

Lichens and (Air) Pollution



No air pollution



With air pollution

Early Observations in Europe

- The “city effect” (decreased lichen diversity) was recognized in the 1800s in many regions of England, Austria, and France
- Early workers attributed the decline to coal soot
- Later, SO_2 was recognized as the major phytotoxin involved

A Classic Example from England

- **Peppered moth vs. melanistic forms**
- As trees lost their foliose, gray and green lichens (good camouflage for the peppered moth against predation by birds), the melanistic form (black) increased in numbers (blended in better on dark, lichen-free tree trunks)
- Change in populations was due to pollution from burning of coal

The Peppered Moth of England



Biston betularia,
the peppered
moth and the
melanistic form
of the species

Effect of Air Pollutants

- **High sensitivity** of lichens is related to their physiology and morphology
- Alteration of the symbiotic balance between the partners leads to a breakdown of the association
 - This can come about by accumulation of toxins, metabolic interference, or altered nutrition favoring one partner of the other

Types of Pollutants

- SO₂
 - By-product of coal or fuel oil combustion, ore reduction, paper manufacture, and automobile exhaust
- Photochemical toxins such as ozone, NO₂, PAN (peroxyacetylnitrate)
 - Combustion products, automobile exhaust (common pollutants in “smog” and “smaze”)

Types of Pollutants (cont.)

- Acid Rain

- SO_2 and NO_2 dissolved in both rain and snow
- Ability of the substrate to “buffer” acidic conditions helps lichens survive on limestones and some barks (elm)

- Heavy Metals

- Lead (Pb) from gasoline (tetraethyl lead) or from industrial activities
- Fluorine as a by-product of aluminum, zinc and phosphate ore reduction or from power plants

