ACIDITY OF TREE BARK AS A BIOINDICATOR OF
FOREST POLLUTION IN SOUTHERN POLAND

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ABSTRACT

pH values and buffering capacity were determined for bark samples of 5 deciduous trees (oak, alder, hornbeam, ash, linden), one shrub (hazel) and one coniferous tree (scots pine) in the Cracow Industrial Region (Southern Poland) and for comparison in the Białowieża Forest (North-Eastern Poland). The correlation was found between acidification of tree bark and air pollution by $SO_2$ in these areas. All trees showed the least acidic reaction in the control area (Białowieża Forest), more acidic in Niepołomice Forest and the most acidic in the centre of Cracow city. The buffering capacity of the bark against alkali increased with increasing air pollution. The seasonal fluctuations of pH values and buffering capacity were found. Tree bark is recommended as a sensitive and simple indicator of air pollution.

1. INTRODUCTION

Industrial gas emissions, predominantly those of sulphur dioxide, cause acidification of rainfalls with sulphuric acid (Odén 1968). $SO_2$ is given off into the atmosphere where it is oxidized and hydrated and as a result returns to earth with precipitation in form of sulphurous or sulphuric acid. This in turn causes acidification and sulphuration of the environment including various components of the forest ecosystem. Sensitive bioindicators of chemical changes in the forest environment include many biological materials e.g. pH of tree bark (Skye 1968, Staxäng 1969, Grodzińska 1971). The tree bark represents a material which persists in the ecosystem for exceptionally long periods. Deciduous trees usually have lower bark acidity than coniferous trees (Barkman 1958). Bark acidify is readily affected by air pollution (Skye 1968, Staxäng 1969, Grodzińska 1971, msc.a,b). Tree bark acidity was used as a bioindicator in the Cracow Industrial Region in Southern Poland. Three zones were selected in this area: (1) the centre of Cracow city (700,000 inhibitants); (2) the neighbourhood of the steel mill and (3) Niepołomice Forest situated 20-40 km to the east from Cracow and the steel mill. Since north western winds prevail in this region (Anioła, Małecki 1967, Hess 1967, 1969) Niepołomice Forest is strongly affected by pollutants from the steel mill and from the city. Niepołomice Forest is a large forest complex (11,000 ha), It consists mainly of scots pine and to a smaller extent of deciduous trees (e.g. oak and hornbeam). The Białowieża Forest, a relatively unpolluted region in north eastern Poland, was used as a reference standard.

## 2. MATERIALS AND METHODS

Five species of deciduous trees: linden *(Tilia cordata Mill.)*, ash (*Fraxinus excelsior* L.), oak (*Quercus robur* L.), hornbeam (*Carpinus betalus* L.) and alder (*Alnus incana* (L.) Mnch), one deciduous shrub - hazel (*Coryllus avellana* L.), as well as one coniferous species - pine (*Pinus sylvestris* L.) were selected for the investigations. These species are common both in the natural forests and in the city parks.

Bark samples were collected from 170 trees on the average from 5 specimens of a given species in each locality. All the samples were collected in the early spring (March - April 1970 and 1971). The modified Swedish method was used in preparing the samples for analysis and in determining their pH and buffer capacity (Skye 1968, Staxäng 1969, Grodzińska 1971). pH was determined with a pH-meter, type LBS-66, with a glass electrode.

## 3. RESULTS

The bark of all tree species showed acid reaction (Fig. 1). The lowest values were found for pine bark and the highest ones for ash bark. In all cases, differences in bark acidity between samples could be related to particular localities. The localities form a logical series starting from the less acidic in the unpolluted area of the Białowieża Forest, then through the slightly polluted Niepołomice Forest up to more acidic areas in the neighbourhood of the steel mill and the most acidic one in the centre of Cracow. Bark samples from individual stations differed not only in the pH value per se, but also in buffer capacity (Fig. 2, 3). This capacity increased with concentration of $SO_2$ in the air. During titration of the oak bark, 2 ml of alkali were required for neutralization of the samples from clean forests of Białowieża, while samples from the centre of Cracow required 5 ml 1 n NaOH. A similar phenomenon was observed during analysis of the barks of linden, ash, hazel and pine. All samples showed greater capacity to buffer against alkali than against acid. Very large

