THE EFFECTS OF A HIGH-STACK COAL-BURNING POWER PLANT ON THE RELATIVE pH OF THE SUPERFICIAL BARK OF HARDWOOD TREES

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ABSTRACT

The Allen S. King Generating Plant near Bayport, Minnesota delivers 420 tons of sulfur dioxide to the atmosphere daily from a 789 foot (240 m) stack. Dispersal from this height theoretically minimizes harmful effects of the gases on vegetation. Six years of post-operational pH tests on hardwoods, in the area, show fluctuations in, but no significant increase of the bark acidity. Recorded pH values around the power plant were not significantly different from values obtained in several other localities in Minnesota. None of the pH values in Minnesota were within the ranges shown to be damaging to lichens in Swedish studies. Values for pH ranged from 4 to 9.

INTRODUCTION

In 1968 Northern States Power Company opened the Allen S. King coal-powered generating plant near Bayport, Minnesota on the St. Croix River. At full production about 420 tons of sulfur dioxide are emitted to the atmosphere daily from a 789 foot (240 m) high stack. Dispersal from that height theoretically minimizes harmful effects on vegetation. To check these effects several vegetation studies were implemented using known SO_2-sensitive species such as white pine, *Pinus strobus*, various lichen species and various agricultural crops. Since lichens are sensitive to the ultimate effects of sulfur dioxide, several lichen plots were marked on various trees in the vicinity of the King Plant and in control areas 150 km from the plant. Incidental to the study was the monitoring of bark pH of various hardwood trees to determine if the acidity was in the range damaging to lichens. It is these pH values and others taken for comparison purposes which will be reported in this paper.

DATA COMPARISON

The critical pH for prevention of corticolous lichen growth was determined by Skye (1968). Some of his pH data are given in Table I for seven species of trees in a lichen free zone, a transition zone, and in a control area near Stockholm, Sweden.

	Control Area pH	Transition Zone pH	Lichen Free Zone pH
Acer platanoides	6.2 - 5.1	4.5 - 3.2	3.7 - 2.9
Tilia vulgaris	4.7 - 4.1	3.3 - 2.8	2.9 - 2.4
Ulmus spp	7.1 - 4.7	3.9 - 3.1	2.9 - 2.4
Quercus robur	4.5 - 3.8	3.2 - 2.6	2.8 - 2.4
Fraxinus excelsior	5.9 - 5.4	4.9 - 3.5	3.5 - 2.9
Pinus silvestris	3.4 - 3.1	3.0 - 2.7	2.9 - 2.5
Betula spp	4.5 - 3.3	3.6 - 2.8	4.1 - 2.7

Table I. The lichen free zone is within Stockholm, Sweden, the control area is in the agricultural landscape and the transition zone is in between.

To determine whether damaging ph ranges existed in the King Plant area, bark samples were tested beginning in 1970 and during each year through the early part of 1975. The resulting pH values are given in Table II. Fourteen trees in the vicinity and three control trees between 80 and 150 km from the King Plant are included. Six of the trees increased in bark acidity after the original 1970 sample but two of the six were control-area trees. Ten of the trees from the King Plant vicinity decreased in the acidity when the 1975 samples were compared to the 1970 samples. Acidity in all cases was less than those shown by Skye (1968), Table I, to be critical for prevention of lichen growth.

Several other tests were made to show the range of variation in bark acidity: (1) among different size trees of the same species; (2) among several samples from a single tree; (3) among several species from the same forest stand; (4) among trees in the vicinity of another power plant before operation; (5) among trees of the same species along a transect at intervals of 30 km from Grand Rapids to St. Cloud, Minnesota; (6) on different sides of trees in the vicinity of a power plant

