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COAL-FIRED POWER PLANTS

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CERL-005

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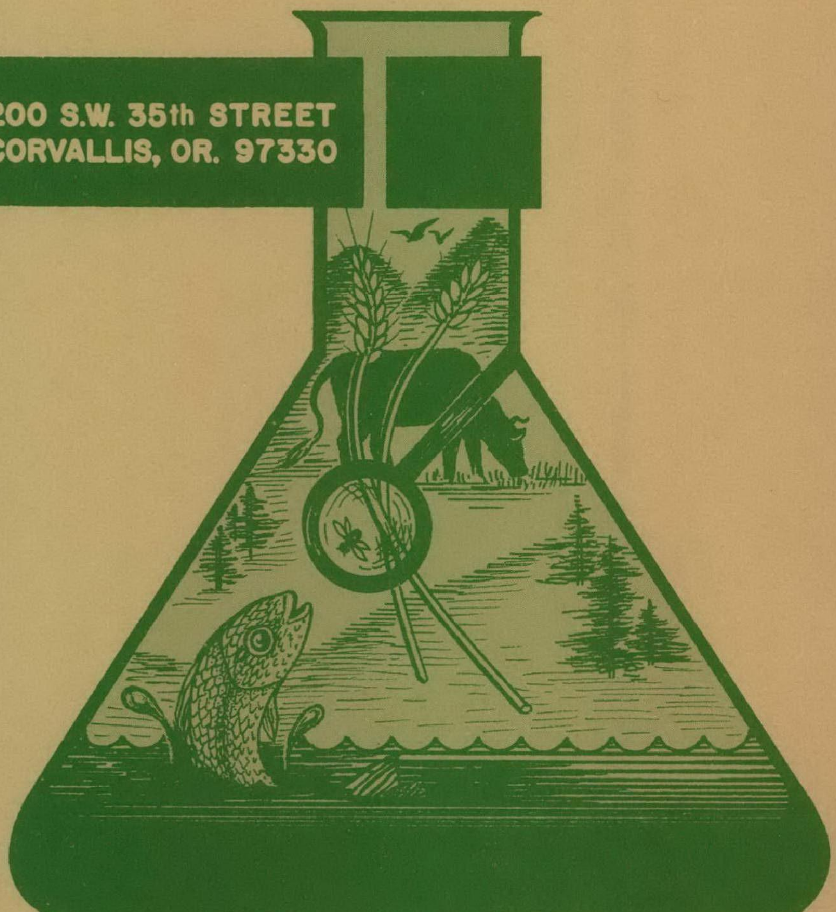

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Sulfur dioxide (SO_2) in the atmosphere is known to create many adverse effects upon health and welfare. It appears to be a major causal agent affecting vegetation. Out of 23,360,000 tons of sulfur dioxide emitted to the air over the United States in 1963, 60 percent was from coal burning, and about two-thirds of that was emitted by power generating plans that burn sulfur-bearing fuel. The remaining 40 percent of the 23,360,000 tons of sulfur dioxide comes from industrial and commercial buildings heated by coal or fuel oil, industrial facilities such as petroleum refineries, and some chemical plants (1).

Sulfur dioxide causes both acute and chronic plant injury. Acute injury is characterized by clearly marked dead tissue between the veins or on the margins of leaves as a result of exposure to high concentration of the pollutant for relatively short periods. Chronic injury is marked by brownish-red, turgid, or bleached white areas on the blade of the leaf.

Plants are particularly sensitive to sulfur dioxide during periods of intense light, high relative humidity, adequate plant moisture, and moderate temperature. They are, therefore, especially sensitive to sulfur dioxide during the growing season in late spring and early summer.

Length of exposure and levels of toxicant affect plant sensitivity to sulfur dioxide. Plants exposed to sulfur dioxide concentrations during the early or late daylight hours are less affected by the gas than plants exposed from 10:00 a.m. to 2:00 p.m. At night, when the stomata (openings in the leaf for gas exchange with the atmosphere) of most plants are closed, the plants are much less susceptible to sulfur dioxide injury.

