Acid Lakes and Thin Soils

A recent acid rain study shows that soils and water flowpaths significantly affect lake acidification

Illustrations: EPRI

Rainwater sampling at an Adirondack lake.

By IVARS PETERSON

Among hundreds of deep, clear glacial lakes nestled in the Adirondack Mountains of upstate New York, three lakes illustrate the complexity of acid rain effects. Woods Lake is already considerably acidic, Sagamore Lake shows wide swings in acidity, and Panther Lake has remained neutral. Yet all three — intensively studied for the past few years — are within 30 kilometers of each other and receive similar amounts of acid deposition — in rain or snow or as dry particles. Why are these lakes so different?

To answer that question, the Electric Power Research Institute, the research arm of the electric utility industry, undertook one of the most elaborate of recent acid rain research projects (SN: 2/16/80, p. 107). More than 30 scientists, already well known for their work in fields from geology to biology, participated in the study. Called the "Integrated Lake-Watershed Acidification Study" (ILWAS), the $5 million program began in the fall of 1977 and officially ended on Dec. 31, 1982. Reports of the study's findings are now beginning to appear.

The study's aim was to learn how lake waters become acidic. At the same time, this information was built into a mathematical model that attempts to represent all the biological, geological and chemical processes that are likely to control lake-watershed acidity.

The model routes water through a cascade of compartments, from the atmosphere, through the forest canopy and snowpack, down into the soil and then into bogs, streams and lakes. At each stage, mathematical equations represent processes that produce or consume acids and shift chemical balances.

To provide the raw data for calibrating and verifying the model, field workers scrambled through dense brush and weathered rain and snow for four years to collect the necessary soil and water samples and to map the Woods, Panther and Sagamore watersheds. They discovered that the depth and type of soil and the path that water follows as it drains through a watershed have a large effect on a lake's vulnerability to acid rain. Because deep mineral soils can neutralize acid solutions, lakes surrounded by such soils are less likely to become acidic.

Geologists Robert M. Newton of Smith College in Northampton, Mass., and Richard H. April of Colgate University in Hamilton, N.Y., studied the surface geology of the three watersheds. Newton says, "The really important thing is the flowpath of the water through the system, and that is in part controlled by the depth of material." The soils around neutral Panther Lake are, on the average, eight times deeper than those surrounding acidic Woods Lake. In Woods Lake, most of the water runs off on the surface or passes only through the uppermost, already naturally acidic, organic layers of soil. If, as in the case of Panther Lake, the water seeps into the deeper, underlying sand and gravel layers, it is neutralized.

"It becomes a question of how much surface lake water is ultimately coming from water that is moving through surficial sediments versus how much is coming from direct runoff and direct precipitation," says Newton.

The work of April and Newton may also provide useful information on the acidity of rain in the past. The minerals present in the soil react with incoming acidic substances, carried by the water, and thus neutralize the acids. The minerals themselves are "weathered." Now, Newton and April are confident they can see the effect of acid rain on weathering rates. They can calculate the weathering rate in glacial times, thousands of years ago, and compare it with the present rate.

"If you're increasing the amount of acidity that's coming into a particular watershed, it seems logical that you will increase the amount of weathering," April says. "We think we can show the present rate of weathering may have increased somewhat due to acid precipitation."

One interesting question is whether Woods Lake has always been acidic. April says, "We don't believe it was ever a neutral lake,... but 30 years ago the ranger up there was able to fish in Woods Lake, and today he won't even bother because there are no fish. Something has happened in the past 30 years to bring that pH down a full unit to increase the acidity. The evidence that we have for the reason why it is acid now is that the watershed material can simply not soak up the incoming acidity."

Elmar R. Altwicker of the chemical and environmental engineering department at Rensselaer Polytechnic Institute in Troy, N.Y., was one of the researchers who monitored rain and snowfall in the three watersheds. The measurements showed that all three basins received comparable concentrations of sulfate and nitrate ions in the precipitation.

