounds from the atmosphere to the earth's surface.

Acid rain: A popular term used to describe precipitation with a pH of less than 5.0. In this guide, "acid rain" is used to refer collectively to wet and dry acid deposition.

Alkalinity: A measurement of dissolved carbonates in water. These dissolved carbonates (CaC03 or MgC03) act to neutralize acids.

Basic: Refers to a substance with a pH greater than 7. Often neutralizes acid.

Buffering capacity: The ability of soil or bodies of water to resist change in pH by neutralizing added acids or bases.

Calcareous soil: Soil with high concentrations of calcium and magnesium carbonate (CaC03 and MgC03) that resists changes in pH.

Dry deposition: Acid molecules that fall from the atmosphere to earth alone or attached to dust, soot or other fine particles.

Ecosystem: A natural community of any size with interacting biological (living) and physical (non-living) parts.

Fossil fuels: Hydrocarbon fuels, such as gas, oil and coal, derived from living matter of a previous geologic time.

Granite: Hard igneous rock composed mainly of quartz, with low permeability to water and low chemical ability to neutralize acid.

Limestone: Sedimentary rock composed of calcium or magnesium carbonate (CaCO3, MgCO3). that has a high ability to neutralize acid.

Nitrogen oxides (NO,): Compounds composed of nitrogen and oxygen. Some of these are converted into acids in the atmosphere (e.g. nitric acid, HN03) which are a main component of acid rain.

Normal precipitation: Precipitation with a pH near 5.6. It is naturally slightly acidic because carbon dioxide in the air combines with water to form a weak carbonic acid solution.

pH: A measure of the hydrogen ion (H +) concentration in a solution. The pH is the numerical scale commonly used to describe acidity and alkalinity. The pH scale ranges from 0 to 14 – pH 1 is very acidic (battery acid), pH 7 is neutral, and pH 13 is very alkaline (lye). Abbreviation for "potential of Hydrogen."

Sulfur oxides (SO,): Compounds composed of sulfur and oxygen. Some of these oxides are converted into acids in the atmosphere (e.g. sulfuric acid, H2SO4) which are a main component of acid rain.

Tall stacks: Arbitrarily defined as smokestacks over 180 meters tall. Many stacks over 300 meters tall were built to reduce sulfur and nitrogen oxides near their emission sources. When oxides are injected higher into the atmosphere, air currents disperse them.

Terrestrial: Living on land.

Wet deposition: Precipitation (rain, snow, sleet, hail, fog, dew) that contains dissolved sulfuric and nitric acids.

Activities

Activity #l: Acids Unveiled

Grade Level: 4-12

Goal: To determine the acidity of familiar liquids and draw comparisons between the acidity of these liquids and acid rain.

Materials:

- full-range litmus paper (available at biological -supply companies and some drug and pet stores)
- clean glass containers (small beakers, oetri dishes. babv food jars)
- solutions to test (tap water, distilled water, rain water, soft drink, coffee, tea, lemonade, liquid antacid, other liquids you would like to test)
- tape and marker for labels
- notebook for each group

Background: See section in this study guide called " 'Acid' Rain: What Does It Mean?"

Procedure: Divide the class into small groups. Give to each group one glass container for each solution to be tested. Students should:

1. Label each container with the name of the solution that will be placed in it.

2. Draw the following data sheet in their notebook :

	solution	predicted pH	actual pH	acidic/neutral/basic?
1				
2				
3				
etc.				

3. Place enough of the appropriate solution in each container to cover the bottom (about 1/2 inch).

4. Predict the pH of each solution and record it.

5. Test the pH of each solution by dipping the full-range litmus paper in the solution. Record results.

Questions:

1. Which solution is most acidic? Which is neutral? Which is most basic?
2. Which solution has the lowest pH? Which has the highest pH?
3. Which solution has the highest concentration of H^+? Which has the lowest concentration of H^+?
4. What was the pH of tap water? What might determine the pH of tap water in your area?

Going Beyond:

1. Have students draw a pH scale and write the name or draw a picture of each solution they tested next to its corresponding pH on the scale. (See Figure 1 for sample pH scale.)

2. Collect rain or snow samples in clean glass containers, at school and/or at home. Note where samples were collected – runoff from roofs or trees may have an altered pH. Record the data suggested in the sample data sheet below.

