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CONTENT

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1 INTRODUCTION

Many heavy metals and other trace elements are because of their volatility emitted to the atmosphere in high-temperature combustion and metal extraction processes, or during their industrial or technological application. A part of these emissions, concentrated on the small particles, is subject to long range transport in the atmosphere.

Different studies have been made at the Norwegian Institute for Air Research to assess: 1) sources and amounts of heavy metals emitted, 2) their concentration levels in the atmosphere, and 3) the metal behaviour during atmospheric transport. Heavy metals have also been used as signatures to assign source regions (or source groups) to material sampled at a receptor point. In the present work some measured air concentrations of trace elements at stations in Scandinavia and the Norwegian Arctic have been related to long range transport and emission of the same elements from European source regions.

2 EMISSION SOURCES OF TRACE ELEMENTS

The emissions of 16 trace elements: As, Be, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V, Zn and Zr from different sources in Europe and the Soviet Union have been estimated on the basis of information available from the chemical literature, economic surveys, geographical encyclopedias, etc. As an example of the results, the spatial distribution of vanadium emission in Europe in 1979 is presented in Fig. 1. The shaded areas represent locations with emissions higher than the average in a grid of 150x150 km. The results indicate that Be,

Co, Mo, Sb and Se are emitted chiefly by coal combustion, while Ni and V mainly come from oil combustion. Smelters and secondary non-ferrous metal plants release the largest amounts of As, Cd, Cu and Zn. Emissions of Co and Mn are mainly from factories producing iron, steel and ferro-alloys. Finally, Pb enters the atmosphere primarily as a result of gasoline combustion. The amounts of these elements released from natural sources in Europe are insignificant compared to this, mainly due to the absence of desert areas in Europe and low emission from European volcanoes. However, for several elements our knowledge about the emissions from natural sources is limited, and very few direct measurements have been made.

3 CONCENTRATIONS OF TRACE METALS

The emissions from source regions in Europe often affect the levels of air pollutants in Scandinavia, and releases from sources in Northern Soviet Union are measured in Spitsbergen. To illustrate this some data from a cooperative nordic program including measurements at Birkenes (Southern Norway), Rørvik (Southern Sweden) and Virolahti (Southern Finland) in the period February-June, 1980 may be used. The Zn concentrations are shown in Fig. 2. The peaks during 14-16 April at Birkenes and Rørvik are due to long range transport of air pollution from the central parts of Europe. For both stations, the wind trajectories at 850 mb indicated the air masses had passed source regions in the Federal Republic of Germany, the Netherlands and the German Democratic Republic.

A simple trajectory model was then used to calculate the different metal concentrations at the stations for this episode (14-16 April) from the emission surveys. Calculations and measurements are compared in Fig. 3. A good agreement for several elements can be used as a confirmation of properly selected source regions. The poor agreement in the case of V and Pb is due to additional emissions from local residual oil and gasoline combustion.

Local sources can contribute significantly to the trace element concentrations. As an example, the wind direction shows that the well defined peak of Zn at Rørvik on April 5 (see Fig. 2) probably is a result of Zn emissions from metal works in Gothenburg, 30 km north of the station.

To separate the contributions from local sources and long range transport, the size-differentiated composition of the aerosol can be used. Measurements in the Arctic during episodes of long range transport of air pollutants, show an increase of the metal concentrations in the size fraction with particle diameter below 2 µm. This fits well with the size of particles generated during high-temperature processes in energy production and industry. An example of the metal concentrations versus particle size at Ny Ålesund on Spitspergen is presented in Fig. 4a and b for normal conditions and an episode of long range transport, respectively. Other studies, carried out around copper-nickel smelters and coal-fired power plants indicate that only 5 to 15 per cent of the total emission of trace elements from high temperature sources are deposited locally within a distance of 30 km from the plant.

The impact of metal emissions in Europe on the concentrations measured in Scandinavia, can be assessed not only from concentrations measured during episodes of long range transport, as shown in Fig. 2, but also from a sector analysis of daily mean concentrations over a certain period of time. As an example, the average concentrations of Pb in fine (< 2 µm) and coarse fractions of particles arriving from 4 sectors at Birkenes, Rørvik and Virolahti are shown in Fig. 5. The two "European" sectors dominate when considering concentrations measured at Birkenes and Rørvik. The sector distribution of the Pb-concentrations at Virolahti is rather even, cfr. the Zn concentrations in Fig. 2. The sectorial contributions may then be related to the emissions within these sectors in Europe. The data in Table 1 show the ratio of metal concentration to metal

emission in given sectors realtive to the concentration and emission of vanadium. The values higher than 1 indicate an underestimate of the emissions. Generally, a good agreement has been obtained for S, Mn, Ni, Cu, As, Se and Pb, particularly for the two sectors from Europe. The disagreement in some cases is likely due to an incomplete emission inventory, viz. disregard of natural sources (Mn, Zn and Se in the NW and NE sectors at Birkenes) and local emissions.

