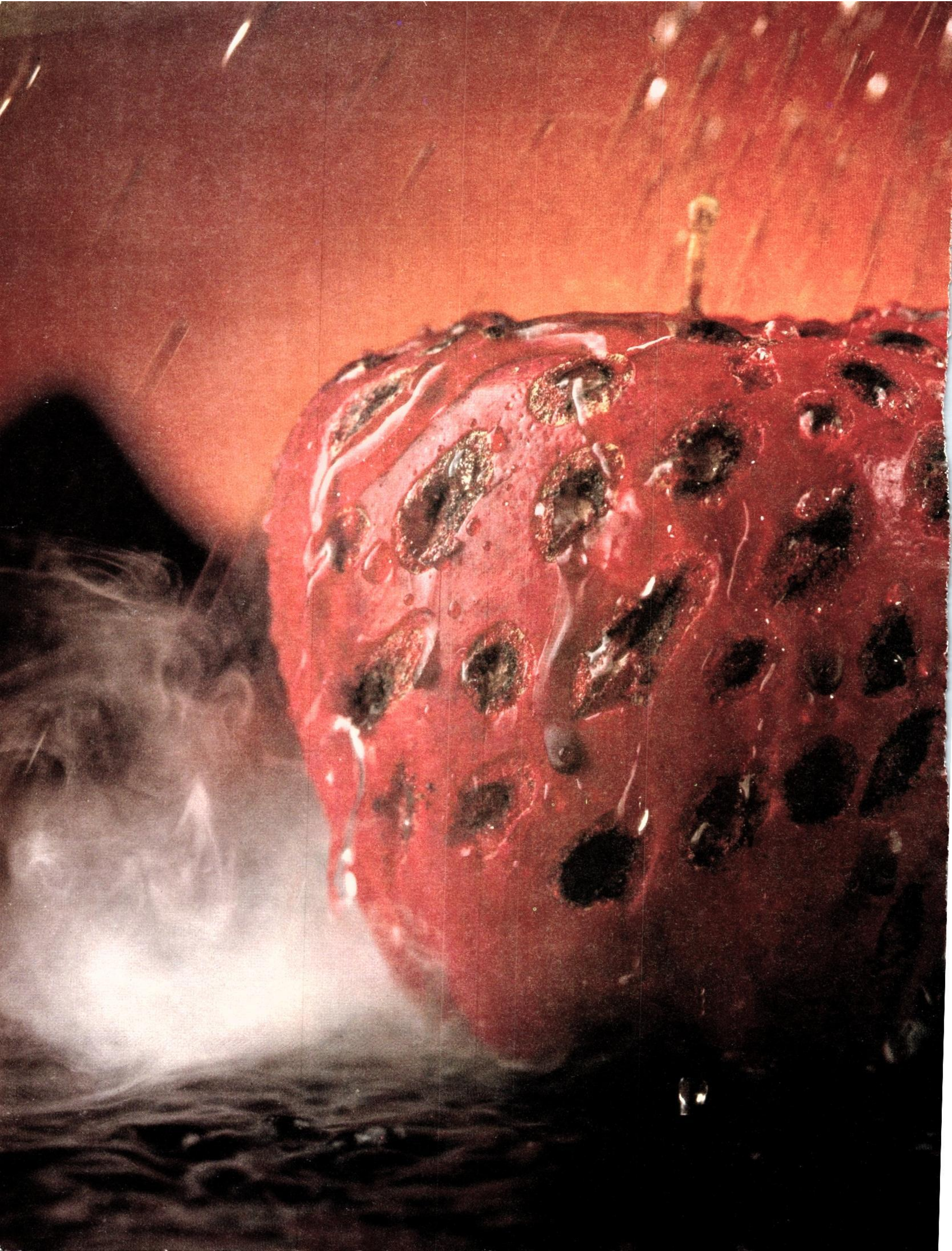


Acid Rain

by Leonard Bertin

"The process of the acidification of our lakes ends in crystal-clear waters whose apparent beauty belies the fact that they are now empty mirrors — tantalizing, alluring, but lifeless." John Fraser, a former minister of environment.

Acid rain, which already poses a serious threat to the ecology of eastern Canada and the north-eastern United States, may increase dramatically as a result of two measures now being considered in the U.S. The first would force 80 electric generating stations in the north-eastern states to switch from oil to coal fuel; the second, a move to amend existing clean air legislation, could relieve U.S. utilities from the obligation to install effective anti-pollution equipment in some 350 new coal-burning stations that are scheduled to be constructed by 1995.