Air Pollution Effects on Bark pH

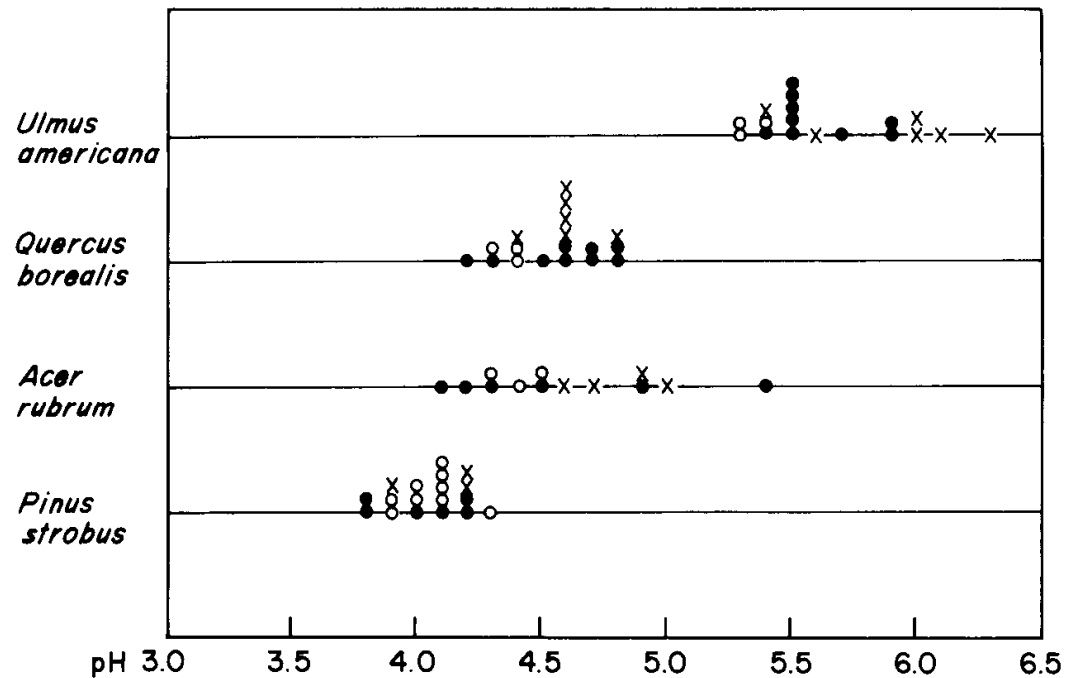
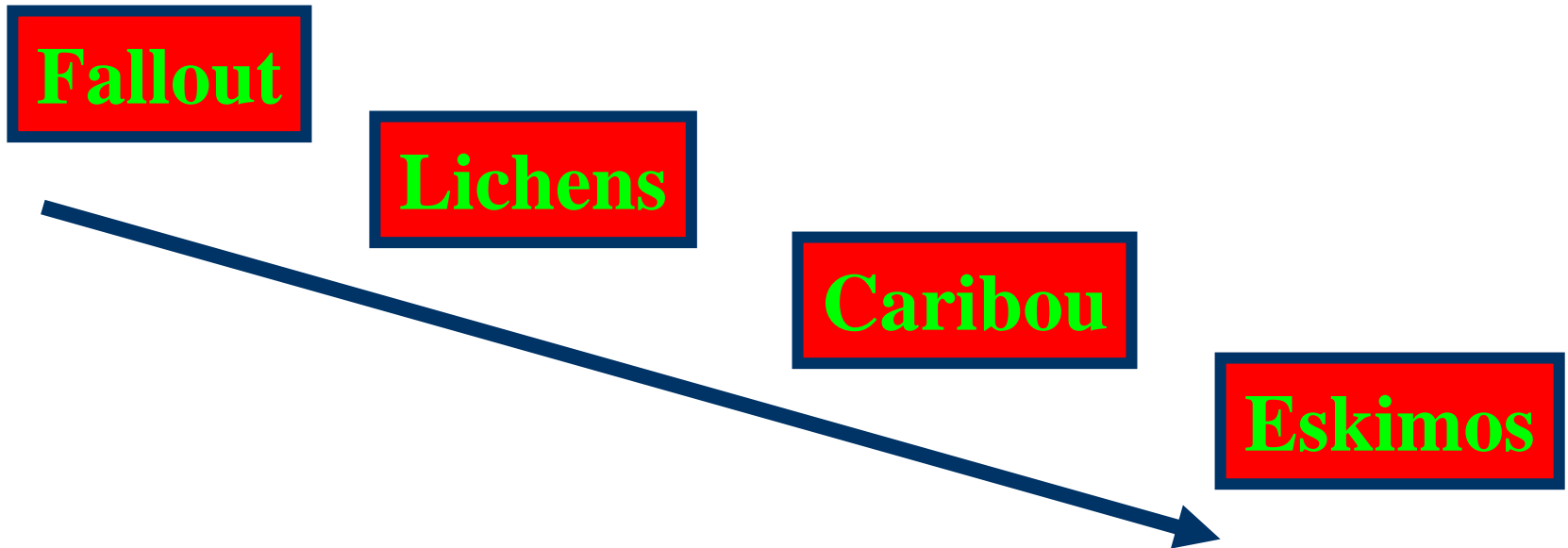


Fig. 8.1 pH analysis of bark from four tree species at three distances northeast of a paper mill in Wisconsin, U.S.A. ● = 1.6–8.0 km; ○ = 9.7–16.1 km; x = 17.7–29 km. After Newberry.¹⁸⁸

Types of Pollutants (cont.)

- Nickel (Ni) from coal combustion, industrial processes, and automobile exhaust
- Mercury (Hg)
- Zinc (Zn) from automobiles
- Chromium (Cr) from power plants
- Oil Spill Pollution
- Ionizing Radiation
 - ^{137}Cs and ^{90}Sr from nuclear testing or accidents