Altwicker says falling snow usually had much higher nitrate than sulfate levels, even compared with a winter rain. Snow seems to be an efficient scavenger of nitric acid. The buildup of nitrate levels in the snowpack results in a massive input of acidity into lakes during the spring snowmelt. The water runs off the land instead of soaking into the soil. This results in "flashing," a rapid increase in surface lake acidity also seen during heavy storms. However, both Sagamore and Panther lakes quickly recover to their normal less acidic states.

One of the greatest difficulties was measuring the amount of material that falls as dry particles. "Dryfall is one of those hotly debated issues," says Altwicker. "Everybody's measuring it, but nobody has a good way of measuring it." However, dry deposition makes up a significant proportion (from 20 to 50 percent) of the total input of acidity. "We've attempted to interpret our measurements as a minimum value," says Altwicker.

Nicholas L. Clesceri, also of Rensselaer Polytechnic Institute, looked at what happens to rain and snow as they pass

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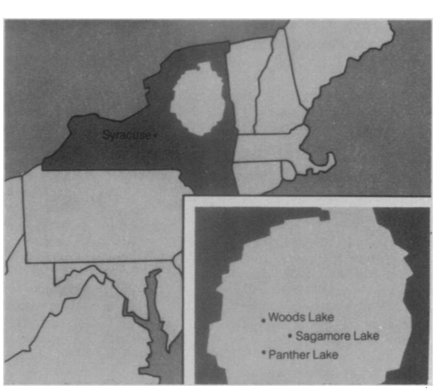
through the forest canopy. He observed that water droplets that pass through a conifer, such as a pine tree, usually become more acidic. Deciduous trees, on the other hand, seem to lower the acidity of incoming water drops. Clesceri says the needles of a pine tree are more efficient collectors of particles and gases than the leaves of a maple or an oak. "Then, when it rains, you get this intensified, higher concentration in the throughfall under the conifer," he says.

Nevertheless, Clesceri is not sure how much biological processes contribute to altering the water's composition. The rain could be leaching vital elements out of trees and plants. For example, potassium concentrations increase. "We normally have to say that it's got to be coming out of the tree," says Clesceri, "but we don't have good explanations as to why there are these differences." Another important factor could be the water flow down plant stems and along bark. "Stemflow may represent 10 percent of the total loading to the forest floor," says Clesceri. "It's definitely picking up a lot of material." But the significance of this process is not clear.

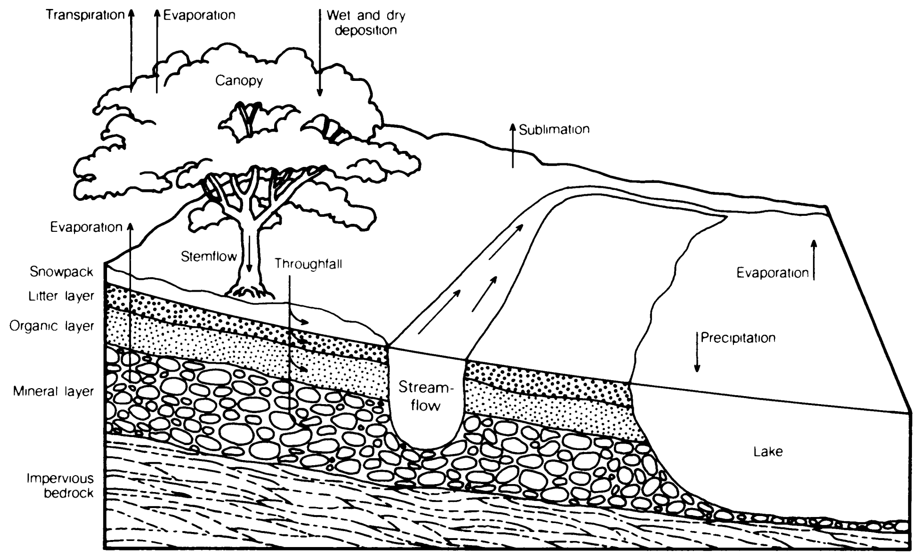
"One of the things that we've underscored," says Clesceri, "is that you must study the throughfall to get the true picture of what the loading is to the forest floor. People considered that the input was above the forest level. That neglects the ability of the forest to pick up particles and gases."