4 BEHAVIOUR OF TRACE METALS DURING ATMOSPHERIC TRANSPORT

This depends mainly on the particle size distribution, discussed already, and the sink processes. Quantitative measurements of dry and wet deposition are necessary to validate predictions of the fate and effects of emissions to the atmosphere. In the present calculations the following dry deposition velocities proved to be representative: 0.1 cm s^{-1} for Cd and Pb, 0.2 cm s^{-1} for As and Sb, 0.3 cm s^{-1} for V and 0.4 cm s^{-1} for Cu, Cr, Mn and Zn. As the effect of precipitation was not considered, these values may not be generally valid.

5 FINAL REMARKS

The main conclusion from the studies is that trace metals from the many sources in England and Central Europe, do not appear in concentrations high enough to cause accute effects in Scandinavia. They may, however, be used to trace the origin of other pollutants on a regional scale. Thus, trace elements used in models and statistical approaches, can be applied in source apportionment of the deposition at receptors in remote

areas in Europe. However, in applying this technique to other problems, differences in scavenging rates have to be carefully considered.

Preliminary results indicate that Sb and V might be good reference elements to calculate elemental ratios for source assignation on a regional scale in Europe. Ratios to V or Sb of selected trace elements which are either totally pollution derived or have a pollution component which can be calculated accurately, meet all requirements for elemental tracers. These ratios are capable of long range transport and are conserved during the transport. Statistically different signatures can then be derived for different regions in Europe.