Radionuclides in the Environment



Classic study conducted in Arctic America

Growth Effects from Chronic Radiation

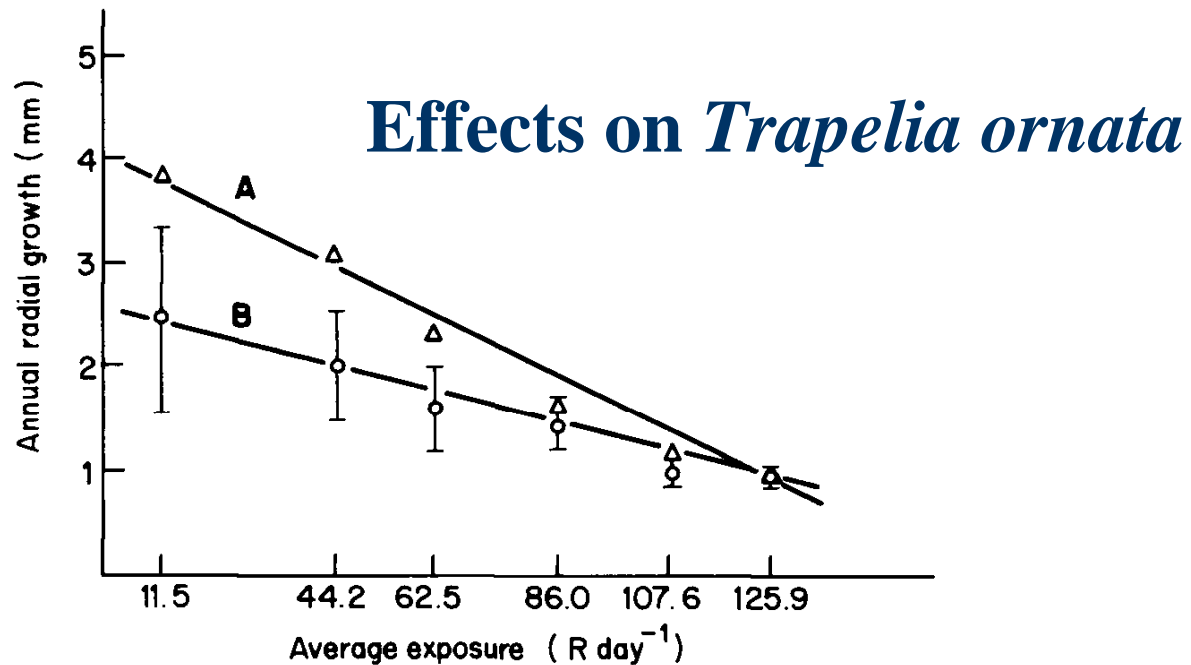


Fig. 8.3 Regression lines for maximum growth **(A)** and average annual radial growth **(B)** by *Trapelia ornata* under chronic ionizing radiation stress in Georgia, U.S.A. Vertical lines in **B** depict ± 1 standard deviation. After Snyder and Platt.²⁵⁰

Air Pollution Studies

- Emphasis over the last 30 years in three areas:
 - **Mapping of lichens (communities)** in relation to air pollution
 - **Morphological and anatomical** changes due to pollution
 - **Physiological effects** of pollutants on lichens

Mapping Studies

- Earliest studies in Stockholm, Sweden, in 1926
- By 1970 the correlation of SO₂ and lichen population decline was sufficiently obvious to develop a “quantitative scale” for community mapping (Hawksworth & Rose)