Location	Host Tree	1970	1971	1972	1973	1974	1975
1. Point Road	Ulmus americana	5.65	5.87	6.23	6.68	6.55	6.09
2. Monitor 4	Quercus alba	5.78	6.07	6.35	6.50	6.80	5.93
3. Monitor 4	Quercus velutina	5.30	5.60	6.00	5.77	5.70	5.25
4. Monitor 5	Quercus macrocarpa	5.91	5.85	6.70	6.07	6.40	5.82
5. Monitor 7	Ulmus americana	7.07	5.94	6.70	6.43	6.80	6.20
6. Monitor 2	Ulmus americana	5.43	6.27	6.40	6.14	6.60	6.34
7. Monitor 3	Quercus macrocarpa	5.60	5.87	6.22	6.25	6.80	6.29
8. Square Lake	Quercus macrocarpa	5.50	5.67	6.11	6.03	6.22	5.70
9. Monitor 6	Quercus velutina	5.80	5.57	6.06	5.81	5.69	5.53
10. Monitor 1	Quercus macrocarpa	5.50	5.91	6.05	5.43	5.86	5.87
11. Monitor 1	Quercus velutina	----	5.35	5.85	5.56	5.52	5.54
12. Carlson M 1	Ulmus americana	----	5.48	6.32	6.16	6.20	6.17
13. Monitor 8	Populus grandidentata	5.20	5.83	6.22	6.20	6.60	5.99
14. KDWB Tower	Quercus macrocarpa	5.55	5.62	6.90	5.79	5.43	5.67
15. Monticello	Quercus macrocarpa	5.68	6.27	6.90	6.70	6.40	5.95
16. Fair Haven	Quercus macrocarpa	6.65	6.85	7.08	6.40	6.90	6.06
17. Fair haven	Tilia americana	----	6.32	6.25	6.72	6.90	6.00

Table II. Trees are arranged in order of distance from the A.S. King Generating Plant. Trees 1 through 14 are in the near environs, tree 15 is about 80 km west and trees 16 and 17 are about 150 km west.

with known acid-rain fallout from a faulty stack scrubber. The results of each of these tests will be discussed below.

(1) Bur oak trees were tested at two locations north of St. Cloud, Minnesota, near Heim's Mill Dam and at Little Rock Bayou. The following pH values were recorded on 13 May 1973 for nine trees, the first figure is the circumference in centimeters, the second is the pH of the bark: 79 cm, 6.05; 81 cm, 6.02; 91 cm, 6.11; 104 cm, 6.51; 117 cm, 6.90; 132 cm, 6.85; 160 cm, 6.20; 173 cm, 6.52. The difference between the lowest and highest pH was 0.88 but tree size does not appear to be a significant factor in bark pH. A similar comparison was made in Partch's Woods north of St. Joseph, Minnesota using ten sugar maples on 5 April 1975: 68 cm, 5.64; 114 cm, 6.66; 127 cm, 6.40; 155 cm, 6.45; 160 cm, 6.22; 165 cm, 5.74; 165 cm, 7.06; 173 cm, 6.66; 177 cm, 6.31; 190 cm, 6.00. The pH difference is 1.42 with no apparent size correlation.

(2) On 13 March 1975 twelve bark samples, from four sides and three different levels between the base and up to 3 meters, of a white oak in Partch's Woods were tested to determine pH variation of a single tree. The pH ranged from 5.90 to 6.38 with no correlation of direction or distance above ground.

(3) Several other trees were also tested in Partch's Woods with the following results, circumference in centimeters, species and pH listed in that order: 38 cm ironwood, *Ostraya virginiana*, 6.21; 41 cm ironwood, 6.57; 46 cm ironwood, 6.09; 26 cm paper birch, *Betula papyrifera*, 5.13; 58 cm paper birch, 5.03; 239 cm red oak, *Quercus rubra*, 5.79; 91 cm basswood, *Tilia americana*, 6.02; 53 cm basswood, 5.79; 89 cm sugar maple, *Acer saccharum*, 5.66; 61 cm american elm, *Ulmus americana*, 6.25.

(4) Similar tests were made on 18 trees in connection with pre-operational studies at a new power plant in Sherburne County, Minnesota. Most of the pH values were between 5 and 9 with the exception of a Russian olive, *Elaeagnus angustifolia*, with a pH of 4.91. An american elm near Bertram Lake west of Monticello, Minnesota had a pH of 9.10 in 1974 and a year later two different readings on the same day of 7.15 and 5.19.

