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Project Summary

Impact of Air Pollution on Vegetation Near the Columbia Generating Station: Wisconsin Power Plant Impact Study

T. W. Tibbitts, S. Will-Wolf, D. F. Karnowsky, and D. M. Olszyk

This report documents the extent of air pollution from the 1050 MW coal-fired Columbia Generating Station and its impact on vegetation. The station, located in south central Wisconsin, began operation in 1975. Monitoring activities began in 1971 and continued through 1978.

Background concentrations of SO_2 and NO_2 were generally higher than amounts emitted from the power plant. SO_2 emissions produced an average of two fumigations per month at ground level, at concentrations between 100 and 250 $\mu g/m^3$ for two- to three-hour periods. At one station, a maximum of 389 $\mu g/m^3$ was recorded. NO_2 emissions produced fumigations at concentrations between 60 and 80 $\mu g/m^3$ for two- to three-hour periods, with a maximum of 101 $\mu g/m^3$ for one hour. Ambient ozone levels occasionally reached 140 to 180 $\mu g/m^3$. A maximum of 311 $\mu g/m^3$ was recorded with clear skies and southerly winds.

Alfalfa, lichens, and white pine were sampled in the field before and after the power plant began operating. Alfalfa showed no visible evidence of injury from air pollutants, and there was no change in yield of harvestable forage at 16 sites. Samples of alfalfa collected in 1978 contained significantly more S than samples collected in 1974, but both values were within the optimum range of S content for alfalfa and within the range of the normal annual variation of S uptake from soil.

Each year, before the power plant began to operate, from 1 to 4% of white pine trees at 15 sites showed injury to needles from air pollution. This proportion did not increase after the station began operating; nor did operation of the power plant cause a decrease in the number of species of lichens on oak trees at 29 sites. A few species showed statistically significant changes in distribution between the 1974 sampling and the 1978 sampling, but these changes were of questionable importance because the species involved were relatively uncommon, occurring on less than 10% of the trees.

Studies in open-top field chambers revealed no measurable effect of air pollution on growth or yield of alfalfa. However, the large variations of yield in the field plot limited the significance of comparisons. Furthermore, levels of radiation and evaporation differed between open areas and the experimental chambers.

In controlled environment studies of crop species grown in the area,

varieties of alfalfa, carrots, mint, peas, beans, and trembling aspen were exposed to SO_2 and O_3 to establish threshold levels for injury. All species tested had thresholds for SO_2 higher than concentrations recorded around the generating station, and only trembling aspen had a threshold for O_3 lower than concentrations found around the station. When plants were exposed to SO_2 and O_3 in combination, thresholds for injury were lowered. Again, only trembling aspen was injured by a combination of SO_2 plus O_3 that was less than the levels of these pollutants around the generating station.

This Project Summary was developed by EPA's Environmental Research Laboratory, Duluth, MN, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

The research described in this report was undertaken to document the incidence of injury by air pollution to terrestrial vegetation, before and after a new power plant began operating. The study area was within a circle of radius 15 km from the Columbia Generating Station near Portage, in south central Wisconsin. This is an area of rolling farmland, the only major elevation being a ridge rising 200 to 250 m above the station, to the west. Prevailing winds are southwesterly during summer and northwesterly during winter. The only other important source of air pollution within 120 km of the site is the Madison metropolitan area, with its population of 225,000.

The Columbia Generating Station burns subbituminous western coal with an average sulfur content of 0.8%. It has two generating units, each with a capacity of 527 MW. The first unit went on line in March 1975, and the second, in June 1978. This study covers the period from 1971 through 1978.

