The Effects of Environmental Pollution on North American Temperate Forests

Of the 7,936,191 chemicals registered by the American Chemical Council in July 1986, only 6 - less than one in a million - are considered by the EPA in its review and regulation of air quality. One of those six, lead, is not monitored by state air quality management agencies.

Temperate Forests

Temperate forests are less complex than rain forests, generally being comprised of two layers - the trees and an understory of shrubs. Sunlight penetrates the tree foliage and reaches the ground allowing for the growth of an herbaceous and moss ground layer. Rain is generally spread out over the year and is adequate to support plant growth. In some areas of the world, including Alaska's southeast coast, rain is so plentiful and plant growth so luxuriant that these temperate conifer and deciduous forest areas are referred to as temperate rain forests.

There are several different types of forest, based primarily on the mix of trees found there. The Pacific Northwest is a coniferous forest containing redwood, Western red cedar and hemlock. Hemlock is also found in the Great Lakes coniferous and deciduous region, along with pine, oak, birch and maple. In the eastern states, the broad-leaf deciduous forest includes a variety of oak species as well as beech, ash and chestnut.

Although there are relatively few species of trees in the temperate forest, the forest itself is home to a large variety of woody and herbaceous shrubs and plants, as well as ground, burrowing and arboreal mammals, birds, reptiles and insects (Whitfield, 1989, p. 72).

Coniferous and deciduous temperate forests now cover some 2 billion hectares (20,000,000 sq. km) around the world; of that, 1.1 billion hectares (11,000,000 sq. km) are coniferous forests typically cut for lumber products. 90% of this type of forest lies in the United States, Soviet Union and Scandinavia.

Once covering 180,000 hectares (1,800 sq. km), one of the greatest coniferous forest on earth once ranged from Alaska, down Canada's western coast, through the Pacific Northwest and down into Northern California. While 60% of Canada's forest has been felled, 90% of the United States's forest is gone. Government and timber industry optimists estimate that the remaining 10% will be cut down by the middle of the next century; conservationists predict it will all be gone within the next two decades (Lean, 1990, p. 81). Home to some of the world's largest and oldest trees, most of the remaining forests are on public, government-owned land. Canada has minimal controls and does little to protect its ancient forests. The U.S. has controls and legislation in place, but those laws are suborned by congressional and Forest Service directives pushing timber production (Sierra, 1992, p. 67).

Nutrients are processed and stored in the soil and in plant tissue. Rain, failing through the foliage onto the plants and soil below, carries whatever substances have mingled with the water molecules as well as washes the dry deposits off the leaves and branches. Microorganisms in the soil break down the organic litter and detritus on the forest floor, a process that can take decades before the organic matter is available in molecule form to be taken up by plant roots (Whitfield, 1989, p. 72).

Deforestation has been occurring on the North American continent ever since white settlers hit the eastern shores. Through the past 300 years, forests have been felled to provide agricultural land, timber and lumber products and, more recently, for energy and mineral extraction (Sierra, 1992, p. 67). For the past several decades, however, a new agent has been at work destroying trees, especially those at high elevations seemingly apart from man's habitations and commerce (Whitfield, 1989, p. 72).

Waldsterben (tree death) is one of the more serious effects of acid fallout. Although the natural leaching of soil elements over time leads to the acidification of the soil, the primary source of acidity now comes from the acid precipitation - clouds, fog, rain, snow and hail - and dry deposits (Whitfield, 1989, p. 164).

Clean Air

Scientists have finally come up with a definition of clean air and precipitation. Unfortunately, no one thought to do this while the air was actually clean. Thus any discussion of clean air is based upon what scientists think the air quality was like before major industries, power plants and vehicular transportation became so common a part of our socioeconomic landscape.

Clean air is generally defined as air found far from, and without the effects of, human habitation and commerce. Comprised of oxygen, nitrogen and rare gases such as argon, neon, helium, ozone, carbon dioxide, krypton, xenon and naturally occurring radioactive materials from the earth, it also has various sulfur and nitrogen compounds. Mixed up with all of these chemicals is water vapor and suspended solid particulates and liquid substances. Known collectively as aerosols, these may be defined as dust particles and nuclei. The latter include chloride salts, sulfuric and nitrous acids, phosphorus compounds and other chemical substances. The nuclei have an attraction to water vapor, and are important in the transformation of vapor to fog, clouds, rain and snow. The dust particles, while up to 10 times larger than the nuclei, occur in smaller numbers (Miller and Miller, 1989, p. 4).

