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Acid Rain in Virginia: Its Yearly Damage Amounts to Millions of Dollars

by Jacob H. Kahn*

OVERVIEW

A poll conducted for the Water Center in May-June 1985 by the Gallup Organization indicates that only 30 percent of the Commonwealth's citizens think acid rain is a moderate or severe problem where they live.' In fact, Virginia's rain is 10 times more acidic than unpolluted rain, and a growing body of evidence suggests that acid deposition threatens the vitality of our rivers and lakes and the productivity of our forests and croplands. Apart from the potential ecological losses, a U.S. Environmental Protection Agency (EPA) study estimates that acid rain causes $39 million annually in damages to man-made structures in seven Virginia cities.

The acidity of Virginia's rain is the same as in Massachusetts where the governor has characterized the environmental effects of acid rain as "an ecological emergency." Sulfur dioxide and nitrogen oxide emissions from fossil fuel combustion by power plants, industries, and motor vehicles outside Virginia are believed to be the major contributors to acid rain in the Commonwealth.

Fortunately, most of Virginia's soils and waters appear to have a greater buffering capacity than those in the northeastern United States and the ecological effects of acid rain have therefore been delayed. Studies of watersheds in the mountains of Shenandoah National Park suggest, however, that if present acid deposition trends continue, this buffering capacity will be used up in 10 to 40 years. The resultant acidification of many of the Commonwealth's inland waters may devastate fish and other aquatic life.

Acid rain is an insidious threat to the Commonwealth's natural resources. By the time the ecological effects of acid deposition become widely observable, the options for dealing with the problem may be curtailed and the major components of the state's physical and biological resource systems maybe irreversibly altered. Research is needed now to determine the sensitivity of Virginia's soils and waters to acid rain, to increase understanding of air pollutant transport patterns, to measure the effects of acid rain on Virginia's environment, and to assess the potential economic impact of acid rain in the state. With an investment of $1 million a year - less than 3 percent of the estimated yearly damage caused by acid rain in seven of Virginia's urban areas - research can begin to help the Commonwealth design a strategy to deal with this serious and pervasive environmental threat.

THE ACID RAIN PHENOMENON

"Acid rain" is the popular term for the deposition of acidic air pollutants that reach the ground by means of *wet deposition* (rain, snow, hail, sleet, dew, frost, or fog) or dry *deposition* (particles and gases). Unpolluted rainwater is slightly acidic *(Figure 1)* because of the natural presence of carbon dioxide, sulfur dioxide, and nitrogen oxides in the atmosphere. In eastern North America, man-made emissions of sulfur and nitrogen oxides are at least 10 times greater than emissions from natural sources and the precipitation is generally at least 10 times more acidic than normal rain.

How does acid rain form? Combustion of fossil fuels (coal, oil, natural gas, and gasoline) releases sulfur dioxide and nitrogen oxides, which combine with water vapor and other gases in the air to form sulfuric and nitric acids. Prevailing winds can carry these pollutants over long distances before they fall to earth as acid rain or dry deposition *(Figure2).* Sulfur dioxide is mainly produced by power plants and industries, while nitrogen oxides are principally produced by motor vehicles and power plants.

[1]The survey had 1628 respondents, with an error rate of plus or minus 3 percent at a 95 percent confidence level.

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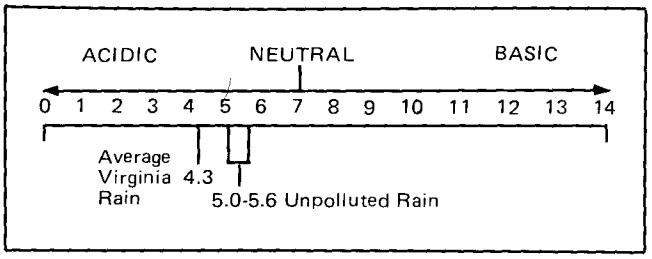

FIGURE 1

The pH scale measures acidity or alkalinity of a solution. A pH of 7 is neutral, less than 7 is acidic, more than 7 is basic (alkaline). The scale is logarithmic: a pH of 5 is 10 times as acidic as a pH of 6; a pH of 4 is 100 times as acidic as a pH of 6.