Approach

This study consisted of three major areas of research:

1. Monitoring of ambient air near the generating station. This was to establish background concentrations of major air pollutants before the power plant began operating and, later, to measure emissions from the station itself. The pollutants monitored were nitrogen oxides (NO_x), sulfur dioxide (SO_2), and ozone (O_3).
2. Field sampling of several plant species known to be bioindicators of SO_2. Species sampled regularly were alfalfa (*Medicago sativa* L.), eastern white pine (*Pinus strobus* L.), and lichen species growing on black oaks. Two other sensitive native species, blackberry (*Rubus* sp.) and giant ragweed (*Ambrosia trifida* L.), were observed in conjunction with the alfalfa sampling.
3. Controlled environment experiments to measure threshold levels of sensitivity to SO_2 and O_3 and to determine dose-response relationships. Test species included varieties of five crops commonly grown in the vicinity of the power plant and one tree species, trembling aspen (*Populus tremuloides* Mich.). The crop plants were varieties of pea (*Pisum sativum* L.), carrot (*Daucus carota* L.), mint (*Mentha piperita* L.), bean (*Phaseolus vulgaris* L.), and alfalfa.

Specific measurements were made as described below:

1. Four SO_2 monitors were placed within 10 km of the station and two more at 15 km. NO_x and O_3 were monitored at two sites within 10 km.
2. Fifteen white pine plantations of from 20 to 350 trees were monitored. These plantations were within 12 km of the power plant, in all directions from it. Each tree was checked for foliar injury during the fall, and at the end of the study needles were sampled from six sites for determination of their S content.
3. Samples of lichens were taken from 10 black oak trees at each of 29 sites in the winter before the plant went into operation and from 10 adjacent trees at each site at the end of the study. Trees were chosen at 5, 10, 16, 32 and 48 km from the station. On each tree sampled, two quadrats of bark 25 cm on a side and 1.4 m above the ground were sampled. One was on the side facing the generating station and the other was on the opposite side Bark was removed and taken to the laboratory for species identification.
4. A permanent network of monitoring sites for alfalfa was established in 1971. In subsequent years, if the field was planted in another crop or if the alfalfa stand became very poor, a new field was chosen within 0.5 km of the original one No site was within 18 m of a road or field boundary. Sites were sampled three times during each summer, just before the normal harvesting times. After plants were scored for the degree of chlorosis and necrosis of the leaves, yield was determined by fresh and dry weights of all the plants in four 0.2 m^2 plots at each site. S content of the leaves was determined from the first harvest in 1973 and 1978.
5. Nine plots of alfalfa were established for tests in open-top field chambers. Three plots had chambers with charcoal filters, three had chambers without filters, and three were open field plots with no chambers. The alfalfa in each plot was harvested three times during one growing season, to determine leaf injury, plant height, and yield. Levels of radiation and rates of evaporation were measured in all plots.
6. Varieties of peas, beans, carrots, alfalfa, and mint were grown in controlled-environment rooms under conditions which produced succulent plants sensitive to pollution. Two plexiglass chambers were used for experiments. In the control chamber, plants were maintained in filtered "clean" air In the fumigation chamber, plants were exposed to different concentrations of SO_2 and O_3 for varying lengths of time. The extent of visible injury to the leaves was established or measured for each species, and the chlorophyll content of pea, bean, and alfalfa leaves was determined. Similar studies were done on greenhouse-grown plants from trembling aspen root cuttings.

Findings and Conclusions

Air Pollution Monitoring

Emissions from the generating station caused ground-level fumigations of SO_2 at concentrations of from 50 to 350 $\mu g/m^3$. These episodes usually lasted two or three hours. Levels exceeding 240 $\mu g/m^3$ (0.10 ppm) occurred during no more than five hourly intervals per year at any site, and did not occur at all at distances greater than 10 km from the station. The average number of fumiga-

tions per month per site was 1.8 (Table 1 and Figure 1).

NO_2 emissions produced fumigations at concentrations between 60 and 80 $\mu g/m^3$ for two- to three-hour periods, with a maximum of 101 $\mu g/m^3$ for one hour.

There is evidence that the major part of the SO_2 and NO_x recorded by monitors originated in urban areas to the south, from Madison and Chicago and perhaps as far as St. Louis.

Ambient ozone levels occasionally reached 150 to 180 $\mu g/m^3$. With clear skies and southerly winds, a maximum of 311 $\mu g/m^3$ was recorded.

- Continuous monitoring for SO_2, NO_x, and O_3 indicated that levels of these emissions from the generating station were low in comparison to background levels and were not high enough to cause serious damage to plants.