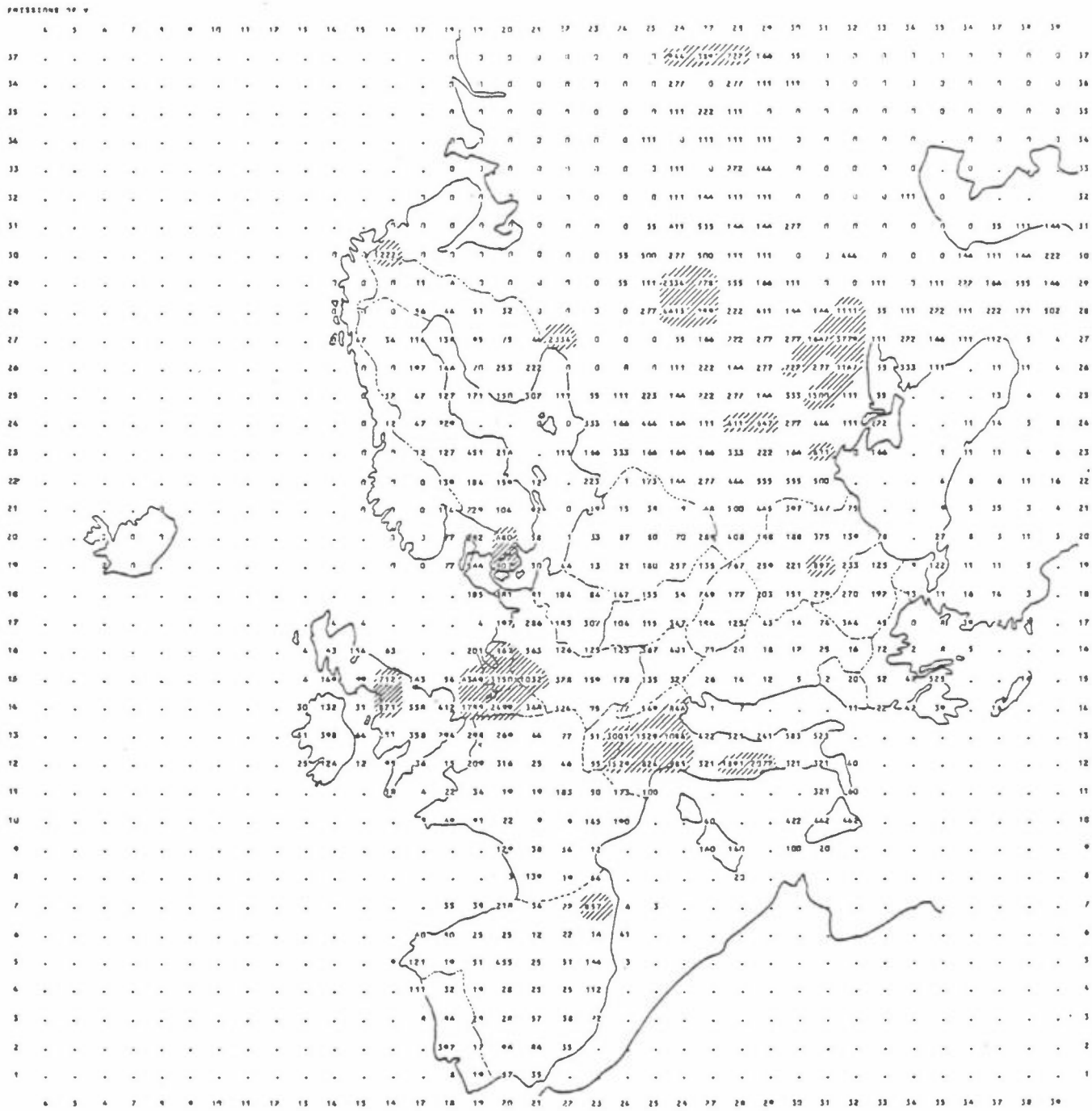

Figure 1 : Spatial distribution of vanadium emission in Europe in 1979 in 10^2 kg/year. The shaded areas represent locations with emissions higher than the average for the grid area.