THE EFFECTS OF ACID RAIN

Soils and waters have varying levels of natural buffering capacity-the ability to chemically neutralize acids without increasing the acidity of the soils or waters. Over variable periods of time acid rain can "use up" this finite buffering capacity, and further acid deposition rapidly makes soils and streams acidic. This process, known as acidification, can have severe effects on plant and animal life in lakes and streams, as shown by laboratory research and studies of acidified lakes in the northeastern United States, eastern Canada, and Scandinavia. Aquatic life is affected not only by the acidity, but also by the other chemical changes that precede or accompany acidification: increased sulfate concentrations; reduced calcium levels; and increased concentrations of toxic metals, such as aluminum, which are leached from soil and sediments. Many aquatic organisms are unable to reproduce or are poisoned by high metal concentrations in acidified waters.

When freshwater systems begin to be acidified, small organisms are commonly the first to be affected. Population declines occur among tiny plankton (floating plants), shrimp, snails, crayfish, mussels, and insects, which serve as food for fish *(Figure 3).* As the aquatic environment becomes more acidic, fish populations decline because of reduced food supplies, decreased resistance to environmental stress, and declines in reproductive success. Fish in the early stages of life are far more sensitive to acidity; hence, a fish species may disappear totally from a freshwater system *before* acidity reaches a level that is lethal to adult fish. Other wildlife, such as birds that feed on aquatic plants or animals, may also be reduced in numbers when freshwater ecosystems are altered by acid rain.

