# Acid Rain

Sixteen-year-old Dan Shuman of Dover, Pennsylvania, noticed that the trees in his backyard were dying. And when he fished, he caught fewer trout and bass in the lakes and streams near his home. He suspected that acid rain was to blame.

He read in a fishing magazine that Dickinson College provided acid rain monitoring kits. So Dan recruited fifteen energetic Boy Scouts and raised money from several sports clubs. (The testing kits were $20 each.)

With his volunteers and kits, Dan set out to monitor twenty-two streams in the area. After a year of testing streams, Dan sent the information to Dickinson College for analysis. The college reported that the water was contaminated by acid rain.[1]

Yes, Dan and his crew of Scouts may have found that the streams they tested were contaminated with acid rain, but they did *not* find proof that acid rain was killing fish. And, the likelihood that his trees were dying from acid rain is slight. As we shall see in this chapter, while acid rain does exist, it does not have the widespread effects that are claimed for it.

## Dead Fish, Dying Trees

"Acid rain is now the most controversial form of air pollution in the developed world," declares one text. "Factories spew forth sulphur oxides and nitrogen oxides, which dissolve in rain before returning to earth as sulphuric and nitric acids." It continues to say that "the result is a corrosive solvent 1,000 times as acidic as natural rain."[2] Other texts may not be so dramatic, but they convey the same message.

- *Innovations in Science* cautions that "acid rain . . . pollutes lakes and rivers, damages forests and farmland, corrodes limestone and metal structures, and affects the health of humans, plants, and animals."[3]

- *Investigating Terrestrial Ecosystems* says that "recent studies suggest that acid rain is affecting growth and regeneration of forests."[4]

- "Trees in the maple forests of Quebec are dying, and some people are predicting the end of the maple syrup industry," as a result of acid rain, according to the geography text, *Canada in a Changing World*.[5]

- "It is now feared that acid rain will cripple or destroy the maple sugar industry in eastern Canada," says *Journeys in Science*.[6]

- "Acid rain has produced serious effects in the northeastern United States, Canada, and Scandinavia," says *Earth Science*. "Many lakes have become so acid that fish can no longer survive in them."[7]

Our children learn that air pollution from cars and coal-burning power plants in the midwestern states are carried by winds to the northeastern states and Canada. There, acidic rain and snow pollute lakes, streams, and the ground. Forests, fish, and crops are dy-

ing and buildings and statues are crumbling. Rarely do textbooks indicate that there is any question about the cause-and-effect relationship between acid rain and dying forests and lakes. Textbooks and other materials suggest experiments to dramatize the perils of acid rain.

- *The Canadian Junior Green Guide* instructs children to compare seeds sprouted in vinegar to seeds sprouted in water. Not surprisingly, the seeds exposed to vinegar don't grow.[8]

- Other textbooks suggest making a heavily acidic solution and spraying it on living plants. After several weeks, children observe that the plants wither and die.

- A book for children called *Ecology* instructs children to use a fish tank to create a closed system that has fish that produce carbon dioxide and grass that produces oxygen. The child experimenter sends sulfur dioxide gas into the air in the tank through a tube. Soon, the grass and fish die due to the acid rain that has been created in the mini-environment.[9]

- A *Teacher's Place Activity* located on the Environment Canada website instructs the teacher: "Pour vinegar onto five paper towels and place around the classroom before students come in. Note their reaction when they enter the class. Note their reaction to the odour when they enter the class. Tell the students what you did, and explain to them that you wanted them to experience the discomfort of a pollutant in their environment. Transition the class' thoughts to what it would be like for aquatic life in a pond or lake with increasing acid levels."[10]

These lab experiments are not accurate representations of the complex cause-and-effect relationships that surround acid rain.

- In the *Canadian Junior Green Guide* experiment, students are using vinegar with a pH level of 3. Acid rain in North America typically has a pH of 4.6. This means that the water used in the experiment is about forty times more acidic than the average acid rainfall.

- In the other projects, student are not told how to calculate or control the pH level of the acidic water.

## What, Exactly, Is Acid Rain?

The term "acid rain" sounds ominous. It makes us think of rain so contaminated that it resembles car battery acid, and, in *Projects for a Healthy Planet: Simple Environmental Experiments for Kids*, Shar Levine and Allison Grafton actually claim that "acid rain has been recorded with the same pH as battery acid."[11] But, in fact, the term simply means rain that has a higher concentration of hydrogen ions than natural rain. It occurs when clouds or raindrops pick up substances from vehicle exhaust and coal-burning power plants that form acids when dissolved in water. This moisture can be transported over some distance before it falls as "acid rain."