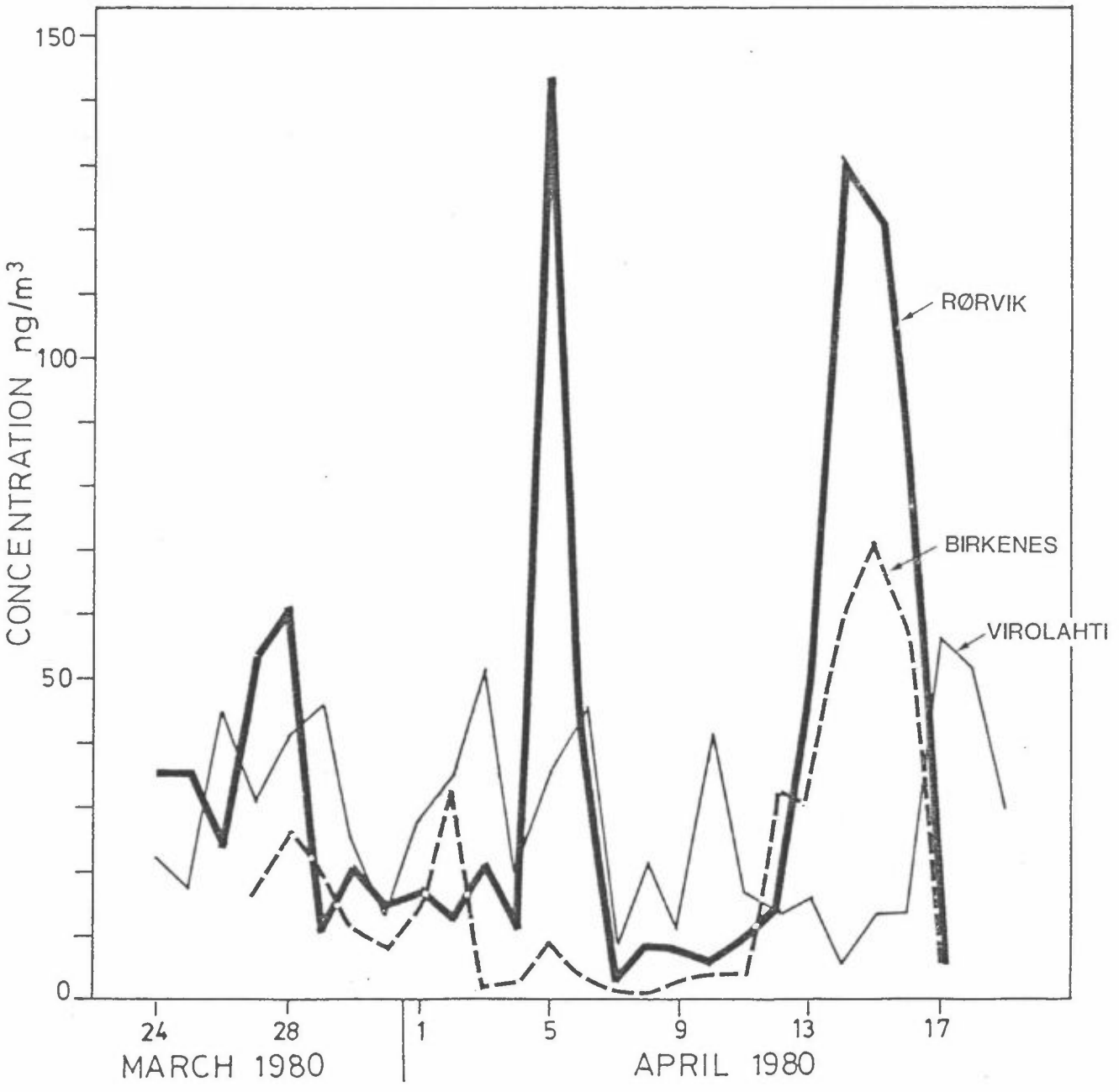

Figure 2: Zn concentrations at Rørvik (——), Birkenes (----) and Virolahti (——) in the period March 24-April 17, 1980.