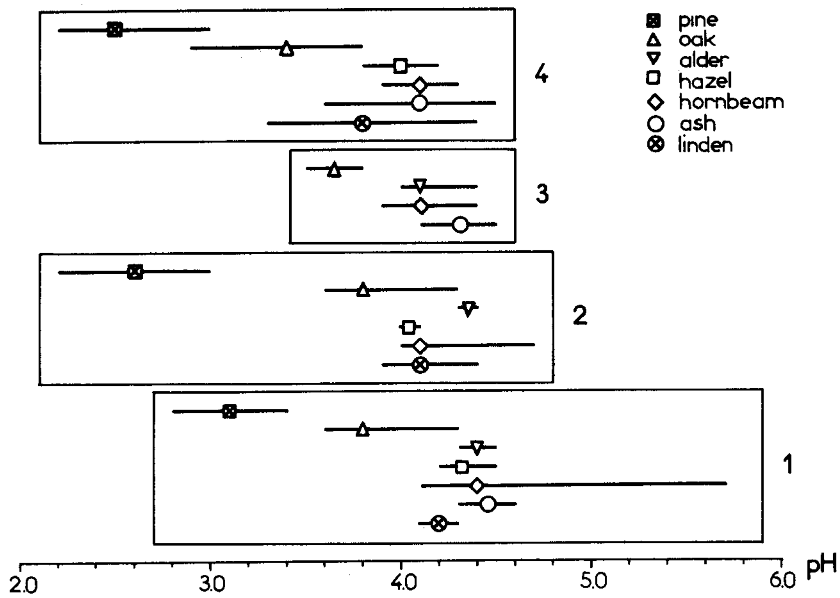


Figure 1. Total range and mean of pH of tree bark sampled from different localities. 1- Białowieża Forest; 2- Niepołomice Forest; 3- neighbourhood of the steel mill; 4- Cracow City.

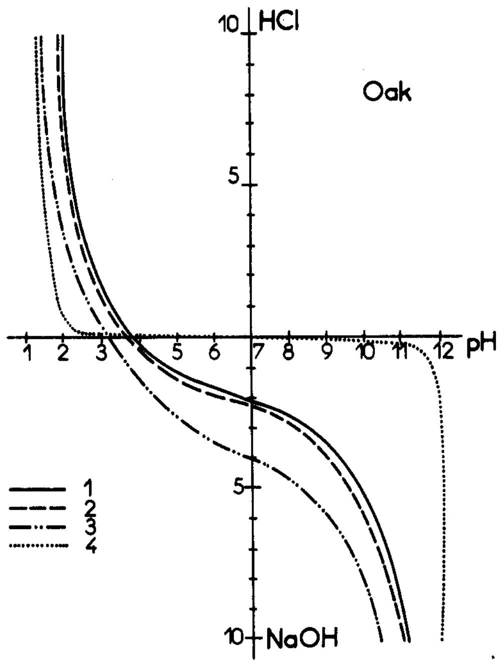


Figure 2. Buffer curves for oak from different localities. 1- Białowieża Forest; 2- Niepołomice Forest; 3- Cracow City; 4- distilled water.

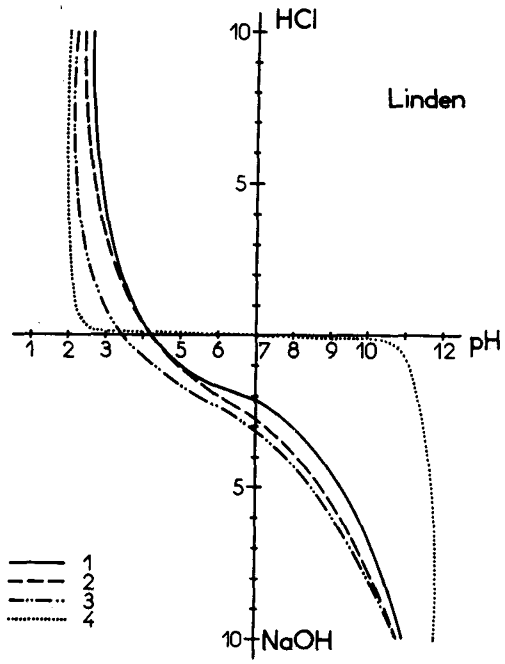


Figure 3. Buffer curves for linden from different localities. 1-4 as in Figure 2.

buffering capacity was found for the oak and linden (Fig. 2, 3).

