Journal of the Minnesota Academy of Science

Volume 45 | Number 1 Article 2

1979

Lichen Deterioration About a Coal-Fired Steam Electric Generating Plant

Elmer L. Schmidt
University of Minnesota, St. Paul

R. J. Zeyen
University of Minnesota, St. Paul

Lichen Deterioration About a Coal-fired Steam Electric Generating Plant

ELMER L. SCHMIDT,* R.J. ZEYEN**

ABSTRACT — A survey of three common epiphytic species of foliose lichens was conducted about a coal-fired steam electric station in North-central Minnesota during the summer of 1977 to assess general lichen health on a gradient basis from a point-source of air pollution. Health, as judged by abnormal form and color, of nearly 3,500 lichen specimens was recorded in 35 vegetation survey plots from a total of 291 trees. Lichen discoloration and degeneration decreased with increased distance from the power plant, and little deterioration was observed beyond 3 miles. Within the plant vicinity, lichen damage was noted on tree boles facing the plant which were impacted with fly ash. Maximum damage of lichens followed the pattern of prevailing winds (NW-SE). Sulfur analysis of lichen thalli was not correleated with visible damage distribution tended to decrease at the most distant plots (30 mi. from source).

Considering the sensitivity of foliose lichens to declining air quality (especially SO_2 pollution), pollution sources in the rural environment are bound to affect lichen communities, as this study indicates. More sophisticated lichen surveys coupled with future monitoring of pollution would be a valuable contribution to the general environmental impact assessment of coal-fired electrical energy production.

Lichen deterioration as a result of air pollution has been under investigation for more than a century. Hundreds of papers now constitute the body of knowledge concerning lichens and air pollution. Research and surveys in nearly a dozen countries have demonstrated convincingly that it is possible to correlate the distribution of lichens around air pollution sources with mean pollutant levels. In some cases, lichen behavior over time has been used to monitor the distribution and severity of pollutant emissions (Ferry, *et al,* 1973; Skye, 1968).

Lichens are considered aesthetically important in natural landscapes, but unfortunately they are considered to be among the most sensitive of organisms to pollution - especially SO_2. The conspicuous lichens (Macro-lichens) react adversely to SO_2 at chronically occurring levels below 100 micrograms per cubic meter. In modern industrial societies, the prospect of reducing SO_2 to harmless levels for lichens is considered clearly unrealistic (Ferry, 1973) and few, if any, sensitive species now exist in major urban areas.

Pollution sensitivity of epiphytic lichens is demonstrated by a reduction in growth and fertility, and also in a decline in the number of species and their luxuriance (amount of lichen cover on substratum) as the source of pollution is approached (Ferry, 1973; Gilbert, 1973; Skye, 1968). The inhibition of photosynthesis, respiration, growth, reproduction, and other metabolic processes are pollution induced responses of lichens (LeBlanc Rao, 1975). To the eye, SO_2damage appears as whitening, browning, or violet tinging of marginal lobes of the lichen thallus which eventually spreads until the lichen is shriveled and dead. This syndrome has been reported from lichen transplant experiments and has been observed in the field where new pollution sources have started in rural areas (Gilbert, 1973). Slow lichen death by SO_2 toxicity is superficially similar to death by other means, but when there are no obviously adverse conditions, symptoms of degeneration and discoloration (especially if associated with elevated S levels in the thallus) can be taken as indicating a preliminary stage in the expansion of a lichen desert (Gilbert, 1971). In temperate climates lichens grow most actively during spring and autumn, and are thus most active when air pollution potential is greatest (Skye, 1968).

A limited number of approaches have been used in studying lichen flora about major pollution sources (Ferry *et al.*, 1973; Hawksworth and Rose, 1970; Leblanc and Rao, 1973). These include (1) construction of detailed distribution maps of lichen species (eg.-9); (ii) observing transplanted lichens on bark discs in polluted areas; (iii) development of an index of atmospheric purity (IAP) based on sensitivity of particular species and numbers of those species; (iv) delineation of generalized zones based on luxuriance and total number of species; and (v) qualitative estimation of general SO_2 pollution concentrations by the presence of absence of certain lichen species on trees at varying distances from the source. All such approaches require collection of field data far beyond that attempted in this investigation. Consequently, only a cursory study was performed on a few easily identified lichen species which were widespread in the study area.

