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THE RESPONSE OF WOODY SPECIES TO AIR POLLUTANTS IN AN URBAN ENVIRONMENT[1]

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Abstract

New Jersey is a small, heavily industrialized, highly populated state. Its air quality frequently exceeds the critical concentrations of several pollutants causing extensive plant damage. In a study conducted from 1973-1975 we systematically documented and evaluated the effect of air pollutants on trees. Among the gaseous pollutants that caused significant damage to many species were hydrogen fluoride and ozone. Sulfur dioxide damage was conspicuously absent, no doubt due to legal restrictions on burning high sulfur fuels during that period. A particulate causing extensive damage was cement dust, and this occurred in a native oak forest some 30 years after the dust had been emitted into the ambient air from a local source. Along heavily traveled highways another particulate, cadmium, was detected in appreciable quantities in certain tree species, particularly pin oak. Although it did not cause visible damage to the tree as did the other pollutants, there are aspects of the pollutant-plant interaction that merit attention.

If you consult the World Almanac of 1975 for information on New Jersey, you will find that the opening line asserts that the importance of New Jersey is disproportionate to its modest size. We would like to develop the theme that it is precisely because of its small size that the state has an air pollution problem. In its 7,836 square miles are contained over 7 million people with all their attendant activities including the operation of 3.9 million automobiles. A giant chemical industry, as well as pharmaceutical, petroleum, and even textile industries, is squeezed within its borders. And along with all this exists a limited but valuable farming industry, to quote the Almanac again.

Air Quality in New Jersey

For the sake of comparison, we have listed in Table 1 the populations and motor vehicle densities of New Jersey, the subject of this article; California, which is widely known for its smog problems, and Michigan, the site of the 51st International Shade Tree Conference. New Jersey has far more people and cars per square mile than either of the other states.

Table 1. Populations and Motor Vehicle Densities (number/sq. mile)

	Population	*Motor Vehicle*
New Jersey	933.1	492
California	127.6	81
Michigan	156.2	86

For further evidence of the extent of the air pollution problem in New Jersey we have only to peruse the report of the Federal Environmental Protection Agency listing the air quality regions in the United States according to the severity of air pollution. Almost at the top of the list, in unenviable positions 2 and 3, stand the New York-New Jersey-Connecticut interstate area and the Metropolitan Philadelphia area. From the map (Fig. 1) you will note that these two areas comprise about two-thirds of the state of New Jersey. These ratings were based on the sulfur dioxide and particulate content of the ambient air.

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The paper was presented to the International Shade Tree Conference in Detroit, Michigan in August 1975.

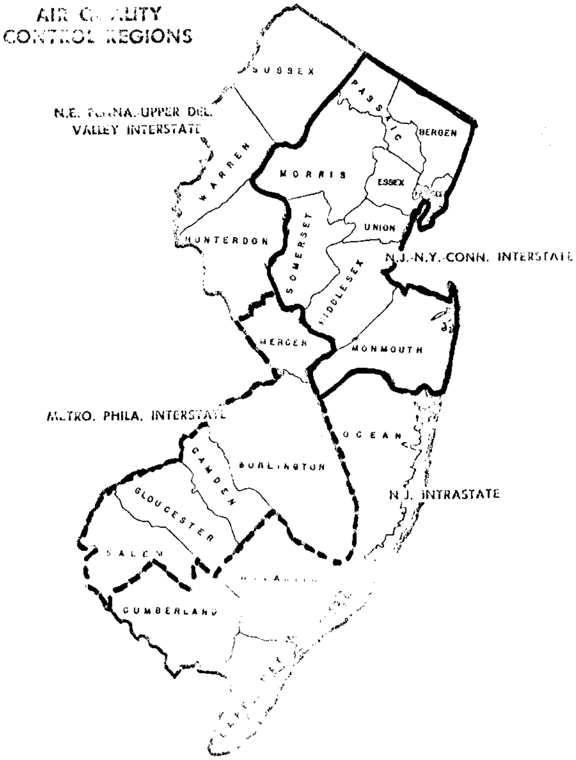

Figure 1.