Collect samples over a period of three weeks to several months. Compare the pH of samples collected at different locations during the same storm, or of samples collected at different times at the same location. Do the pH's differ at all? What are possible explanations for similarities or differences? For example, how might the path of a storm affect the pH of its precipitation? Check weather reports and maps to track where the storm came from. Remember, normal rain has a pH of 5.6.

3. Take a field trip to collect water samples from nearby streams, lakes, bogs, or ponds. Be sure to label the samples. If possible, collect several samples from each location so you can get an average pH reading. Compare the pH's of the samples and record them on a data sheet. What might the pH tell you about what aquatic organisms can live in the water from which you got the samples?

sample	date collected	location	type of precipitation	PH
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

Activity #2: Spinning a Web

Grade Level: 1-6

Goal: To simulate an aquatic food web and how acid rain might influence it. To help students understand the interdependence of organisms in an ecosystem.

Materials:

- a ball of string
- index cards with string attached for students to hang around their necks (one/student)
- marker

Background: An ecosystem is a community of interrelated physical and biological components. Physical components are sun, water, air, space, chemicals, etc. Biological components are the plants and animals that live in the ecosystem. All components interact with each other, and if one changes (for example, a lake's water chemistry changes) the others may be affected. Figure 8 is a representation of a food web in an aquatic ecosystem. It shows the primary producers (plants), primary consumers (animals that eat plants) and secondary consumers (animals that eat other animals). Imagine the possible effects of acidic input into this aquatic ecosystem. For example, if increased acidity prevents tadpoles and fish from surviving, how will this influence the heron or otter that eats them?

In this activity, students will become plants, animals, or other components of the aquatic ecosystem (e.g. air, water, sun, soil) and will develop a food web of their own. Encourage student creativity, but suggest that the organisms and relationships that they select be ecologically realistic. Key concepts that can be introduced and discussed in this activity include interdependence, predator-prey relationships, food chains, food webs and energy flow through an ecosystem.

Aquatic ecology resources are listed in the Resources section.

Procedure:

1. Pretend that an area on the ground is a pond or lake. Have students select the plant, animal or other component of the environment whose role they would like to play in the web, write the name on an index card and place the card around their necks. One student should play the role of acid rain and should wait until the web is developed before he or she enters.
2. Have a plant hold the string and stand in the lake near its edge.
3. Ask an insect that eats plants to take the ball of string and unwind it while going to stand on the opposite side of the lake. The string connects the insect to the plant it eats.
4. With the string, connect the insect to another plant, or to an animal that eats it, or to a physical component that it needs. Continue to build a web by connecting each student to **two** things that it needs or that need it.
5. Once the web is constructed, ask the students to keep their eyes closed. Now have the student who is acid rain take hold of one of the students in the web. This organism is now "harmed" and should tug on the string to indicate that the web has been affected. Whoever feels a tug should also tug on the string. The result will be that all students will be tugging the string, representing that when one type of organism in the food web is affected by acid rain all organisms are affected., Have the students open their eyes so that they can see that all elements of the web are tugging on the string and are interrelated. Discuss these connections.

