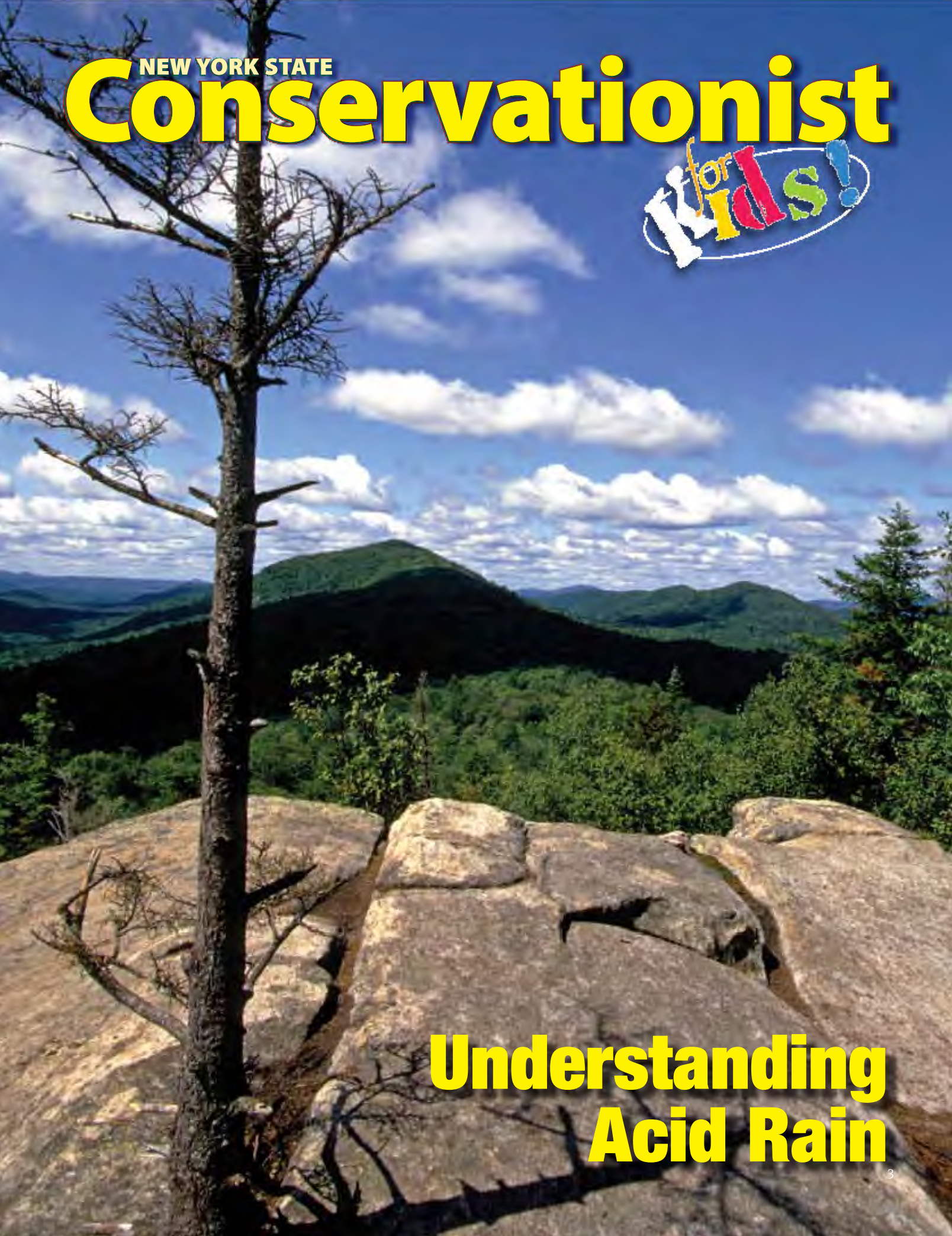
NEW YORK STATE
Conservationist
for Kids!
Understanding Acid Rain

Welcome to NEW YORK STATE Conservationist for Kids!