Natural Pollution

Naturally occurring air pollution is caused by natural events occurring in the life of the planet and of the local biosystem: volcanic eruptions, smoke from forest fires and carbon dioxide and methane diffusing from lake beds (and from a variety of wildlife).

Effusions from volcanos erupting vertically impact global weather patterns. In 1815, Tambora on the Indonesian island of Sumbawa erupted, injecting four times the atmospheric dust into the air as did Krakatoa in 1883. The year of 1816 became known as the "year without summer", so dense was the global layer of particulates and gases, blocking much of the sun's light from penetrating through the stratosphere. Although global temperatures were only 1°F below normal, it was enough to cause crop reductions and outright failures, setting off famine, riots and disease (Fisher, 1990, p. 33). The plume of particulates from the 1982 eruption of Mexico's El Chichon was 2-3 times smaller than that of 1991's eruption of Mt. Pinatuba in the Philippines. It was felt that El Chichon's cooling affect was canceled out by the global warming then occurring (Discover, 1992, p. 46); scientists are still debating Pinatuba's probable impact on global weather patterns.

Forest fires pour gases and particulates into the air. The ecosystems in which these fires occur are adapted and may even require the heat and burn-off to maintain their high reproductive and varietal success. The smoke from forest fires, which generally does not go outside the troposphere, is brought to ground after the first rain (Miller and Miller, 1989, p. 9).

Lake gases, such as carbon dioxide and methane, are generally held down by the cold water layer in the deepest part of the lake, or are quietly diffused into the air with the constant or seasonal circulation of warm and cold water within the lake. An increasing source of carbon dioxide and methane is the growing area devoted to rice paddies and the increasing number of cows raised to feed an every expanding human population (Miller and Miller, 1989, p. 10).

Dirty Air

Humans have shown an uncanny ability to rapidly modify their environment to satisfy growing social pressures. While there have been short-term gains for humankind, the natural world has not fared as well.

Human pollution is either emitted directly into the air, formed by photochemical reactions in the air, or blown into the air from surface deposits. The following tables show the direct pollutants, their sources and those airborne pollutants created as a result of photochemical reactions (Miller and Miller, 1989, p. 11).

CHEMICAL SOURCES	**DIRECT EMISSIONS**
Arsenic (As)	coal and oil furnaces
Benzine (C_6K_6)	refineries, motor vehicles
Cadmium (Cd)	coal and oil furnaces, burning wastes, smelters
Carbon Dioxide (CO_2)	burning fossil fuels
Carbon Monoxide (CO)	coal and oil furnaces, smelters, steel plants
Chlorine (Cl_2)	chemical industries
Floride ion (F^-)	steel smelters and plants
Formaldehyde (HCH)	motor vehicle exhaust, chemical plants
Hydrogen Chloride (HCl)	Incinerators
Hydrogen Floride (HF)	smelters, fertilizer plants
Hydrogen Sulfide (H,S)	refineries, pulp mills, sewage plants
Lead (Pb)	motor vehicles, smelters
Manganese (Mn)	steel and power plants
Mercury (Hg)	coal and oil furnaces, smelters
Nickel (Ni)	smelters, coal and oil furnaces
Nitric Oxides (NO_x)	motor vehicles, coal and oil furnaces
Radioactive Materials:	
Iodine-131, Cesium-137, Strontium-90	nuclear industry accidents
Silicon tetrafloride (SiF_4)	chemical plants
Sulfur Dioxide (SO_2)	coal and oil furnacs, smelters
Photochemical Reactions:	
Hydroxyl Radical (OH)	hydrocarbons + NO_x produces acids
Nitric Acid (HNO_2)	formed from NO_2
Nitrogen Oxide (NO_2)	formed from NO to produce ozone (O_3)
Nitrous Acid (HONO)	formed from NO_2 + H_2O
Ozone (O_3)	from hydrocarbon + NO_x
Peroxyacetyl Nitrate (PAN)	from nitric oxides + hydrocarbons

Sulfuric Acid (H_2SO_4)	from sulfur dioxide (SO_2) + hydroxyl atoms (OH)
Indoor Pollution:	
Carbon Dioxide (CO_2)	gas and kerosene stoves and heaters, wood-burning stoves
Carbon Monoxide (CO)	gas and kerosene stoves and heaters, wood-burning stoves
Nitric Oxides (NO_x)	gas and kerosene stoves and heaters
Sulfur Dioxide (SO_x)	gas and kerosene heaters
Aldehydes, volatile organics, and particulates	gas, kerosene and radiant heaters