SEE HANDOUT

Index of Atmospheric Purity

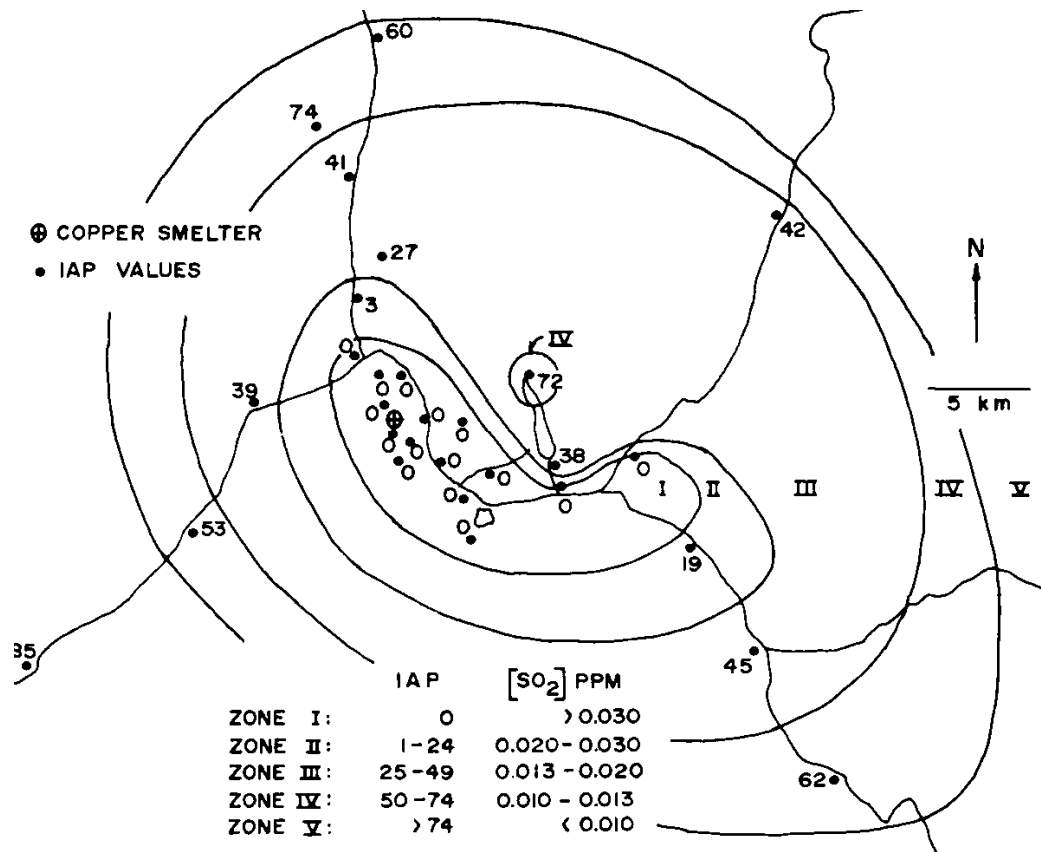
- Another approach was developed by LeBlanc and De Sloover (1970)
- The Index of Atmospheric Purity (**IAP**) was based not only on presence or absence, but on the species frequency and an “ecological index” for the species
- Hundreds of studies around the world have used these methods (both to document declines **and**, more recently, reinvasions)

Index of Atmospheric Purity

$$\mathbf{IAP} = \frac{1}{10} \sum_{i=1}^n \mathbf{Q}_i \mathbf{f}_i$$

n= the number of species at the site, **Q_i** = ecological index of toxiphoby of the *i*th species expressed as the average number of species found with it, **f_i** = frequency-coverage on a scale of 1 to 5.
Larger vales = cleaner air.

Example of IAP Plot (Canada)