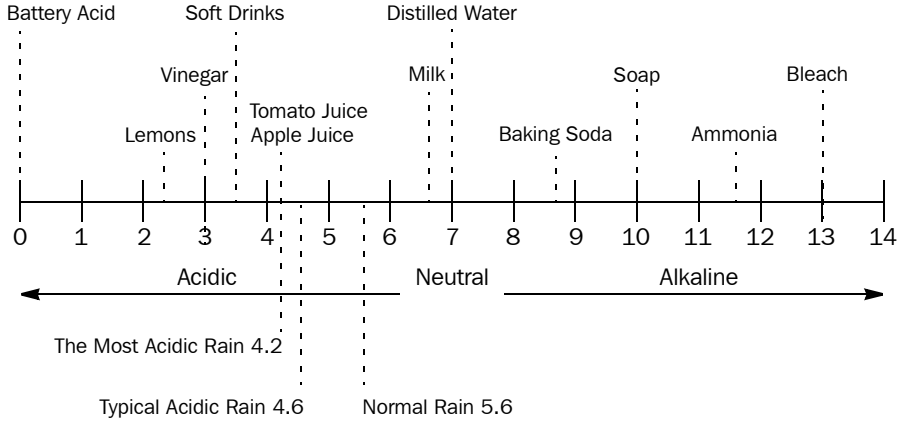
Most *natural* rainfall is slightly acidic because of natural carbon dioxide and nitrogen oxides in the air.[12] But pollutants can, indeed, make rain more acidic. Electrical power plants and automobiles emit sulfur dioxide and nitrogen oxides into the air when they burn coal and gasoline. These chemicals combine with water vapor to produce dilute sulfuric and nitric acids in rain.

Scientists measure acidity on a scale from 1 to 14. This scale, known as the pH scale, measures the concentration of hydrogen ions. A value below 7 indicates that the liquid is acidic; a value above 7 indicates that it is basic or alkaline. This scale is logarithmic; that means that one number represents a value ten times more acidic

than the number just above it. For example, 4 represents a value ten times more acidic than 5 (or 100 times more acidic than 6).

Normal rain has a pH of about 5.0. Acid rain typically has a pH of 4.6, and the most acidic rain in North America (found in western Pennsylvania and nearby areas) has an average pH of 4.2.[13] That is similar to the acidity of tomato or apple juice.

**The pH Scale and the pH Levels of Acid Rain and Some Typical Household Substances**




## What Scientists Say

In the late 1970s, many people became alarmed about acid rain. A few small lakes, especially in Nova Scotia and in Adirondack Park in upper New York State, were found to be acidic. Fish couldn't live in them, yet people remembered a time when some of these lakes did have fish. What had happened?

About the same time, people also began to see forests with many dead and dying trees, especially in Europe. They suspected, incorrectly, that the cause was acid rain resulting from sulfur dioxide emissions from European power plants.

The fear aroused at that time entered the textbooks. Unfortunately, the more complete story that has emerged from scientific studies has not replaced it.

Rarely do any books even hint that there is a large body of evidence that counters the apocalyptic claims about acid rain. Yet this evidence exists. It was collected by the US government.

This ten-year study, the National Acid Precipitation Assessment Program (NAPAP), cost more than $500 million and involved hundreds of scientists and technicians and resulted in hundreds of reports. US Congress authorized the program in 1980 to find out what harm acid rain may be causing. A final report was issued in 1990, and its conclusions, which countered many of the previous assumptions about acid rain, are equally relevant to the situation in Canada.

The scientists found that while acid rain may be harming some lakes and some trees, it is a much smaller problem than most people believed.[14] In fact, it may be beneficial for some agricultural crops and trees. The "Assessment Highlights" of the report came to these conclusions:

- In its nationwide survey of waters, less than 5 percent of the lakes and 10 percent of the streams were found to be "chronically acidic." However, this acidity was not necessarily caused by acid rain.

- Florida, which receives minimal acid rain, not the Northeast, has the highest percentage of acid lakes (23 percent). These lakes appear to be acidic due entirely to natural processes—the lakes are surrounded by highly acidic soils, for example.