This chemical stew is created by the demands of modern society for energy, consumer goods, and the cars in which we go out to buy those goods and materials. The effects of these pollutants are wide-ranging, from damage to low-power electrical contacts in computers to an increased rate of melanomas and lung cancers, from acidic deterioration of lead and copper pipes to increased fetal birth defects. Even minor effects, such as outbreaks of gastroenteritis from acid-resistant strains of bacteria in acidified groundwater to the accelerated deterioration of paint, nylon, cotton and paper, cause no small inconvenience and expense to a society bent on producing and consuming an ever-increasing variety of goods (Miller and Miller, 1989, pp. 38-39).

Ever since Eville Gorham first identified sulfuric acid as a component of the gentle rains falling upon England's Lake District in the early 1950's (Miller and Miller, 1989, p. 16), the existence and effects of acid rain has been disputed by various government agencies, power utilities and chemical manufacturers (Adler, 1973, p. 98). Despite the then-current knowledge of weather patterns and air currents, no one believed that chemicals thrust into the air could travel so far.

Svante Oden, often referred to as the "father of acid rain" (Miller and Miller, 1989, p. 17) was the first to identify distant sources in West Germany and other countries in western Europe more than 1,000 miles away, as the cause of the pollution in Scandinavia. The northern countries of Scandinavia, Finland and Norway sit on the Fenno-Scandian plain, swept clean during the last Ice Age. Since then the slow work of fungi and algae, working together as lichens, have slowly decomposed and altered the underlying rock to form a thin layer of soil. Like the Canadian Plain in the North American continent, this land has a very low alkaline content and is unable to buffer much of the acid deposition (Luoma, 1984, p. 39).

Carbon dioxide (CO_2) concentration has increased by 25% over the past 100 years. Analysis Of CO_2 bubbles in the glacial ice of the north and south poles show increases from the preindustrial level of CO_2 at 280 parts per million to 350 ppm in the late 1980's. It is expected to double to over 600 ppm in the 21st century.

Methane exists in relatively oxygen-free environments: in the guts of animals, in permafrost, in the muddy bottoms of rice paddies and in the lower layers of landfills. A natural gas, it is released through coal mining and petroleum exploration. Methane has 20-30 times more infrared heat trapping capacity than does CO_2, and accounts for as much as 20% of the human-caused greenhouse effect. Methane currently exists in the atmosphere at 1 ppm, less than 1% of the existing level of CO_2 (approximately 0.03% by volume [Miller 1989, p. 46]), but should increase as a result of continued deforestation to provide room for more livestock and rice paddies for the world's expanding population, energy exploration and development (Schneider, 1989, pp. 99-101).

Chlorofluorocarbons, or CFCs, existing in 1 part per billion quantities, are a major factor in ozone depletion due to the repetitive reactions caused by its chlorine contribution to the upper air layers and may account for 25% of the CO_2-induced warming effect by the next century unless drastic measures are taken to reduce or eliminate CFC emissions now (Schneider, 1989, p. 101).

The amount of CO_2 held in the atmosphere is 750 billion ton. By contrast, terrestrial organisms store the following amounts of CO_2 (Schneider,1989, p. 102):

Living plants (primarily trees)	750 billion tons
Non-humans (animals, insects)	1-2 billion tons
Humans	.5 billion tons
Bacteria (atoms, by weight)	1-2 billion tons
Fungi	.5-1 billion tons
Dead organic matter	1,500 billion tons
Total terrestrial CO_2 (in billion tons)	2,253 to 2,255.5

Living matter in the oceans contain 3 billion tons of carbon; 10,000 times that amount is dissolved in the oceans, mostly in non-living form, in addition to the 65 billion tons of carbon found in the rocks and carbonate sediments in the continental crust and ocean floor. Slow removal of CO_2 from the atmosphere is done by the oceans, through biological and chemical processes which take decades, if not centuries, to complete. It is unknown how the effects of global warming will alter this CO_2 absorption, but it is estimated that at least 50% of the amount of CO_2 injected into the air will remain in the air in the 21st century (Schneider, 1989, pp. 101-102).