Lichens, originally dubbed by Linneaus as the "poor trash of vegetation," should be considered an integral part of any study which seeks to ascertain the impact of pollution-ecosystem interactions. The first European Congress on the Influence of Air Pollution on Plants and Animals (Wageningen, 1968) resolved that cryptogamic epiphytes (lichens, etc) should be strongly recommended for general use as biological pollution indicators (LeBlanc, 1975). Specific advantages in utilization of lichens in biomonitoring studies (Skorepa and Vitt, 1976), include:

1) The cost of a study using lichens as bioindicators of air quality is not as great as the purchase and maintenance of air monitoring equipment.

2) Lichens reflect the actual cumulative effects of pollution on the ecosystem rather than measuring pollutant concentrations at a given time as do monitors.

3) Upon completion of a pilot study, the identification of the most important lichen species and the use of particular lichen associations to show pollution levels can be accomplished by relatively unspecialized personnel.

*ELMER L. SCHMIDT, a research assistant in the Department of Plant Pathology at the University of Minnesota, St. Paul, is currently on leave pursuing work in Mississippi.

**R.J. ZEYEN is an associate professor in the Department of Plant Pathology, University of Minnesota, St. Paul.

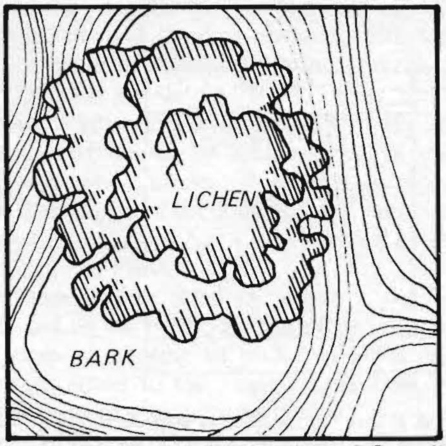

Fig. 1a. Marginal discoloration of *Parmelia* species 1 mile from plant.

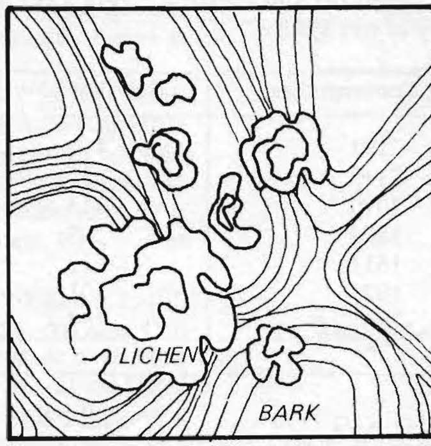

Fig. 1b. Deterioration and fragmentation of *Parmelia* thallus ½ mile from plant.

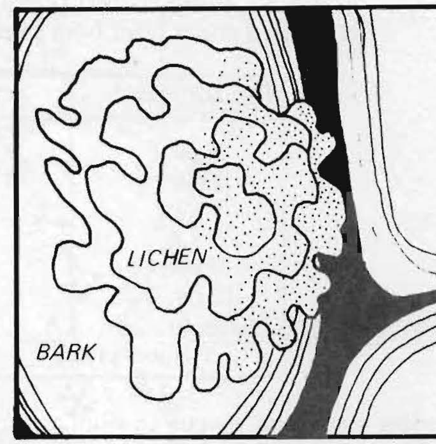

Fig. 1c. *Parmelia* discoloration near bark fissure.

4) Lichens are the most sensitive component of the vegetation to SO_2 and other types of air pollution, and as such can have predictive value in assessing future effects on the vascular plant vegetation.

A survey of lichen appearance was performed to aid in health assessment of the terrestial vegetation about a rural Minnesota coal-fired power plant which had begun operation within the past seventeen years. This investigation was part of an environmental setting study completed for the Minnesota Pollution Control Agency with the support of Minnesota Power and Light Co. during June and July, 1977. Sulfur analysis of one lichen species throughout the study area was performed to supplement visual evaluation.

Survey methods and distance

Observations on the epiphytic lichen flora were made at 33 vegetation study plots distributed along 6 transect lines from the power station at intervals of ¼, ½, 1, 3, 6, and 12 miles. In addition, two "remote" sites (more than 30 miles distant) were included in the survey. At each plot, representative trees of each species supporting foliose lichens were scrutinized, and data of concern were recorded. From 6 to 11 trees per plot were studied, depending on the available species supporting macrolichens. Lichens representative of the plot area were studied on trees up to 250 meters from the plot center if adequate examples did not fall within the arbitrary 46 meter radius. Larger, open-grown trees were preferentially chosen for scrutiny as they generally supported the richest macrolichen flora.