The switch from oil to coal, provoked by increasing pressure from the Organization of Petroleum Exporting Countries (OPEC), would be required by an energy bill, backed by President Jimmy Carter, that was passed by an 86-7 vote of the Senate, late in June, 1980. The U.S. Environmental Protection Agency has estimated that this move alone will increase by 16 per cent the acidity of precipitation on the north-eastern U.S., with a serious spillover into Canada. The bill has still to be passed by the House of Representatives.

The construction of the 350 additional generating stations, needed to meet anticipated new energy demand, will be cause for more serious concern, because most of the sulphur dioxide (SO_2) produced in the U.S. comes from coal-burning generating stations. While the Clean Air Act does not compel existing stations to install anti-pollution equipment, it does at present require new ones to do so.

Douglas M. Costle, administrator of the U.S. Environmental Protection Agency, has already expressed fears this Act may soon be watered down. He told a meeting in Montreal recently: "Compared to other types of air pollution, acid rain is less well understood and of less immediate concern in the minds of our respective officials; many would prefer to dismiss or defer concern over it in today's energy-minded economy . . . Congressional review of the Clean Air Act could come up again as early as next year. While I believe there is room for improvement in the law, I am concerned that it could be substantially gutted if people do not pay attention to what is happening." The Act, he said, was a troublesome and complex statute, tailor-made for opponents of the program. At the beginning of the year, there were nearly 2000 "political action committees" in Washington, organized to channel funds to candidates for Congress. Of these, 512 represented trade associations and 949 represented corporate interests. One magazine has estimated that the associations among them have $55 million to spend. "This," said Costle, "is the context in which the Clean Air Act will be reviewed in Congress." Add to it the fact that it will be discussed against the backdrop of a troubled economy.

Costle recalled that, in the U.S., sulphur dioxide levels were cut by 65 per cent between 1964 and 1972, and by a further 17 per cent between 1972 and 1977, mainly because states promoted a switch from coal to oil and gas in the late 1960s. "Now, 15 years later, and all of us sadder but wiser about the price of energy dependence and dwindling oil supplies, we face the challenge of a national commitment to increasing coal use . . ."

Canadian Environment Minister John Roberts has strongly criticized the U.S. for a lack of political commitment in the matter of acid rain. In June, he told a meeting of scientists, mainly from the U.S., that the federal government was so concerned about "the lack of awareness of the average American about acid rain that we are seriously considering handing out leaflets on the problem to every tourist who enters our country from the U.S." He said, "We have not chosen an appropriate theme yet. Perhaps it could be: 'Come and see our fish and forests before they fade into memory!'"

"The U.S.," went on Roberts, "is not only predicting increases in sulphur dioxide and enormous increases in oxides of nitrogen, but it is pursuing deliberate action to make sure it happens."

In part, the present lack of public awareness stems from the fact that the menace of acid rain, though real, is invisible to the eye, undetectable by the palate and is often so slow and insidious in its effects on the environment that many do not notice change until it is irreversible.

In many parts of North America and Europe today, smokeless chimneys, or chimneys topped with short wisps of condensing steam, are giving people the misleading impression that, in those areas at least, air pollution is a thing of the murky past. In industrial areas and centres of dense population where once the sun was rarely seen, blue skies now provide the same impression that all is well in the heavens. Oh, that it were so!

The reality is that, while there have been major improvements, many older sources of pollution are just as bad as ever. Now that visible emissions have disappeared from other chimneys, scientists are becoming increasingly aware of some less visible yet serious pollution problems that even the most sophisticated remedial measures can hardly eliminate.

The term "acid rain" is so new that it cannot be found in most dictionaries. Graham Scott, Ontario's Deputy Minister of the Environment, remarked recently that "a year ago, acid rain barely existed in the vocabulary of Ontarians, or indeed of Canadians."

Acid rain is produced when gases like sulphur dioxide (SO_2) and oxides of nitrogen (referred to generically as NO_x because there are several of them), combine with oxygen in the air and with water vapour to form sulphuric acid (H_2SO_4) and nitric acid (HNO_3).

The SO_2 is derived from the burning of coal, oil and natural gas fuels that contains sulphur and a variety of non-ferrous metal ores. Oxides of nitrogen are a product of the chemical combination of oxygen and nitrogen at high furnace temperatures and in the hot, high pressure conditions in internal combustion engines.

One of the unhappy things about today's acid rain is that it rarely stays around to plague those who cause it. There are now in North America more than 200 stacks from 120 to 360 metres high. In great measure, because of them, gaseous emissions are now being ejected high into the atmosphere and may be carried hundreds — even thousands — of kilometres, before they are washed down to the Earth's surface. And the farther they travel, the longer they are exposed to the energizing rays of the sun. The atmosphere thus becomes a vast chemical factory where these gases combine, first with more oxygen and then sometimes with other atmospheric contaminants such as unburned hydrocarbons. The pollutants are also absorbed by tiny airborne droplets of water — to form faintly-coloured liquid lenses that scatter sunlight and produce visible haze.