**IAP zones
around a
copper smelter**

Concentrations of F in *Parmelia sulcata* and IAP Values

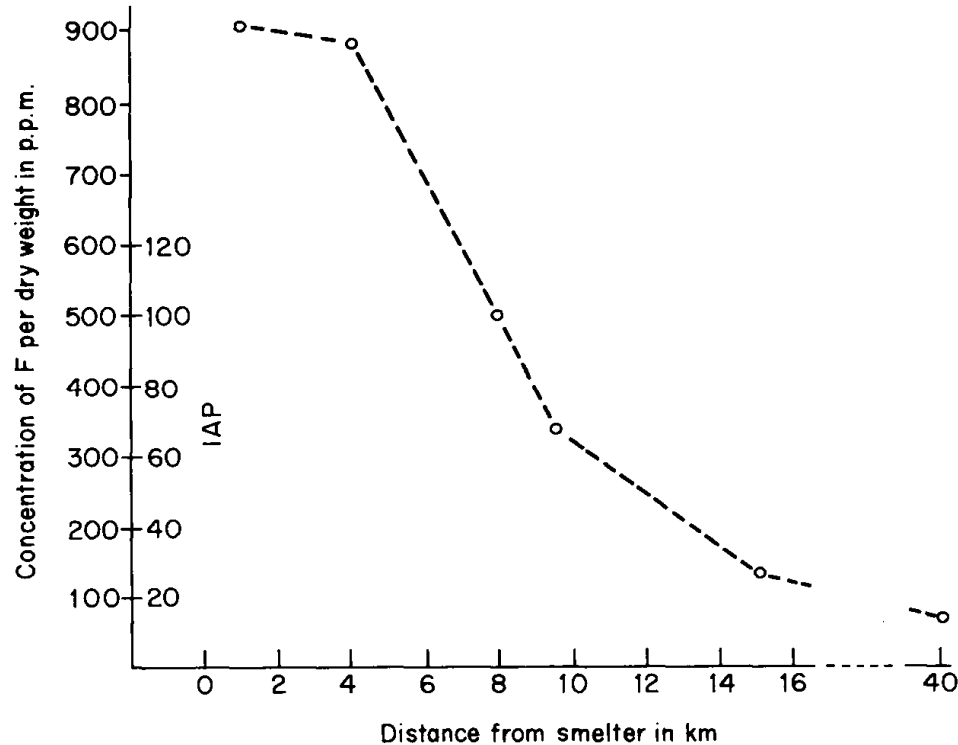


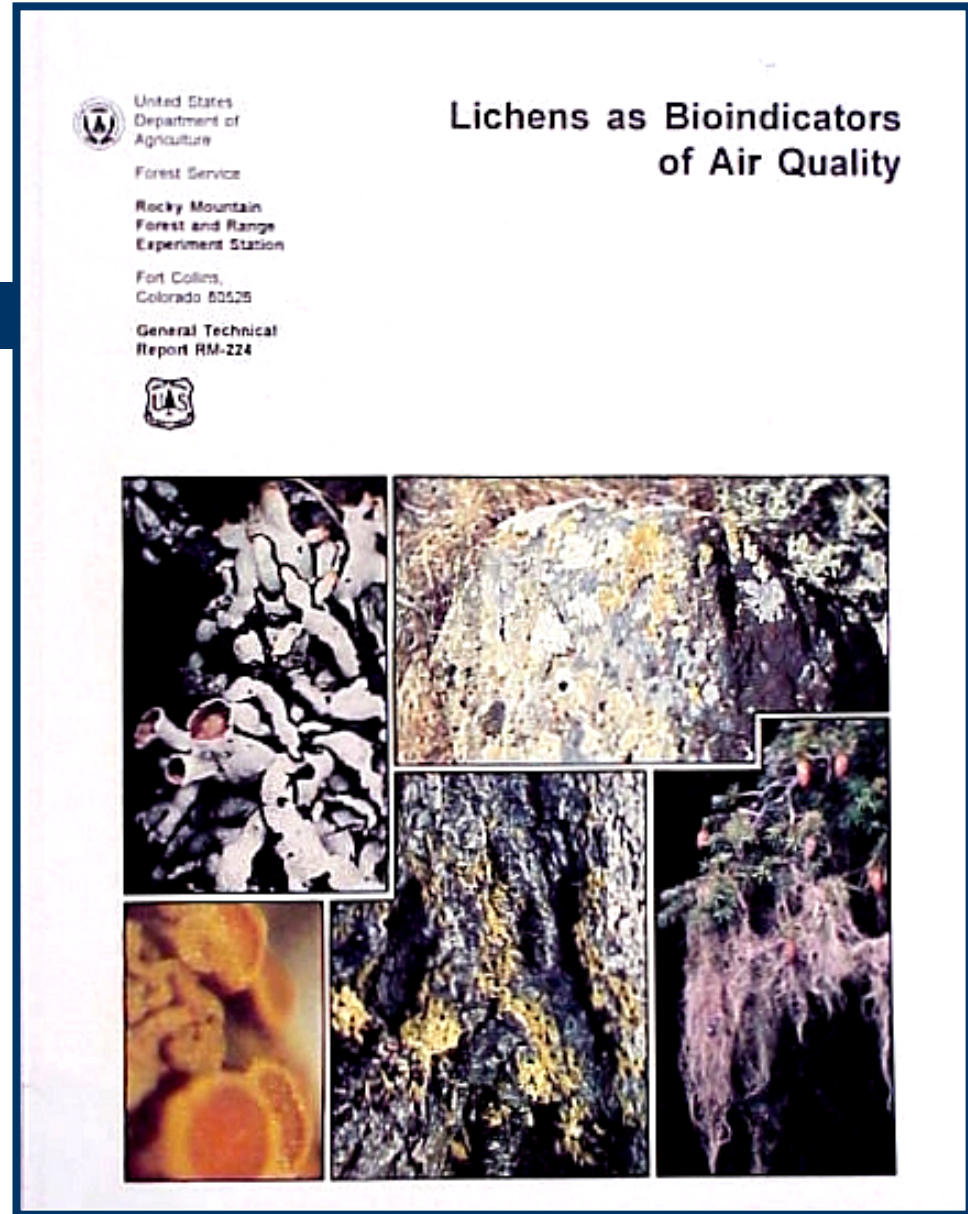
Fig. 8.2 Relationship between fluoride content in *Parmelia sulcata* and distance from a smelter in Canada. IAP = Index of Atmospheric Purity. After LeBlanc, Rao, and Comeau.¹⁶⁰