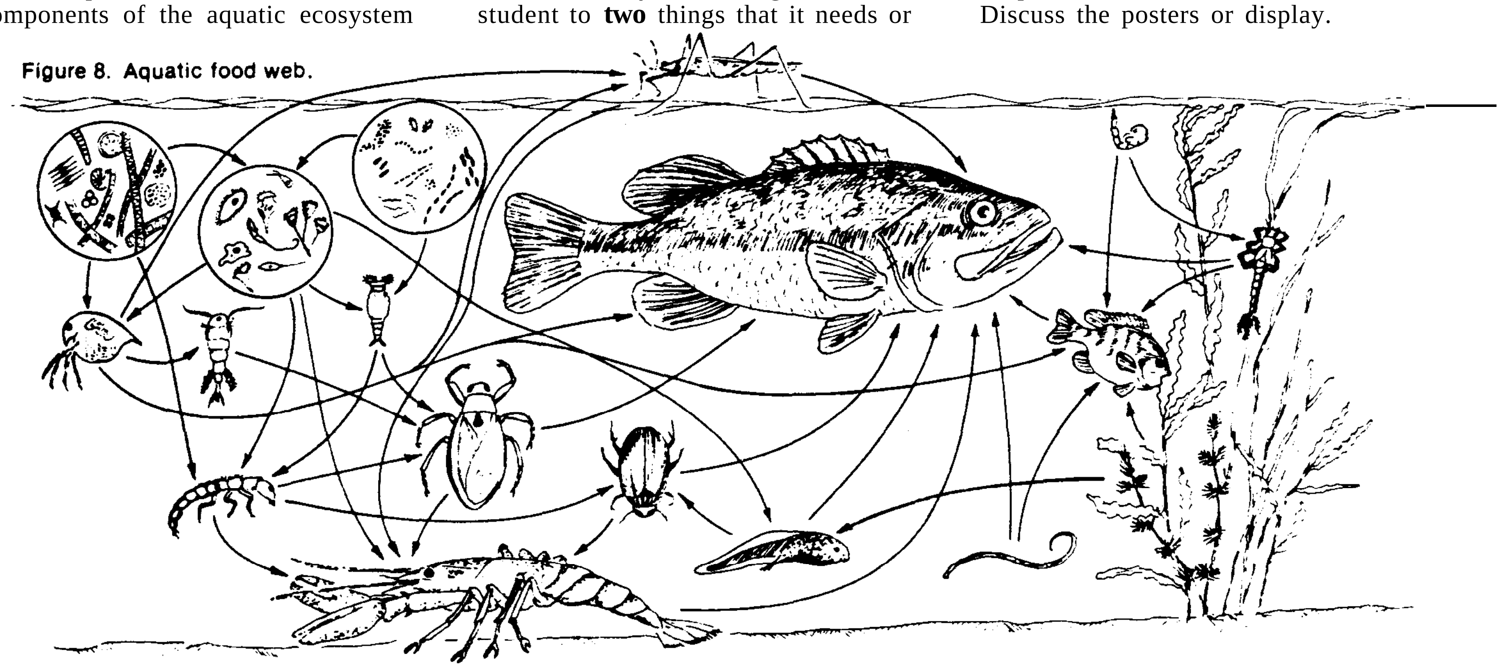
Questions:

1. What might happen to a food web if even one species of plant or animal is affected by acid rain?
2. Do you think people are affected when acid rain causes change in the chemistry of a lake? How are we influenced?

Going Beyond:

1. Have the students make a large poster of the food web that they made in class or reconstruct the web on a bulletin board by tacking up the index cards used in the activity and connecting them with brightly colored string or yarn. Include acid rain and its possible sources and effects. Discuss the posters or display.

Figure 8. Aquatic food web.



Activity #3: Acids in Your Hometown

Grade Level: 5-12 .

Goal: To encourage students to consider the effects of acid rain in their own community.

Materials:
- text section of this study guide
- **The Acid Test,** a DNR publication (see Resources)
- information gathered by students

Background: Acid rain is pervasive and its effects may influence each of us, since we are part of our environment. This activity is designed to help students find out what effects acid rain may have on their local natural and human-made environments, and how these effects may be perceived by people in their community.

Procedure:

1. Have your students find and read articles from the newspaper that address the topics of airborne pollutants and acid rain. **As** background information, have them read the text section of this study guide and articles in **The Acid Test.**

2. Discuss the subject of acid rain – what it is, how it forms, what its sources are, what effects it has on our environment, why it is a problem and what each of us can do to help solve the problem. Focus on the effects of acid rain on your immediate community: How might it influence a farmer's crops? What affect might it have on local buildings, statues or gravestones? How might it affect the fish in nearby lakes or streams? Is the water we drink influenced by acid rain?

Going Beyond:

1. Have students interview or poll local adults, including their parents, for opinions about whether acid rain is a detriment or benefit to the community, or whether it is a concern at all. Discuss the interview results in class, making sure that the students understand that even if acid rain is not perceived to be a problem, this does not mean that the problem does not exist. If the students want to learn just how acidic the rain, snow, lakes, or streams are in their community, they could conduct their own study. Use "Activity #l: Going Beyond" as a guide for conducting this study.

2. Have the class poll students and teachers to determine the degree of acid rain awareness in the school.

3. Have the students interview scientists, environmental quality experts, environmental activists, legislators and other professional people in their community who are knowledgeable about acid rain and compare and discuss responses.

Activity #4: A Burning Issue

Grade Level: 4-12

Goal: To have students share their knowledge with other students and adults. To encourage team work and creativity.