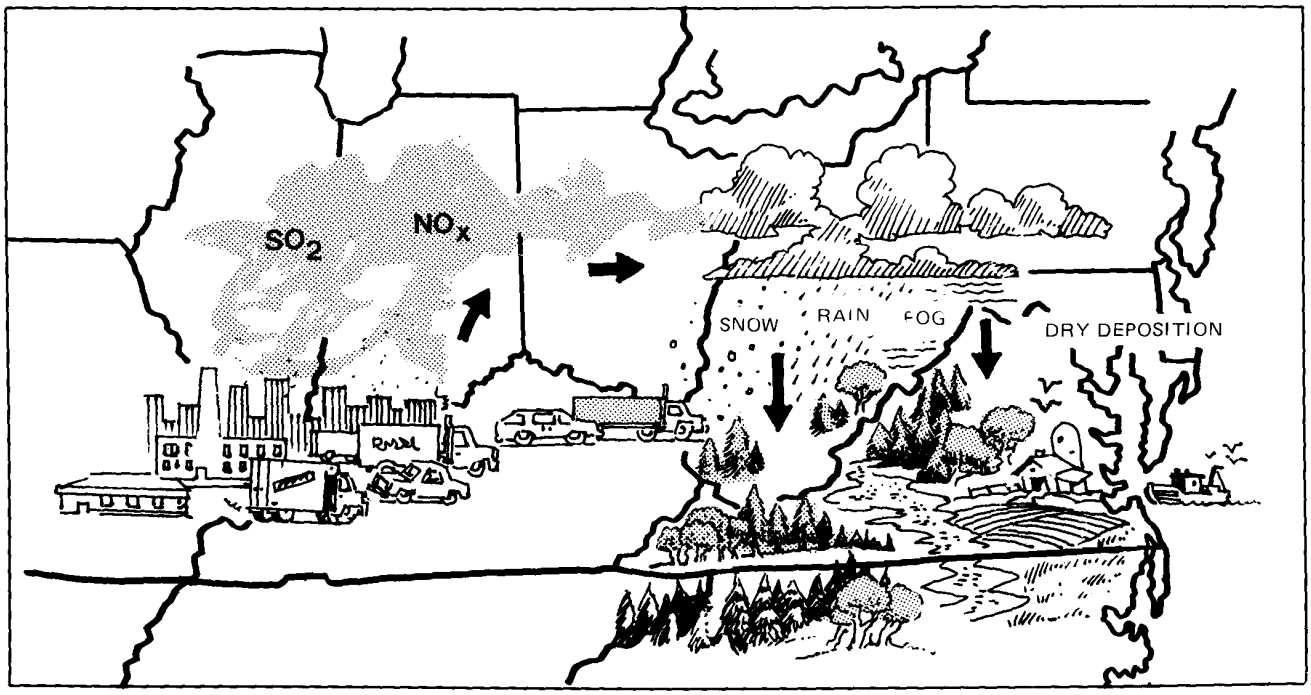

FIGURE 2

Sulfur and nitrogen oxides produced by the combustion of fossil fuels are released into the atmosphere and may travel hundreds of miles before coming back to earth as wet or dry acid deposition.

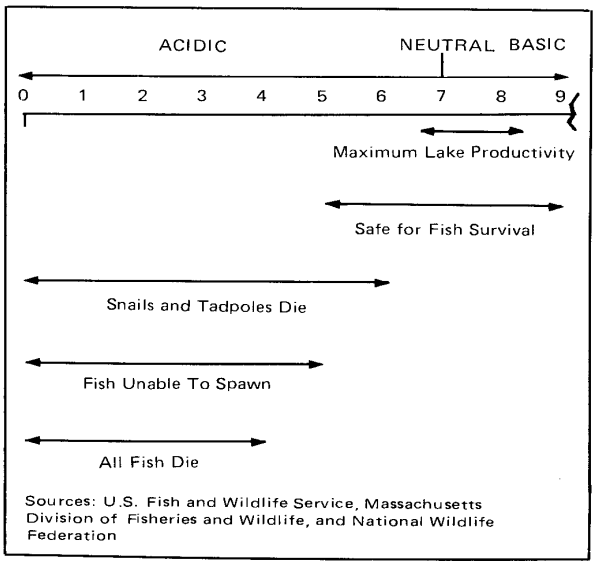

FIGURE 3
As a lake or stream is acidified, aquatic organisms are affected at various pH levels. Environmental effects become noticeable when the pH drops below 6; a lake is essentially "dead" when the pH reaches 4.

Acid rain in combination with other air pollutants may be a cause of forest die-back, particularly in the evergreen forests found in mountainous areas of the eastern United States. However, the links between acid rain and reductions in forest or crop productivity are not fully understood and scientific studies of these connections are underway.

Acid rain has also been implicated for damaging paint, masonry, historic buildings, and statues. A 1985 EPA draft study estimates that acid rain annually causes $7 billion in material damages of this sort in 17 midwestern and eastern states including Virginia. Direct effects of acid rain on human health have not been proven.

HOW ACIDIC IS VIRGINIA'S RAIN?

The chemistry of Virginia's precipitation is monitored by the Virginia Acid Precipitation Network(VAPN). The eight VAPN stations are located in Chesterfield, Fairfax Louisa, Page (Luray), Roanoke, King William (West Point), and Wise counties and the City of Hampton *(Figure 4).* Rainwater is collected weekly at each of these sites, pH of the samples is measured on-site, and the samples are shipped to Virginia Tech for further chemical analysis.

The mean yearly pH value for Virginia was 4.3 in 1984, about 10 times more acidic than unpolluted rain and approximately the same pH as the acid rain in the northeastern United States and eastern Canada, where acid rain is an acknowledged problem. Over 90 percent of the 1984 VAPN measurements were between a pH of 3.5 and 5.0; the least acidic rain had a pH of 7.0 (neutral) and the most acidic had a pH of 3.4 - approximately 100 times more acidic than unpolluted rain. No significant regional differences in rainfall acidity within Virginia are evident.