CO_2, methane and CFC have varying interactions. CO_2 can cool the atmosphere, slowing the photoreaction causing ozone destruction. At the same time, however, the cooling causes high altitude clouds to interact with the CFC, destroying the ozone. Methane, which can be produced or destroyed in the troposphere (depending upon what other chemicals are present), also affects the chemicals that produce ozone at the earth's surface.

Getting From Here To There

The lyrics of a song popular in the 1970's called the ocean a desert with "the perfect disguise above." The air, too, can be considered an ocean in disguise - an ocean without the massive amounts of water. While containing water in the form of H20 molecules, the air moves in eddies and currents, swirling horizontally and vertically around the planet. Like the ocean, the air circles the hemispheres with its cargo of molecular particulates, aerosolized chemicals, clashing atoms, dancing gases, ions grasping at polarities, all transformed by the sun's energy, all going on above our heads and all around us day by day, sight (almost) unseen.

In the U.S. the winds generally come from the Pacific, drifting against the ocean cliffs, brushing against the metropolitan, industrial and agricultural areas, picking up sulfides and hydrocarbons. As the day progresses, the air drifts higher and eastward, skimming the deserts of Nevada and Arizona, often reducing the visibility over the Grand Canyon, jazzed up with a bit of plutonium from Colorado. When the winds and temperature and water content mixtures are just right, the haze may extend as far as Utah before heading over the Rockies. Here the currents circle, some continuing east, others heading south (Brown, 1987, p. 3).

As the high currents head over the great plains, they pick up bits of detritus from the f arms and factories, smoke from wood stoves and power companies while heading north and east. Here they meet and mingle with currents from the south, perfumed with the rising plumes of waste from paper mills and chemicals manufacturing.

Continuing ever eastward, from the Bread Basket to the rusted Iron Belt, the currents eddy and separate, heading to New England and the Florida keys, there to be met by the Atlantic off-shore currents, mingling and migrating ever eastward.

Throughout all this traveling and commingling of air and space, the molecules diffuse and collide, break apart and join, moving up through the troposphere to the stratosphere. Or falling to earth. On our crops. In our water. Killing the trees.

Acid Rain

Acid rain is more properly called acid precipitation or wet deposition: the depositing of pollutant chemicals on the ground, plant growth and man-made structures via a wet medium such as fog, rain or snow. Dry deposition, which some scientists believe to be equal in volume to wet deposition (at least over the North American continent), is carried aloft by the winds and air currents, falling without moisture as a medium of transport (Miller and Miller, 1989, 22).

The eastern U.S. is more severely affected by acid deposition as there is a greater concentration of polluters in the region, and the soil from the seacoast inland through most of the midwest contains areas of very low to low alkalinity, soils less capable of buffering the acidity. The soils on the west coast and parts of Wyoming, Utah, Arizona and New Mexico are also low in alkalines (Editorial Research Reports, 1982, p. 65).

In the west as in the east, lakes and streams are the first to show the affects of acid deposition. In Colorado, lake failure was initially thought to be caused by depositions from Denver. It has now been shown to be from coalfired power plants elsewhere in Colorado as well as from surrounding states (Miller 1989, p. 28). A study of 64 lakes in the Olympic and Cascade Mountains in Washington all show low pH, resulting in declines in fish populations. Declines in forest populations are now being seen in the Sierra Nevada range in California, especially in the high elevations consistent with the effects of acid precipitation in other high altitude forested areas (Miller and Miller, 1989, p. 34).

In the east the primary damage is in the Appalachians and Great Smokey Mountains. The worst damage, however, is considered to be in the Adirondacks These high altitude forests in New York, Vermont and New Hampshire have suffered extensive destruction. In studies conducted from 1965-1975, seedling production and tree density fell by one-half. In 1975, over 50% of the spruce trees on Camel's Hump were dead. Not far behind is North Carolina's Mount Mitchell, now covered with dead and dying trees (Lean, 1990, p. 84).

As with Camel's Hump and Mount Mitchell, scientists have linked the death of the Ponderosa and Jeffrey pine trees in the San Bernardino Mountains east of Los Angeles with that city's nitrous oxide reacting with its hydrocarbons. In the San Bernardinos, comparisons were done between the 30-year period between 1941-1971 with the preceding 30-year period; scientists found radial growth decreased by 38% and, in the areas exposed to the greatest ozone level, marketability decreased by 83% (Miller and Miller, 1989, p. 36). Research in Europe and the U.S. on core samples from deciduous and coniferous trees show that these trees have been undergoing stress for the past three decades. Samples from thousands of trees show that annual growth rings have become smaller since 1970 (Lean 1990, p. 84). The greatest losses in these forests have been on the slopes facing the prevailing winds (Miller and Miller, 1989, p. 36).