Materials:
- art and writing materials
- reference materials (see Resources)

Background: Acid rain is a topic that many people have heard about. However, their understanding of acid rain **issues** may be limited. This activity provides students with the opportunity to inform others by sharing what they have learned about acid rain.

Procedure: Discuss with your students possible strategies for disseminating information about acid rain and assist them in organizing and enacting their selected strategy. For example, help them organize into a production staff for a newsletter by having them divide into teams to do research, writing, artwork, layout, or other jobs. They also could write articles, poems, songs, essays and editorials, make posters, draw cartoons and illustrations and create puzzles and activities all designed to increase public understanding of acid rain. Help them display or distribute their final product.

Going Beyond:

1. Send the students' product to congressional representatives and other government officials to let them know their constituents' views.

2. Have students contribute articles and cartoons to the school newspaper or other organizations' newsletters if time does not permit them to write their own newsletter.

Activity #5: Acid Policies

Grade Level: 7-12

Goal: To help students gain an understanding of the legislative process and existing air pollution and acid rain policy.

Materials:

- this study guide
- **your** local library
- **The Acid Test,** a DNR publication (see Resources)
- writing materials for each student

Background: Ever since acid rain was recognized as an environmental problem, the public and legislators have sought ways to control the emissions that cause it. While addressing the problem through elected legislators is desirable, it also is difficult. For example, a state may pass effective emission control laws, yet still receive acid rain from a neighboring state that has weaker emission control laws. Legislators are forced to address the problems of what standards to set for controlling emissions, financing the costs of emissions control and establishing enforcement strategies.

Procedure:

1. Have your students investigate existing legislation about acid rain and airborne pollutants (e.g. Wisconsin sulfur cap law; national Clean Air Act; the report: A Course of Action to Reduce Acid Rain in Wisconsin). Provide time in class for students to present their findings. Discuss the legislation with these questions in mind: What is the legislation's goal? How successful has the legislation been in accomplishing its goal? What do the students think the laws should do? Who is affected by the legislation and how are they affected? What are the costs and benefits of the legislation, economically and ecologically? Who pays the price for the changes that the laws create?
2. After they have reviewed the existing legislation, have students write their own bills and present them to the class for a vote. Hold a discussion of the relative merits of the proposed bills, and allow .students to amend them until they can be passed by a majority.

Going Beyond: Have the class send the bills that they have proposed to their state and federal representatives and legislators as suggestions for possible legislation. Discuss the replies received from these individuals.

More Activity Ideas!

Here are more activities you can do:

- Have students put together a bulletin board that presents information, newspaper articles, illustrations, research reports, etc. about acid rain.

- Investigate the history of acid rain: causes, recognition as a problem, research, legislation and environmental impacts.

- Research the technologies that are available to industries for controlling emissions.

- Visit a local electric power generating plant, paper plant, or other industry. Discuss air pollution technologies, what controls the plant is using and what the plant's views, policies and concerns are about emissions controls.

- Investigate what controls help reduce emissions in cars, trucks and other vehicles. What legislation exists that addresses automobile emissions? How would emissions controls affect: the economics of the automobile industry; the cost of a car; the environment?

- Collect acid rain and air pollution cartoons from newspapers and magazines and display and discuss them.

- Have students use the words listed in the glossary of **The Acid Test** to design an acid rain crossword puzzle or word search puzzle.

- Have your students correspond with students in other states or countries about acid rain. Develop an exchange of information and viewpoints.

- Have students assume the roles of different people concerned about acid deposition (industry representative, forester, farmer, environmentalist, pollution scientist, citizen), research their person's viewpoint and debate the issue of acid rain.

- Contact local natural resource specialists to find out what impact, if any, acid deposition is having on lakes, forests, groundwater, etc. in your area.

- Ask your students to imagine that they are scientists. Have them design a research project that investigates some aspect of acid rain. Discuss the research question, research design and possible answers. Have a local scientist review the proposed research and comment on it.

- Investigate acid rain research being conducted in Wisconsin to discover if research is underway in your area. Take a field trip to a research site.

- Have students investigate local and regional weather patterns to determine the origin of your area's weather. Investigate whether your area is receiving acid forming emissions and where they might be originating.