Effects on White Pines

Tipburn injury occurred on an average of from 2.3% to 2.5% of white pines both before and during operation of the generating station. The number of injured trees varied considerably from year-to-year. This variation probably resulted not only from variations in levels of pollutants but also from variations in growing conditions which caused greater or lesser sensitivity to pollutants.

Although both SO_2 and O_3 occurred at levels capable of causing injury to white pine, the frequency of potentially harmful O_3 levels was much higher than that for SO_2. It is likely, therefore, that the injury observed was due primarily to O_3.

The S content of pine needles did not differ significantly in different directions from the generating station, nor was S content correlated with the amount of tipburn observed. The results of this sampling were not conclusive, however, because of the large variation in S levels between trees at the same site.

- Needles of white pine showed evidence of tipburn injury from ambient levels of SO_2 and O_3. This injury resulted from background levels of pollutants, primarily O_3. It did not increase after the power plant began operating.

Effect on Lichens

There were no decreases in either the number of lichen species or in the frequency of their occurrence. Statistically significant changes did occur in the distribution of 3 of the 48 species identified, but these species were found on less than 10% of the trees sampled and at less than half of the sites. The rarity of these species makes it difficult to evaluate the importance of the changes observed.

- Air pollution from the power plant had no effect on populations of lichens growing on black oaks.

Table 1. *Number of Days with Fumigations of SO_2 at Monitoring Sites Near the Columbia Generating Stations from May 1976 through June 1978**

Site	Total (days)	Monthly Average (days)	Period with Valid Data (%)
Lake George (6 km E)	49	1.9	91
Dekorra (4 km SSW)	55	2.1	95
Messer (8 km W)	35	1.3	96
Genrich (8 km N)	60	2.3	94
Bernander (14 km E)	55	2.1	96
Russell (16 km NE)	34	1.3	93

**A fumigation was defined as the occurrence for at least a one-hour period of concentration at one site that exceeded by 50 $\mu g/m^3$ the average concentration at the other sites during a time when the wind direction was $\pm$ 45° from the Columbia Generating Station toward the site.*

