VEGETATION AND AIR QUALITY

Air Quality as Reflected by Injury to Metropolitan Vegetation

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ABSTRACT.—Chemical monitoring is the classical way of defining air quality. However, the ability of plants to reflect changes in air quality must not be overlooked because certain species respond in definite ways to gaseous pollutants. In New Jersey, chemical-monitoring data and plant-injury data have proved supportive for SO_2. While oxidant concentrations seemed to agree with plant data, recent changes in monitoring procedures have made the relationship unclear. Plant data have provided the only evidence for the presence of toxic amounts of fluoride in the air and have warned of the existence of as yet unidentifed substances that impair air quality.

EVALUATION OF AIR QUALITY of an urban environment can be based on two criteria: chemical data obtained by standard monitoring procedures and biological data collected in health and vegetation studies. Ideally, for each pollutant one would like to know the concentration present in the ambient air and the response that it elicited in a sensitive receptor, be it human or plant. Having been concerned with both types of evidence in New Jersey, we will discuss three kinds of situations we have encountered.

Before we do this, it might be appropriate to indicate just how urban an environment New Jersey is. The Garden State has a modest area of 7,836 square miles and a population of more than 7 million people squeezed into it — a density of 953 people per square mile, the highest in the Nation. The number of registered motor vehicles is more than 3.5 million, a density of 492 per square mile.

SULFUR DIOXIDE DATA IN AGREEMENT

The first situation is one in which monitoring data for the concentration of a pollutant in the ambient air are in agreement with plant-injury observations, and this involves sulfur dioxide (SO_2).

Sulfur dioxide has a long history of damage to vegetation in many parts of the United States. The major sources of SO_2 emissions in New Jersey are shown in table 1. However, since 1968 New Jersey has had in effect regulations

Table 1.—Sources of SO_2 emitted into the air in New Jersey in 1970

Source	Proportion attributed
	Percent
Power plant fuel	45
Commercial and industrial fuel	27
Residential fuel	12
Manufacturing processes	9
Transportation	6
Incineration	1

Source: New Jersey Department of Environmental Protection.

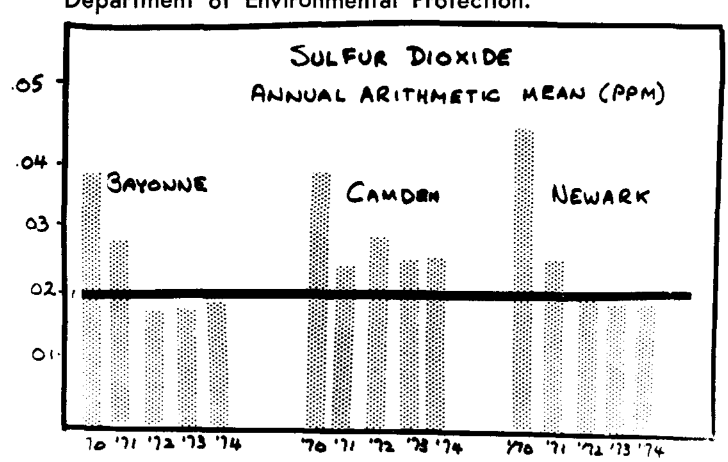
controlling the sulfur content of fuels used in the State. These regulations have been very effective in reducing SO_2 content of the air, as can be seen in the figures from the New Jersey Department of Environmental Protection Air Monitoring System for three locations in the State (fig. 1). Ambient SO_2 concentrations are now at or below the federal standard of 0.03 ppm maximum annual average. In the 2½ years during which we have been conducting a state-wide survey of air-pollution damage to woody plants, SO_2 injury has been notable for its absence.

Even when we made it a point to visit the site of power-generating stations, some of which burn coal and some oil, we were unable to find SO_2 damage on normally sensitive plant species such as crabapple *(Malus sp.)*, birch *(Betula spp.)*, zinnia *(Zinia elegans)*, tomato *(Lycopersicon esculentum)*, blackberry *(Rubus spp.)*, and white pine *(Pinus strobus)*. Inspection trips were made to the vicinity of six power plants in June 1974 and two others in July 1975. These stations were located in urban, relatively suburban and rural settings. The only site where probable SO_2 injury was observed was in northwestern New Jersey at a Christmas tree plantation 1½ miles downwind of a Pennsylvania power-generating station. Pennsylvania hasn't as rigid restrictions on sulfur content of fuels as New Jersey. It remains to be seen what will happen in terms of plant damage now that economic pressures have forced a relaxation of the regulations in New Jersey. At this time we can conclude that the chemical and biological data in respect to SO_2 are supportive.

OZONE-OXIDANT SITUATION UNCLEAR

Until 2 years ago we would have stated that the data for oxidant concentrations and plant damage are generally in agreement. Air-quality

Figure 1.—Ambient SO_2 concentrations (annual mean) in three New Jersey cities, 1970-74. Source: New Jersey Department of Environmental Protection.



standards for ozone were established in 1970 at 0.08 ppm as an maximum hourly average based on data obtained with the Mast (Mast Development Co., Davenport, Iowa) total oxidant meter. In New Jersey we have consistently observed ozone damage on sensitive species such as bean and tobacco following elevated Mast readings. A study conducted simultaneously at several locations in the Northeast attempted to correlate Mast total oxidant-monitoring data with injury to ozone-sensitive Bel W-3 tobacco *(Jacobson and Feder 1974)*. Although there were some variations, generally the most severe tobacco injury occurred at the sites that also had the greatest number of high Mast readings. However, recent changes in the monitoring technique required by the Environmental Protection Agency (EPA) have complicated the picture.