- Contact the natural resource management and/or environmental protection agencies of Canada or states adjacent to Wisconsin **Research and report on acid rain** research, issues and laws. **Are the issues** similar to or different from **Wisconsin's? Do they affect Wisconsin? How?**

- **Explore the subject of buffering capacity. Relate classroom activities with what occurs in the environment. Obtain copies of geologic maps that show Wisconsin rock types from Wisconsin Geologic and Natural History** Survey, 3817 Mineral Point Rd., Madison, WI 53706, 608-263-7389. What regions of the state have rock types that will or will not buffer acid input? What does the buffering capacity indicate about the susceptibility of lakes in different parts of the state to acid input?

- Take a field trip to a cemetery. Look for signs of weathering on the gravestones. What can you say about **rates** of **weathering** of different types of rock? Be sure to take the dates of the gravestones into consideration when comparing weathering.

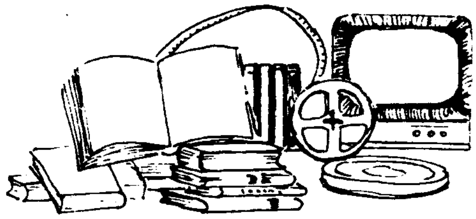
- View some of the fine films and TV special programs on acid rain (see Audio-Visual Materials).

- Have students investigate other forms of air pollution (e.g. ozone, wood smoke, toxic gases, dust) and their effects on our environment.

- Think of ways that you can change your daily activities to reduce your use of energy. List them. For example:

  - ☐ Instead of driving to school or **to the store, walk, bicycle, or take the bus.**
  - ☐ Try to car-pool when you have to use a car.
  - ☐ Consider driving a small car. It will burn less gas than a big car, and will still get you to the same place!!
  - ☐ Investigate alternate, less-polluting energy sources for heating your school or home, like natural gas or solar energy.
  - ☐ Turn off electric lights or appliances in your school or house when nobody is using them.
  - ☐ Recycle recyclable materials (glass, aluminum, newspaper).
  - ☐ Substitute recreational activities that use gas and oil with those that don't. Go wind-surfing instead of water skiing; try cross-country skiing instead of snowmobiling; tour the state by bicycle instead of by car. An added benefit is that these forms of recreation improve your health!
  - ☐ DO some of the things you suggested!

Is acid ram affecting you?



RESOURCES

Resource Lists

Acid Precipitation: An Annotated Bibliography. 1984. U.S. Geological Survey, Distribution Branch, Text Products Section, 604 S. Pickett St., Alexandria, VA 22304.

Acid Rain Resources Directory. 1985. The Acid Rain Foundation Inc., 1630 Blackhawk Hills, St. Paul, MN 55122.

A Bibliography: The Long-Range Transport of Air Pollutants and Acidic Precipitation. 1980. Environment Canada, Information Directorate, Les Terrasses de la Chaudiere 10 Wellington St., Ottawa, Ontario K1A OH3 Canada.

General Acid Rain References

Acid Deposition: Atmospheric Processes in Eastern North America, A Review of Current Scientific Understanding. 1983. National Academy Press, 2101 Constitution Ave. NW, Washington, DC 20418.

Acid Rain. 1983. Robert H. Boyle and R. Alexander Boyle. Schocken Books, Inc., 200 Madison Ave., New York, NY 10016.

Acid Rain. 1983. Kathlyn Gay. Franklin Watts, Inc., Shermann Tpke., Danbury, CT 06816.

Acid Rain: A Critical Perspective. 1981. Joshua J. Schneck. Tasa Publishing Co., 5230 W. 73rd St., Minneapolis, MN.

Acidification — A Boundless Threat to Our Environment. National Swedish Environment Protection Board, Box 1302, S-171 25 Solna, Sweden.

A Killing Rain: The Global Threat of Acid Precipitation. 1984. Thomas Pawlick. Sierra Club Books, 2034 Fillmore St., San Francisco, CA 94115.

Supplements, Pamphlets and Reports

A Course of Action to Reduce Acid Rain in Wisconsin. 1986. Wisconsin Acid Deposition Review Committee Final Report, Department of Administration, Division of State Energy and Coastal Management, 101 S. Webster St., Madison, WI 53702.