The degree of turgidity of test plants is extremely important in sulfur dioxide sensitivity. Soil dry enough to cause a slight wilting increases plant resistance to sulfur dioxide injury. Turgid tomato leaves are severely injured by sulfur dioxide, but slightly wilted leaves will be uninjured by the same concentration of the toxicant. Young plants are more resistant than old plants, and the middle-aged leaves are most susceptible. These differences are probably caused by variations in the number, size, and activity of the stomata and the quality of the cytoplasmic contents of the cells.

Microscopic examination of leaf tissue injured by sulfur dioxide reveals that the mesophyll cells are affected and the chloroplasts become plasmolyzed or bleached out. The spongy tissues are often more easily affected than the palisade. Under severe conditions the epidermis cells are also plasmolyzed. The mid-rib and large veins remain intact and green, even though most of the leaf has collapsed.

Low concentrations of sulfur dioxide can interfere with the growth and functioning of a plant without leaving visible injury. This invisible injury may interfere with or reduce photosynthesis. Grain crops may suffer a reduction in yield, especially if crops are damaged by sulfur dioxide at the blossom stage. [2]

Reinert[3] reported reductions in several growth parameters for Bel W_3 tobacco variety when exposed to 0.1 ppm SO_2 8 hrs/day, 5/days/week, for 4 weeks in greenhouse exposure chambers. Other studies (4) demonstrated reduced roots weight of radishes without visible injury from sulfur dioxide exposures of 40 hrs/wk for 5 wks at concentrations of 0.05 and 0.06 ppm.

Injury to agricultural crops exposed to a given concentration of sulfur dioxide is greater than the injury to laboratory-exposed plants subjected to the same concentration. This is possibly due to additional toxicants present in the uncontrolled ambient atmosphere. Thus, injury to agricultural crops is usually greater than can be projected from laboratory experiments involving only one toxicant.

It has been reported that an ordinarily harmless concentration of sulfur dioxide (Figure 1), when combined with ozone, produced ozone-type injury to Tobacco Bel W_3 plants.[5] No injury developed from exposure of similar plants to identical concentrations of the individual gases (Table 1).

Table 1. Synergistic Effect of Ozone and Sulfur Dioxide on Tobacco Bel W_3 Plants[5]

Duration, hr.	O_3		SO_2	Leaf damage, %
2	0.03			0
2			0.24	0
2	0.027	+	0.24	38
4	0.031			0
4			0.26	0
4	0.28	+	0.28	75

Laboratory work has indicated that a single 4-hour exposure to nitrogen dioxide below 2 ppm or to sulfur dioxide below 0.7 ppm did not injure tobacco. Exposure for 4 hours to a mixture of 0.1 ppm of nitrogen dioxide and 0.1 ppm of sulfur dioxide produced moderate injury to the older leaves of Tobacco var Bel W_3. Preliminary experiments with ozone, nitrogen dioxide, and sulfur dioxide suggest that a mixture containing 0.05 ppm of each of these toxicants injures tobacco.[6]

Hindawi and Gordon (7 & 8) reported broad leaf injury and abnormal growth on Scotch Pine at the Mount Storm area of West Virginia and Maryland. The local coal-fired power plants often caused injury to vegetation grown around the plant. In July 1972, 30 to 35 miles per hour winds of Hurricane Agnes reached the Mount Storm area, took the plume from the 350 foot stacks of 1160 megawatt coal-fired power plant (Figure 2) and pushed it along at ground level for over 15 miles. This fumigated pine trees and other broad leaf plants causing severe sulfur dioxide and acid mist injury (Figure 3 & 4).