In fairness to the State we must also note that the sulfur dioxide content of the air has declined significantly since the burning of high sulfur coal was prohibited in 1970. Figure 2 illustrates the trend toward a lower sulfur dioxide content in the ambient air, to the extent that the national standard (0.03 ppm annual mean) is met.

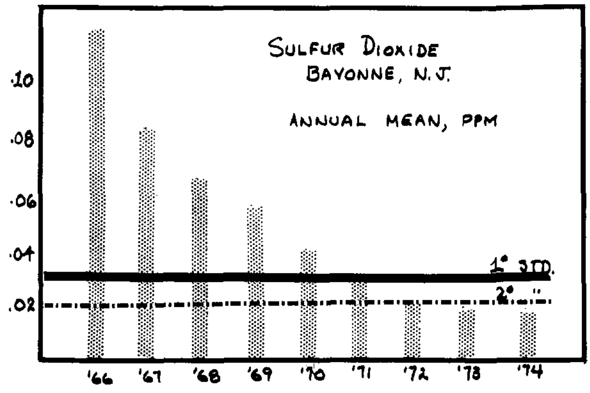

Figure 2.

On the other hand, the so-called photochemical oxidants, including ozone, show no indication of decreasing over the past five years (Fig. 3). The concentration frequently exceeds the national air quality standard (0.03 ppm for 1 hr). This pollutant complex is insidious in that it occurs not only in urban areas but also in rural areas which one might assume to be free of sources of pollution (Table 2).

Table 2. Photochemical Oxidants—Maximum 1-hr average (ppm)

Urban	**'73**	**'74**
Bayonne	.18	.21
Camden	.20	.20
Elizabeth	—	.10
Newark	.24	.14
Rural		
Ancora	.18	.18
Asbury	.23	.17
Chester	—	.17
Somerville	—	.20

Although you have probably heard more about sulfur dioxide and ozone than any of the other pollutants, you must not disregard such phytotoxic gases as flourine, chlorine, ammonia, and ethylene. As yet there are no federal or state regulations controlling their concentration in ambient air, but the damage they do defies the "minor gas" category to which they are often assigned.

Plant Damage

We wish to consider at this time how the air quality is reflected in the appearance and growth of woody vegetation. While we have studied herbaceous vegetation for many years at Rutgers, it was only in the past three years that we were able to systematically evaluate the effect of air pollution on trees in New Jersey. A grant from the Pinchot Consortium of the Northeast Forest Experiment Station made it possible. In a state like New Jersey, we are concerned about the native forests that cover about 50 percent of the land area, the commercial plantings of nurserymen and fruit growers, the large-scale plantings established along major highways, in parks, and public places, and finally in the private plantings in which homeowners invest their time and money.

Hydrogen Fluoride

We will report some of the most significant occurrences of the past 3 years by starting with fluoride damage to woody plants. In 1974, three incidents of severe damage by fluoride were documented. The pollutant was emitted from a manufacturer of fiberglass, an oil refinery, and a molybdenum reduction plant. This was by no means a unique situation. Our records of the late 1940's cited the very same occurrences. Table 3 lists some of the sources that have been responsible for a fluoride problem to vegetation.

A series of pictures will illustrate the kind of damage that was observed on various species. Scotch pine Christmas trees were rendered unsaleable by the severe necrosis that developed on all of the current year's needles. White pine needles were also extremely sensitive as were other conifers such as Norway and Blue spruce, Douglas and white fir. Peach and cherry leaves showed marginal necrosis bounded by a characteristic purple band. The peach trees soon defoliated. Had this fluoride episode occurred later in the season, we would have observed a condition on the fruit known as soft suture. Shade trees that were injured included ash, ginkgo, pin oak, trembling aspen, and linden.

Since this very severe fluoride damage occurred in early June some species such as Douglas fir were stimulated to produce a new flush of growth. In the event that a severe winter ensued, its ability to survive the winter might have been diminished.

You may inquire if fluoride damage can have any long-term effect on trees, in addition to rendering them unsightly and unsaleable in the short run. In California, research with citrus trees showed that a long fumigation at a low concentration reduced leaf size, tree height, and crown volume.

In field episodes such as these, it is equally important to note those species that can tolerate high concentrations of fluoride. In fluoride-polluted areas, we might recommend planting such tolerant species as American holly, mulberry, Norway maple, white birch, hemlock, and flowering dogwood.