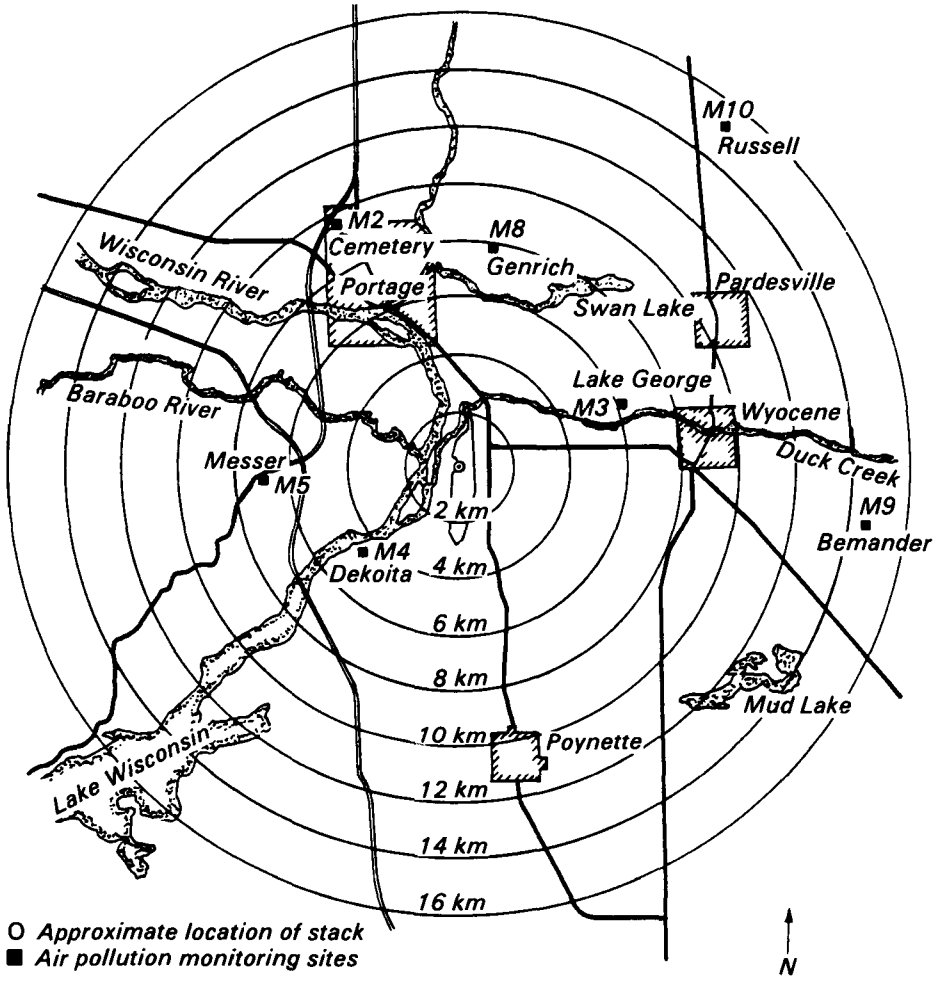

Figure 1. *Location of air pollution monitoring sites around the Columbia Generating Station.*

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Effects on Alfalfa and Native Plants

Alfalfa, blackberry, and giant ragweed showed no symptoms of injury from SO_2. The amount of chlorosis and necrosis on the plants did not increase when the power plant began operating.

Yields of alfalfa varied greatly from field to field and from year to year. However, no consistent decreases occurred after the station began operating, even in those fields experiencing the greatest increases in SO_2 from the station.

Sulfur levels in alfalfa leaves were higher in 1978 than in 1974. This increase, however, was within the range of normal annual variation and was well below levels that would cause injury to the tissue. In fact, many of the alfalfa fields in Wisconsin are deficient in S, and additional S from the power plant might benefit the crop.

Data from the experiments with field chambers documented differences in the microenvironments of the chambers versus the open field. Radiation levels in all plots were approximately the same when the sun was either low in the sky or near the zenith, but during morning and afternoon levels were about 15% lower in the chambers. Rates of evaporation were higher in the open plots; which subjected plants in the open plots to greater water stress, probably rendering them less sensitive to pollution. Growth of plants in the chambers was faster than that of field-grown plants early in the season, and at the end of the season the chambers protected the plants from early frosts.

- Alfalfa fields surrounding the power plant exhibited no evidence of air pollution injury. The sulfur concentration of alfalfa forage did not exceed normal levels.

  Experiments in open-top field chambers failed to demonstrate any effect of ambient pollution on growth and yield of alfalfa.

Controlled Environment Studies

The experimental species exhibited large differences in sensitivity to SO_2 and O_3. The most sensitive species was trembling aspen. Although the threshold level for injury from SO_2 was higher than any levels monitored around the power plant, the threshold for injury from O_3 was below the high background concentrations found in the area around the power plant.

Among crop plants, the most sensitive were alfalfa and peas. Even these species, however, had sensitivity thresholds above the maximum levels of pollutants recorded in the field. For peas, the threshold level of sensitivity to combinations of SO_2 and O_3 was only slightly higher than maximum levels of these substances in the field. Nevertheless, the chance of injury from the combination of pollutants is small because elevated concentrations of the two pollutants rarely occur simultaneously.

- Crop plants are not threatened by the concentrations of air pollutants commonly found around the Columbia Generating Station. Occasional high levels of O_3 may cause minor injury to trembling aspen.

T. W. Tibbitts, S. Will-Wolf, D. F. Karnowsky, and D. M. Olszyk are with the Institute for Environmental Studies, University of Wisconsin, Madison, WI 53706.

***Gary E. Glass** is the EPA Project Officer (see below).*

The complete report, entitled "Impact of Air Pollution on Vegetation Near the Columbia Generating Station: Wisconsin Power Plant Impact Study," (Order No. PB 82-258 591; Cost: $19.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:
Environmental Research Laboratory
U.S. Environmental Protection Agency
6201 Congdon Blvd.
Duluth, MN 55804

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