In this issue:

Researchers study acid rain to learn about how it affects the environment and people. They look for ways to reduce the air pollution that causes acid rain and to counteract the effects it has on our world.

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Visit **www.dec.ny.gov** for information for kids interested in the environment. Search for ***Conservationist for Kids*** to find activity sheets and cool Internet links.

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On the cover: Puffy clouds dot an Adirondack sky. Acid precipitation–in the form of rain, snow, sleet, hail and fog–causes damage to the environment, affecting the health of plants and wildlife. Trees and aquatic wildlife are especially sensitive to the effects of acid rain.

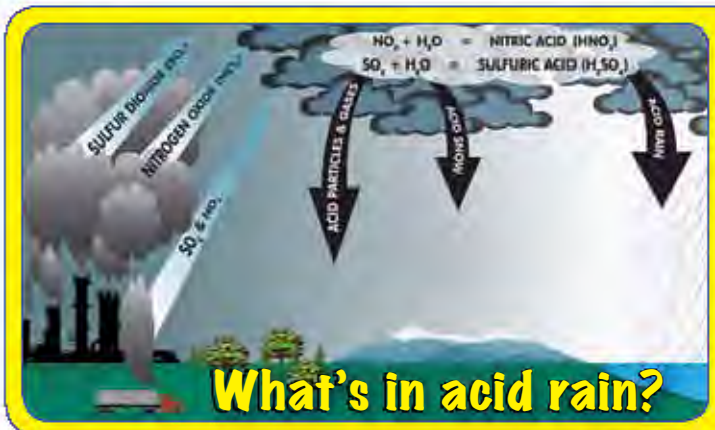
Special thanks to DEC's Division of Air Resources for assisting with the development of this issue of *Conservationist for Kids.*

What's in rainwater?

Raindrops form when water vapor condenses on tiny particles of dust floating in the atmosphere.

As more water vapor condenses, the tiny droplets continue to grow. Eventually, they become so large they fall to the ground. Besides water and dust, raindrops also contain chemicals mixed in from the atmosphere. When water and chemicals in the atmosphere combine and react with each other, the water becomes slightly acidic. Normal "clean" rainwater has a pH around 5.6. (See "What is pH?" on this page.)

The average pH of rainfall in New York State is between 4.5 and 5.0—acid rain.



We burn fossil fuels (coal, oil, natural gas) to generate electricity, run factories, and power our vehicles.

When we burn these fuels, sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are among the polluting gases released into the atmosphere. They mix and react with moisture in the air and form sulfuric acid and nitric acid. Extra acids in the air make rain more acidic. If rainwater has a pH lower than 5.6 (normal clean rain), it's considered to be acid rain. Any form of precipitation—rain, snow, sleet, hail, even fog—can become acidic from pollution.

Wind carries air pollution far from its source. Most acid rain that falls in New York State began its journey hundreds of miles away from here.

Acid deposition can...

- damage forests
- harm plants
- harm animals
- damage soil
- pollute water
- damage buildings and other structures (stone, concrete, metal)

It's not just the rain

Acids from the atmosphere also settle to the ground as dry particles and gases. They are deposited on forests, lawns, lakes, buildings, and more. We call this "dry deposition", and it causes damage, just like wet deposition (rain, snow, etc.).

Environmental Effects	pH Value	Examples
	pH=0	Battery acid
	pH=1	Sulfuric acid
	pH=2	Lemon juice, vinegar
	pH=3	Orange juice, soda
Few fish survive (4.2)	pH=4	Acid rain (4-5)
		Acidic lake (4.5)
Frog eggs, tadpoles, crayfish, and mayflies die (5.5)	pH=5	Bananas (5.0-5.3)
		Clean rain (5.6)
Rainbow trout begin to die (5.5)		Milk (6.5-6.8)
Sensitive minnows die (6.2)	pH=6	Normal lake (6.5-8.0)
	pH=7	Pure water
	pH=8	Sea water, eggs
	pH=9	Baking soda
	pH=10	Milk of Magnesia
	pH=11	Ammonia
	pH=12	Soapy water
	pH=13	Bleach
	pH=14	Liquid drain cleaner