Advantages of IAP-Type Studies

- Air pollution monitoring with atmospheric collectors involved expensive equipment
- Lichen studies are, in most cases, just as accurate and can be done with less expense in equipment and human resources
- Large areas can be monitored more easily

Other Literature

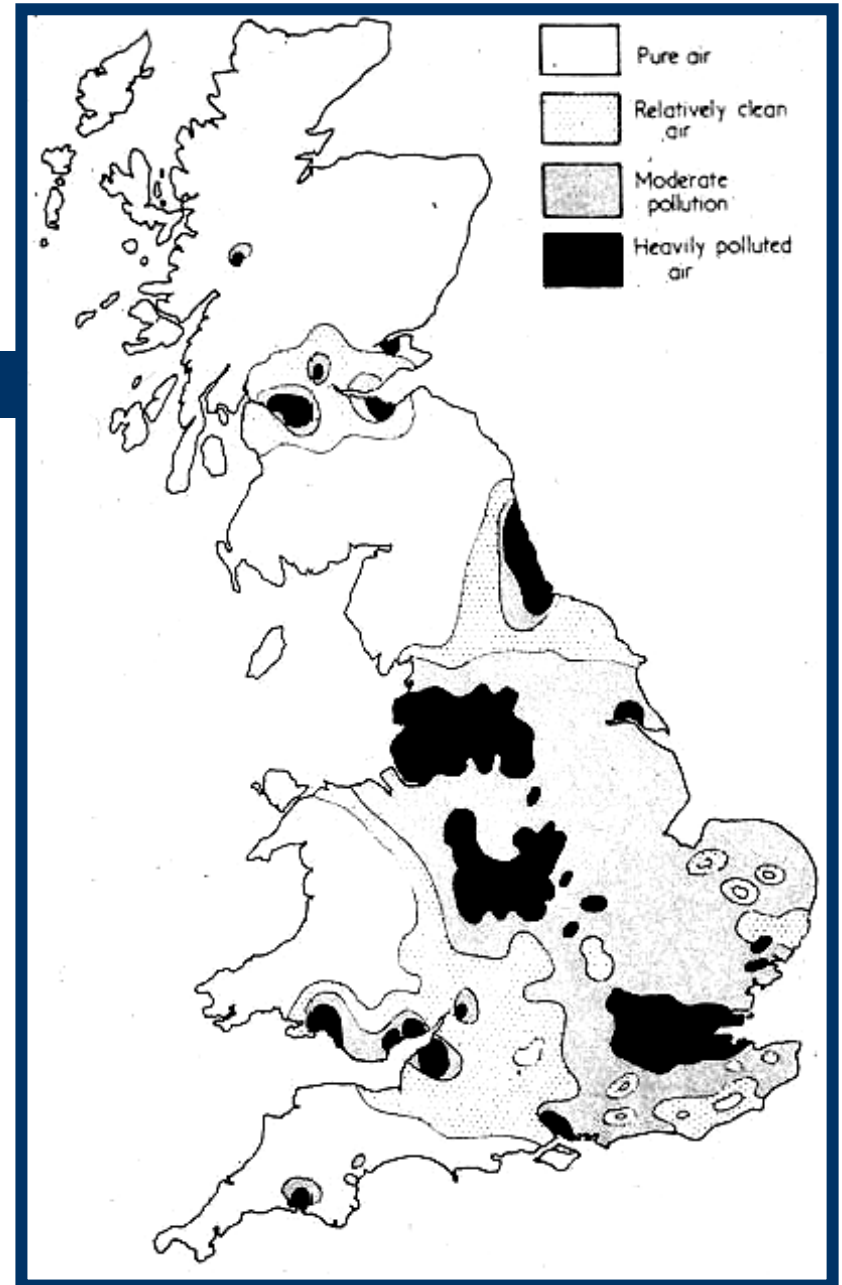
A “How To Survey” book recently published by the US Forest Service