Table 3. Sources of HF

Manufacturing Processes
Superphosphate
Aluminum
Brick
Glass and fiberglass
Petroleum Refining
Manufacturing of Fluorides
Freon
F-plastics
Atomic Energy Installations
Combustion of Coal

Ozone

The ozone component of smog is formed in the presence of sunlight from raw materials (NO_x and hydrocarbons) that emanate from motor vehicles. Recently some naturally-produced precur- precursors and stratospheric ozone have also been implicated as contributors of this form of pollution.

What have we seen that could be interpreted as ozone damage to woody species in New Jersey? The classic fleck on white pine needles has been observed in areas throughout the state as well as the classic stipple of grape leaves. However, it is the unclassic symptom on white pine that is so difficult to interpret. In 1972 in a stand of white pine in central New Jersey, one particular tree had very severe needle necrosis and the neighboring tree was healthy. A visiting scientist suggested to us that the tree was acutely sensitive to ozone. In 1973 this susceptible tree had severely dwarfed and mottled needles and in 1974 tip necrosis appeared again. We made grafts from these apparently sensitive and resistant trees and repeatedly fumigated them with ozone in a controlled chamber for relatively short periods of time. Our results have not indicated any distinct difference in their sensitivity. We will conduct a long-term ozone fumigation and also subject them to a mixture of ozone and sulfur dioxide.

We have also placed these grafted white pine seedlings into so-called "open-top" modules to see how they perform. One module has ambient air circulating through it, and the other charcoal-filtered air. If the symptom is caused by polluted air, it should not occur on plants in the clean air module. We will also be looking at the possibility that the shedding of white pine needles after only 1 year is related to an air pollution phenomenon.

On deciduous trees we have observed an uppersurface stipple on several species in mid-to-late July. This symptom, which resembles normal fall coloration, has occurred on green ash, American linden, mulberry, Zelkova, wild cherry, and dogwood. Since under experimental conditions ozone causes an increase in phenols that imparts a bronzed appearance to foliage, it is tempting to classify this as ozone damage in the field. However, at the levels of ozone that occur in ambient air, we have not reproduced this symptom. Since we have an apparent contradiction here, it is an appropriate time to point out that many genetic and environmental factors as well as exposure conditions influence plant response.

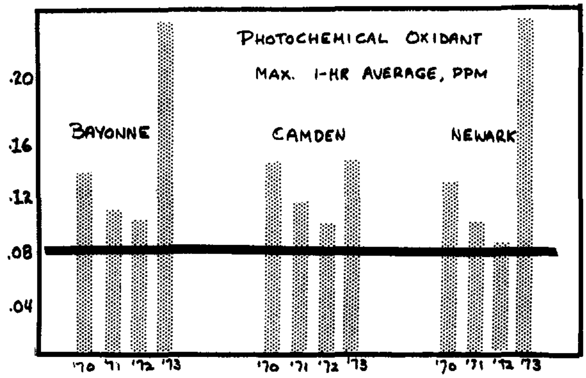

Figure 3.

Sulfur Dioxide

In years past, typical sulfur dioxide symptoms consisting of intercoastal necrosis were frequently seen on such sensitive species as crab-apple, hawthorne, ornamental quince, and peach. During the last three years although sulfur dioxide damage has been looked for, little of it has been found. To verify that we could still identify SO_2 damage, one of us (A.R.) inspected a polluted area of West Virginia and Ohio to document SO_2 injury. What was seen in those states is not apparent in New Jersey. What we do find to some extent is SO_2 damage to herbaceous plants in improperly ventilated greenhouses.

Particulates

In addition to phytotoxic gaseous pollutants, we have evidence of phytotoxic particulates in New Jersey. We will describe two problems, one of long standing and the other relatively new.