ACIDIC

NEUTRAL

BASIC

What is pH?

pH is a measurement of how acidic or basic (alkaline) a substance is. A reading of 0 is the most acidic on the pH scale, while 14 is the most basic, and 7 is neutral, neither acidic nor basic. Substances at the extreme ends of the scale—either very acidic or very basic when concentrated—can cause chemical burns. Just as mixing hot and cold water makes warm water, acids and bases can cancel out each other and result in a more neutral pH.

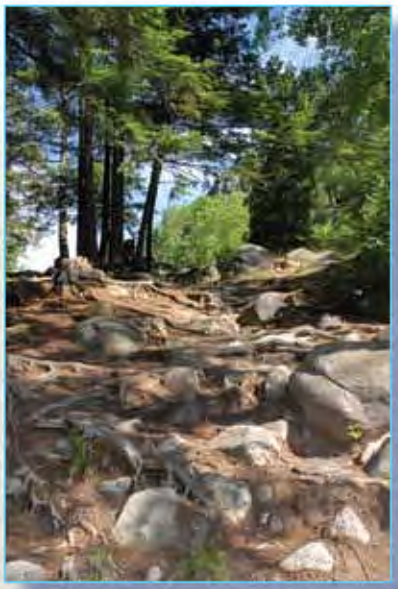
Acid deposition affects specific components of the environment.

Soils

Rainfall seeps into soil. It drips off tree leaves and branches to the forest floor below. The water runs across and through the soil on its way to nearby streams, rivers and lakes.

Base nutrients, including calcium and magnesium, are found in soil and are essential for plant growth. They also neutralize acids and, in a process called "buffering," help soil resist the effects of acid rain. Some soils are thin and/or have only a limited amount of these nutrients. They are not as effective at buffering acid rain as thicker soils and those rich in nutrients. Thin, nutrient-poor soils, such as those found in the Adirondack and Catskill Mountains, are especially sensitive to the effects of acid rain. Over time these soils can become increasingly acidic, reducing their ability to support healthy plant life.

Over a long period of time, soils affected by acid rain can become so acidic that aluminum, which occurs naturally in the soil, dissolves and is carried by the rainwater into lakes and streams. Dissolved aluminum is very toxic to all aquatic life.

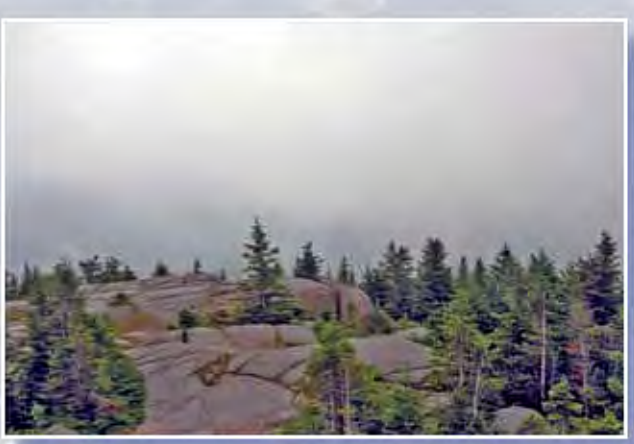


High Mountain Areas

Areas of higher elevation, such as New York's Adirondack and Catskill mountains, are very sensitive to the effects of acid rain. Soils are thin and unable to buffer acid rain as well as areas with deeper soils. Acid fog or clouds are a problem at high elevations, too. Acids are more concentrated in this form than in rain—with a pH as low as 3—nearing the acidity of lemon juice and vinegar. When high mountain plants are damaged, they are less able to cope with the harsh weather of the region. Their growth may slow, or they may die. Plants and animals in these communities are affected when the health of their habitat declines.