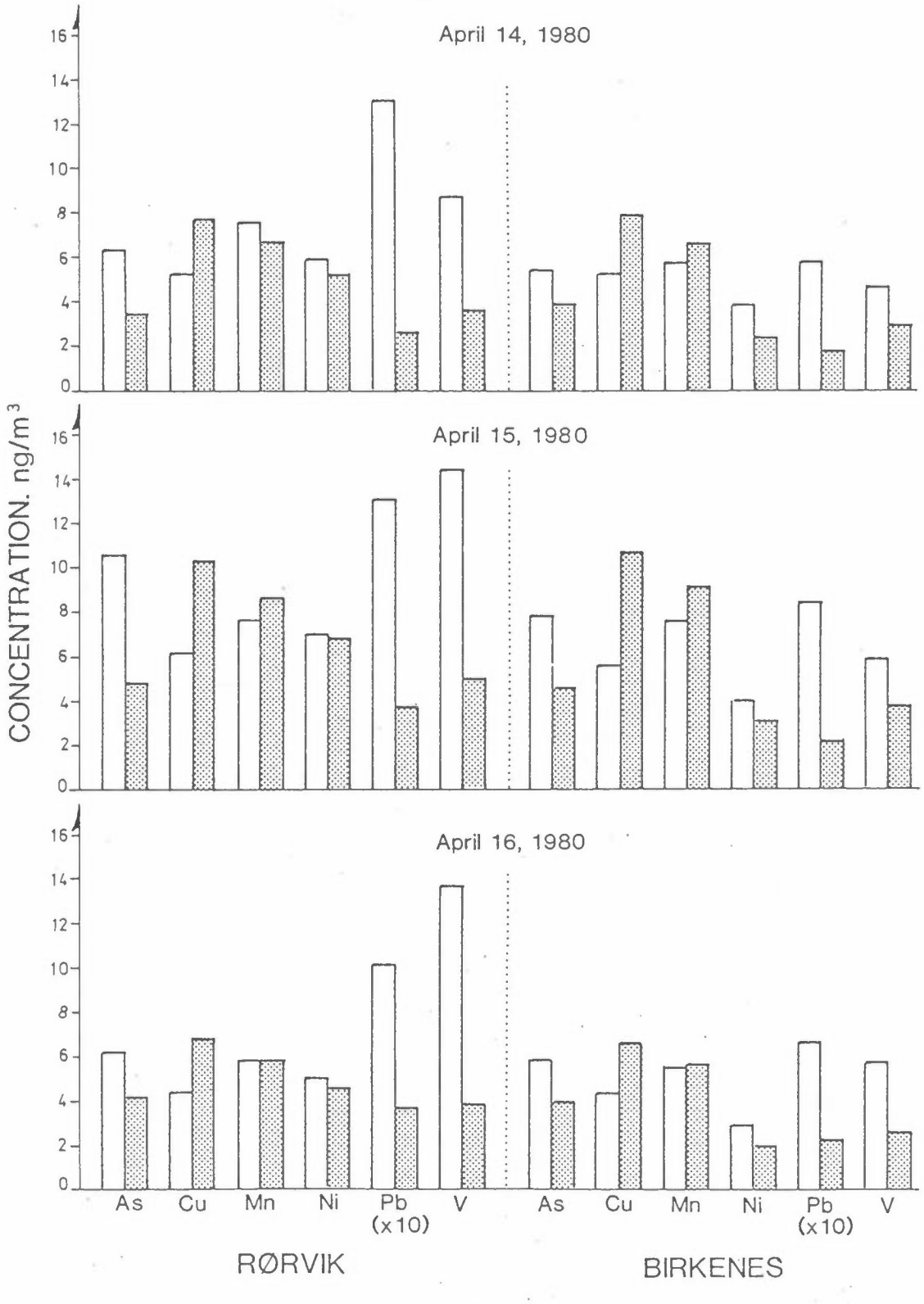

Figure 3: Measured (empty bars) and calculated concentrations (dotted bars) of trace elements at Rørvik and Birkenes in the period April 14-16, 1980.

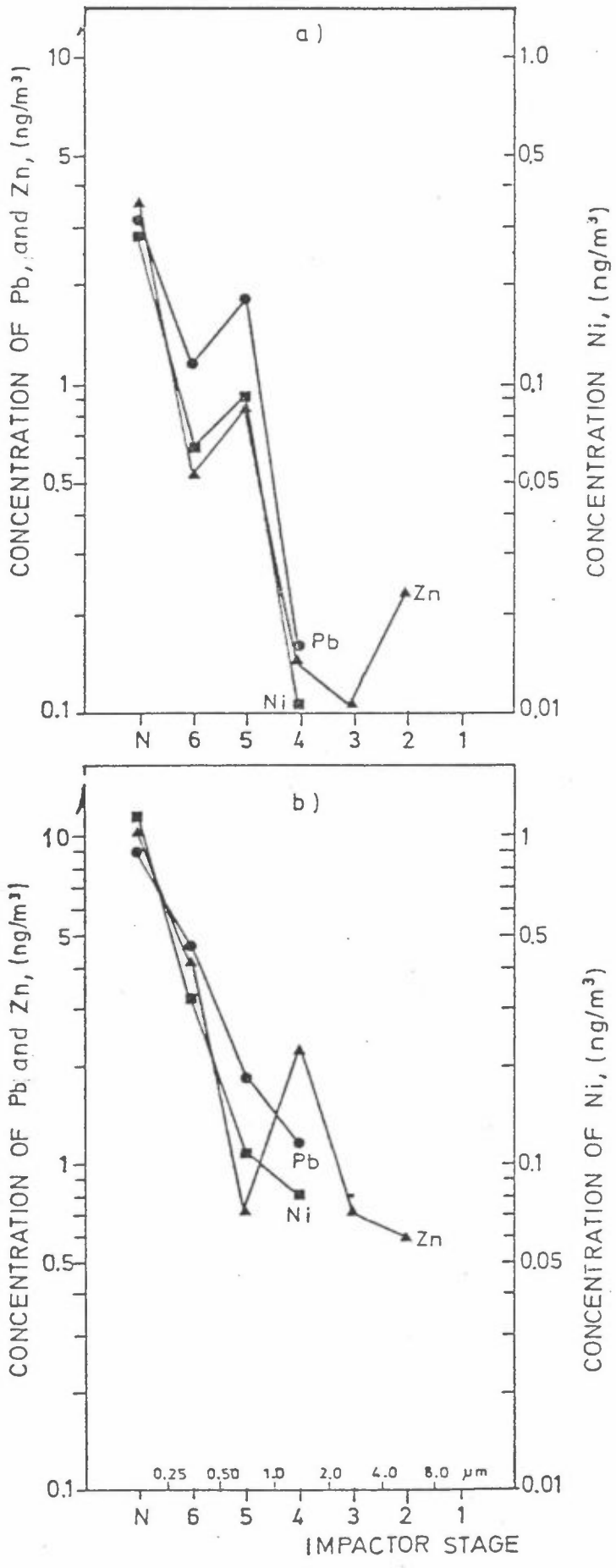

Figure 4: Trace element concentrations vs. particle size at Ny Ålesund, Spitsbergen. a) Average values for samples collected during non-episodic conditions. b) Average values for samples collected during an episode of long-range transport.