In evergreens, the first sign of pollution damage is the yellowing and early dropping of the needles, followed closely by the deformation of the shoots, root deterioration, thinning of the crown and, finally, death. Other trees try to conserve energy by shedding leaves. Still others try frantically to reproduce, putting out masses of sterile cones and seeds. In many places, the vegetation in the understory and the ground itself is diseased, dead. Weakened, dying, the trees are unable to battle the effects of cold, drought, or pathogenic infections (Lean, 1990, p. 84).

Soil: The Bottom Line

Soil appears to be a critical factor in the forest's ability to withstand pollution. Unfortunately, most of the soil in the forested areas of the United States is not able to fend off much additional acidity.

Acid pollutants destroy the cation-exchange capacity of the soil. Positive ions are normally bound to the negatively charged surfaces of the soil particles. Increasing the soil acidity causes the hydrogen atoms to displace the positive ions (cations), resulting in a high concentration of hydrogen ions in the soil water. These interact with the negatively charged sulfate and nitrate ions, enabling positive ions to be leached from the soil, stripping the soil of necessary hydrogen nutrients (Gould, 1985, p. 67).

Negatively charged nutrients such as boron, molybdenum and phosphorus are normally taken up by the plant roots in exchange for hydroxide and bicarbonate ions. Increased acidity alters this exchange as there is a reduced number of hydroxides and bicarbonates available to be exchanged for the trace nutrients. Acidity also enables toxic metals to be leached out of the ground; phosphorus becomes unavailable to the tree as it becomes bound up with metals; molybdenum is no longer available to promote healthy leaf structure (Gould, 1985, p. 67).

The changing pH changes the structure of the soil itself by altering its ability to absorb and channel water to the roots and surrounding watersheds. Soil organisms necessary to the maintenance and growth of the soil are killed or become nonfunctional at pH levels below 3 (Bewley, 1983, p. 427-428); earthworms no longer aerate the soil, and microorganisms no longer exist to break down organic matter and rock, thus soil is not turned, and new soil is not formed. The earth becomes hard, the water runs off, plants dehydrate, growth is stunted, seedlings fail, soil erodes and washes away.

Tests on lake and stream waters near affected forests show large concentrations of phosphorus and calcium, all leached out of the surrounding soils. This leaves the soil itself high in metals such as aluminum, vanadium and other potentially toxic metals (Gould, 1985, p. 67).

Other Possible Factors

Some scientists believe that, as the amount of CO2 increases, photosynthesis will increase, causing plant tissues to absorb more CO2, thus reducing the total CO2 in the air, slowing the greenhouse effect. However, as soil and dead organic matter contain twice the amount of CO2 as in living plants and the atmosphere, and soil bacteria break down dead organic matter into CO2 and methane, some scientists speculate as to just how this soil-organic C02 change into atmospheric CO2 will be affected by the warming. Calling it a "sleeping giant," Dan Lashof of the Environmental Protection Agency identified several biological processes that could change our current estimates of the rate and effect of greenhouse gases, concluding that by working together, these processes could double the sensitivity of the climatic system to the greenhouse gases (Schneider, 1989, pp. 102-103).

Laboratory experiments have shown this to be a not unlikely scenario. The rate of CO2 evolution in decomposing wood, while dependent upon such variables as diameter and length of the wood, moisture content and type of decomposer microorganisms at work, increases as the ambient temperature increases. Thus, the greenhouse effect of global warming, which may increase both relative humidity as well as overall average temperature, the rate at which CO2 is diffused into the atmosphere can be expected to increase through a type of positive feedback loop (Boddy, 1983, p. 509). The resultant increase in atmospheric CO2 may in turn lead to further ozone destruction over a shorter period of time.

Also an unknown is just how much impact other natural and human-induced factors such as drought, disease and pathogenic infection may have on forest growth in conjunction with a system already under the stress of polluted air, soil and water. While governments, captains of industry and scientists still debate the question of just how much acid deposition is too much and how to determine the impact of natural cycles of stability and decline, others debate the question as to how the pollutants work on the trees: directly through the leaves, or through the soil and nutrient uptake system, or a combination of both. The role played by insects, fungi and bacteria in the biosystem's immunity, and how the organisms themselves are affected by the pollutants (Whitfield, 1989, p. 164) and soil composition (Bewley, 1983, p. 428) are also the subject of research.