- A special study of the Adirondack Lakes, where high acidity had aroused great concern, found that up to 30 percent of the small (two- to ten-acre) lakes in the region are acidic. But many of the lakes have natural organic acids, which can make the water acidic regardless of the acidity of the rain.

- "There is currently no widespread forest or crop damage in the United States related to [acid rain]," said the report. "Some areas may benefit through nutrient enrichment by nitrogen and sulfur deposition."

- Scientists discovered some harm to high-elevation red spruce in the Appalachians when acid rain was present with other factors such as stress from extremely cold winters. These forests account for only a small fraction of one percent of eastern woodlands.

The NAPAP study also found:

- While acid rain contributes to corrosion of building materials, the magnitude "has been difficult to assess."

- Sulfate particles in the air, which lead to acid rain, reduce visibility in some places by causing haze.

A later report from NAPAP studied the problems of European forests.

- The effects of air pollutants "are small compared with other stresses affecting tree condition," the report said. (These include abnormal weather conditions and insect damage.)

- Overall forest productivity has increased in Europe since the nineteenth century.[15]

Unfortunately, most children in our schools have never heard of NAPAP's findings. The *Teacher's Place Activity* on a federal government website was updated as recently as 10 April 1997, more than six years after the NAPAP study published its conclusions. But the NAPAP study was ignored. Environmentalists seem to work harder at scaring students than at correcting their mistakes.

## Those Acid Lakes

Acid rain does not always make lakes acidic. Often, rain falls onto nearby ground and slowly moves through the soil before it enters the lake. If that soil is alkaline—that is, if it has many pieces of limestone in it—the limestone will neutralize the acid.[16]

So, while the NAPAP study found that some Adirondack Lakes are acidic and cannot support fish, one important reason is that the lakes are not surrounded by alkaline soil. If acid rain falls on the streams that feed into these lakes, they gradually become acidic because the surrounding soil does not neutralize or buffer the acidic water.

Nova Scotia has highly acid lakes and streams.[17] Many of them have been recorded with pH levels of 4.7 or lower. The culprit is unlikely to be acid rain, however, since, like Florida, rainfall over Nova Scotia tends to be much less acidic than that over the Adirondacks.

What could be the explanation? Edward C. Krug, a soil scientist who worked on the NAPAP project, offers one. Citing a 1986 study conducted by Environment Canada, he notes that Nova Scotian forestry practices at the turn of the century involved mass burning. In fact, the southwestern 90 percent of the province was "literally burned down to the underlying granite bedrock leaving behind alkaline ash."[18]

Thus the lower pH levels that came about following reforestation efforts may be natural for the area. Krug points out that Kejimkujik Lake in southwestern Nova Scotia had a pH of 4.0 in 1850. After logging and regional burning, pH levels rose to 5.0, but since the regeneration of the surrounding forests, the lake has dropped to 4.8.[19]

In the United States, too, NAPAP researchers found evidence (by studying fossils of algae) that some Adirondack Lakes were acidic in preindustrial times but temporarily lost some of their natural acidity during the late 1800s.[20] (The fact that the Iroquois word "Adirondack" means "bark-eater" also suggests that fish were not plentiful.)

The researchers also found that some Adirondack lakes lost fish for other reasons than acid rain. Changes in water levels caused by beaver-made dams or human-made dams and the introduction of predators explained some losses, for example. Out of the 409 Adirondack lakes that contained brook trout in the past, 282 (about two-thirds) still contain brook trout. Of the 127 that no longer support brook trout, only 44 (about one-third) apparently lost the trout because of acid rain.[21]

One of the studies prepared for NAPAP said that the acid lakes in the Adirondacks could be neutralized by adding lime to the lakes. This would cost $170,000 per year or a total of $500,000 per year for the entire Northeast.[22] This would have corrected the biggest problem caused by acid rain. But the U.S. Congress didn't seriously consider this alternative.

## Controlling Acid Rain

Our children's materials recommend stronger laws to control acid rain but seldom consider whether the costs are worth the benefits.