Many pollutants fall to Earth even in dry conditions and, sooner or later, when the meteorological conditions are right, the remaining water-soluble ones will also precipitate to Earth as rain or snow. They may change the chemistry of soil, making it less alkaline and more acidic; they may damage foliage that absorbs them; and they may change the chemical balance of vulnerable lakes and rivers, so that they can no longer support aquatic life.

This close-up of a smoke stack in Sudbury, Ontario illustrates part of the pollution problem. The use of scrubbers and other emission controls has reduced visible pollution but the amount of acid rain continues to rise. NFB Photothèque ONF photo by Crombie McNeill

Rain water, it should be pointed out, is rarely neutral, because of ever-present carbon dioxide (which forms carbonic acid when it combines with water) and also because of various acid ions it picks up from sea water spray and from gases emitted by volcanoes and other natural sources of sulphurous gas.

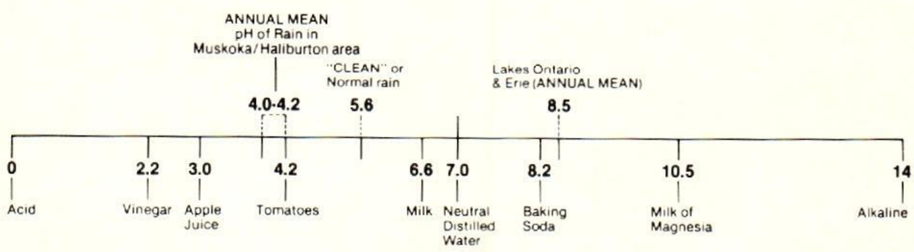
On a scale of 0 to 14, known as the pH, or potential ion scale, where seven is neutral and low numbers mean more acidity; high ones more alkalinity, natural rain usually rates a mildly acid pH of 5.6. The scale, it should be said, is logarithmic. That means that each difference of 1.0 represents a factor of 10. Rain that registers 3.6 is 100 times more acidic than a shower that only registers 5.6.

The acidity of precipitation varies a great deal from day to day, depending on the strength of the polluting source, the distance travelled by the gas and the amount of water present in the atmosphere. At its worst, and only on very rare occasions, precipitation has been noted with pH values comparable to apple juice (pH = 3.0) or vinegar (2.2).

In the case of long range transportation, the actual concentrations are generally small and nearly always below levels at which acute effects will be felt by the various components of the ecosystem. It is the long-term accumulation or "loading" of such precipitation, whether wet or dry, that counts.

A report issued by Environment Canada says that concern is often on account of the "synergistic" effects, or the additive result of loadings of a whole range or combination of interacting materials. In synergistic situations, normal arithmetic does not apply because the combined effects are larger than the total of the individual ones.

Top Right: This advertisement, prepared by Inco, which appeared in the Toronto Star and other newspapers throughout Ontario, is an attempt to show that while Inco emissions are down acid rain is still up. While Inco is trying to improve its performance, any gains made will be wiped out by increased use of coal in the U.S. and in Canadian generating stations.



NOTE: The scale is logarithmic which means each difference of 1.0 represents a factor of 10. Rain that registers 3.6 is 100 times more acidic than a shower that only registers 5.6.

Dr. Peter Rennie of the Canadian Forestry Service points out that "civilisation as we know it depends very much upon the inherent productivity of a very thin layer of the Earth's crust . . . upon a variety of renewable resources — wild crops, intensively managed agricultural harvests, forest products, hunted wild life and fish catches." Fluctuations in their yields, he says, have triggered historically some of the most profound migrations and contestations of people. In Canada alone, fisheries net $700 million in a year, forest products $5.8 billion, and agricultural harvests nearly $9 billion. Even small percentage decreases in such figures can represent very large absolute losses and could cause major economic concern, at home and abroad, among people who depend on such resources.

Dr. David Peakall, chief of the Wildlife Toxicology Division of the Canadian Wildlife Service, emphasizes that the impact of acid rain on wildlife is via the effects on their habitats, rather than directly on the wildlife itself. "Less dramatic changes in habitat are capable of exerting larger and more permanent effects on wildlife populations than direct mortality of individuals." He lists three areas of concern from a wildlife point of view, ranked in the order of effects seen:

a. Fish-eating birds and other aquatic wildlife;
b. Animals that depend on lichens; and
c. Terrestrial fauna, due to the effects on forests.