The pH values of tree bark changed during the year. The most acidic reaction was shown by the bark in early spring, while the least acidic reaction was found in the summer. Maximum differences were found in linden bark (0.61 pH units), slightly less in oak bark (0.35 pH units) and the least in pine bark (0.26 pH units). Buffering capacity also fluctuated during the year. In all tree species, the greatest buffer capacity against alkali was found at early spring. For example, the neutralization of pine bark required 6 ml 1 n NaOH in April but only 4 ml during the summer season. This trend is also clearly evident in the linden and oak bark. The buffering capacity against acid was small in all trees and did not show clear fluctuations during the year. The acidification of tree bark in particular months was correlated with the concentration of $SO_2$ in the air and rainfall.

## 4. DISCUSSION

Sulphur dioxide is produced during the burning of fuels containing sulphur. Coal is the chief energy source used for heating homes in the city of Cracow and for steel production. This coal contains 1-3% sulphur. Cracow city emits five times more $SO_2$ than the processing plant (Anioła, Małecki 1967). For this reason the highest concentrations of $SO_2$ were recorded in the centre of Cracow, slightly lower in the outer zone of the city and in the neighbourhood of steel mill and the lowest in the Niepołomice Forest (Kasina 1971, Morawska-Horawska 1971). A good correlation was found between the $SO_2$ concentration in these areas and the acidity of the tree bark (Grodzińska 1971, msc. a,b).

The $SO_2$ emissions are subject to seasonal change (Kasina 1970), the largest occuring in wintertime, the smallest in the summer months. Similar changes were observed in tree bark acidity (Grodzińska msc.c). For this reason all samples for the study were collected in early spring i.e. after the winter season during which $SO_2$ concentration is the highest.

Bark acidity changed with the depth of bark (Härtel, Grill 1972) the external parts of the bark (< 3 mm) being the most acidic. The difference in pH between external and internal layers of bark was especially significant in the strongly polluted areas. For this reason, the external layers of bark should be taken for bioindication studies.

Acidity of oak and scots pine bark was determined in some other regions in Poland (Grodzińska msc. b, Zdanowska msc.). Bark of both species showed less acidic raaction in Copper Centre in south western Poland (Grodzińska msc. b) and in the neighbourhood of the steel mill near Warsow (Zdanowska msc.) than in the Cracow Industrial Region. The observed acidity was correlated with the magnitude of $SO_2$ emissions in these areas. In all these industrial centres, however, the bark was more acidic than in Białowieża Forest, the control region.

The pH values and buffering capacity of the bark of linden, ash, oak and pine in the Cracow Region are similar to those found in the polluted area of Southern Sweden (Skye 1968, Staxång 1969), but they are still less acidic than in Stockholm (Skye 1968). On the other hand, tree bark in the Białowieża Forest is more polluted than the bark in some areas of Sweden (Skye 1968, Staxång 1969). Thus larger differences in the pH values of tree bark are observed in Sweden than in Poland, where bark samples from all localities are relatively acidic. This fact may be explained by the higher acidification of rain and snowfalls in all of Central and Western Europe.(pH 4.5-5.0) in comparison with the Scandinavian countries (pH 4.5-6.0) (Odén 1968).

Both from these and from earlier studies (Skye 1968, Staxång 1969, Grodzińska 1971) it follows that pH of the bark is a sensitive indicator of air pollution by $SO_2$. The bark of linden and ash trees being the least acidic and most rough in surface texture is particularly suitable for determination of the degree of air pollution.

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