During the three years VAPN has been in operation, the average acidity of Virginia's precipitation has remained constant. Several Virginia stations in the National Atmospheric Deposition Program and the Multistate Atmospheric Power Production Pollution study have recorded similar levels of acidity. No systematic analysis of rainfall chemistry was done in Virginia prior to 1976, so long-term historical trends are unknown. It is also unclear what portion of Virginia's acid deposition is in the form of wet deposition (rain, snow, etc.) as compared to dry deposition, since a standard method for measuring dry deposition has not been developed.

Tracing the long-range transport of the pollutants responsible for acid deposition is difficult and the source of Virginia's acid rain is not scientifically certain. Considering the prevailing westerly winds in North America, Virginia is essentially downwind from major air pollution sources in the Ohio Valley. Three individual sources in Ohio, Tennessee, and Kentucky each emit more sulfur dioxide than *all* sources within Virginia. According to ASTRAP, a model of long-range transport developed at Argonne National Laboratory, only 7 percent of the sulfates in Virginia's acid rain originate within the state.

EFFECTS OF ACID RAIN IN VIRGINIA

So far, the environmental impacts of acid deposition in Virginia are not widely observable. Detailed studies of watersheds in the Shenandoah National Park by James N. Galloway of the University of Virginia Department of Environmental Sciences have shown that acid rain is being buffered by the soils. The research suggests that soils are now 20 to 60 percent saturated with sulfur from atmospheric deposition. At the current rate of sulfate deposition, in 10 to 40 more years the soils will be unable to absorb any more sulfates. When the soils become saturated with sulfates, further acid deposition will cause sulfates to be released into mountain streams and acidification of freshwater systems will occur. Stream acidification and consequent chemical changes in water quality will affect the entire aquatic food web and potentially