© Martin Lofgren / Wild Bird Gallery

In the Catskills and Adirondacks, **Bicknell's thrush** rely upon red spruce trees for nesting and foraging. Changes to its habitat threaten the survival of this sparrow-sized bird. It is designated as a species of "Special Concern" in New York State.



Water droplets in low-lying fair weather clouds carry pollutants they have picked up from dirty air along the way. When these clouds pass over mountain tops, they surround the land like fog, depositing droplets on trees and shrubs. The water droplets often have a very low pH. Acid fog and clouds are 30% to 40% more acidic than summer rains in the same area.

Everything connected to them is affected as well.

Forests

Acid rain removes minerals and nutrients from soil that trees need to grow properly. Trees affected by acid rain are unhealthy and grow more slowly. They are weak and more likely to be damaged by cold, insects and disease. Acid on trees' leaves and needles—especially when concentrated in acid fog—wears away their protective waxy coating. When leaves are damaged, they can no longer use photosynthesis effectively to make enough food to keep a tree healthy and growing. A healthy forest provides food and shelter for many different kinds of wildlife, but an unhealthy forest does not.

Manfred Mielke, USDA Forest Service, Bugwood.org

Red spruce grows in mountain areas (Adirondacks, Catskills), where soils are thin and less able to neutralize acid deposition. At higher elevations, low-lying clouds can surround trees with acid fog, damaging their needles.

New York's state tree, the **sugar maple**, does not grow well in acidic soils. Fewer seedlings survive to maturity, and more adult trees die.

Lakes, Ponds and Streams

Most clear-water lakes and streams—water bodies that are not boggy or dark colored—naturally have a pH between 6 and 8 and support a wide variety of plants and animals. If waters become acidic, the numbers and types of fish, insects and other animals drop. The variety of plants drops, too.

Many species cannot tolerate acidic waters. Some leave and some die. The eggs of some species of fish fail to hatch. If lake water appears very clear, it may be a sign that few of the plankton (microscopic plants and animals) can survive. As water bodies stay more acidic, the variety of life they support stays low.

Melting snow combined with early spring rains can concentrate the release of a lot of pollutants into the water. Acidity increases sharply then tapers off. Aquatic life has no time to adapt to the changing conditions. In some cases, the huge volume of water in large lakes can dilute the acid. Smaller ponds and streams don't have this advantage. A "spring surge" is especially damaging for streams.

Rainwater falls directly onto lakes, ponds, rivers and streams. It also runs across and through land areas (the watershed) before reaching water bodies. The soils, vegetation and human activities in a lake's watershed all influence the chemistry of the lake, including its pH.

Monitoring Acid Rain

Research is important for discovering how acid rain affects different parts of an ecosystem and why some places seem better able to buffer acid rain than others. Research can also help find ways to reduce acid rain. Monitoring stations are set up to automatically collect samples of wet deposition (rain and snow), gases, and particles carried in the air. Researchers also take samples of lake and stream water to better understand the effects of acid rain on the environment. Samples may be analyzed (tested) automatically by the monitoring equipment, by hand or in a laboratory.

Sue Capone, Adirondack Lakes Survey Corp.

Brooktrout Lake is one of many lakes in the Adirondacks that are studied to monitor the effects of acid rain.

Richard Brandt

Tests may be conducted hourly, daily or weekly—whatever interval is most appropriate for the information being gathered. By measuring the same things at regular intervals (amount of precipitation, pH, types of pollutants, etc.), researchers can see changes over time, such as increases or decreases in acidity. Other air measurements are collected when watching for specific problems, such as factories or power plants polluting the air, or checking vehicle emissions.

Researchers involved in atmospheric modeling combine the different types of data gathered through monitoring to learn what is happening in the air, our lungs and the environment. Computer models are then used to forecast air quality and to predict the effects that changing air quality may have on fish, wildlife and people.

