A Killing Rain

The Global Threat of Acid Precipitation

Thomas Pawlick

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A Killing Rain

for Peg, Ruth and Ed

Preface

"Sexy" issues are as changeable in politics as rock bands are in pop music. They rise, peak and eventually fall from public attention with sometimes astonishing speed. In a presidential election year the rising and falling occur at an even faster rate, as campaign managers experiment first with one, then another symbol for their candidates to brandish. Like the contestants themselves, issues that lack staying power tend to fade in the primaries. Only the truly tough ones survive.

In this context, it will be interesting to see what happens to the issue of acid deposition—better known by the less accurate title of acid rain. As a physical phenomenon, acid rain has been around a long time. The term itself was coined in England in the early 1900's by scientists studying the effects of coal burning on local crops. As a major political issue in countries other than the United States it has also been around for awhile—more than ten years in Europe and at least five in Canada.

At this writing, however, acid rain is just beginning to hit the charts in the U.S., hovering down around eight or nine among the top ten subjects of controversy. Where will it be by November? Perhaps the politicians will have had a great game with it, kicking the new football around, scoring points against opponents, racking up numbers in the polls. Perhaps it may not have proven sexy enough, ending its election year career in limbo.

While the posturing goes on, however, the rain will keep falling, and unlike the promises of politicians its effects are real. The damage being done is factual, physical and in too many cases irreparable. Time is running out. Even if Congress should temporarily save the day and come through with a compromise abatement bill before the 1984 election, a tremendous amount of damage will still be done before controls can actually be put in place.

Given the strength of any such bill's opponents—chief among them the Reagan administration—it is entirely possible that its restrictions may not be strong enough or that, under an executive branch firmly opposed to pollution control, enforcement of the law could be lax.

The situation is fluid, chancey. The prospects are uncertain.

It would be pleasant to discover, at some future date, that this book played even a small part in tipping the scales in favor of the environment—and that they tipped when it still counted, before it was too late.

T. Pawlick
February 1984

Contents

One

The Acid Earth

It begins with heat: jets of coal dust and air bursting into flame at 3,500° F in the fire chambers of electric power plants; molten sulphide ores bubbling and blistering in smelter furnaces; gasoline exploding at 4,500° F under the steel cylinder heads of trucks, buses and automobiles; diesel oil, Exxon regular, bituminous coal, anthracite, lignite, the ores of nickel and copper, pyrrhotite, pentlandite, niccolite, chrysolite, burning until the heat cracks their internal electron bonds and breaks each compound into its constituents, to rise, as gases, vapor or microscopic particles, into the air.

"Precursors," chemists call them, harbingers of things to come.

Because of them, and their end products, 50,000 to 200,000 people with asthma or other lung disorders will die prematurely this year. Because of them, relations between the United States and Canada have fallen to their lowest point in decades. Because of them, whole sectors of such industries as lumber, paper and pulp, inland sport and commercial fishing, tourism and agriculture could face losses ranging from millions of dollars per year to bankruptcy. The maple sugar industry in Vermont and Quebec is threatened. The sport fishery in Ontario, Nova Scotia and upstate New York has sustained heavy losses. Corrosion damage to homes, buildings, outdoor monuments and vehicles across the continent exceeds $2 billion per year.

Because of the heat and the smoke, something has come into existence that wasn't here before.

At American Electric Power Company's General James M. Gavin plant, a 2.6-million-kilowatt generating complex whose thousand-foot, dun-colored smokestack juts up from the banks of the Ohio River near the town of Cheshire, Ohio, the fuel for the fire comes in great batches—600 tons of coal an hour for each of the installation's boilers. So much coal is needed to run the 25-story units that AEP, whose multistate power grid has ranked for years among the nation's worst polluters, has to operate its own mines, three of them, just to supply Gavin. Millions of tons of coal flow each year along a 10-mile-long conveyor belt that winds across the wooded hills of rural Meigs County from the mines to the plant. But even this mountain of black rock, ripped from the earth by the revolving steel teeth of "continuous mining" machines run by an army of 1,800 miners and their support staff, isn't enough. Still more coal must be brought in from other sources, by railroad car and river barges, to feed the flames that change water into steam and turn the huge station's turbines.