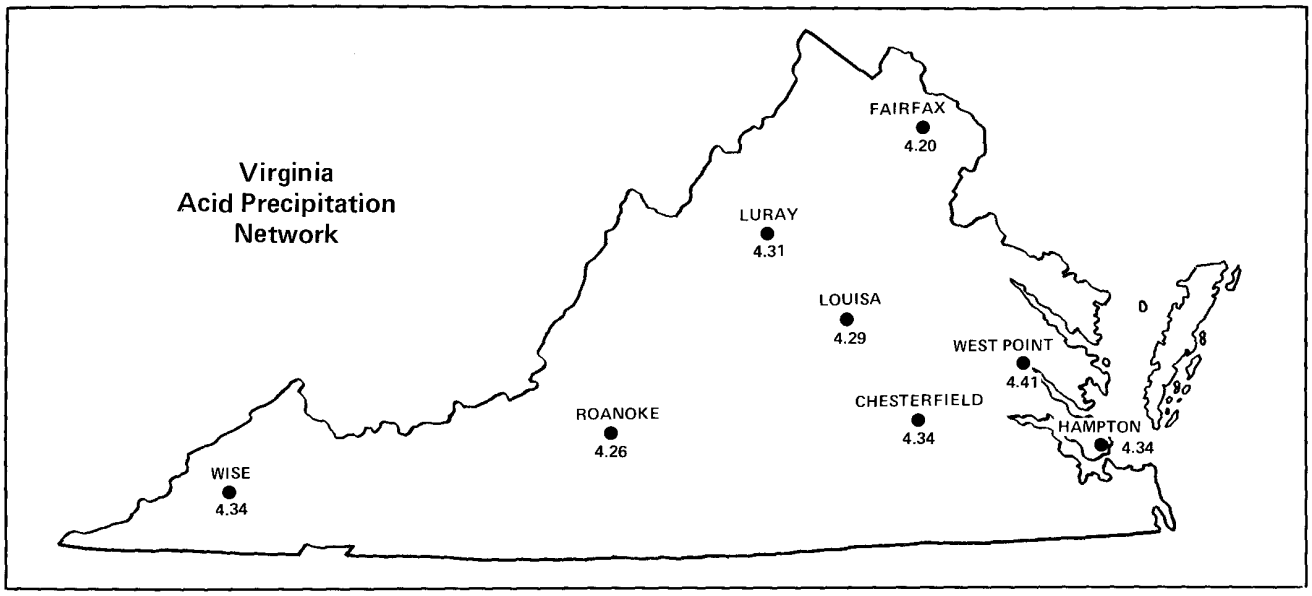

FIGURE 4
Average pH levels for 1984 at the eight VAPN stations ranged from 4.20 at Fairfax to 4/41 at West Point.

wipe out many species including insects, snails, crayfish, salamanders, trout, and other game fish. Galloway predicts that eventually stream acidification in Virginia "will be as bad as in the Northeast."

Virginia soils are generally believed to have greater buffering capacity than those in areas of the northeastern United States and eastern Canada that were scoured by glaciers and hence have thinner and "younger" topsoils. This greater ability to buffer acidity explains in part why acid rain has not yet affected surface waters in Virginia as severely as in New York's Adirondack Mountains and eastern Canada, where scores of lakes have been acidified and are largely devoid of fish. However, no statewide study has been done in Virginia to determine the buffering capacity of soils or the alkalinity of surface waters, so the local sensitivity of Virginia's soils and streams to acid deposition is unknown in most parts of the state.

U.S. Fish and Wildlife Service researchers are probing a possible link between acid rain and the sharp decline of striped bass (rockfish) that spawn in tributaries of the upper Chesapeake Bay. Field studies in Maryland tributaries have shown that spring showers during the spawning season cause pulses cf acidity in these small streams, and researchers hope to learn whether these brief acidic episodes harm eggs or young rockfish. The Virginia Institute of Marine Science studied the same question at two Pamunkey River sites in April and May 1985, but the results were inconclusive, in part because of a spring drought. The Virginia Commission of Game and Inland Fisheries has begun similar studies to correlate the reproductive success of Virginia's landlocked striped bass with acidity and aluminum concentrations in spawning areas of the Roanoke and Dan rivers.

Impacts of acid deposition on forest and crop productivity are not yet obvious in Virginia and forest die-back has not been observed in the state. William E. Winner and other researchers at Virginia Tech's Laboratory for Air Pollution Impact to Agriculture and Forestry and the Miles C. Norton, Sr., Center at Mountain Lake have shown that levels of ozone (a form of oxygen that also results from combustion of fossil fuels) and other pollutants present in Virginia's air can cause leaf discoloration and reduce growth rates of native trees, grasses, and agricultural crops, such as tobacco and peanuts. Research suggests that ozone alone is now causing a 5 to 20 percent crop loss in Virginia. Although trees have not been studied as thoroughly as crops, evidence exists that forest

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plants are also vulnerable to ozone. The *combined* effect of air pollutants (including acid deposition) on Virginia's crops and forests is unknown.

EPA's 1985 draft study of acid rain damages to man-made structures produced estimates of the annual cost of material damage (to paint, masonry, buildings, and statues) in seven metropolitan areas of Virginia *(Table 1)*. Estimated annual damages range from $2.2 million in the Charlottesville area to $14.2 million in the Richmond area. On a per capita basis, annual material damages in all seven cities are between $19 and $24.

The potential for acidification of Virginia's reservoirs and groundwater aquifers that serve as drinking water supplies is unknown. Acidic well water, which occurs in some sections of Western Virginia, is a possible threat to human health since it can leach toxic metals out of household plumbing.

WHERE DO WE GO FROM HERE?

Proposed Solutions

Efforts to mitigate the adverse effects of acid deposition fall into two categories: (1) treatment of affected areas after acidification or (2) reduction of pollutant emissions that cause acid rain.