Another unknown is how the ocean's processing and ultimate release of C02 will be affected by the rising world temperature, and how this will affect greenhouse gas levels in the next century (Schneider, 1989, p. 103). Other climatic cycles may alter the timing and impact of acid depositions. For example, a 22-year double sun spot cycle has been correlated with the variability of droughts in the Great Plains region of the U.S. Scientists now suspect that variations in the high-altitude wind direction may be related to sunspot activity. A relationship between the sun's radiant energy output and earth temperature variations has been postulated but not yet confirmed (Schneider, 1989, p. 91).

Tying It All Together: Earth, Wind And Chemical Genocide

Isle Royale is a national park, an island located in the far reaches of northern Lake Superior. The nearest town, Thunder Bay, Ontario, lies more than thirty miles away.

More than one hundred years have passed since man last used Isle Royale for anything other than hiking. After the last copper mines were shut down, the island reverted to its original inhabitants - beavers, fox and moose. There were never any cars or smokestacks or sludge to sully this wilderness. The only way to get around the island park is on foot, following one of several foot paths.

Nestled in the upper elevations of Isle Royale is a small lake, Siskiwit, fed by natural springs, separated from the waters of Lake Superior. Isolated, never having been the sump or repository of agricultural run-off or manufacturing waste, too remote to be used as a dumping ground for toxic materials, the lake and island both promised to be a pristine outpost in the midst of the increasingly toxic North American continent. But as Clifford Wetmore and other scientists found, Siskiwit and Isle Royale have not been protected by their seclusion (Brown, 1987, p. 10-11; Kiester, 1991, p. 53-56).

In the early 1980's, Cliff Wetmore climbed Isle Royale's cliffs and hiked its forests. A botanist from the University of Minnesota, Wetmore was out for more than a day hike. He was out for lichens. Scraping and bagging samples, he collected several different types of lichens from around the island. Back in his laboratory, he subjected the samples to a number of different tests. What he found was that the apparently clean air of the island was rife with sulfur dioxide, the prime ingredient of industrial and urban emissions.

Lichens are rootless organism, part algae and part fungi. The fungus enmeshes the algae in a network of threads, feeding off the algae's products of photosynthesis. Originally thought to be a symbiotic partnership, scientists now believe that the relationship is more of a controlled parasitism: the fungus actually destroys the algal cells, but the algae reproduces so successfully that it is continually replacing itself, thus maintaining the lichen organism.

Lichens extract the nutrients and moisture they need from the air; unfortunately, they also take in things they do not need - sulfur dioxide, heavy metals, radioactive dust. Although lichens are amongst the oldest inhabitants of the earth with some living more than 4,000 years, they are now dying in many areas due to the effects of the pollutants they are drawing out of the air.

Lichens live in a number of different environments, from dry rocky outcroppings to trees overhanging a waterfall, surviving the desert heat and Antarctica's long, frigid dark season. Different lichens react differently to pollutants, with some tolerating higher doses of certain chemicals than others. Monitoring lichens has become a way in which to monitor air quality in different areas; they are more widespread and local collection and laboratory study is much less expensive then setting up high-tech monitoring equipment. In Finland, the northern region's lichen populations have been thoroughly mapped, enabling the Finns to trace pollution back to the source country, often to the polluting industry. The United States and Canada have now begun mapping lichens across the country; in the continental U.S., Maine's Acadia National Park and California's Sequoia National Park have been studied. The Environmental Protection Agency has recently begun a study to determine the source of a haze now seen in the Brooks Range, which lies north of the Arctic Circle, during winter. This should be of particular interest as the Brooks Range area has very little in the way of human population. Most of the range consists of mountains and forests in national parks and preserves. The only significant industry in this enormous area is in the petroleum and natural gas fields along the Arctic Ocean coast, between Barrow and Prudhoe Bay (Kiester, 1991, p. 5356; Hammond, 1989, p. 196).