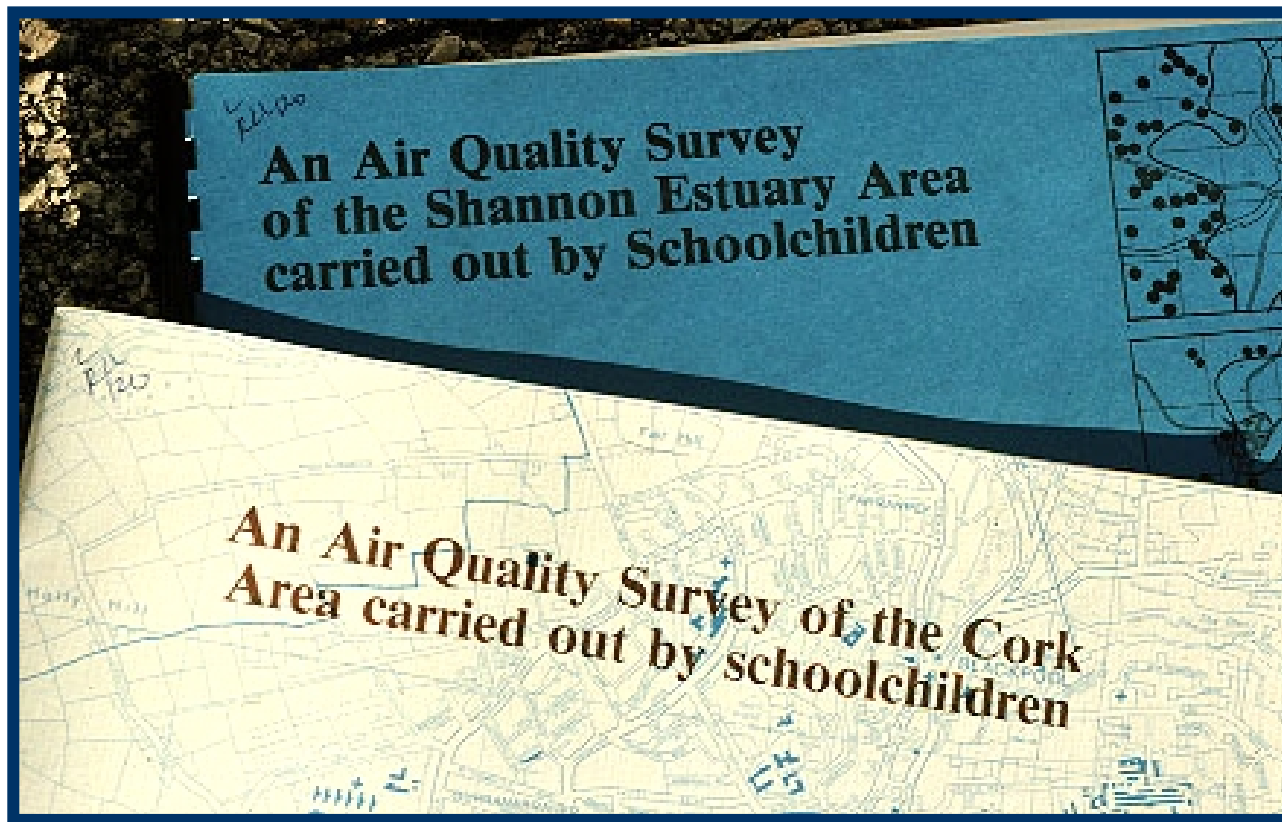
Other Literature (cont.)