Men in hard hats, gray twill jumpsuits and black rubber boots, engineers, technicians, laborers and miners, do the heavy work, taking and giving orders in the twangy, half-Southern drawl of the Ohio/Kentucky border region. They work in heat and dirt and constant noise, in the mines where digging and air-circulation equipment roar, in the coal preparation plant where clattering machines crush and crack the coal, press it, bathe it in water and filter it, in the power plant itself, where fire and steam and the wild whine of the turbines drown even the loudest shout.

The washing process they oversee in the preparation plant removes impurities from the coal that could cut the efficiency of Gavin's boilers. Along with ash, a certain amount of sulphur-containing compounds, called pyrites, are taken away by rinsing the coal and passing it through various meshes until the heavier pyrite settles out. But not all of the 3.7 percent sulphur in the fuel mined for Gavin comes in pyrite form. In fact, only 0.2 percent is eliminated by washing. The rest, with nitrogen, hydrogen, oxygen and a long list of trace metals and other elements chemically bonded to the carbon in the coal, is separable only by burning.

When the coal does burn, as hard-hatted technicians watch the dials, buttons, gauges and warning lights that make the plant's control room look like the bridge of a space ship, its sulphur is released as SO_2—poisonous sulphur dioxide gas—and its nitrogen as toxic nitrogen oxides (NO_x). Equally toxic trace elements, chiefly mercury, arsenic and aluminum but including nearly 50 others, volatilize or escape as minute particles, and the Gavin smokestack, at 1,103 feet among the highest in the United States, carries them aloft, into the atmosphere, into the infinite chemical complexity of the air, to react and be reacted upon.

Hundreds of power plants across the United States and Canada follow similar cycles 24 hours a day, around the clock, with more than 60 of the largest, their power outputs greater than 50 megawatts each, clustered in the Ohio Valley alone. Together, the makers of electricity contribute more than half of the 35 million tons of SO_2 released each year from man-made sources in North America, and a quarter of the 24.5 million tons of NO_x. The rest comes mainly from ore smelters, other industrial boilers, home heating and from the exhaust pipes of cars, trucks and other vehicles, which exhale only a tiny fraction of SO_2 but emit more than 40 percent of the total NO_x.

The smoke flies up.

Compressed and placed on the balance tray of a vast, imaginary scale, the daily continental emissions of sulphur and nitrogen oxides would weigh more than 163,013 tons: the equivalent, by weight, of 4,075 fully loaded railroad freight cars being tossed into the air every day.

And they mark only the starting point. Though toxic in themselves, their function is preliminary.

The tall stacks that bear so much of this initial burden were mainly built between the late 1950s and the early 70s, when fear for the environment was growing into a major political issue and the original Clean Air Acts were being passed in the United States and Canada. The stacks marked a crucial departure then, an engineering milestone that seemed to bring genuine blessings in the control of local air pollution.

Nowhere were such blessings more needed than in the northern Canadian mining town of Sudbury, Ontario, a city whose name has become symbolic of the ills of industrialism.

Wounded Sudbury. Like the victim of some terrible, violent crime, it stirs first pity, then outrage, then admiration. Its people refuse to give up, despite a century of corporate pillage. They hang on. They would make rocks bloom.

Their community was once a forest and subsequently, after 19th-century lumberjacks clear-cut many of the trees to supply railroad ties for the Canadian Pacific Railway, a region of thriving farms. Then came doom. In 1883 rich deposits of nickel and copper that had been ignored for 30 years were rediscovered, and by 1886 a group of American investors, forerunners of today's Inco Limited (until 1976 called the International Nickel Company) had begun mining and smelting operations in the area.