Researchers in the 1970's and 1980's were trying to find out how Lake Superior was being polluted by toxaphene, a chemical as toxic as DDT. While not as long-lived in the environment as DDT, toxaphene causes thyroid cancer in rats, and is biomagnified up the food chain, thus causing problems to the fish- and water fowl-eating humans at the top of the chain. Subject to less stringent exposure guidelines than DDT, toxaphene had built up to such levels in Lake Superior that eating fish from the lake was banned. Puzzled scientists tried to determine where the toxaphene was coming from. Their search took them to Isle Royale and Siskiwit.

Expecting to find the waters pure, the scientists were shocked to find that fish caught in Siskiwit had twice the amount of PCBs than had been found in Lake Superior fish, and almost ten times the amount of DDE, a metabolite of DDT. While theories could be posited as to how Lake Superior became contaminated (primarily through manufacturing wastes disposed of directly into the lake or feeder streams), the theories did not fit the situation at Siskiwit.

The search for answers led the researchers across the country, ending in the cotton fields of the South where toxaphene is used in the control of the boll weevil. Thought to remain earthbound, scientists found that it in fact becomes airborne and, rather than remaining locally in the troposphere, relatively high concentrations of the chemical traveled hundreds of miles north to end up in Lake Superior and Siskiwit (Brown, 1987, p. 10-11).

The Smoking Gun

The scientists can tell you how it is done. They can track the chemical reactions of thousands of the chemicals in the air, water and soil as they interact with each other and with the lifeforms that live in the soil, on the land and in the water. They know the effects on the human body when it is exposed to many of these chemical and compounds. But they have not been able to follow the bullet from the gun to the body. Scientists know the effects of dioxin on the human body, but, without being able to follow each dioxin molecule as it leaves a chemical manufacturing plant and is inhaled into someone's lungs, the manufacturer can continue to maintain that their product or waste was not responsible for the resultant cancer or other health or reproductive problem. Without being able to follow sulfites and nitrites through the air and soil into a specific tree, there is no smoking gun. There is, however, a growing number of dead and dying trees.

Interference with the cation-exchange not only eventually starves a tree, it also allows metals to leach out of the rock into the soil, and thence to streams, rivers and lakes. In the water, it becomes part of the food chain, and biomagnifies its way up until the top predator, man, eats a fish caught on a sultry summer day. Will eating that fish cause several people to die? Unlikely. Will that man's life or the lives of his children be affected by eating that fish? Ah, now that's the scary part - we just don't know.

We do know that the ingestion by eating, touching or breathing of various chemicals and metals is "potentially" toxic to man. Potentially meaning that getting a lot of it will harm you a lot. But what about little bits over a long period of time? We know that DDT caused reproductive failure in birds that were at the top of their food chains. What about the humans that ate fish in water laced with DDE, and ate crops dusted with DDT and eldrin, or sat out on their porch swing just downwind from a cotton field? Scientists can postulate that yes, it will cause harm, but chemical manufacturers and their senators can turn right around and demand that cause and effect be proved. Of course, we are talking about decision-makers and agency heads who were raised in homes and taught in schools coated with leaded paint and insulated with asbestos and plumbed with lead pipes and solder, whose children are raised on chlorinated water which, as every aquarium owner soon finds out, kills fish.

Conclusion

" Despite major research efforts by a large group of concerned individuals and agencies, the evidence of widespread damage from acid rain remains less than convincing," said Alan W. Katzenstein, public relations consultant to the electric utilities lobby." (Luoma, 1984, preface).

As has become evident during the preliminary talks in preparation for this June's "Earth Summit," the United States continues to profess concern for the environment but still does precious little for it. While making demands on underdeveloped Third World countries to reduce population and conserve resources, the U.S. continues to expand its population and rabid consumption of resources. Blocking any further discussion on the disposal of radioactive materials and international transport of hazardous waste, the U.S. also refused to commit to stop cutting the old growth forests, most of which is sold to the Japanese at discount prices for such indispensable consumer goods as disposable diapers (Lean, 1990, p. 81).

Humans conveniently forget that they exist as a part of an ecosystem which is part of a larger biomass, on a single planet with limited resources available at any given time. Instead there is a frenetic harvesting or destroying of everything that grows or is buried in the ground, accompanied by the wholesale spewing of garbage into the air, on the land, into the ground, in the oceans, streams and lakes. Any species, plant or animal, vertebrate or invertebrate, not found to have marketable value is deemed expendable. Humans are also infinitely capable of closing their eyes to that which they do not wish to see. Representatives of underdeveloped and developing countries have made it clear that they will not be dictated to as to how they use their resources, regardless of what lessons there may be to learn from others who have gone before them (Schneider, 1989, p. 280). Everyone wants their own Industrial Revolution, apparently oblivious to the accompanying pollution and disease that will inevitably follow should the Western model be followed.