(5) Bur oak pH values were obtained at 30 km intervals between Grand Rapids and St. Cloud, Minnesota. The location, circumference and pH are listed as follows: Cohasset, 216 cm, 6.11; Remer, 79cm, 5.95; Emily, 79 cm, 5.63; Ironton, 41 cm, 5.47; Brainerd, 107 cm, 6.06; Little Falls, 94 cm, 6.03; Little Rock Lake, 175 cm, 5.86.

(6) In response to a reported malfunction of a power plant stack-scrubber in northern Minnesota, several pH values were obtained to determine if any abnormal acidification resulted: (a) Ten bark samples were collected from a single 94-cm basswood tree 400 meters northwest of the power plant. Five of the samples were taken from the northwest side of the tree away from the power plant and five were taken from the southeast side facing the plant. The samples were collected at 30 cm, 90 cm, 150 cm, 210 cm and 270 cm above the ground in both directions. The pH values from the side facing the plant ranged between 5.09 and 5.19, while the values from the other side of the tree ranged between 5.57 and 5.73. Height above the ground was not significant in either direction. (b) Five other trees were sampled at the same time and place. Two samples from each tree were taken from the southeast and northwest sides. The circumference, species, direction and pH are listed in that order as follows: 94 cm green ash, *Fraxinus pennsylvanica*, NW 5.84, SE 5.05; 68 cm ironwood, *Ostraya virginiana*, NW 5.85, SE 4.38; [illegible] cm bur oak, *Quercus macrocarpa*, NW 6.04, SE 5.49; 140 cm basswood, *Tilia americana*, NW 5.48, SE 5.17; 91 cm sugar maple, *Acer saccharum*, NW 4.35, SE 4.45. (c) A 94 cm bur oak at a distance of 3.2 km had a pH of 5.67 on the side facing away from the power plant and 5.52 facing toward the plant. At a distance of 6.4 km east of the plant, the east side of a bur oak had a pH of 6.17 and the west side facing the plant had a pH of 6.26. Apparently only very near the plant was there a directional effect with higher acidity on the side facing the plant.

GENERAL CONSIDERATIONS

Several explanations for variation in the acidity of bark have been suggested by various researchers. Sjögren (1961) discusses differences in pH for samples of small and large pieces of bark. He says that pieces smaller than 1 cm^2 show lower pH values than samples consisting of larger pieces of bark. He also considers that these larger samples show better agreement with pH in bark under natural conditions. Hale (1955) states that by pulverizing the samples one would obtain slightly incorrect pH values. Skye (1968) pulverized his samples while in this study the samples were not pulverized. This could account for some of the less acidic values. The pieces of bark were also of variable size, consisting of both small and larger pieces, resulting in an average value for pH. The nature of soil, prevailing winds and general air mass movements can also influence pH. In Minnesota the western part of the state has soil of limestone origin and air mass movements are west to east which could bring in dust to act as a buffer giving more basic pH values. Lichens are sensitive to strong acidity but in no case has any evidence of injury by acid rain to lichens or of any pH which would be in the range necessary to cause injury to lichens.

In considering the effectiveness of the high stack in dispersing sulfur dioxide and other gases in the King Plant area, there has been no increase of bark pH of any significance. Only a few trees have shown an increase in acidity in the critical zone around the plant while the rest have decreased. It can be assumed that there is little or no fallout of damaging acid rain in the area. The changes which have occurred are insignificant compared to the variations in a single tree or among those of one species. In the case of the other power plant where known acid rain fallout occurred, the acidity became greater on the side of the trees facing the power plant but the effect became insignificant only a short distance away. In that case the stack was also shorter and had developed a faulty scrubber.

The sampling technique has been the same throughout this study and no significant increase of acidity has developed. The primary objective of this study was to determine changes in pH which might be detrimental to the growth of lichens. The pH values are generally less acidic than in the Swedish studies possibly due in part to differences in technique but more likely because of greater amounts of atmospheric pollutants in Sweden. Major changes in acidity should eventually become evident if methods of evaluation remain the same. Another reason for more acidic values is the difference in buffering action of bark of different species.

LITERATURE

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