Conservation Foundation Letter. Dec. 1982, "Acid Rain – A Major Threat to the Ecosystem" and Jan. 1983, "Will Congress Swallow an Anti-Acid Bill?" Conservation Foundation, 1255 23rd St. NW, Washington, DC 20037.

The Acid Rain Primer. 1982 Pollution Probe Foundation, 12 Madison **Avenue,** Toronto, Ontario M5R 2S1 Canada.

The Acid Rain Story. 1984. Environment Canada, Information Directorate, Les Terrasses de la Chaudiere 10 Wellington St., Ottawa, Ontario KIA OH3, Canada.

The Acid Test. 1984. *Wisconsin Natural Resources* magazine supplement, Nov-Dec., Vol. 8, No. 6. Bureau of Information and Education, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

Aquatic Ecology References

Effects of Acidic Precipitation on Benthos. 1981. Robert Singer, Editor. North American Benthological Society, Box 878. Illinois Environmental Protection Agency, Springfield, IL 62705.

Field Book of Ponds and Streams. 1930. Ann Haven Morgan. G.P. Putnam and Sons, 200 Madison Ave., New York, NY 10016.

Pond and Brook: A Guide to Nature Study in Freshwater Environments. 1985. Michael J. Caduto, Prentice-Hall, Inc., Englewood Cliffs, NJ 07632.

Pond Life. 1967. George K. Reid. Golden Press, Western Publishing Co., Inc., 850 Third Ave., New York, NY 10022.

The Life of the Pond. 1967. William H. Amos. McGraw-Hill Book Co., 1221 Ave. of the Americas, New York, NY 10020.

Curriculum Materials

Acid Precipitation Awareness:

Currently available from:

The Acid Rain Foundation, Inc., 1630 Blackhawk Hills, St. Paul, MN 55122.

Laboratory and Classroom Activities for Science, Social Studies, Environmental Sciences, Grades 6-12.

Eiementary Interdisciplinary Activities, Grades 4-7.

Also available in Sept. 1986:

Science Project Booklet for Students, Grades 6-10.

Effects of Air Pollutants on Forests: Curriculum Materials.

Acid Rain. Software for Apple Computer, Grades 5-12. Diversified Educational Enterprises, 725 Main St., Lafayette, IN 47901.

Acid Rain Bio-Kit. No. 65-3075. Carolina Biological Supply Co., Burlington, NC 27215.

Acid Rain Teacher's Kit. 1983. Activities for Grades 4-12. Item No. 79678. National Wildlife Federation, 1412 16th St. NW, Washington, DC 20036.

Acid Rain Test Kit. Natural Resources Council of Maine, 271 State St., Augusta, ME 04330.

Acid Rain Visual Learning Packet. Twelve transparencies and teacher's guide. Media Associates, 5230 W. 73rd St., Minneapolis, MN 55435.

Air Pollution. Software for Apple Computer or TRS-80 Model III and IV, Grades 7-12. Educational Materials and Equipment Co., P.O. Box 17, Pelham, NY 10803.

Audio-Visual Materials

Acid From Heaven. 16mm print. National Film Board of Canada, Suite 313, 111 E. Wacker Dr., Chicago, IL 60601.

Acid Rain. Wisconsin Educational Television video, 20 min. 1986. Part of Science, Technology and Society Project, Interactions Video Series. Check: **Parade of Programs,** Instructional Television Programming Schedule. Accompanying computer simulations for Apple IIe/ + . Wisconsin Educational Television and Radio Networks, 3319 W. Beltline Hwy., Madison, WI 53713-2899.

Acid Rain – The Choice Is Ours. Slide/tape. Media Associates. 5230 W. 73rd St., Minneapolis, MN 55435.

Acid Rain: New Bad News. Video-cassette 60 mm. NOV.4 – WGBH, Boston.' Dec. 11, 1984. Time-Life Video, 100 Eisenhower Dr., Paramus, NJ 07652.

Acid Rain: Requiem or Recovery. 16mm print. National Film Board of Canada, Suite 313, 111 E. Wacker Dr., Chicago, IL 60601.

Acid Rain Update – Man and Molecules. Audio-tape, #1095 1982. American Chemical Society News Service, 1155 16th St. NW, Washington, DC 20036.

A Hard, Hard Rain. Video-cassette, 15 min. Freshwater Foundation, 2500 Shadywood Rd., P.O. Box 90, Navarre, MN 55392.