The former strategy generally involves putting lime (calcium carbonate) in lakes and ponds to neutralize the excess acidity. Once the natural flora and fauna of a lake have been altered by acidification, liming alone cannot instantly restore the former community of freshwater organisms, so native species, such as game fish, must be reintroduced in conjunction with liming. Liming is expensive, must be repeated to

Metropolitan Area	Total Damages	Per Capita Damages
Charlottesville	$2.2 million	$19.26
Danville	2.5 million	22.51
Lynchburg	3.1 million	20.38
Newport News	8.0 million	22.08
Petersburg	3.1 million	23.65
Richmond	14.2 million	22.45
Roanoke	4.9 million	22.06

Source: EPA, National Acid Precipitation Assessment Program Draft Study, 1985

TABLE 1

Estimated Annual Acid Rain Damage in Seven Virginia Cities

The levels of ozone and other pollutants present in Virginia's air can cause leaf discoloration and reduce the growth rate of trees, grasses, and agricultural crops.

prevent reacidification, and is a local measure that only treats the effects of acid rain. Liming is not a practical solution to stream acidification, since the water in a steam is continually being replaced.

In 1983, the National Academy of Sciences recommended a 50-percent reduction in sulfur dioxide emissions and control of nitrogen oxide emissions to prevent acidification of lakes and streams. Recent congressional debate over acid rain bills has centered on the size of such an emissions cut, the best means of achieving reduced emissions, and the question of who will pay for the cut. Utility and industry representatives argue that it is not known how much of an emissions reduction is needed to achieve a given decrease in acid deposition. The Reagan administration insists that further study of acid rain is needed *before* any new regulations are established to control emissions.

In January 1985, Virginia Secretary of Commerce and Resources Betty J. Diener called on the General Assembly to urge Congress to give coal-powered utilities the option of meeting sulfate reduction standards by burning low-sulfur coal rather than being required to use "best available technology" and install expensive scrubbers. Diener noted that writing this option into acid rain legislation would expand the market for Virginia's low-sulfur coal industry and would cause smaller increases in consumers' electric costs than if Congress adopts '"technology-based" standards requiring scrubbers.

Research Needs in Virginia

Scientists and resource managers contacted during preparation of this report have suggested that acid rain poses a major environmental threat to the Commonwealth and that more work must be done to assess the condition of Virginia's natural resources and the effects of acid deposition. The consensus is that Virginia needs baseline environmental data now to determine what resources are at risk. Comprehensive statewide surveys of surface water alkalinity and soil buffering capacity are necessary to determine how sensitive each section of Virginia is to acid deposition. Further research must be done to determine the cumulative effects of air pollutants

(acidity, ozone, nitrate, sulfates, and heavy metals) on Virginia crops and forests, since acid deposition is occurring in conjunction with other air pollutants. Continued monitoring of the chemistry of Virginia's rainfall, additional studies of long-range transport of air pollutants, and monitoring of fish populations and spawning success are also necessary to define the causes, extent, and impact of acid rain in the Commonwealth. To address these research needs, the State Air Pollution Control Board has requested $4 million from the General Assembly to fund a 4year acid deposition study that would be coordinated by the board and conducted by a number of state agencies and university researchers.

Acidification of Virginia's mountain streams may occur as early as the mid-1990s. The eventual impact on the Commonwealth's 450 public fishing streams, 1,500 miles of trout streams, and $3 billion-a-year tourist industry is potentially great.

CONCLUSION

Virginia's acid rain problem may be far more severe than has been perceived. Ecological effects are not yet obvious, but the buffering capacity of the Commonwealth's soils and waters is finite, and streams, forests, and crops may suffer appreciable damage within a few decades. Millions of dollars of material damage to buildings and monuments is already occurring each year. Attention should be focused on *preventing* further acid rain damage to the Commonwealth's resources. Immediate action is needed to determine what resources are at risk, the time frame within which acid rain will affect our resources, and the potential economic impact of acid rain on agriculture, forestry, recreation, and the tourist industry in Virginia.

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