Three decades of atmospheric metal deposition in Norway as evident from analysis of moss samples

Temporal trends and progress in 2010

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25th Task Force meeting of the ICP vegetation. Brescia. Italy. 31 January - 2 February 2012
Metal deposition surveys in Norway:

Ca. 500 sites

Hylocomium splendens

Moss biomonitor

Hylocomium splendens

Moss annual segments
Analytical techniques used in Norwegian moss surveys

A. 1977, 1985

**INAA:** Na, Al, Cl, Sc, V, Cr, Mn, Fe, Co, Zn, As, Se, Br, Rb, Mo, Ag, Sb, I, Cs, La, Sm, Hg, Th, U (24 elements)

**AAS:** Ni, Cu, Cd, Pb


**ICP-MS:** Li, Be, B, Na, Mg, Al, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo, Rh, Ag, Cd, Sn, Sb, Te, Cs, Ba, La, lanthanides, Au, Pt, Tl, Pb, Bi, Th, U (54 elements)

**AFS:** Hg

Priority elements, European moss survey: V, Cr, Fe, Ni, Cu, Zn, As, Cd, Hg, Pb
Objects of the 2010 Norwegian national moss survey:

A. Mapping geographical patterns in atmospheric deposition of trace elements (1977 - present)

B. Characterizing atmospheric deposition of metals around major industries in Norway (2000 - 2005 - 2010)

C. Testing the feasibility of moss samples for monitoring levels of selected groups of organic contaminants (2010)
Pb in moss in Norway (µg⁻¹):

Temporal trends 1977-2010
Sb in moss in Norway ($\mu$g$^{-1}$):

Temporal trends 1977-2010
As in moss in Norway (µg⁻¹):

Temporal trends 1977-2010
Cd in moss in Norway (µg⁻¹):

Temporal trends 1977-2010
V in moss in Norway (µg⁻¹):

Temporal trends 1977-2010
Zn in moss in Norway ($\mu$g$^{-1}$):

Temporal trends 1977-2010
Ni in moss in Norway (µg\textsuperscript{-1}):

Temporal trends 1977-2010
Conclusions from the 2010 nationwide moss survey in Norway:

- Most metals of key interest are still declining. The current Pb deposition in the south is only about 5% of the 1977 level.

- Elements previously shown to be derived mainly from long range atmospheric transport are still supplied by this way.

- In the far north-east Russian smelters are supplying high amounts of Ni and Cu to Norwegian territory.

- In the case of Zn monitoring of current deposition levels is difficult because of 1) the high natural background of Zn in the moss and 2) leaching of Zn from the moss due to airborne marine cations.
Characterizing atmospheric deposition of metals around major industries in Norway (2000 - 2005 - 2010)

Purpose:
Mapping of local deposition of metals from industries, mostly aluminium and iron alloy manufacturing plants situated within or adjacent to densely built-up areas, and comparing with data from previous surveys

Extent:
Sixteen industries distributed among 13 towns

Sampling:
Five sites around each enterprise

Elements:
59 elements determined by ICP-MS
Distribution of Copper and Tellurium around the Kristiansand copper-nickel smelter (ppm in moss)

- Other elements showing similar distribution: Ni, Co, Ag, Bi
Distribution of Beryllium around the Årdal aluminium smelter (ppm)

- Other trace elements showing similar distribution:
  - Ni, Ga, Sb, Te, Bi
Sampling network around the mixed metal industries in Mo i Rana:

A. Ferromanganese smelter
B. Ferrosilicon factory
C. Recovery of metals from mixed scrap metal
Distribution of some elements among sites close to the Mo industrial area:

A closer look
Distribution of four metals in moss at sites surrounding the Mo industries

- Be
- Cr
- Mn
- Zr
Some results from the study of emissions from local industries:

- Some factories have reduced their emissions substantially over the period 2000-2010.

- In other cases no appreciable improvement is noted, and still much remains to be done to achieve satisfactory levels.

- In several cases appreciable emissions of elements normally receiving little attention in industrial emissions were observed. Examples are Be, Zr, Nb, Mo, Ag, In, Te, W, Bi.

- In one particular case with three different enterprises located within the same industrial area the distributions of elements among sampling sites may help to identify the major source of each element.
Transect for air sampling of POPs using Semi-permeable Membrane Devices (SPMD)
(Lancaster University/Trondheim University: 1994-present)

PCB air sampling in the UK and Norway

10,000 pg PCB/SMPD

1994-1996
1998-2000
2000-2002
2002-2004
2004-2006
2006-2008
Sampling sites for 2010 study of POPs in moss

Substances investigated:

- 32 PCBs
- DDT/DDE
- HCB; PeCB
- HCH: 3 isomers
- 16 PAHs
- 17 brominated flame retardants

Sampling:

Whole moss plant, clean hands. 3 liters in clean glass jar. Sample stored at -21°C

Clean-up and determination:

Depending on the substances concerned
PCB in moss at different sites in Norway 2010 (pg/g)

Site numbers refer to map

<table>
<thead>
<tr>
<th>Congener groups</th>
<th>South (1-2-3)</th>
<th>North (19-20)</th>
<th>Ratio south/north</th>
<th>Oslo (5)</th>
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<tbody>
<tr>
<td>3CB</td>
<td>94</td>
<td>38</td>
<td>2.5</td>
<td>79</td>
</tr>
<tr>
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<td>108</td>
<td>44</td>
<td>2.5</td>
<td>388</td>
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<td>6CB</td>
<td>219</td>
<td>61</td>
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<td>7CB</td>
<td>126</td>
<td>23</td>
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<tr>
<td>CB 194/206</td>
<td>4.3</td>
<td>0.50</td>
<td>8.6</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Conclusions:

- The atmospheric deposition of most metals has declined substantially in Norway over the last 30 years, and there is still a decline from 2005 to 2010.

- Deposition of several toxic metals in southern Norway is still influenced by transboundary atmospheric transport from other parts of Europe.

- The moss technique is shown to be useful in monitoring metal deposition in the vicinity of Norwegian aluminium and ferro-alloy smelters.

- Persistent organic pollutants such as PCB, DDT, PAH, and brominated flame retardants are retained in moss, and their observed geographical distribution in 2010 samples indicate that moss may reflect their atmospheric deposition patterns adequately.