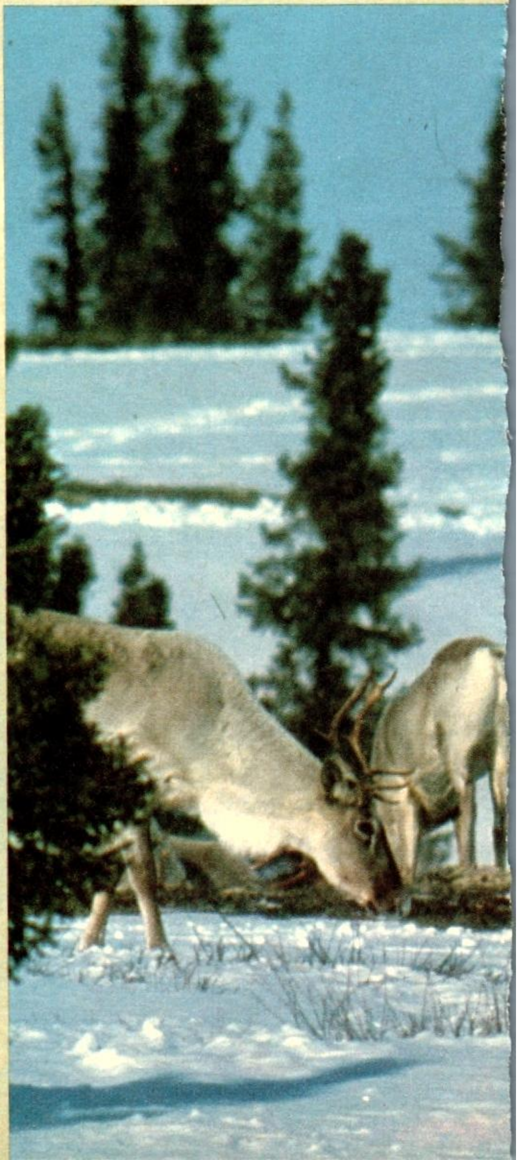
Man's own adaptability to an almost infinite range of living conditions — a constant source of wonderment — is probably one reason why he has been so late to appreciate the deleterious effects that minor variations in pH can have on some lower and less complex forms of life. It is understandably hard for someone who can live for long periods on a diet of fruit juice and meat, or vegetables and beer — even bread and water — to realize that a change in water quality that he himself may not detect can wipe out a whole species of fish in a lake and threaten the survival of such amphibians as the spotted salamander.

It is harder still to understand how the same modest change could affect the mighty caribou, yet some researchers believe that it can happen by damaging that animal's natural habitat in ways that are undramatic but long lasting. The caribou depends on lichens and mosses for sustenance and these are very sensitive to increases in acidity of rain or snow.

Dr. Peakall says that the decrease in fish stocks has been well documented. "The sensitivity of various fish species to decreasing pH varies considerably," he points out, "but, eventually, loss of total fish populations occurs." This, in turn, hurts birds that depend on the fish. About 70 per cent of common loon reside within the zone of acid fallout and the same is true of the bald merganser. About half of the range of the bald eagle lies within the same area.

Dr. Rennie recalls that the first documented case of acid rain from a point source was probably that of 1852, in the district around Swansea in Wales, where what was described as "corrosive rain" was observed to have serious debilitating effects on the growth of meadows, the health of cattle and on soil fertility.

Since then, Dr. Rennie says, the experience of Trail, B.C.; Sudbury, Ontario; Thompson, Manitoba; and Noranda and Murdochville, Quebec, have illustrated how acid rain, acting in conjunction with strong ambient concentrations of sulphur dioxide, have brought about clearly recognizable harmful effects upon plant growth and soils. P. J. Dillon and associates reported in the Journal of the Fisheries Research Board of Canada in 1978 that some lakes in the Haliburton-Muskoka area of south-central Ontario have lost 40-75 per cent of their acid-neutralizing capacity in a decade or less. According to



Left: The disappearance of aquatic life also causes the death or migration of birds such as the seagull. Ontario Ministry of Natural Resources