The monitoring station at the summit of Whiteface Mountain, the fifth-highest peak (4,867 feet) in the Adirondacks, is a special one. In addition to the standard samples, it collects samples of cloud water.

The New York State Department of Environmental Conservation (DEC) has been monitoring wet acid deposition in New York State for more than 30 years. Recently, DEC joined the **National Atmospheric Deposition Program (NADP)**. NADP's goal is to monitor the chemistry of precipitation and the atmosphere for long periods to watch for changes over time. Its members include federal and state agencies, tribal nations, universities and others who share information from air monitoring. By working together, each group has access to a lot more data than they would be able to gather on their own. The data they gather are used in different ways.

Research led to the development of different types of control equipment that remove many harmful pollutants from smokestacks before they get into the atmosphere.

Looking to the Future

Laws today set limits on how much pollution is allowed from factories, power plants and vehicles. Since these laws were enacted, there have been significant reductions in the amount of acid rain-causing pollutants added to the atmosphere by human activity. The health of affected forests, lakes and waterways is improving, but many still have a long way to go before they're completely recovered.

As acidic lakes become less acidic, they can again be home to fish and other wildlife. Forests can recover when the soil again provides nutrients that trees and other plants need to grow properly. Wildlife will not thrive until the habitat has enough good food, shelter and water. It can take decades–even an entire century–for natural areas to completely recover from damage due to acid rain.

Smallmouth bass

Eric Engbretson, US Fish and Wildlife Service, Bugwood.org

You Can Make a Difference

Your actions can help to reduce the problem of acid rain. Everything you do that cuts back on air pollution created by power plants, factories and vehicles will help reduce the sulfur dioxide and nitrogen oxides in our atmosphere.

Here are a few ideas for you and your family:

- Learn more about the causes and effects of acid rain and tell others about them.
- Turn off lights and electrical devices when they're not needed.
- Drive less. Carpool, take public transit, walk or ride a bike.
- Maintain all fossil fuel engines such as cars, lawn mowers and home heating furnaces. Well-maintained engines burn more efficiently and use less fuel.
- Participate in citizen science programs, such as Cornell Lab of Ornithology's "Birds in Forested Landscapes" project, and contribute to real research about acid rain and its effects on wildlife. Go to **www.birds.cornell.edu** to learn more.

To protect the Adirondack Mountains, New York was the first state in the nation to adopt an acid rain control program that considered pollution coming both from within and outside the state.

Research leads to Understanding–Understanding leads to Prevention

Acid rain was first described in Europe in the 1840s and 1850s. By the early 1900s, scientists there recognized that acid rain was harming forests. During the 1960s, scientists in the United States began monitoring precipitation for signs of acid rain. In 1990, Congress passed amendments to the 1970 Clean Air Act, including adding regulations to control acid deposition. Research continues around the world to study the causes and effects of acid rain, to test how effective laws to control acid rain have been, and to find new ways to prevent it.

For more information:

Acid Rain: Our Planet in Peril by Louise Petheram (Bridgestone Books/Capstone Press, Mankato, MN, 2003)
What Can We Do About Acid Rain? by David J. Jakubiak (Power Kids Press/The Rosen Publishing Group, Inc., New York, 2012)
www.dec.ny.gov/chemical/283.html DEC's Acid Rain webpage
www.epa.gov/acidrain/education/index.html EPA's educational resources regarding acid rain
www.epa.gov/acidrain/education/site_kids/index.htm EPA's Acid Rain Kids Site (grades 1-3)
www.epa.gov/acidrain/education/site_students/index.html EPA's Acid Rain Students Site (grades 4-6)
nadp.sws.uiuc.edu/educ/acidrain.aspx National Atmospheric Deposition Program
www.adirondacklakessurvey.org/ Adirondack Lakes Survey Corporation
asrc.albany.edu/observatories/whiteface/whiteface.html Whiteface Mountain Observatory

The OUTSIDE Page

Ideas for Exploring Your Environment!