The first crude smelter, located five miles outside of Sudbury at Copper Cliff, employed a method called "heap roasting." Raw ore was simply dumped on top of great piles of cordwood, cut from what was left of the already depleted forests, then set ablaze and allowed to smolder for months, until the metal separated from the rock. Thick blankets of foul, sulphurous fumes smothered the surrounding region, choking, deadly. Later smelting methods employed by various mining companies attracted to the area, though slightly less crude, did little to thin the clouds of sulphur oxides, or the shower of copper, nickel, zinc and other toxic metal particles that accompanied them.

Gradually, over the years, almost everything that had been alive in the smelters' vicinity—except the ruthlessly exploited mine and smelter workers and their families—died. Farmers went bankrupt, their crops withered. The last remnants of the original white pine forest faded away. The paint on the workers' houses peeled. The miners themselves, their lungs ravaged with every breath drawn above or below ground, inside the smelters or out, endured bronchitis, silicosis, lung fibrosis, cancer and skin diseases, while their city became a national joke: The booby prize in a Canadian raffle was an all-expenses-paid trip to Sudbury.

The price of this corporate vandalism in damage to human health, vegetation and property was set in a 1974 federal government report (*The Sudbury Pollution Problem: Socio-Economic Background*, Environment Canada, unpublished) at $465,850,000 per year.

By 1970, however, the national mood had begun to change. Like its American counterpart, Canadian public opinion had responded to the environmental movement of the 60s by bringing heavy pressure to bear on the politicians who had given companies like Inco free rein for decades. The company, whose Copper Cliff smelter had been pouring out 6,000 tons of SO_2 *per day* throughout the previous years, making it the largest single source of sulphur pollution in North America, was at last ordered by a reluctant Ontario government to begin cleaning up. The order called for a moderate initial drop in daily emissions to 5,200 tons, followed by a reduction to 3,600 tons by 1976. It also mandated replacement of the smelter's three 500-foot-and-under chimneys with a much taller new stack "to dilute and thus disperse the smelter's gases" away from the city of Sudbury.

Actually, as an Inco vice-president noted in a published report, the company had decided on its own, three years earlier, to build such a stack as the most economical way to comply with the local ambient air standards of the government of Ontario Air Pollution Act, 1967. The chimney it had already decided to erect would come eventually to be known as the Superstack—1,250 feet tall, the highest chimney in the world.

The best way to see it is alone, on foot, from across the miles of barrens that surround the stack's approach—a landscape from a nightmare, more sinister than Tolkien's Land of Mordor "where the shadows lie," because its shadows are real.

Charred black rock, its granite face pitted with tiny holes like the surface of a sponge, seems to stretch forever in all directions, jagged and bare. No trees grow, no grass, not even weeds. There are no birds. No insects buzz. The sound of a rock dislodged by a climber's foot echoes in emptiness as it clatters down the bleak slopes. Here and there, in the hollows between hills, the smashed gray branches and trunk of a long-dead pine are strewn in a heap, like bleached driftwood. A steady wind scours the rubble, whipping at pant legs. Nearer to the plant the sound of seagulls can be heard, and a solitary black crow sails overhead: There is a garbage dump near the smelter, an island of filthy but nevertheless organic detritus for scavengers to feed upon.

And then there is the stack. It looms over the crest of a hill, distant, wrapped in haze, flanked by the smaller chimneys it replaced. White aircraft warning lights near its top flash intermittently, tiny specks far away, and the stack plume, a miles-long trail of gas, streams like a great white banner against the sky, east and south. Its silence is striking. It seems alive.

Because of the stack's height, the acrid sulphurous fumes that once strangled Sudbury no longer touch ground near the smelter itself. Often as hot as 700° F, rushing up the stack at 55 miles per hour, they debouch instead into a higher air layer. Sudbury's air, in consequence, is measurably cleaner. The city can breathe at last, and in that limited sense the Superstack has fulfilled a purpose. But company claims in 1970 that the stack would prove "the quickest remedy for sulphur dioxide" have proven to be a myth, as have similar claims by the American factories and utilities that also chose tall stacks as a panacea. (In the Ohio Valley, the average stack height of electric power generating stations in 1950 was 320 feet. By 1980 it had risen to 740 feet, with numerous stacks towering over the 1,000-foot mark.)