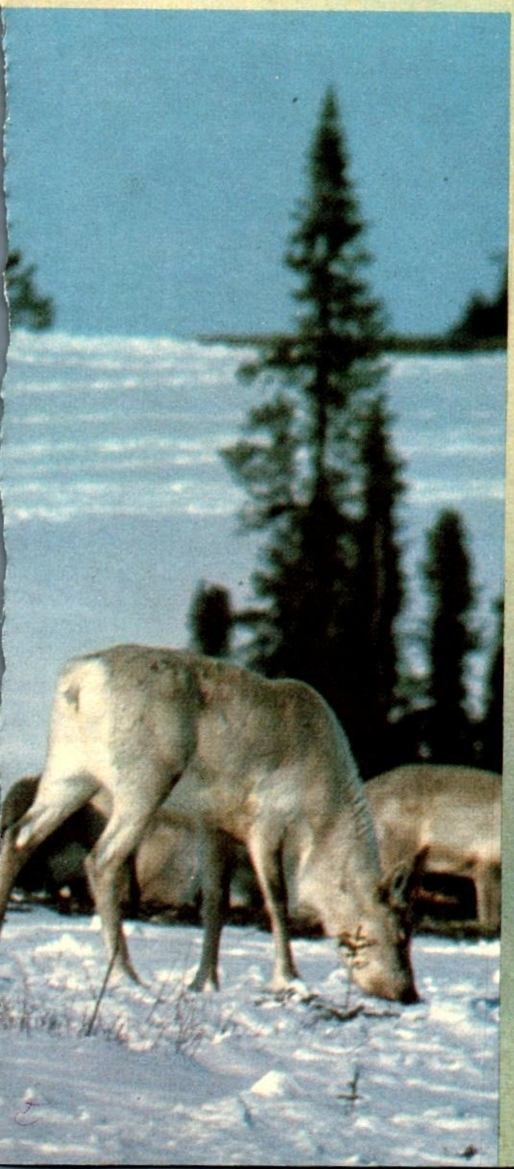
Right: The bald eagle, already on the endangered species list, is an inhabitant of the area most affected by acid rain. A further break in its food cycle could be disastrous. NFB Photothèque ONF

the LRTAP (United States - Canada Research Consultation Group on the Long Range Transport of Air Pollutants) report, 140 lakes in Ontario, primarily in the Sudbury area, have been acidified and thousands of lakes in eastern Canada are showing signs of acidification.

Dr. Anne LaBastille, Commissioner of the Adirondack Park Agency, in a report on the effects of acid rain, last year, said: "Recent research has shown that the pH readings in the Adirondack waters are in the 4.0 to 5.0 range, with extreme lows of 3.0 to 4.0 during spring run-off and heavy autumn rains. As compared to the 1950s, this is an increase of 20 times.

"The most obvious effect," she said, "has been in the reduction of trout and other species of fish in Adirondack lakes. In a survey of more than 200 lakes at higher altitudes in the western Adirondacks, 90 per cent were found to be devoid of fish and pH readings were below 5.0. A similar study, carried out between 1929 and 1937 showed only four per cent of lakes fishless. . . . Most fish, especially eggs and fingerlings, succumb to acid precipitation in the early spring," she explained, "when the thaw carries accumulated acids from winter snows into body waters. Adult females may experience lowered serum calcium levels during reproduction, which decreases fertility and alters spawning behaviour."

Below: The caribou, like other large mammals, can also be affected by changes in its natural habitat. Lichens and mosses that provide food for these animals are very sensitive to increases in the acidity of rain or snow. NFB Photothèque ONF



Dr. LaBastille says the normal appearance of a lake or pond turned sterile by acid precipitation is that of extreme clarity, tinged with blue. Little aquatic life survives and fish-eating animals become scarce. Most aquatic vegetation, including phytoplankton, is suppressed, but there may be blooms of green algae and sphagnum moss. Waterfront values may be adversely affected, especially in tourist regions, and recreational opportunities are impoverished. Others have noted that the acidity of several Nova Scotia rivers increased significantly in the period between 1954 and 1977. As an example, the pH of the Mersey River changed from about 6.0 to 5.0 and its alkalinity — the power to buffer acid — has been essentially exhausted.

In the opposite direction, the Boundary Waters Canoe Area, which includes Voyageurs National Park of Minnesota, the process of lake acidification is just beginning and only the most susceptible lakes are affected. About two-thirds of the 85 lakes sampled in 1978-79 were found susceptible to change. If these lakes are representative of lakes in the "wilderness area," then the potential for serious ecological damage is serious.

The LRTAP report notes that, while there is much to be learned about acid precipitation, there is every indication that it is deleterious to crop yield and production and recent evidence links the decline in success of the Atlantic salmon spawning in Quebec and the Maritime provinces with increasing acidity of streams. Vast areas of eastern Canada, particularly in Quebec, Nova Scotia, New Brunswick and Newfoundland are regarded as highly sensitive.

The precise response of terrestrial ecosystems to acidic and other toxic material is extremely difficult to measure and predict, the LRTAP report points out. The problem is that to await an unequivocal demonstration of damage (for example, a 15-20 per cent loss in forest productivity) is clearly unacceptable, for the loss by then could be great and the site degradation irreversible. A complicating factor is that acid rain often includes small concentrations of potentially toxic elements such as zinc, arsenic, cadmium and copper. Furthermore, when it reaches ground level it has the capacity to dissolve such elements in the soil and assist in their transfer to the roots of plants.