Scientists Look at Acid Rain. Audio-tape, 29 min. NPR Journal, No. 820222. National Public Radio, 2025 M St. NW, Washington, DC 20036.

Stop the Rain. Slide/tape, 25 min. 1985. Sigurd Olson Environmental Institute, Northland College, Ashland, WI 54806.

To Catch a Cloud: A Thoughtful Look at Acid Rain. Video-cassette, 27 min. Edison Electric Institute, 1111 19th St. NW, Washington, DC 20036.

What Price Clean Air? Video-cassette. 1982. Films, Inc., 5547 N. Ravenswood Ave., Chicago, IL 60640.

For Information About Acid Rain, Write or Contact:

Wisconsin

The League of Women Voters, 121 S. Hancock St., Madison, WI 53703-3447.

Sigurd Olson Environmental Institute, Northland College, Ashland, WI 54806.

University of Wisconsin – Extension, Environmental Resources Center, 216 Agriculture Hall, 1450 Linden Drive, Madison, WI 53706.

Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707. (Bureau of Information and Education, 608-266-6790; Bureau of Air Management, 608-266-77 18)

Wisconsin Environmental Coalition on Acid Rain (WECAR). Contact the following member organizations:

Citizens for a Better Environment, 150 W. Juneau Ave., Suite 206, Milwaukee, WI 53202; 111 King St., Madison, WI 53703; 1270 Main St., Green Bay, WI 54302.

Sierra Club, John Muir Chapter, 111 King St., Madison, WI 53703.

Wisconsin's Environmental Decade. 14 W. Mifflin St., Madison, WI 53703; 230 W. Wells St., Suite 309, Milwaukee, WI 53203; 214% E. College Ave., Appleton, WI 54911.

Wisconsin Lung Association, 1701 W. Wisconsin Ave., Box 424, Milwaukee, WI 53201.

Your local utility company.

United States

Acid Rain Foundation, Inc., 1630 Blackhawk Hills, St. Paul, MN 55122.

American Paper Institute, National Forest Products Association, Environmental and Health Program, 1619 Massachusetts Ave. NW, Washington, DC 20036.

Conservation Foundation, 1255 23rd St. NW, Washington, DC 20037.

Edison Electric Institute, 1111 19th St. NW, Washington, DC 20036.

Electrical Power Research Institute, Environmental Assessment Department, 3423 Hillview Ave., P.O. Box 10412, Palo Alto, CA 94303.

lzaak Walton League of America, 1701 N. Ft. Myers Dr., Suite 1100, Arlington, VA 22209.

Mid-Continent Area Power Pool, 1250 Soo Line Building, 507 Marquette Ave. Minneapolis, MN 55402.

National Audubon Society, 645 Pennsylvania Ave. SE, Washington, DC 20003.

National Coal Association, 1130 17th St. NW, Washington, DC 20036.

National Wildlife Federation, 1412 16th St. NW, Washington, DC 20036.

Trout Unlimited, National Headquarters, 118 Park St. SE, Vienna, VA 22180.

U.S. Environmental Protection Agency, 401 M St. SW, Washington, DC 20460.

U.S. Environmental Protection Agency, Region V, 230 S. Dearborn, Chicago, IL 60604.

Canada

Canadian Coalition on Acid Rain, 105 Davenport Rd., Suite 201, Toronto, Ontario M5R 1H6, Canada.

Canadian Nature Federation, 75 Albert St., Ottawa, Ontario K1P 6G 1, Canada.

Environment Canada, Information Directorate, Les Terrasses de la Chaudiire, 10 Wellington St ., Ottawa, Ontario K1A OH3, Canada.

Ministere de l'Environment du Quebec, Service de I'education, 5199 rue Sherbrooke Est, Bureau 3860, Montreal, Quebec H1T 3X9, Canada.

National Survival Institute, 53 Queen St., Suite 27, Ottawa K1P 5C%, Canada.

> The purpose of **Department of Natural Resources study guides is to help increase** Wisconsin citizens' **knowledge about and understanding of our state's environment.** We hope to **provide information about important environmental issues, encourage respect for the environment and help citizens become informed and active stewards of our natural resources.**

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Your comments and suggestions on this study guide are welcome. Please address your reply to:

Environmental Education Specialist
Wisconsin Department of Natural Resources
Box 7921
Madison, WI 53707