EPA has specified a chemiluminescent procedure as the required method of ozone monitoring. Unlike the Mast meter, it is specific for ozone, the major component of the total oxidant complex. Since New Jersey air-monitoring facilities replaced Mast meters with chemiluminescent devices in 1973, the apparent ozone level in ambient air has increased. This increase has not been accompanied by a discernible increase in plant injury. As far as we know, no one has systematically compared ozone levels obtained by a chemiluminescent technique and plant response. Until this is done, we will not know the significance of the data in terms of effects on sensitive plant species. Since primary and secondary air-quality standards are based on effects on human health and plant life or property, respectively, it would seem of the greatest importance to resolve this matter as soon as possible and establish new standards based on new monitoring technology if that proves necessary.

Meanwhile we do have evidence from our observations of sensitive plant species that an ozone problem exists in New Jersey, whatever the magnitude of the concentrations. Plantings of beans at New Brunswick and the Rutgers South Jersey Research Center in 1974 and 1975 provide ample evidence of damaging levels of ozone. Ozone fleck on white pine also occurs throughout the State. In addition, we commonly observe a dark upper-surface stipple on ash *(Fraxinus americana)*, zelkova *(Zelkova serrata)*, dogwood *(Cornus florida, C. stolonifera)*, and linden *(Tilia tomentosa, T. europaea, T. enchlora)* developing in midsummer. This symptom is similar to ozone toxicity symptoms on herbaceous species such as bean. However, more experimentation is necessary to determine to what extent ozone or other stresses are involved in this symptom development.

Further controversy has recently been injected into the ozone-oxidant picture with the finding that certain remote rural sites show surprisingly high ozone levels. Various hypotheses, including natural sources, long-distance transport from urban areas, and consumption of ozone in urban atmospheres, have been proposed to account for these high levels. Again a correlation with plant injury is lacking. Simultaneous observations of sensitive plants could help to clarify the significance of these monitoring data. With ozone we therefore have a situation where there is a demonstrated need for the simultaneous collection of monitoring data for pollutant concentration as determined by chemiluminescent procedures and of plant-injury data.

PLANTS LEAD THE WAY

The third type of situation is the case where injury to plants is our only definitive clue to the presence of injurious substances in the air. Hydrogen fluoride (HF) is a case in point. The New Jersey Department of Environment Protection does not monitor HF because the state has not established standards for atmospheric fluorides. Statewide surveys of air-pollution damage to agronomic crops conducted in 1971 and 1972 showed HF damage amounting to 3 percent and 18 percent of the total losses, respectively *(Feliciano 1971, Pell 1973)*. Characteristic HF damage to woody and herbaceous plants continues to reflect the presence of toxic levels of this pollutant. In 1974 HF was the major cause of air-pollution damage to woody vegetation in the state *(Rhoads and Brennan 1975)*. Fluoride injury appeared as marginal scorch on a variety of species, including gladiolus, *(Gladiolus* hyb.), wild cherry *(Prunus virginiana)*, grape *(Vitis labrusca)*, linden *(Tilia americana)*, blueberry *(Gaylussacia spp.)*, and aspen *(Populus tremuloides)* and as tip necrosis of various coniferous trees. Even oaks *(Quercus alba, Q. velutina,* and *Q. prinoides)*, which are considered only moderately sensitive to fluorides, were severely injured. Trees showing resistance during this extreme episode included *Acer platanoides, Ilex opaca, Malus* spp., and *Betula populifolia*. Tissue analyses of leaf samples collected in the affected area helped to pinpoint atmospheric fluorides as the cause of the injury, and gave homeowners whose plants had been affected the local industrial sources. Unfortunately it is not possible to make a quantitative estimate of ambient HF concentrations from tissue fluoride levels. Monitoring procedures for the pollutant must be initiated.

UNKNOWN POLLUTANTS

We have encountered another type of situation where we have neither chemical air-monitoring data nor specific plant data. We know that plants are being injured by some air pollutant, but we do not know its identity. One case involves a distinctive tip injury on Austrian pine *(Pinus nigra)* which is always delimited by a dark band at the base of the necrotic area *(Brennan and Davis 1967)*. This symptom occurs on certain sensitive trees year after year, with varying severity. Other neighboring trees are consistently resistant to whatever the causal factor is. We have evidence for an atmospheric cause of the Austrian pine tip-burn symptom as a result of the use of two open-top air-pollution modules, one supplied with charcoal-filtered air and the other with unfiltered ambient air *(Mandl et al. 1973)*. Using grafted trees prepared from scions of mature Austrian pines showing sensitivity and resistance to this sympton, we have shown that the incidence of tip burn was much greater on the sensitive grafts grown in the unfiltered module than on those in the filtered module or on the resistant grafts. We have been unable to duplicate this symptom through controlled fumigations with O_3, SO_2, or a combination of O_3 and SO_2. The combination approximates the symptom, but the dark band does not become evident until 3 or 4 weeks after fumigation.

In summary, we emphasize the necessity of using both chemical monitoring devices and biological systems to evaluate air quality. Chemical monitoring alone may yield data on ambient levels of many different pollutants. However, unless we can relate these levels to effects on receptors, they are meaningless abstractions. Plants alone are not a satisfactory monitoring system, for although most pollutants elicit a characteristic response, it is too easily affected by other environmental variables *(Pell and Brennan 1975)*. Our observations in New Jersey indicate that, at present, monitoring data and plant effects are well correlated in the case of SO_2. The ozone-oxidant situation is not as clear. Recent mandated changes in monitoring techniques require a reassessment of the degree of plant injury associated with certain ozone levels. In the third instance we find plant data yielding information about a pollutant, HF, which probably should be included in a monitoring program. And finally, we see reflected in vegetation the presence of as yet unidentified chemical substances in the atmosphere that are indicative of further impairment of air quality.

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