Health scientists have found, too, that acid rain and snow, when allowed to remain in metal water mains, leaches out lead and copper from pipes and solder. The longer the water stays in the pipes, the greater the heavy metal contamination. Pitting and corrosion occurs at an accelerated rate and leads to plumbing problems.

Dr. LaBastille reported that even Adirondack spring water that had not been exposed to pipes has shown copper and lead levels "at or slightly above the recommended safe drinking standards and also remarkably high levels of aluminum." These trace elements are leached out of lake sediments, bedrock and soils by acid precipitation and may account in part for the increased amounts of dissolved heavy metals that are being found in lakes and rivers.

Because some soils contain lime or other alkaline combinations, they are able to "buffer" the acid, neutralize it and render it harmless. The pH of Lake Ontario water, for example, is 8.5. Two University of Guelph professors have pointed out that, in some cases, including areas of southern Ontario, acid rain may even improve soil productivity by adding needed nutrients.

Problems created by the long range transportation of air pollutants and their deposition in acid rain were first recognized in Sweden in the early 1960s. Scientists there noted a steady increase in atmospheric SO_2 and NO_x and correlated this with the increased acidity of rain. In 1972, in response to evidence of measured effects on some Scandinavian lakes, the Organization of Economic Cooperation and Development (OECD) initiated a cooperative technical program to measure long range transportation of pollutants. The report, published in 1977, confirmed that long range transportation did occur and did cause damage.

Because acidity remains locked in snow until it melts, and because the age of snow can be measured by various techniques, scientists have been able to show that, since World War II, the average acidity of precipitation has increased in many parts of the world. Gradually, pieces of the jig-saw puzzle from elsewhere are fitting together to present a worrying picture.

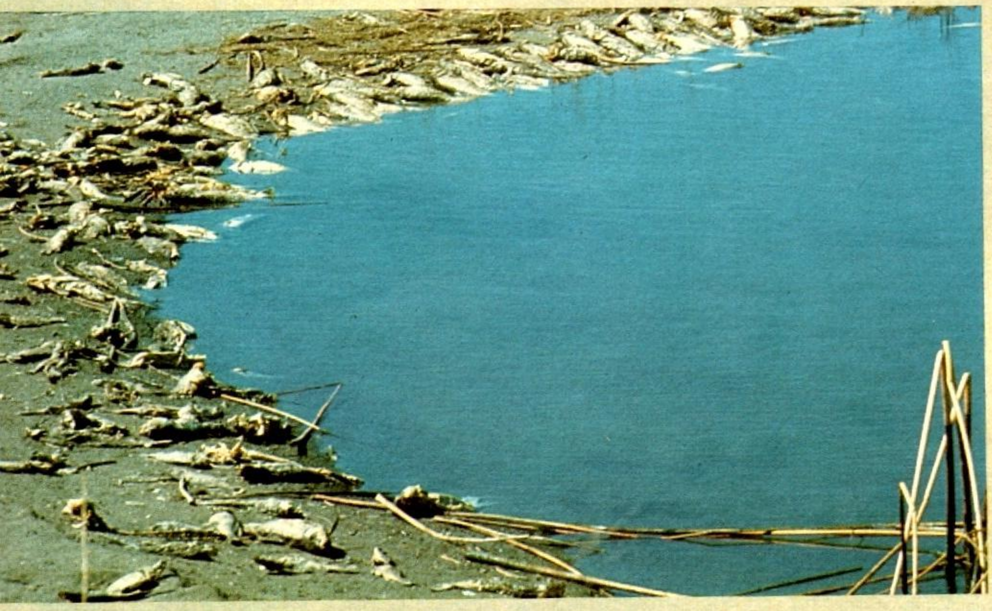
The LRTAP report, published last year cites oxides of sulphur as being responsible for two-thirds of acid precipitation, with oxides of nitrogen responsible for one-third.

In Canada, the sulphur dioxide is mainly the product of the smelting of non-ferrous metal ores. In the U.S., the main source is electric generating stations. About one-half of the oxides of nitrogen are generated by transportation, the rest from power generation and other combustion sources. Canada produces about five million metric tonnes of sulphur dioxide a year; the U.S. 25.7 million tonnes.

Approximately 1.9 million tonnes of oxides of nitrogen are emitted in Canada annually and 22.2 million tonnes in the U.S. These figures are expected to increase significantly because the total amount is related directly to the amount of energy released by combustion. NO_x emissions are also much more difficult to control than those of sulphur.