Notes on the apparent health of foliose lichens were confined to the following epiphytic species which were easily identified and fairly ubiquitous throughout the study area (these species have been used as indicator species in previous pollution investigations): *Parmelia caperata* (L.) Ach. and *Parmelia ulophyllodes* (Vain.) Sav. ("Green Shield Lichens"), *Parmelia sulcata* Tayl. and *P. saxatilis* (L.) Ach. ("Blue Shield Lichens"), *Physcia aipolia* (Ehrh.) Hampe, and *Hypogymnia physodes* (L.) Nyl. Other species of the foliose genus *Physcia* were common, but not included in data collection as their numbers and difficulty in identification precluded field assessment. Only lichens on tree trunks were recorded, because species of lichens growing on trees generally exhibit far greater sensitivity to pollution than those growing on other substrata, and, therefore, epiphytes are of primary interest in pollution studies (LeBlanc, 1975). Lichen health, as judged by color and form of the thallus, was noted for each lichen species on a particular tree after consideration of all individuals of that species within good eye resolution (up to 5 meters above ground). Status of each species was recorded as normal (N) (compared to those in remote plots), some specimens discolored or moribund on the bole (N–M), or essentially all individuals dead, disintegrating, or discolored-moribund(M).

Lichens showing death or discoloration due to proximity of bark cracks caused by tree disease, bleeding, or swollen branch stubs were not considered representative and were not included in the overall health status recorded for each species. Color slides of individual lichens were taken at most plots as documentation of appearance.

Sulfur content of one species of lichen surveyed *(Parmelia caperata)* was determined at the plots along the transect lines to compare accumulation of this element with presence of visible degeneration of the lichen thallus. Approximately 500 milligams (4 cm^2) of lichen thallus was collected and pooled from at least two trees of the same species at each plot. Care was taken to collect as little bark and extraneous material as possible. Samples were ground in a micro-mill for 30 seconds and sent, under code, for sulfur analysis to the Soil and Plant Analysis Laboratory of the University of Wisconsin, Madison. Sulfur analysis was performed using a standard barium chloride-nephelometric technique. The tree species from which lichen samples were collected included Bur, Oak, Red Maple, American Elm, Black Ash, and Paper Birch. Lichen samples also were collected from three "remote" areas more than 30 miles distant from the power plant and removed from any obvious sources of anthropogenic pollution.

Results and implications of lichen investigation

Lichen health, as judged by form and color deviations from that considered normal, was recorded for several selected species from observation of 291 trees in 35 vegetation plots. The overall health of each of the three major indicator species *(Parmelia caperata, P. sulcata,* and *Physcia aipolia)* at each plot was judged after observation of approximately 12 specimens per tree, making a total of almost 3,500 individual health assessments. The incidence of lichen flora discoloration or degeneration (Figure 1) decreased with increased distance from the power plant (Figure 3). Lichens were generally normal in appearance in plots more than 3 miles from the plant with notable exception at plot IV-5 (6 miles East), where all species showed some discoloration. The proximity of this plot to a large iron ore spoil bank may possibly have a bearing on this anomalous health condition of the lichen flora. Within the immediate plant vicinity (less than 3 miles), lichen flora was most visibly affected in W-NW and SE transects. Lichen zone maps corresponding to different pollution levels have been found to follow the pattern of pre-

Table 1. Sulfur content (ppm) of lichen thalli of *Parmelia caperata* collected at various distances from a coal-fired power plant from a variety of tree species.

Plot Distance	Sulfur Concentration	Std Deviation	Number of Samples
¼ mi.	2191	452	11
½ mi.	2113	412	8
1 mi.	2029	448	12
3 mi.	1867	365	12
6 mi.	1811	537	9
12 mi.	1925	301	8
30+ mi.	1367	288	6
(remote plots)			

vailing winds and assume an elliptic shape (LeBlanc, 1973).

Trees ringing the plant which showed obvious fly ash impaction were generally devoid of lichens on that portion of the bole so covered (Figure 2), and the bare zone invariably faced the plant regardless of the direction of the transect. The observed orange color associated with thallus degeneration of *Parmelia sulcata* and *P. saxatilis* has been reported from polluted and nonpolluted areas, and may be the result of alkaline moisture seepage (Gilbert, 1971). Marginal bleaching, more suggestive of pollution injury, was commonly noted in *Parmelia* species within 3 miles of the plant.