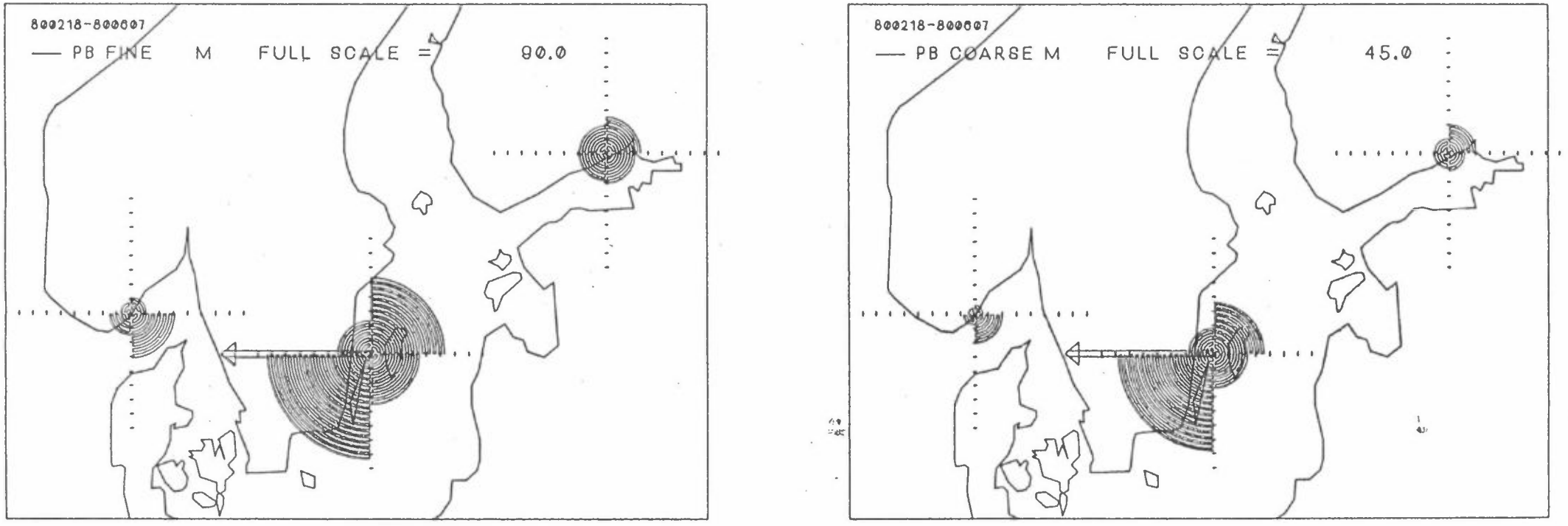

Figure 5: Sector analysis of the Pb concentrations at Rørvik, Birkenes and Virolahti in the period February-June, 1980.

Table 1: Comparison of measured mean concentrations with expected values using vanadium as reference elements (see text for explanation).

Metal / Station sector	S	Mn	Ni	Cu	Zn	As	Se	Pb	Cr
Birkenes									
NW	1.8	14.0	4.5	1.0	0.9	2.6	19	1.7	0.8
NE	1.1	23.0	4.1	4.1	15.0	3.7	3.3	6.4	0.8
SE	0.5	2.5	1.2	1.5	6.2	4.9	1.5	3.4	0.4
SW	1.0	2.8	1.7	1.3	3.9	2.6	3.4	2.0	0.3
Rørvik									
NW	0.9	1.8	1.3	0.7	3.5	1.0	3.5	1.9	0.3
NE	0.3	2.2	1.1	1.9	7.7	12.0	1.0	2.9	1.1
SE	0.2	1.1	0.9	0.6	3.0	1.7	0.6	1.6	0.1
SW	0.7	2.0	1.3	1.6	6.3	4.8	3.0	3.0	0.3
Virolahti									
NW	0.8	1.5	1.3	0.6	2.4	1.1	0.8	2.5	0.4
NE	0.2	4.2	1.0	1.0	7.0	1.6	0.2	2.2	0.7
SE	0.2	1.5	1.0	0.7	3.7	0.7	0.5	1.3	0.3
SW	0.4	1.4	1.1	0.7	1.8	0.7	0.7	1.0	0.1

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TITTEL
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ABSTRACT (max. 300 characters, 7 lines)
Measured air concentrations of trace elements at stations in Scandinavia and the Norwegian Arctic have been related to long range transport and emission of the same elements from European source regions. It was concluded that trace elements used in models and statistical approaches, can be applied in source apportionment of the deposition at receptors in remote areas in Europe.

* Kategorier: Åpen - kan bestilles fra NILU A
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