The tall stacks carried gases up and away from the local communities, but they did not eliminate the problem. The fumes were simply blown further afield, to other communities downwind. Worse: In traveling the gases had time to metamorphose, reacting with the rich variety of chemicals in the atmosphere and taking on new forms—more dangerous forms. In dispersing the fumes, the tall stacks are spreading a plague.

Studies conducted for the U.S. Environmental Protection Agency (EPA) and other scientific bodies have begun to reveal the complicated mechanisms involved, starting with the fate of the initial stream of hot gases as they emerge from a smokestack. *Erupt* may be a better word. Moving at 50 miles an hour or better, they can shoot in seconds to levels double the stack's actual height—to more than 2,200 feet in the case of the Gavin plant. Then, bending horizontally under the pressure of the prevailing wind, the gases stream away in a widening plume.

In simplified terms, what happens next depends on several variables, including the season of the year, local weather conditions and the contour of the surrounding land surfaces. On a warm summer morning in the Ohio Valley, a moving plume emitted at 7 A.M. might retain a fairly compact shape, traveling east and north with prevailing air currents for up to 20 miles. Then around midmorning, as the air near ground level warms in response to the heating of the soil by the sun, an unstable "mixing layer" of shifting air currents develops and grows. This layer, rising gradually from the land surface toward the plume overhead, finally contacts and captures the plume, dispersing its gases in every direction from 4,500 feet to ground level. By 6 P.M., diffused particles from the original plume may have touched ground up to 100 miles away from the stack that emitted them that morning.

At night or in winter a plume can travel even farther in the same amount of time. After sundown the mixing layer collapses, leaving the upper air vertically stable. A plume emitted at night may thus remain "decoupled" from the ground, be picked up by a nocturnal jet stream—a high-altitude river of air coursing through the atmosphere at velocities of 130 miles an hour or higher—and be blown 200 miles downwind before the next day's mixing layer even begins to develop.

In winter, cooler temperatures also prevent daytime mixing layers from rising to much more than half their normal summer altitudes. Only rarely do they reach as high as the crest of a tall stack. As a result, winter stack plumes can stay decoupled from the surface for not hours but days, traveling 300 or 400 miles, sometimes more, before starting to break up.

They do not, of course, travel alone. Other plumes from other stacks move with, around and through them, as do particles from the so-called "urban plumes" that envelop major cities in a pall of auto exhaust, heating and factory smoke. These amorphous metropolitan clouds, more diffuse than tall stack plumes because they emerge near the surface and well within the mixing layer, are made up chiefly of nitrogen oxides and hydrocarbons. Their well-stirred contents can nonetheless waft as high as the passing tall stack gases, meet and blend with them and, eventually, filter with them back to earth.

The journey down is often a slow process, and what finally touches ground may be entirely different from what the stacks and auto tailpipes sent up. A recent attempt to outline what happens chemically when SO_2 reacts with only *one* atmospheric component—the hydroxyl radical, HO—ran to no fewer than 17 lines of chemical equations. Whole pages of formulae have been elaborated to try to describe the interactions between sulphur and nitrogen oxides and the ozone, water vapor, carbon dioxide, methane, hydrocarbon pollutants and a host of other substances in the air. The authors of an EPA report summarizing the state of current scientific knowledge of the subject were forced to admit "we are still struggling to assemble . . . the individual pieces."

Two things nevertheless are certain: Whatever the intermediate steps in sulphur dioxide's interactions, eventually it combines with the moisture in the atmosphere to become H_2SO_4—sulphuric acid—while the oxides of nitrogen end their aerial wanderings as HNO_3, nitric acid. Floating and falling, rising and shifting among clouds and currents of air, they exist as aerosols, finer than the spray of the sea, suspended, waiting. Acids in an acid sky.

Sulphuric acid, also known as oil of vitriol, is one of the most corrosive chemicals known. Oily and colorless, it can char living tissue on contact. Nitric acid, known to medieval alchemists as *aqua fortis*—strong water—is equally caustic, capable of causing severe burns.