Sulfur content of *P. caperata* did not correlate well with observed health conditions of the thallus, as most deteriorating specimens were within 3 miles of the plant, but no significant shift of S content in the species was observed beyond this distance. From the limited data (66 pooled samples) however, a trend toward lower S content at the greater distances was noted (Table 1).

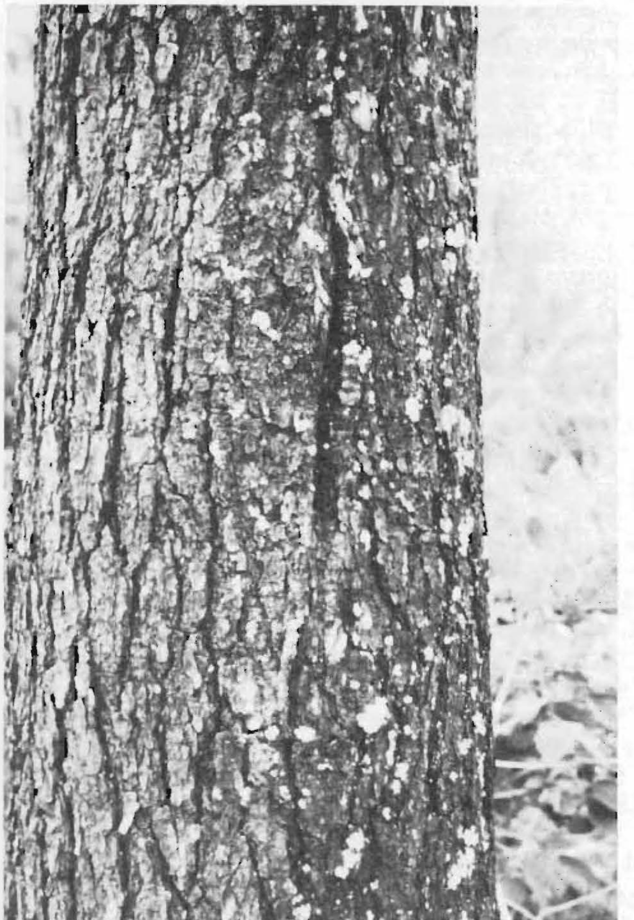

Fig. 2. Segregation of lichen growth on bole of white pine (¼ mile from plant).

Comparing lichen data from this study with others to infer pollution levels involves certain limitations. Foreign studies which have noted the particular species observed in this field survey have generally indicated that *Parmelia caperata, P. sulcata,* and *P. aipolia* are moderately to highly sensitive to SO_2. Their presence eventaully is eliminated where chronic levels exceed 40 micrograms per cubic meter (Gilbert, 1973; Denison, 1973; Hawksworth and Rose, 1970). Such information is based on studies, primarily in Europe, which have mapped species about existing lichen deserts, rather than recently-started sources of pollution, and it is prudent to assume that scales and tolerance limits can not be reliably employed in geographic areas other than those for which they were originally worked out (Ferry, 1973). Difficulties in interpretation of a survey of lichen damage include differences in lichen behavior according to physiological strain, habitat, and the physico-chemical nature of the bark of the trees which varies with age (Ferry, 1973). Lichen species on acid substrates are considered far more sensitive to SO_2 than those on basic substrates. Poor bark habitats, such as acid boles of conifers and birch, are the most susceptible to pollution as they lack sufficient buffer capacity to allow rapid oxidation of SO_3 to less damaging SO_4 (Hawksworth, 1970; LeBlanc, 1975). The greater resistance of lichens on eutrophiated (basic) tree trunks to SO_2 may be due in part to alkaline earth dusts trapped in the roughened bark which helps maintain a high rate of conversion of SO_3 to less damaging SO_4 (LeBlanc). Lichen damage may result from bark changes or exudation resulting from tree infection by fungi and should be carefully considered when recording visible injury. It remains uncertain whether lichen distribution data reflects mean or peak concentrations of pollutants; and exact knowledge is lacking on the speed with which lichens respond to air pollution (Gilbert, 1973).