The forests are dying. No politician or industry leader is willing to make that leap of faith that says, yes, we are killing them and everything around them with our garbage and our waste. Instead, chemical manufacturers keep blowing toxic waste into the air and water or dumping it on the ground. Consumers are supplied with an ever-increasing array of goods to buy as the population continues to expand despite an ever-diminishing availability of natural resources. And what are the lessons we still choose to ignore? Put in very basic terms, if the stuff that falls out of the air can kill a tree, what is it doing to us and to our children? It may take three decades to kill a 100-year old tree; how long before it kills us? Or has it already started?

The fact is that the trees are dying due to the pollutants and toxic elements in the air, water and soil. Ironically, the timber industry waves a red flag, warning of all the jobs that will be lost if they are not allowed to cut down the trees.

The joke is that there seems to be a race to see what will wipe out the trees first: pollution or the timber industry.

Unfortunately, it won't be long before we see who wins. We will, however, all be the losers.

"It's hard to argue with a dead fish."
George Hendrey, acid rain researcher.

Bibliography

"We're going to amend the Endangered Species Act so people count as much as birds in this process."
- Now former Sen. Bob Packwood (R-Ore) at a rally during January 1992's, at the "God Squad" hearings (*Defenders*, 1992, 67(l), p. 6).

"Representative government has broken down. Our politicians represent not the people who vote for them but the commercial interests who finance their election campaigns. We have the best politicians money can buy."
- Edward Abbey

Abbey, Edward. 1989. A Voice Crying in the Wilderness. St. Martin's Press, New York, NY.

Acid-flecked candy colored sunscreen. 1992. *Discover* 13(l); pp. 44-46.

Adler, C. A. 1973. Ecological Fantasies: A Death From Falling Watermelons. Green Eagle Press, New York, NY.

Air pollution: protecting parks and wilderness from nearby pollution sources. 1990. U.S. General Accounting Office GAO/RCED-90-10. Cover page information: p. 14.

Bewley, R.J.F. and Stotzky, G. 1983. Simulated acid rain (H,SO,) and microbial activity in soil. *Soil Biology and Biochemistry*, 15(4) 425-429-

Boddy, Lynne. 1983. Carbon dioxide release from decomposing wood: effect of water and temperature. *Soil Biology and Biochemstry*, 15(5); 501-510.

Brown, Michael H. 1987. The Toxic Cloud. Harper & Row Publishers, New York, NY.

Editorial Research Reports. 1982. Environmental Issues, Prospects and Problems. Congressional Quarterly, Inc., Washington, DC.

Fisher, David E. 1990. Fire and Ice: The Greenhouse Effect, Ozone Depletion and Nuclear Winter. Harper & Row Publishers, New York, NY.

Gould, Roy. 1985. Going Sour: Science and Politics of Acid Rain. Burkhauser, Boston, MA.

Hammond. 1989. United States Atlas. Hammond Inc., Maplewood, NJ. 396 pages.

Kiester, Edwin, Jr. 1991. Prophets of gloom. *Discover*, 12(9); 52-56.

Lean, G., Hinrichsen, D., and Markham, A. 1990. Atlas of the Environment. Prentice Hall Press, New York, NY. 194 pages.

Luoma, Jon R. 1984. Troubled Skies, Troubled Waters: The Story of Acid Rain. The Viking Press, New York, NY.

Miller, E. W. and Miller, R. 1989. Environmental Hazards: Air Pollution. ABC-CLIO, Santa Barbara, CA.

New forestry:new hype. 1992. *Sierra Magazine*, 77(2); 40..67.

Schneider, Stephen. 1989. Global Warming. Sierra Club Books, San Francisco, CA.

Whitfield, P., Moore, P. and Cox, B. 1989. Atlas of the Living World. Houghton Mifflin Company, Boston. 218 pages.

The paper was written as part of the work required in a biology class at UCLA.

Related Sites

Pollution Scorecard
http://www.scorecard.org

EPA: Guide to Indoor Air Quality
http://www.epa.gov/iaq/pubs/insidest.html

Environmental News Network
http://www.enn.com