- *Pollution: Problems and Solutions* (a Ranger Rick's *NatureScope* title) warns that these laws may meet opposition from lobbyists who ask for more proof. But it cautions that "many researchers feel that coming up with such proof may take too long or may not be possible at all."[23]

- A science text discusses who should pay the cost of the necessary smokestack scrubbers—industry or the taxpayers.[24]

In 1990, the U.S. Congress did, in fact, pass laws to control acid rain. Canada is committed in principle to similar actions. Amendments to the U.S. Clean Air Act required all major electric utilities to reduce

their sulfur dioxide emissions by 50 percent by about the year 2000. These regulations are being phased in gradually but they will still speed up the reductions that would have occurred as old power plants were retired.[25] In 1990 it appeared that the regulations would cost companies and electricity consumers from $2.7 to $4 billion per year.[26]

But the U.S. Congress also instituted an innovative program that allows utilities to reduce the costs of adding scrubbers. Although all major utilities must cut back on their emissions, those that can control emissions cheaply can put on extra controls and obtain payment from utilities that can't reduce emissions so cheaply. This "trading" has made the regulations less costly than they would have been, while still achieving the same overall goals.

## Talking to Your Children

Fortunately, acid rain is much less troubling than most people think. With the background in this chapter, you can answer your children's questions.

- What is acid rain?

  Acid rain is rain that has picked up substances from vehicle exhaust and coal-burning power plants that create acids when they are wet. It has a higher concentration of hydrogen ions than normal rain.

- Can acid rain kill fish?

  Yes, in relatively rare circumstances where the soils around the streams and lakes do not neutralize the excess acid. Such lakes can become too acidic to support fish. A number of small lakes in the Adirondacks are too acidic to support fish and the cause may be acid rain. It is possible, however, that the acidity of lakes in

Nova Scotia and the Adirondacks is primarily due to their natural environment. The acidity of lakes or streams is not a serious problem in most of Canada.

- What causes acid rain?

  Acid rain is caused primarily by coal-burning electric power plants and vehicles that burn fuels containing sulfur dioxide and nitrogen oxides. However, natural causes (specifically, carbon dioxide and nitrogen oxides in the air) make most rain slightly acid.

- What should be done about acid rain?

  In 1990, US Congress passed amendments to the Clean Air Act that required electrical utilities to reduce their emissions of sulfur dioxide. This may slightly reduce the number of acidic lakes. It will not restore most of the acidic Nova Scotian or Adirondack Lakes, but may have some other beneficial effects, such as improving visibility in some places, reducing the acid in some soils, and slowing the degradation of metal and stone on the exteriors of buildings.

## Activities for Parents and Children

You may wish to use experiments to introduce your children to acid rain. The experiments that follow are closer to "real world" conditions than the experiments recommended in the texts.

### *Learning about the pH Scale*

To understand the debate over acid rain, children should understand the concepts of acid and base. These are measured on a scale called the pH scale, which runs from 0 to 14, with 7 representing substances that are neutral.

You can illustrate the concept, using pH paper. It can be obtained from a "laboratory chemicals" company (look under "Chemicals" in the Yellow Pages). Ask for pH indicator strips with a pH range of 0–14. (A box of 100 strips will cost about $25.) Michael and his son Devin tried these experiments. *But we emphasize that these experiments require adult supervision!*

*Understanding Acid and Base*

- Materials needed: distilled water (not spring water), a clean glass, a straw, and pH paper.

  Put about half a cup of distilled water in a clean glass. (Do *not* shake the water before the test.) Test the water using the pH paper. It should measure 7 on the pH scale (neither acidic nor basic).

  Using the straw, ask your children to blow gently in the water for three or four minutes. Test the water again with the pH paper. This time it should measure slightly acidic. The reason is that our breath has carbon dioxide in it. The carbon dioxide reacts with water to make carbonic acid. Normal rain water is slightly acidic because the rain reacts with carbon dioxide in the air, forming carbonic acid.

- Materials needed: pH paper, small amounts of materials such as lemon juice, vinegar, ammonia, apple juice, cola, or baking soda.

  Children should draw a line on a piece of paper with equal divisions from 0 to 14. Ask them to test the common household items above and record the pH readings on their scale.

*From Acid to Base*

- Ask your children to take about one tablespoon of vinegar and mix it with a half cup of distilled water. Have them test this so-

lution. It should measure about 3 on the pH scale. Now ask them to collect about two tablespoons of very fine ash from the barbecue or fireplace. Mix the ash with the vinegar solution. When it is dissolved, test the solution. The pH level should increase.

Explain to your children that the ash is basic, and it has neutralized some of the acid.

### *Visiting a Garden Center*

Take your children to a local garden center or nursery. Ask the owner or manager to discuss differences in soils and how plants react to them. Ask this person to tell your children about plants that thrive in acidic soil, and those that will die in such soil. Then have the manager show your children the different products available to treat soil so that it will be the right pH for specific plants.

## Notes

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