Skorepa and Vitt (1976) have used a relative luxuriance - density index to detect changes in the epiphytic lichen flora on lodgpole pine in an area in Alberta, Canada, where a lichen desert had not yet developed (3 years after a gas plant operation began). They concluded that luxuriance and density of the lichen vegetation may significantly decrease while numbers of species (richness) remains stable. Based on general lichen appearance, they observed certain sensitive species to be depauperate (dwarfed) and dying-out. This trend was observed for the three lichen species in this study within a 3 mile radius of the plant, although qualitative judgment was not based on such an elaborate sampling scheme of luxuriance and density.

Lichen damage near an emission source of SO_2 is not unexpected, and the area obviously affected should expand as time passes until eco-equilibrium is reached.

LeBlanc and Rao (1975) have suggested, based on transplant studies in the Sudbury, Ontario area, that long-range concentrations above 80 micrograms per cubic meter (.03ppm) could cause chronic injury to most epiphytic lichens. At such sensitivity, the likelihood of an lichen desert expanding over time, as has occurred about urban centers, is real about this power plant.

More sophisticated investigation of present lichen health according to methods previously mentioned, coupled with future monitoring of pollution levels, would be a valuable contribution to the general impact assessment of coal-fired steam electric stations in the rural areas of the North Central United States.

ACKNOWLEDGEMENT

The authors wish to thank Ronald M. Hayes and Associates and the Minnesota Pollution Control Agency for assistance in the lichens investigation.

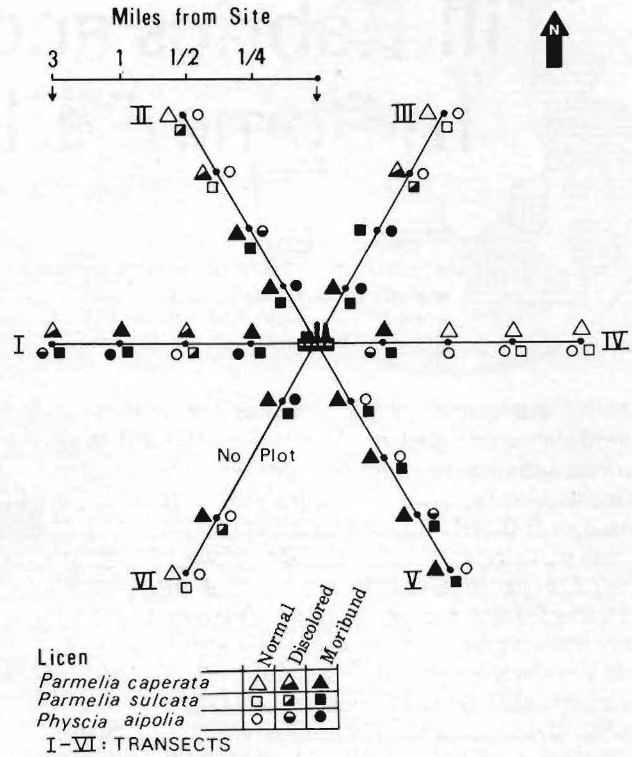

Fig. 3. Appearance of 3 lichen species within 3 miles of a coal-fired power plant.

REFERENCES

FERRY, B.W., BADDELEY, M.S., and HAWKSWORTH, D.L. 1973. Air pollution and lichens. Univ. Toronto Press. Toronto, Canada.

GILBERT, O.L. 1971. Studies along the edge of a lichen desert. Lichenologist, 5.

——— 1973. Lichens and air pollution. *In* The lichens. Ahmadjian and Hale-Ed. Academic Press. N.Y.

DENISON, W.C. 1973. A guide to air quality monitoring with lichens. Lichen Tech. Inc. Corvallis, Oregon.

HAWKSWORTH, D.L., and ROSE, F. 1970. Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. Nature 227.

LEBLANC, F., and RAO, D. 1975. Effects of air pollution on lichens and bryophytes. *In* Response of plants to air pollution. Mudd and Koxlowski, Ed. Academic Press. N.Y.

——— 1973. Effects of sulfur dioxide on lichen and moss transplants. Ecology 54.

SKOREPA, A.C., and VITT, D.H. 1976. A quantitative study of epiphytic lichen vegetation in relation to SO_2 pollution in western Alberta. Environ. Can., Can. For. Serv., North For. Cent. Inf. Rep. NOR-X-161.

SKYE, E. 1968. Lichens and air pollution: A study of cryptogamic epiphytes and environment in the Stockholm region. Acta. Phytogeogr. Suec. 52.