Acid rain won't burn your skin like very strong acids do, but it can affect your health. The same pollutants—gases and tiny particles—that wash out of the air as acid deposition can irritate our lungs when we inhale them. They're especially bad for people with respiratory illnesses such as asthma and bronchitis.

Effects of Acid Rain on Architecture and Monuments

In your community, walk through an area that has older buildings with ornate stonework. Look closely at the carvings. Are the features on carved faces clear or do they look like they're partially dissolved? Depending upon the kind of stone they're made of, headstones and monuments in cemeteries may show similar signs of damage from acid rain. Take photographs of the carvings you see. Look for historical photos of the same buildings showing the stonework. (Your town historian or local library may be able to help you find some.) Compare your photos to the historic photos. **What changes to the stonework do you notice?**

The photo on the left was taken in 1908. The effects of acid rain on the statue are clear in the photo on the right, taken 60 years later, in 1968.

Acid Rain Experiments

Researchers learn about our world by studying and conducting experiments. The U.S. EPA has a list of simple experiments you can do at home to learn firsthand about acid rain. They include making your own pH indicator so you can measure the pH of a substance, and looking at the effects of acid rain on plants, water bodies and metal.

Go to www.epa.gov/acidrain/education/experiments.html for the complete list and instructions.

New York State *CONSERVATIONIST FOR KIDS* Volume 6, Number 3, Spring 2013

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Printed on recycled paper

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Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement (A-00214813-0) to the New York State Department of Environmental Conservation, it has not gone through the Agency's publications review process and, therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

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Joe Martens
Commissioner

Conservationist for Kids

Supplement for Classroom Teachers – Understanding Acid Rain

Acid Precipitation Remains an Environmental Issue

In 1984, landmark legislation addressing the problem of acid rain from in-state sources of air pollution was passed in New York State. The State Acid Deposition Control Act identified the Adirondacks, Catskills and Hudson Highlands as susceptible to acid rain. A multi-year study of hundreds of Adirondack lakes and ponds was conducted to measure the effects of acid rain on chemistry and fish. Now, almost 30 years later, we continue to study the effects of acid rain in New York. We recognize that many lakes are recovering, but there is still a long way to go.

Acid precipitation is an important environmental issue to address with students. Its causes are directly linked to human activity—the burning of fossil fuels. Significant progress has been made in combating acid precipitation through establishing and enforcing regulations, monitoring and remediation. But much work remains to be done to repair damage from decades of acid precipitation.

Lessons about acid precipitation afford an opportunity to remind students there is a clear link between air quality and water quality. Sulfur dioxide and nitrogen oxides in the atmosphere—byproducts of our demands for energy—affect the health of fish and other aquatic wildlife, not to mention forests and the creatures that rely upon them. Students may feel that acid rain is a problem only adults can address. In fact, there are things young people can do to make a difference. Being mindful of how our energy-use choices affect the environment is a huge start. Cutting back on our electricity consumption is achievable for many of us. It's as simple as turning off the lights when we leave a room or opening a window instead of turning on the air conditioner. For short trips, families may choose to walk or ride bikes instead of driving, further reducing their use of fossil fuels.

This Issue's "Outside Page"

The activities suggested on the Outside Page offer a range of possibilities. USEPA experiments illustrate the effects of acid rain using inexpensive, easily obtained materials. Pairing them with a walk in your community to look for real-world effects of acid rain will demonstrate to your students the large- and small-scale lasting influence of this problem.

Teacher Workshops

For teachers who have participated in an Aquatic WILD, Project Learning Tree or Project WET workshop, the activities listed below complement this issue of *C4K*. Visit **www.dec.ny.gov/education/1913.html** for information about workshops and about how to obtain curriculum and activity guides.

Aquatic WILD:	**Project Learning Tree:**	**Project WET:**
What's in the Air?	Pollution Search	Where are the Frogs? (Parts II & III)
What's in the Water?	In the Driver's Seat	

Do you have an interactive white board in your classroom?