In the Mount Storm area there are approximately one million acres of Christmas tree plantations, cultivated by growers during the last 25 years. During the period from 1965 to 1971, two huge coal-fired power plants and a few small ones were built and began steam generation within a 50 mile radius of these conifer tree plantations. These power plants release about 788,000 tons of SO_2 annually into the atmosphere along with large quantities of nitrogen oxides, particulates, substantial quantities of fluoride and an unknown amount of trace elements (9). During my studies and observations in 1970, 1971, 1972 (10) I found that air pollutants occurred on farm locations 2, 10 and 15 miles away from the nearest coal-fired power plant. This 1160 megawatt electric power plant is located at the Stoney Reservoir near Mount Storm, West Virginia (Figure 5). Native vegetation in the area displayed symptoms of sulfur dioxide injury such as needle tip burn (Figure 6) short needle (Figure 7), and injury to the broad leaves (Figure 8). The degree of growth abnormalities in Scotch Pine decreased with increasing distance from the coal-burning power plant. Healthy Scotch Pine that was moved to a contaminated plantation near the power plant developed some injury (Figure 9) and diseased trees moved to a healthy plantation showed some recovery (Figure 10). Plants were exposed to ambient air or carbon filtered air at two sites in the Mount Storm area. Sensitive plants were injured and their growth suppressed only when exposed to ambient air (Figure 11).

Branches (Scions) from Scotch Pine trees grown near the power plant showed short needle; when grafted to healthy trees in a clean area, the new growth was normal. When normal scions were transplanted to unhealthy trees in a plantation where many trees suffered from air pollutant injury, they developed short needle and tip injury symptoms. Table 2 illustrates that hourly peak concentrations of sulfur dioxide ranged from 0.0 to 0.36 ppm at the tree plantation site. Concentration of .01 ppm sulfur dioxide or above occurred 20 to 29 percent of the time at the three sampling sites. The hourly ozone and nitrogen oxide peaks at the three locations in Mount Storm ranged from 0.0 to 0.15 ppm and 0.0 to .08, respectively. Therefore, sufficient amounts of sulfur and nitrogen oxide were present independently or possibly synergistically to cause the damage that occurred in the Mount Storm plantations.

In 1975, I exposed Scotch Pine and a broad leaf plant (bush bean) to low pH acid mist and found that short needles and classical SO_2 and acid mist injury developed on the leaves. The injury was typical of that occurring on plants grown at the Mount Storm plantation.

In my opinion the injury on the broad leaves and the abnormal growth on Scotch Pine was produced from intermittent or continuous level of SO_2, NO_2, O_3 and HF emitted from the coal-fired plants.

In the Cumberland Study, Hindawi (11) surveyed the effects of Toronto power plant emissions on vegetation. The Toronto power plant is located directly across 1/4 mile width of Ohio River from the southern edge of New Cumberland, West Virignia. Pollutants emitting from the stacks are primarily particulate matter, sulfur dioxide and nitrogen dioxide. Emission of particulate matter and sulfur dioxide from the Toronto power plant were estimated at 7,000 and 23,500 tons, respectively for 1968 (12).

Indigenous vegetation was inspected for damage by air contaminants. Severe damage attributed to sulfur dioxide was found on Forsythia (Figure 12, Maple (Figure 13), and Climbing Rose (Figure 14). Classical acid mist injury also was found on beet leaf (Figure 15) grown across the Ohio River from Toronto Power Plant. Various sensitive plant species were placed in two separate greenhouses at The New Cumberland Post Office. In one greenhouse all incoming gases in the air were filtered to remove the phytotoxic gases. Unfiltered ambient air was flowed into the other greenhouse 24 hours a day. Table III shows growth suppression of plants grown in the ambient air as opposed to those in charcoal filtered air.

In my opinion the injury that developed on plants grown in New Cumberland could be attributed to sulfur dioxide and ozone individually or collectively.

The combination of ozone and sulfur dioxide reduces the injury threshold of the leaf tissue and increases the damage beyond that from the individual pollutants. Combination of sulfur dioxide and ozone occurred frequently at the New Cumberland Post Office during the study period. The annual mean sulfur dioxide concentration at New Cumberland was 0.05 ppm. This exceeds the criteria listed for average injury to vegetation (0.03) and for adverse health effects (0.04). Dust was observed on leaves of several plant varieties grown in Cumberland across the Ohio River from Toronto power plant. Settle dust in combination with dew form a relatively thick crust on the leaf surface. This crust cut off sun light, reduced photosynthesis process, and therefore reduces formation of food production.