“Our Mucky Air”
prepared one summer
by 15,000 school
children in England
and Scotland

“The further it stands out from
the tree, the cleaner the air”



Air Pollution Studies in Ireland



Methods for Studying Pollutant Effects on Lichens

- **Transplant Studies**
 - Done in many parts of the world with several foliose and fruticose taxa
 - Good technique for single, point-sources in rural areas (power plants, oil refineries)
- **Controlled Fumigations**
 - Controlled conditions for standardization
 - Can isolate a single pollutant or look at synergistic effects

Morphological and Anatomical Effects

- Reproductive Potential

- Usually **reduced** by pollutants (decline in production of apothecia, photobiont cell reproduction reduced as well as spore germination)
- However, sometimes the effect is to increase production of soredia and isidia

Morphological and Anatomical Effects

(cont.)

- Growth

- A marked reduction in growth rate is typical, especially with SO_2 , NO_2 and lower pH values

- Morphology

- Discoloration (pinkish or brownish) or bleaching occurs with the death of algal cells
- Unusual branching patterns (*Cladonia*)
- Cortical layer thickness changes, cracking

Morphological and Anatomical Effects

(cont.)

- Ultrastructure

- Workers have observed changes in chloroplast shape, swelling of mitochondria, accumulations of unknown granules etc.
- Fungal ultrastructure effects less pronounced
- Some observed changes suggest the mechanism from carbohydrate transfer is being affected

Physiological Effects of Pollutants

- Membrane Integrity
 - Pollutants may interrupt membrane processes such as photosynthesis, carrier channels, and ion exchange sites (often leading to K^+ loss)
 - Metal ions and SO_2 are particularly detrimental to membrane integrity

Physiological Effects of Pollutants (cont.)

● Photosynthesis and Respiration

- **SO₂** (best studied), ozone, HF, PAN and acid rain all tested by fumigations
- Reactions of lichen taxa varies (most show decline in CO₂ exchange rates) and one or two are actually stimulated
- Metals also cause rate reductions in sensitive species: Ag, Hg > Co > Cu, Cd, >Pb, Ni (short term exposures)
- Ag, Hg, Cu >Pb, Co > Ni (long term exposures)

Physiological Effects of Pollutants

(cont.)

- Chlorophyll Fluorescence
 - A new technique for studying “stress” physiology in plants
 - Responses to SO_2 similar to results using higher plants
- Pigment Degradation
 - Bleaching and discoloration caused by chlorophyll breakdown, death of algal cells

Physiological Effects of Pollutants (cont.)

- Nitrogen Fixation

- SO_2 and NO_2 both inhibit N_2 fixation process
- Decline in the *Lobarion* Alliance in Europe, with many N_2 fixing species, is well-documented from field studies

- Other Parameters

- Inhibition of enzyme systems, protein biosynthesis, and lipid biosynthesis are other examples of pollution effects on lichen physiology

Literature

- Hawksworth, D. L. & F. Rose. 1976. *Lichens as Pollution Monitors*. Edward Arnold, London.
- Ferry, B. W., M. S. Baddeley & D. L. Hawksworth (eds.). 1973. *Air Pollution and Lichens*. University of Toronto Press, Buffalo.
- Gries, C. 1996. Lichens as Indicators of Air Pollution, pp. 240-254. *In* T. H. Nash, III, *Lichen Biology*. Cambridge University Press, Cambridge.

Air Pollution Web Sites

- <http://www.mpm.edu/collect/botany/lichens.html>
- <http://www.fs.fed.us/r6/aq/lichen/welcome.htm>
- <http://www.fs.fed.us/r6/aq/lichen/biblio.html>