Cement Dust

From 1903 until 1940 the Edison Portland Cement Company operated a plant in Warren County in the northwestern part of New Jersey. During that time the farmers were aware of the continued fallout of cement dust because it meant that they didn't have to add lime to their naturally acidic soil. Some 30 years later a Rutgers botany student made a study of the effect of cement dust on the native vegetation in an area called the Pohatcong Ridge. She reported a drastic change in composition of the shrub-layer on the wooded slopes facing the cement plant. Ericaceous species were no longer present, and that was not surprising since the pH of the soil was 7.2 and not the normal 4.5 for that region. No apparent alteration was observed in the tree component on the forest (oaks and maples), although it was noted that pines were not present that are normally found in this type of site.

Just 3 years ago some rather startling changes were observed by our group on the stand of native trees covering approximately 300 acres of Pohatcong Ridge. Severe chlorosis, leaf scorch, and branch dieback of chestnut oak, black oak, red oak, and scarlet oak occurred. Red maple, flowering doogwood, and hickory also exhibited slight to moderate chlorosis. Here then we have evidence of pollution effects some 35 years after a source of pollution had stopped operation. It is rather curious that these symptoms on the oaks have developed only during the past 4 years. A possible explanation is that it required all this time for the cement to effect the pH in the root zone of the trees or that possibly some other as yet unidentified stress factor is triggering the symptom at this time.

Cadmium

And now we will consider a relatively new pollutant, cadmium. In the late 1960's the National Air Sampling Network began to detect measurable amounts of cadmium in the ambient air of larger cities. They reported, in fact, that the highest levels (0.42 $\mu g/m3$) occurred in the New York-New Jersey metropolitan areas. Since cadmium is toxic to human beings the initial worry was that people might inhale toxic quantities of the heavy metal and also that the metal might be absorbed by vegetation that people would consume and they would therefore be in double jeopardy. It has since been established that edible vegetables do absorb cadmium from atmospheric pollution and it in turn does contribute to the critical cadmium burden that the body can tolerate. How does all this relate to trees? Since trees have a longer life cycle than herbaceous vegetation, we have wondered if trees are "sinks" for atmospheric cadmium. Do they absorb the cadmium from the air, thus purifying the air to a certain extent? And if they do accumulate cadmium in their tissues, are they themselves injured internally by the metal? Unlike the other pollutants we have discussed, cadmium has not caused visible damage to the trees.

Since automobile tires, motor oil, and gasoline are sources of cadmium, we are sampling foliage of several tree species at fou r roadside sites where the volume of traffic ranges from very few to 60,000 motor vehicles/24 hr. The data are not complete but the inferences are interesting.

Certain species such as pin oak, hickory, and birch are more efficient scavengers of cadmium than ten other species tested. The amount accumulated is proportional to the volume of traffic passing the site. Provided we find no physiological damages to these trees, they may be valuable as air purifiers. Perhaps that is what my local nurseryman had in mind when he put up a sign saying "Grow Your Own Fresh Air—Plant."

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ABSTRACT

Pinnock, Dudley E., Richard J. Brand, James E. Milstead, and Nancy F. Coe. 1975. **Suppression of populations of Aphis gossypii and A. spiraecola by soap sprays.** Journal of Economic Entomology 67(6):

An integrated control program for highway landscape pests is under development in California. Among the pest species in the landscape system are the stem-feeding aphids, *Aphis gossypii* Glover and *A. spiraecola* Patch, which occur in very large numbers on various flowering shrubs, particularly *Pyracantha* varieties. Formerly, the shrubs were treated with organophosphate insecticides to control early outbreaks of these aphids. This treatment, while effective in temporarily suppressing the aphid populations, kills parasitoids and predators of both the aphid species and the redhumped caterpillar, *Schizura concinna* (J.E. Smith), another important pest in the highway landscape. Soap sprays have been a traditional means of aphid suppression for over a century and are considerably less toxic to insects than organophosphate insecticides. Thus it seemed possible that a dilute soap spray could provide the required suppression of the aphids and probably cause less mortality among the parasitoids and predators than would the newer insecticides, thus permitting more effective long-term biological control. A specially formulated soap spray was effective for removal of *Aphis gossypii* and *A. spiraecola* on highway plantings of *Pyracantha* in California. Water alone produced a removal rate of 46-47% for both species, and a general pattern of increased removal rate with higher concentrations of the soap solution was noted. The maximum soap concentration tested, 0.1%, produced removal rates of 72 and 79% for *A. spiraecola* and *A. gossypii,* respectively.