A study in West Germany (13) has shown that 70 percent of the SO_2 emitted from power plant stacks is oxidized to SO_3 within minutes. The trioxide continues to form in the atmosphere, and as the combustion products mix with atmospheric moisture sulfur acid is produced (14 & 15). This acid may be suspended as small dropletes, which cause distinct punctuate spots to appear on leaves. Most often, acid aerosol damage occurs during foggy weather and the injury develops on non waxy leaves. This type of spotted injury has been reported in Mount Storm, West Virginia, Maryland and in Cumberland across the Ohio River from Toronto Power Plant (11). Increased acid input upset mineral equilibrium of soil and could cause leaching of calcium and other nutrient minerals from plant foliage, the leaves do not develop normally, and often have a wrinkled appearance.

Increased acidification of all forms of precipitation has received the greatest attention in the Scandinavian countries where more than 75 percent of all airborne sulfur is due to human activity. The result of extensive pH and SO_2 measurement over large land areas shown in some cases 200 fold increase in rainfall acitvity since 1956. Rain pH as low as 2.8 has been recorded in Sweden (16). Recent information (17) indicated that stronger acid has been observed in rain and snow in the Northern United States, with a single pH value as low as 2.1.

In conclusion, power plant emissions are known to adversely effect health and welfare. These emissions appear to be a major causal agent affecting vegetation. Low concentrations of sulfur dioxide can interfere with plant growth and functioning without leaving visible injury. This injury may interfere with or reduce photosynthesis. Grain crops may suffer a reduced yield, especially if crops experience SO_2 damage at the blossom stage. Injury to agricultural crops exposed to a given concentration of sulfur dioxide is greater than the injury to laboratory-exposed plants subjected to the same concentration. This is caused by additional toxicants present in the uncontrolled ambient atmosphere. A severe fumigation of sulfur dioxide and acid mist at the proper time could so weaken valuable trees that it would not survive the winter.

Finally, as a result of the increasing construction of new power plants, the use of high sulfur coal, and increased sulfur dioxide emissions from the stacks, SO_2 and acid mist in the United States will continue at current or higher levels (low pH) unless improvement in SO_2 controls are achieved.

TABLE II

SUMMARY OF HOURLY SULFUR DIOXIDE MEASUREMENTS, MAY 28 THROUGH SEPTEMBER 28, 1970[a]

Station		Concentration, ppm		per cent observations equal to or exceeding	
		Maximum value	Average value	.02 ppm	.10 ppm
Stoney River	2 miles	.36	.01	10.6	1.2
Steyer #2	10 miles	.11	.01	10.3	.1
Weise McDonald	15 miles	.10	.01	9.0	.1

SUMMARY OF HOURLY NITROGEN OXIDES MEASUREMENTS MAY 28 THROUGH SEPTEMBER 27, 1970[a]

