ECOLOGY

Acid Rain's Dirty Business: Stealing Minerals From Soil

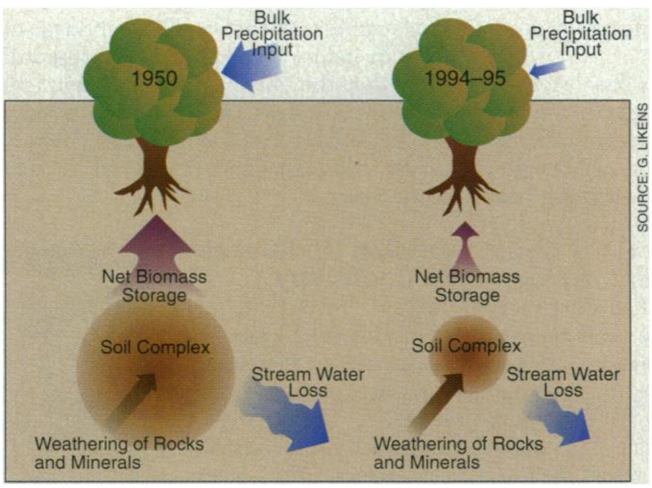
As ecological crises go, the damage done by acid rain had seemed pretty easy to fix. Just cut emissions of sulfur from power plants, and trees would again flourish and acidic waters return to their natural pH. But even though the United States, Canada, and European countries have cut sulfur pollution, forests, lakes, and streams haven't bounced back as quickly as expected. The reason, scientists have suspected, is that acid rain has wrought profound changes in the soil, to which all these ecosystems are linked. Now, after looking over 30 years of data from a New Hampshire forest, researchers may have confirmed this hunch.

On page 244 of this issue, ecologists Gene Likens and Donald Buso of the Institute of Ecosystem Studies in Millbrook, New York, and environmental engineer Charles Driscoll of Syracuse University report that over the past 30 years, acid rain has been leaching the soil in their study area of vast quantities of the base mineral ions that buffer, or neutralize, acids and are essential to plant growth. Given the rate at which these ions are still being depleted, they find it could be decades before the acid-ravaged ecosystems become healthy again. "Soils take hundreds to thousands of years to develop. If their chemistry is changed dramatically, it's a major impact. It will take a very long time for them to recover," Likens says.

The idea isn't new, notes aquatic ecologist David Schindler of the University of Alberta in Edmonton, Canada. "But [other researchers] haven't put the whole story together the way Likens, Driscoll, and Buso have. The documentation is always pretty shocking—to see this thing is really happening and it's not a hypothesis anymore," says Schindler, adding, "This is an extremely important paper." To some researchers, the implications for policy are clear. The findings suggest that the sulfur reductions mandated by the 1970 Clean Air Act and its 1990 amendments won't be enough for ecosystems to recover, Likens says.

After Congress enacted the 1990 amendments, many scientists thought the acid rain problem would soon be licked, for they still thought the acid was exerting its major effects directly on trees, lakes, and streams. "Our view and that of soil scientists had been that soils were so well buffered that acid rain didn't affect them in any serious way," Likens says. But even though the acid has abated somewhat, its effects have lingered. Vegetation in the U.S. Forest Service's Hubbard Brook Experimental Forest in New Hampshire's White Mountains has nearly stopped growing since 1987, for example, and the pH of many streams in the Northeast remains below normal. After years of acid deposition, it seemed, the soil's supply of exchangeable calcium and magnesium ions might be running low.

Researchers at Hubbard Brook and elsewhere had detected a drop in calcium and magnesium levels in soils since 1970. And Likens and co-workers thought they saw more alarming signs in long-term records of the chemistry of stream water and precipitation at Hubbard Brook. He and his colleagues regularly comb the data sets, which go back to 1963, "to see what kind of stories they have hidden among them," he says. When they looked recently, "the calcium changes were very intriguing to us."



Washed out. Past losses due to acid rain *(left)*, along with a reduction in input from rain, have left forest soils depleted in calcium *(right)*.

They found that as industrial pollution fell in the 1970s, so did sulfate—a marker for acid rain—in Hubbard Brook stream water. That was expected, but the group found that levels of calcium, the main base cation, or positive ion, in the stream water, decreased as well. One reason for the calcium drop, Likens speculated at the time, was that the emissions restrictions, while cutting back on acid, had also reduced the amount of calcium-rich soot falling on the forest. The other reason, he guessed, was that the years of acid deposition had simply leached away much of the pool of available calcium in the soil.

To test that idea, Likens's team decided to reconstruct the history of calcium in the Hubbard Brook soil, starting in the 1950s, before acid rain became severe. They estimated the amount of calcium added to the soil by the breakdown of rocks and minerals, added the measured input from precipitation, then subtracted the amount stored by trees and carried away in stream water. The result was the rate at which the soil lost calcium over time. As acid rain intensified in the 1960s, reacting with available soil calcium and dissolving it, the net effect would have been a rapid loss of the ion.

Comparing the loss rate with the total pool of calcium in the soil, estimated from 1970 and 1987 measurements, the group found something that "was very surprising to us," Likens says: The pool of calcium in the soil complex at Hubbard Brook has shrunk by more than 50% in the last 45 years.

What's more, when the scientists extrapolated their results, they found that while the calcium loss has slowed in recent years, rock weathering won't replenish the pool of available calcium in the near future. Stream chemistry won't return to its preindustrial state until well into the 21st century or beyond, and aquatic ecosystems will remain vulnerable to pulses of acidity from pollution-laden storms.

Other forest researchers, while a bit cautious about some of Likens's quantitative conclusions, agree that the group has pinned down an explanation for the slow recovery of forests and streams. "People knew that base cations were part of the equation, but did not appreciate the extent to which they were important," says atmospheric chemist James Galloway of the University of Virginia. The group's conclusion also fits well with other observations, notes plant pathologist Walter Shortle of the U.S. Forest Service. For example, Shortle's group reported in *Nature* last fall that because acid rain is no longer sufficiently neutralized by calcium and magnesium, it is releasing aluminum ions from minerals into the soil, where thay are toxic to plants.

The implications for policy are obvious, Likens says. "Even though we are reducing the emissions of sulfur [to 50% of 1980 levels by 2000], it doesn't look like that's going to be enough," although he won't say exactly how much emissions should be reduced. There may be faster ways to solve the problem, says Dave Grigal, a soil scientist at the University of Minnesota: Spread lime on forest soils, as some European countries have done. Shortle, however, says that may be too expensive in the United States. "There isn't any quick fix," he concludes.

–Jocelyn Kaiser