

ATMOSPHERIC TRACE ELEMENT DEPOSITION: PRINCIPAL COMPONENT ANALYSIS OF ICP-MS DATA FROM MOSS SAMPLES

Torunn Berg,^a Oddvar Røyset,^a Eiliv Steinnes^b & Marit Vadset^a

^a Norwegian Institute for Air Research, P.B. 100, N-2007, Kjeller, Norway

^b Department of Chemistry, University of Trondheim, A177, N-7055, Dragvoll, Norway

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Abstract

Data from a Norwegian survey on atmospheric deposition, including 33 elements in 495 moss samples collected in 1990, are presented. The biomonitor moss used was *Hypnum splendens*, and the analyses were carried out by ICP-MS. Principal component analysis is used to identify possible sources of the elements determined in the mosses. Dominant factors represent long-range atmospheric transported elements (Bi, Pb, Sb, Mn, Cd, V, As, Zn, Ti, Hg, Ga, wind-blown mineral particles (F, Fe, Al, La, U, Th, Ge, Pa, V, Cr), local emission sources (Ni, Cu, Co, and As, Zn, Cd, and Hg; Fe, Cr, and Mn, transport from the marine environment (Mg, B, Na, Sr, Ca), and contribution from higher plants (Ca, Bb, Ba, Mn). Comparison of the results with similar surveys from 1977 and 1985 show a decreasing contribution of most long-range transported elements to southern Norway.

Keywords: atmospheric deposition, trace elements, moss samples, *Hypnum splendens*, principal component analysis.

INTRODUCTION

Using naturally growing moss as a biomonitor is now a well-established technique in studies of atmospheric deposition of trace elements. The basis of the moss technique as a means of surveying atmospheric element pollution sources, is that the carpet-forming species obtain most of their nutrient supply directly from precipitation and from dry deposition of airborne particles (Rühling & Tyler, 1968). Furthermore, mosses have a high capacity to retain several trace elements (Rühling & Tyler, 1970; Gjengedal & Steinnes, 1990). This means that mosses have found many applications as bio-monitors in particular in the Nordic countries (i.e. Rühling & Tyler, 1971, 1973, 1984; Steinnes, 1977; Kambæk & Steinnes, 1980; Pakarinen & Tuolonen, 1976; Pakarinen, 1981; Pilegaard *et al.*, 1979).

Moss surveys are performed regularly in Norway (1977, 1985, 1990) to assess temporal or spatial changes in atmospheric deposition (Schmug *et al.*, 1990; Steinnes

et al., 1992, 1993a,b). Similar investigations are also carried out simultaneously in Sweden, Finland, and Denmark (Rühling *et al.*, 1987), and have recently been extended to other parts of Europe (Rühling *et al.*, 1992). Results from the earlier moss surveys show the following sources to be important contributors to concentrations of elements in mosses in Norway (Sebaug *et al.*, 1990; Steinnes *et al.*, 1992, 1993b):

- (1) long-range atmospheric transport (LRTP) of anthropogenic elements from other parts of Europe;
- (2) local anthropogenic point sources within or closely outside Norwegian borders;
- (3) natural trace element cycling processes, mainly atmospheric transport from the marine environment;
- (4) root uptake in vascular plants from soil, and subsequent transfer to mosses by leaching from living or dead plant material;
- (5) mineral particles, mainly windblown dust, from local soil.

The multi-element technique ICP-MS (inductively coupled plasma-mass spectrometry), has made it convenient to determine the element composition of samples of environmental interest. The feasibility of ICP-MS in the analysis of mosses is demonstrated in Steinnes *et al.* (1993c). Analysis of mosses by ICP-MS tends to produce large sets of data that may be difficult to interpret. Principal component analysis (PCA) can be used in such cases to obtain an overview of the data. The method is described in a number of publications (Mudroewski & Howery, 1980; Henry *et al.*, 1984; Wold *et al.*, 1987). Use of PCA on the data set from the first national survey on mosses in Norway showed the feasibility of the method (Sebaug *et al.*, 1990).

The objective of this paper is to present the results from the 1990 moss survey in Norway. The results are compared with similar surveys in 1977 and 1985 in order to evaluate temporal deposition trends. ICP-MS analysis has made it possible to obtain data for trace elements which had not been measured in the previous surveys, where a combination of instrumental neutron

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