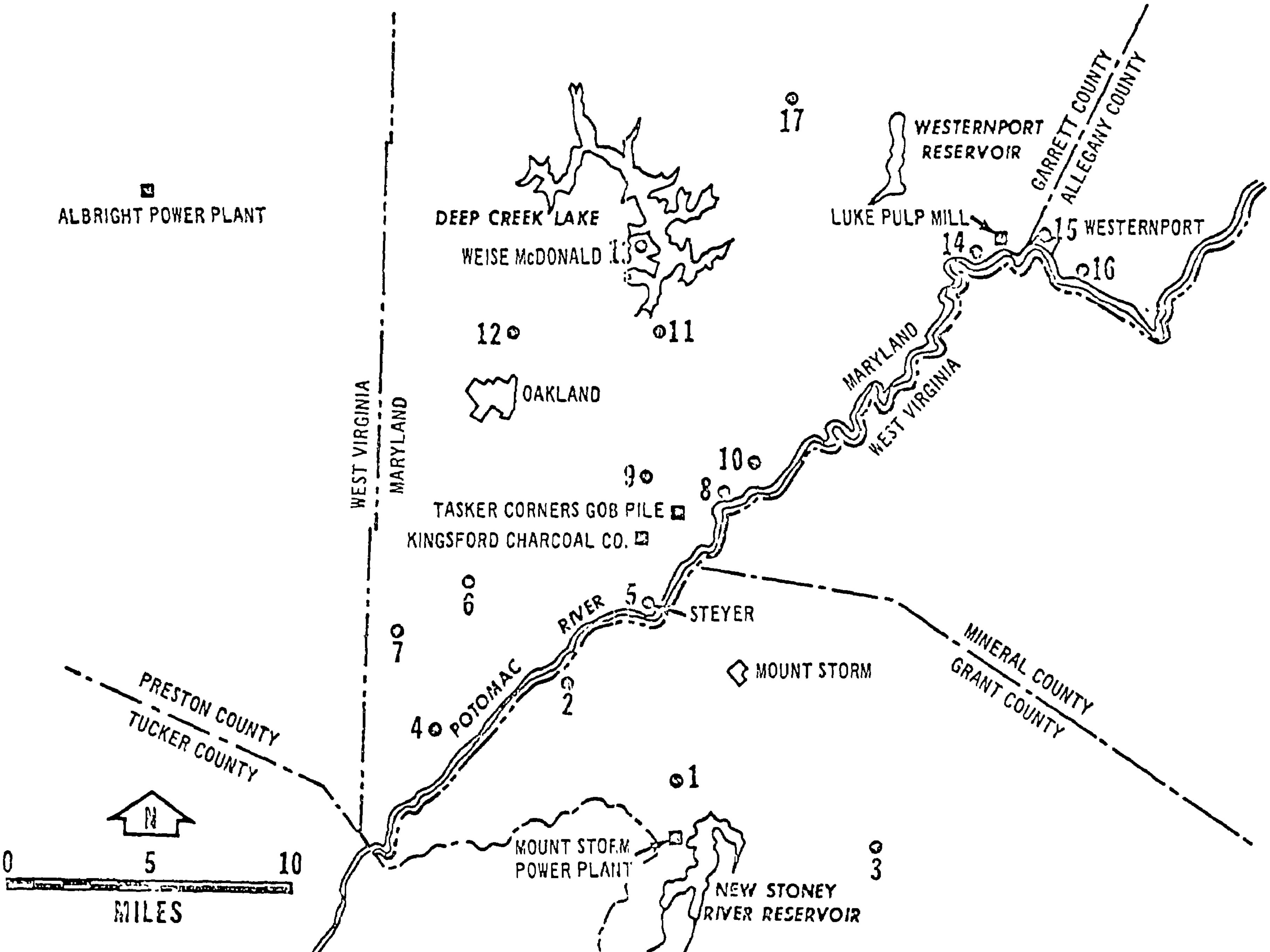
Station		Concentration, ppm		per cent observations equal to or exceeding	
		Maximum value	Average value	.02 ppm	.05 ppm
Stoney River	2 miles	.08	.01	1.9	.4
Steyer #2	10 miles	.02	.01	1.3	.0
Weise McDonald	15 miles	.03	.01	4.8	.0

SUMMARY OF HOURLY OXIDANT MEASUREMENTS, MAY 29 THROUGH SEPTEMBER 28, 1970[a]

Station		Concentration, ppm		per cent observations equal to or exceeding	
		Maximum value	Average value	.06 ppm	.01 ppm
Stoney River	2 miles	.15	.06	60.8	5.7
Steyer #2	10 miles	.13	.05	47.0	3.0
Weise McDonald	15 miles	.13	.06	46.0	3.6

[a]Mount Storm, West Virginia--Gorman, Maryland, and Luke, Maryland--Kaiser, West Virginia, Air Pollution Abatement Activity. U.S. EPA, APCO, Research Triangle Park, North Carolina. 1971. APTD-0656.

FIGURE V



LOCATION OF CHRISTMAS TREE SAMPLING (O) AND SOURCES OF SULFUR DIOXIDE POLLUTION (□) IN THE AREA OF OAKLAND, MD., AND MT. STORM, W. VA.

Table III. GROWTH SUPPRESSION OF PLANTS GROWN IN AMBIENT AIR AT NEW CUMBERLAND POST OFFICE MAY 17 - JULY 8, 1966

Vegetation	Growth suppression,[a] %
Tobacco	45
Pinto bean	25
Petunia	20
Columbine	15
Begonia	25
Cotton	10
Geranium	15

[a]Estimated by visual comparison. A value of 25% indicates that the growth of a plant in the ambient chamber was 25% less than that of a similar plant grown in control chamber.

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