If you use a SMART Board or a similar interactive white board or projection system, consider downloading a PDF of *C4K* and using it in your classroom, along with the printed copies enclosed in this mailing. This issue and all of our back issues are available at **www.dec.ny.gov/education/40248.html**.

Supplemental Activities for the Classroom

Concentration Demonstration

The pH scale is logarithmic. A one-step change on the scale represents a ten-fold change in concentration of hydrogen ions (the amount of acid). Help your students understand the concentration of acids through this simple demonstration.

You will need: White vinegar, distilled water, pH test strips, a very large bowl, teaspoon measure, cup measure

Directions: Follow the steps below in order. At the end of each step, note your results on a chart. Record the volume of vinegar, the volume of water, the total volume, and the pH and taste of the mixture.

Step 1: Measure 2 teaspoons of vinegar and place it in the bowl. Using a pH test strip, measure the pH of the vinegar. Taste a drop of vinegar from the original container. Record your results.

Step 2: Add 2 cups of distilled water to the vinegar in the bowl. Gently mix them together. Measure the pH of the mixture. Taste a drop of it. (Don't forget to record your results.)

Step 3: Add 8 more cups of distilled water and gently mix. Measure the pH and taste a drop of the mixture.

Step 4: Add 8 more cups of distilled water and gently mix. Measure the pH and taste a drop of the mixture.

What happens to the pH as more water is added? The taste? What is the total amount of liquid in the bowl? What fraction of the mixture is vinegar? What fraction is water? What has happened to the vinegar? (The vinegar has been diluted and is spread throughout the water.) What does this tell you about the pH of normal lakes versus acidic lakes? (i.e., An acidic lake, with a pH of 5, is 100 times more acidic than a "neutral" lake with a pH of 7.) Normal rain versus acid rain? Acid fog?

(adapted from *The Backyard Acid Rain Kit Program Guide* from Public Focus)

Online Resources

For Teachers:

www.dec.ny.gov/chemical/283.html DEC's Acid Rain information

www.epa.gov/acidrain/education/index.html EPA's educational resources about acid rain (note especially link to the PDF *Learning About Acid Rain – A Teacher's Guide for Grades 6 Through 8*)

nadp.sws.uiuc.edu/educ/ National Atmospheric Deposition Program: Educational Resources

www.news.cornell.edu/stories/May06/AcidRainMaples.kr.html Cornell University's *Chronicle Online* article about the effects of acid rain on sugar maple trees (May 2006)

www.adkmuseum.org/acidrain/index.shtml Adirondack Museum acid rain information and link for teachers

www.nyserda.ny.gov/Energy-and-the-Environment/Environmental-Research/EMEP/Documents.aspx NYSERDA; scroll down to "Topical Primers" and select "Acid Deposition"

www.asrc.albany.edu/observatories/whiteface/whiteface.html Atmospheric Sciences Research Center (University at Albany): Whiteface Mountain Observatory (follow link for live weather feed and views of monitoring equipment)

metroland.net/2012/10/11/winds-of-change/ *Metroland* "Winds of Change," October 11, 2012 article about acid rain monitoring in New York State

www.adirondacklakessurvey.org/ Adirondack Lakes Survey Corporation (detailed information about monitoring of Adirondack lakes)

www.ec.gc.ca/air/default.asp?lang=En&n=7E5E9F00-1#wsD5D8B879 Environment Canada: Acid Rain FAQ

www.youtube.com/watch?v=VqycafnVa9c Lab demonstration of how acid rain forms

For Students:

www.epa.gov/acidrain/education/site_kids/index.htm EPA's Acid Rain Kids Site (grades 1-3)

www.epa.gov/acidrain/education/site_students/index.html EPA's Acid Rain Kids Site (grades 4-6)

ga.water.usgs.gov/edu/acidrain.html The USGS Water Science School, "Acid Rain: Do you need to start wearing a rainhat?"

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