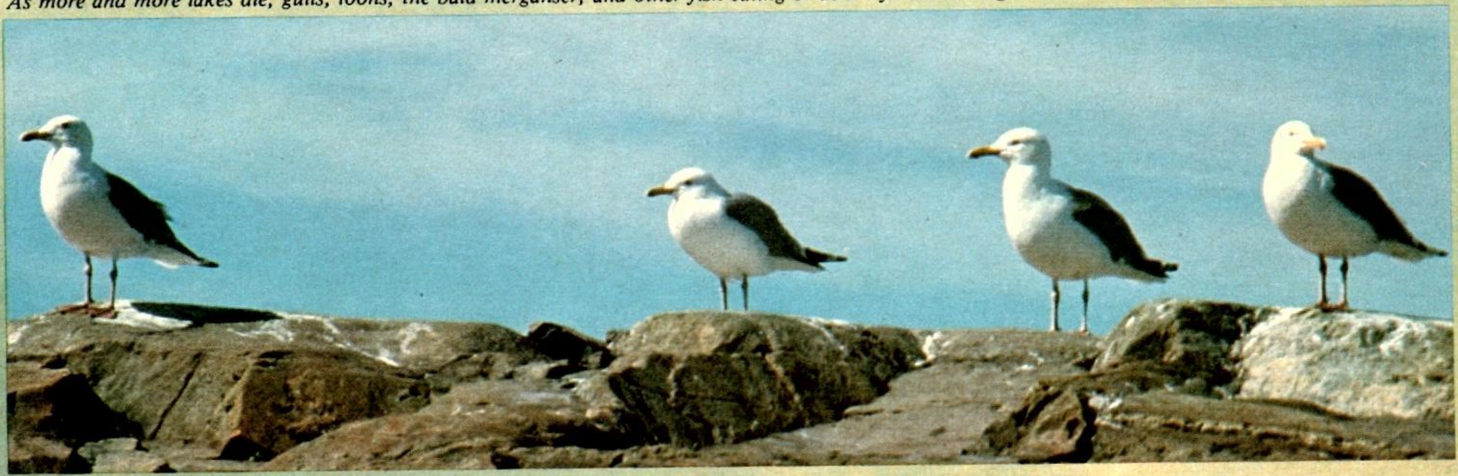
Sulphur compounds, according to the LRTAP report, typically remain in the atmosphere for from one to five days. The net flux is from south to north, across the U.S.-Canadian border. The amount of SO_2 from the U.S. is probably equal to the total Canadian production. On the other hand, the southward flux is between one-third and one-quarter of the amount produced and is therefore substantially less than U.S. emissions. In eastern Canada, about two-thirds of the total pollution burden from all sources comes down as acid rain or snow and one-third in dry periods. Although the Inco high stack has been blamed for increasing acidity of lakes in the Muskoka-Haliburton area of Ontario, Ontario Environment Minister Harry Parrott says an interesting preliminary finding has been that, during a prolonged strike at the Inco and Falconbridge refineries, when all ore smelting in the area of Sudbury was halted, acidic rain levels in the Muskoka-Haliburton area remained constant. This is taken by some as meaningful evidence that the dominant source of contamination for this important area is not Sudbury.

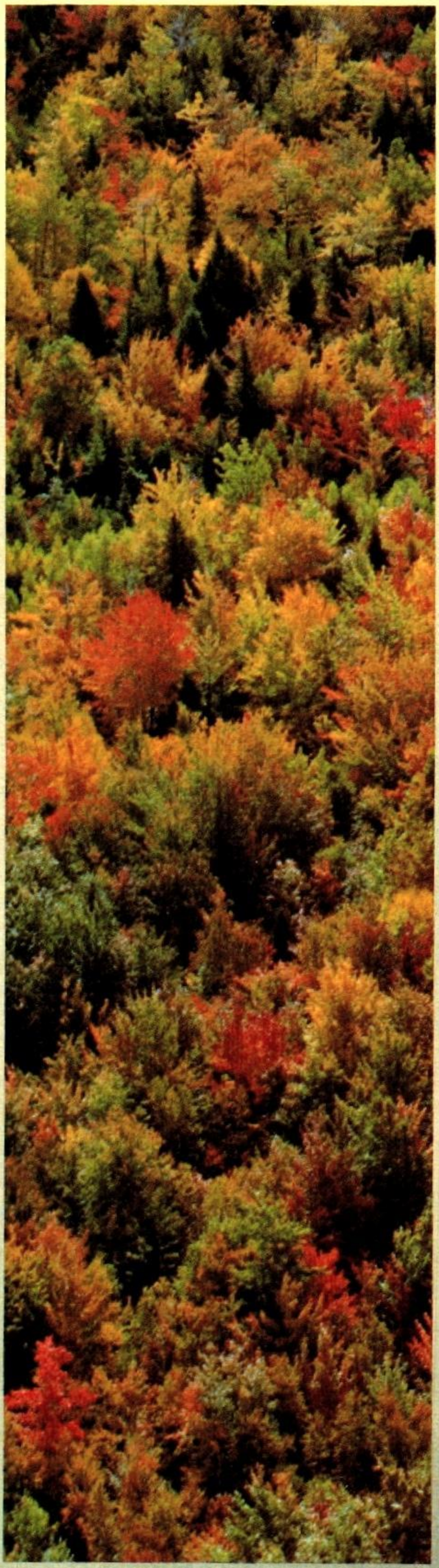
If this is so, then where does the contamination come from? And where does the huge emission from Sudbury end up? The further big question is: What can be done to improve this whole situation?



