STATISTICAL MODELS FOR THE ACCUMULATION OF PAH, CHLORINATED HYDROCARBONS AND TRACE METALS IN EPIPHYTIC HYPNUM CUPRESSIFORME

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Abstract. Concentrations of PAH (1.12-benzoperylene, 3.4-benzopyrene, fluoranthene), chlorinated hydrocarbons (a-BHC, lindane, PCB) and trace metals (Zn, Pb, Cu) in bulk precipitation, as well as PAH and trace metal concentrations in atmospheric dust samples from 14 sites in Bavaria, F.R.G. are presented for two vegetation periods (1979 and 1980).

The same substances were also analyzed in epiphytic moss (Hypnum cupressiforme var. filiforme) sampled from tree trunks in October 1979 and 1980.

Using mean immission values and the amount of precipitation as predictors and concentrations of pollutants in moss samples as criteria, a number of multiple regression models were computed in order to quantify the relationships between absolute air pollution data and accumulated trace substance values.

Beta values of all variables help to determine whether bulk precipitation or atmospheric particulate matter has dominant influence on the uptake of trace substances by mosses. The study shows that epiphytic mosses can be used to monitor both heavy-metal, PAH and chlorinated hydrocarbons.

1. Introduction

In the last few years a number of investigations concerning the regional distribution pattern of trace substances in the atmosphere using bryophytes as bioindicators have been carried out (e.g. Rühling and Tyler, 1973; Little and Martin, 1974; Herrmann, 1976; Ward et al., 1977; Barclay-Estrup and Rinne, 1978; Thomas, 1979).

A direct comparison of investigations where different moss species have been used makes an interspecies calibration necessary (Folkeson, 1979). Furthermore, the accumulation of metals in mosses has been used for the analysis of temporal development of atmospheric pollution using herbarium material (Rühling and Tyler, 1969; Rasmussen, 1977). Both regional and temporal patterns for mosses show relationships between atmospheric pollution levels and accumulated pollutant contents.

Although these relationships seem to be apparent, only few investigations deal with a direct comparison of immission data and accumulation levels in mosses.

The uptake of trace metals by mosses is dependent on a number of variables. As Pilegaard (1979) points out, in heavily polluted areas the trace-metal content of bulk precipitation shows high correlation coefficients to the data on transplanted mosses. In addition to the deposited trace substances, the mosses are able to filter particulate matter from the atmosphere because of their large surface area. Furthermore, the amount of precipitation seems to influence the trace-substance uptake (Grodzińska, 1978).
As accumulation experiments have shown (Rühling and Tyler, 1970), mosses have distinct accumulation rates for single trace metals based on physiological parameters.

The purpose of this investigation is to compute statistical accumulation models for the uptake of organic and inorganic atmospheric pollutants by the epiphytic moss *Hypnum cupressiforme* var. *filiforme* Brid. based on multiple regression analysis. In these models, trace-substance concentrations (mean values of each vegetation period) in bulk precipitation (PAH, chlorinated hydrocarbons, trace metals) and in atmospheric suspended matter (PAH, trace metals), as well as the amount of precipitation are used as predictor variables. The predicted variables, or 'criteria', are the concentrations in moss samples *Hypnum cupressiforme* var. *filiforme* taken from the natural state at the end of each vegetation period (1979 and 1980).

Together with the $\beta$ values for all predictor variables, the enrichment factors help to characterize the individual trace substances according to the efficiency with which they are taken up by the moss. The comparison of the temporal trace-substance distribution in the atmosphere throughout a vegetation period and the resulting residue value of the biological material help to determine whether autumn is the best time for sampling.

Furthermore, it is necessary to evaluate the sensitivity of this method in order to discuss the investigated pollution pattern.

### 2. Material and Methods

#### 2.1. Sampling

At 14 sites in Bavaria, W. Germany (Figure 1), the following samples were collected:

- bulk precipitation and atmospheric dust: May 1979–October 1980; and 3-week intervals;

The sampling sites represent a wide variety of geological subsoil as well as anthropogenic influence. The sites can be briefly characterized as follows:

- site: 13 background type (forest)
- 2, 4 forest
- 6, 8, 11 rural type
- 1, 3, 9, 10, 12, 14 suburb type
- 5 urban type
- 7 near a highway.

Each sampling site was equipped with a bulk precipitation totalizator and a low-volume sampler.

*Totalizator*

For the sampling of bulk precipitation (dry and wet fallout), totalizers with 855 cm² polyethylene funnels were installed 1.2 m above ground.