PROBABILITY OF ACUTE SO_2 - DAMAGE OCCURING ON TREES NEAR EXISTING OR PROPOSED SOURCES OF SO_2

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INTRODUCTION

We have been studying the influence of ozone on trees at Penn State since 1965, and have published a series of papers on this subject. However, during the 1970's, several factors stimulated our interest in studying the effects of sulfur dioxide (SO_2) on trees. These factors were: 1) the possibility of locating an "energy park" (a cluster of perhaps 10 power plants at one location) somewhere in Pennsylvania with resultant SO_2 emissions; 2) the Arab oil embargo and increased interest in using coal as a fuel; and 3) the Three Mile Island nuclear accident in Pennsylvania and, again, increased interest in coal utilization. Increased use of coal may, of course, lead to increased emissions of SO_2. Our new interest in the effects of SO_2 on trees prompted us to apply for a federal grant, and in 1977 we were awarded funds to study the effects of SO_2 on trees and to develop a model to predict the possibility of SO_2 damage occurring at existing or proposed sources of SO_2. The purpose of this paper is to discuss our preliminary model and to acquaint you with our research program.

THE MODEL

Because the details of the process by which SO_2 causes acute injury are not known, any model describing cause-and-effect relationships mathematically is impossible. Thus, a data-based model in which predictive equations are generated by applying statistical techniques to field or laboratory data sets represents the only practicable approach for modeling acute SO_2 injury to vegetation.

The proposed model's structure has as its basis the Larsen-Heck dose-response relationship (see J. Air Pollut. Control Assoc. 26:325-333, 1976). This dose-response relationship must be modified to allow for environmental inputs and species differences. These modifications are achieved via a scaling procedure. Dose-response data are taken at a fixed set of standard environmental conditions. Then the effects of changes in a particular environmental factor are evaluated at a fixed exposure concentration and duration. An assumption is made that the effect of an environmental variable is proportionately the same at all concentrations and for all exposure durations of interest. Thus, based on information from experiments on environmental factors, the predicted injury level can be scaled proportionately upward or downward to allow for the influence of the ambient environment on response. A similar scaling procedure will allow the species' susceptibility classification derived from screening experiments to be re-

flected in the predicted response.

Perhaps the most problematical area of the proposed structure is how to make predictions in the face of stochastically fluctuating pollutant levels and environmental conditions. The Larsen-Heck equation is fit to data from experiments with square-wave doses of pollutant. Virtually all the environmental factor information from any laboratory is gathered using not only constant SO_2 concentrations but also constant temperature, humidity, and so forth. Since data of this kind must be used to predict injury under fluctuating ambient conditions, the choice of an effective algorithm is critical.

The algorithm devised for the model has not yet been fully tested but seems promising. The idea is to divide a total period into intervals (to fix ideas, say a day into hourly intervals) and then compute what might be viewed as 'all possible' injury estimates for the total period. This procedure requires as input hourly average values of pollutant concentration and ambient environmental factors. For each hour the actual concentration is scaled to an 'effective concentration' based on ambient environmental conditions. The effective concentration is the SO_2 concentration at standard environmental conditions that yields the same damage level as that which the actual concentration under ambient environmental conditions is expected to yield. After scaling, what had been hourly fluctuations in both environment and concentration are now hourly fluctuations in effective concentration in a constant standard environment. Now all possible damage estimates are computed. For example, the following series of damage estimates could be generated: 24 estimates for pollutant levels in each single hour, 23 estimates for the 2-hour-average pollutant level in each adjacent pair of hours (i.e. hours 1 and 2, hours 2 and 3, hours 3 and 4, etc.), 22 estimates for adjacent triples of hours, and so forth up to a single estimate for 24-hour overall average. Based on the 300 separate estimates resulting from this procedure, a summary statistic could be reported to give an indication of the worst that might occur during any 24-hour period. The problematical nature of this procedure is clear, but it does appear to be a promising tool for predicting damage in the face of fluctuating conditions when using correlations derived from constant conditions.

LABORATORY STUDIES

A review of the literature revealed that adequate, comparable, input data for the model was not available. Therefore a series of laboratory experiments was designed to generate the necessary data. The following factors were studied: species susceptibility, dosage response, atmospheric temperature, atmospheric humidity, light intensity, and soil moisture. The influence of each factor on foliar injury caused by SO_2 was determined and quantified. Data are currently being analyzed. The methods utilized were as follows.

The relative susceptibility of 60 to 70 species of forest trees and woody shrubs was evaluated during the summers of 1977 to 1980. Three to 4-year old potted seedlings, growing outside, were brought into the laboratory and exposed to acute concentrations of SO_2 (i.e. 0.9 ppm for 4 hours) at bi-weekly intervals throughout each summer. Susceptibility was evaluated using a number of various indices, including percentage of leaves injured and percentage of leaf area injured. In addition, selected species were utilized in dosage-response studies, exposed to 0.3, 0.6, 0.8, 1.2, and 2.4 ppm SO_2

for 1, 2, 4, or 8 hours.

Phaseolus vulgaris, Betula nigra, and Pinus virginiana were exposed to acute levels of SO_2 in controlled environment chambers. Temperature was varied from 13 to 32°C and relative humidity from 40 to 80%. Light intensity ranged from 0 to 45 K lux. Soil moisture content, as regulated by polyethylene glycol solutions or by lack of watering, ranged from approximately 18 to 31%. Data involving the influence of each environmental parameter, and selected interactions, is currently being evaluated. After all necessary data has been analyzed, the final model will be constructed, and in the near future, the model will be field tested.