The net result of excessive pollution of any type in small lakes can be total fish kill. This lake differs from those killed by acid rain only in that because of the rate of death the result is visible. Acid lakes appear clear, blue and peaceful. NFB Photothèque ONF photo by Richard Wright

As more and more lakes die, gulls, loons, the bald merganser, and other fish-eating birds are forced to migrate. NFB Photothèque ONF





Recent evidence unearthed by the LRTAP report shows that acid rain also adversely affects forests. The rain also includes small amounts of toxic elements that are detrimental to plant life. Tom Bochsler

So far as sulphur is concerned, the answer is that much has already been achieved by using coal, oil and natural gas of low sulphur content, by washing coal before use, to rid it of free uncombined sulphur; and by "scrubbing" stack gases with water and weak alkaline solutions. But, in Canada the main source of sulphur pollution is not from electric generating stations but from metallurgical processes and there the sulphur is much more difficult to control because the ores themselves are often chemical compounds of sulphur.

At a time when there is already a glut of sulphur, the best development of all would be the discovery of a new end use for waste sulphur that would pay for the cost of its removal from flue gases. But this does not seem in sight.

Graham Scott, Ontario's Deputy Minister of the Environment, has listed the tools at the disposal of his ministry. They include:

a. Legislation
b. Establishment of air quality standards and criteria
c. Monitoring and inspection
d. Certification and approval
e. Negotiated control programs
f. Formal control orders, and
g. Prosecution

The 1972 Ontario Air Pollution Control Act provided the basis for the first reliable province-wide inventory of contaminants.

In Metro Toronto, sulphur dioxide emission has already been reduced by 85 000 tonnes between 1969 and 1972 and was further reduced by 67 000 tonnes a year by 1978. This was mainly achieved by limiting sulphur content in fuels burned in the area. Furthermore, Ontario Hydro has succeeded in reducing its SO_2 emissions, in spite of expansions in electricity production and the amount of SO_2 per kilowatt has gone down. The practice of insisting on delivery of prewashed coal has, on its own, reduced SO_2 production by from 10 to 15 per cent.

Further reductions have been achieved by buying low-sulphur fuel. Unfortunately, as Dr. Parrott points out, we do not have that option in dealing with smelting operations. "We can't say to Inco: 'Use low sulphur ore!' They have to use what they find in the ground or abandon their operation."

Nevertheless, Inco's SO_2 emissions in 1972 were 45 per cent higher than they are today.

The problem presented by oxides of nitrogen is much less tractable, because the raw materials, oxygen and nitrogen, are derived from air, rather than from the fuel. Once they are formed, there is no satisfactory chemical or physical way of trapping them.

Ironically, the efficiency of any thermodynamic system, whether it be an auto or an electric generating station, is directly related to the highest temperature that can be realised. Yet, the hotter the flame, whether it be in the cylinder of an automobile or the furnace of a coal-burning power-station, the greater will be the quantity of oxides of nitrogen produced. On the Canadian scene, oxides of nitrogen are far less important than the oxides of sulphur but, on the continental scene, the problem presented by oxides of nitrogen is much more formidable. The prime source is transportation — cars, trucks and trains. This is followed by heating plants, electrical generating stations and industrial processes. In both the U.S. and Canada, transportation is a federal responsibility. Unfortunately, the technology to deal with NO_x emissions is largely undeveloped. The 10 to 20 per cent reduction that has been achieved is largely attributed to auto emission controls.

One present approach to the NO_x problem is to devise ways of removing heat from flame more efficiently. Another is to control carefully the amount of surplus air in a furnace. The most effective way of all — and it would take care of the sulphur problem as well — would be to reduce dependence on hydrocarbons and place increased reliance on alternative power sources. That way, we would be less dependent on imports of coal and oil and we would conserve a heritage of hydrocarbons that could be much more productively applied to other uses.

Leonard Bertin is author of several books, including ATOM HARVEST, a history of the British nuclear weapons and power project, and was co-author of **Canadians at War, 1939-45.** *He has served as science correspondent of* **The Daily Telegraph** *and science editor of the* **Financial Post of Canada, the Toronto Star and the Star Weekly.**