George R. Hendrey of the Brookhaven National Laboratory looked at some of the biological processes occurring in the lakes, particularly the decomposition of organic matter like leaf litter. He found that the decomposition rate depended on the leaf species and the lake's acidity. Sugar maple and beech leaves decomposed much more slowly in the acid lake, while red spruce needle decomposition was slow in all three lakes. The data fit in "very well with the very much broader picture concerning inhibition of decomposition rates in acidified lakes," Hendrey says. Why these rates are inhibited isn't yet clear, although several hypotheses have been suggested.

Hendrey is critical that the ILWAS study put very little funding and effort into the



The Adirondack area of New York, where lake acidification was studied.



The flowpath of water through a forested watershed.

biological area. "Despite the fact that it was a very well integrated geochemistry study, it was very poorly integrated biologically," Hendrey says. Many biological processes that either produce or consume acids were not measured.

"The initial concept was to try to find out what sort of biological problems are occurring, and why they're occurring," says Hendrey. But the modelers realized that these were hard things to accomplish. "It's much easier to deal just with geochemistry, so the project very rapidly became geochemical," he says.

The project altered in other ways during its five-year course. When the study started, the major focus was on Sagamore Lake, says Robert A. Goldstein, ILWAS project manager. The initial hypothesis was that Sagamore was at a point of instability, about to turn from a neutral to an acidic lake. That turned out to be untrue, and the emphasis shifted to the two extremes, Woods Lake and Panther Lake.

The Sagamore basin is a much larger and more heterogeneous watershed than the other two lakes. April says, "There are areas of Sagamore that contain thin, impermeable soil [like Woods Lake], and there are areas that contain very thick, permeable deposits of sand and soil [like Panther Lake]. The waters feeding into Sagamore have the properties of both Woods and Panther."

There were also practical difficulties in studying Sagamore Lake. "There's no access to the upper part of the watershed," says Newton. "In some places the wind had blown everything down, and you had to crawl on your hands and knees to get through the spruce thickets." As a result, the data on Sagamore Lake are not as complete as for the other lakes.

The mathematical computer model derived from the first year's results of the study is designed to simulate the biogeochemical processes occurring in a watershed. Given data on atmospheric inputs in subsequent years, the model predicted the resulting changes in acidity at various stages in the water flow through a watershed. These calculations were compared to field measurements.

Goldstein says, "I feel that we've developed a general theory of lake watershed acidification. That general theory is embodied in the mathematical model." However, its validity and applicability have yet to be tested, he cautions.

The ultimate success of the ILWAS model depends on how well it works in simulating acid rain effects in areas very different from the Adirondacks. To test and improve the ILWAS model, follow-on studies have started in watersheds outside the Adirondacks. Now being studied are two "seepage" lakes in Wisconsin, where the lakes have no surface inlets or outflows and sit on sandy soils more than 100 feet thick. A second study area in the southern Appalachians in North Carolina features unglaciated soils millions of years old and the absence of seasonal snowpacks. In addition, to see how the model may be applied to test a region's vulnerability rather than that of individual lakes, about 20 Adirondack watersheds with a wide range of characteristics are being studied.

At this stage, Goldstein says, "We've established the state of the art in terms of the understanding of the overall phenomenon of watershed-lake acidification, but we certainly haven't answered every question, and our knowledge isn't perfect."

April concludes, "I think we understand the process a lot better than we did three or four years ago when the study first began." Newton adds, "We have an enormous amount of data, and it'll take time to digest it all. I don't think that just because the funding aspect is over the study itself is over. The meaningful results will come out in the next four or five years." □