

THE EUROPEAN MOSS SURVEY AS SEEN FROM SCANDINAVIA

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Sampling methods – particulate air pollutants

Air concentration:

Pumping of air through filters

”Bulk deposition”:

Collection of wet and dry deposition in open buckets

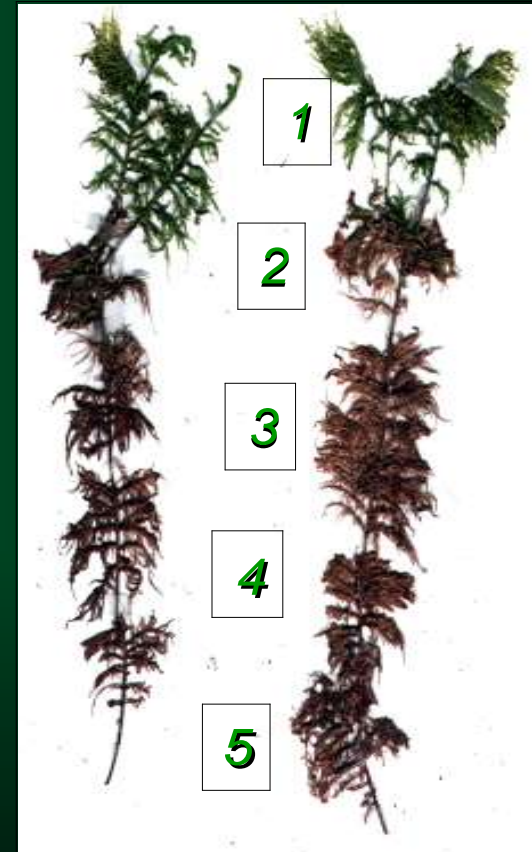
Both methods depend on a certain technical set-up, and therefore are restricted to a limited number of sampling sites.

NILU bulk deposition sampler (Norwegian institute for air research)



Moss biomonitor

*Hylocomium
splendens*



Moss annual segments

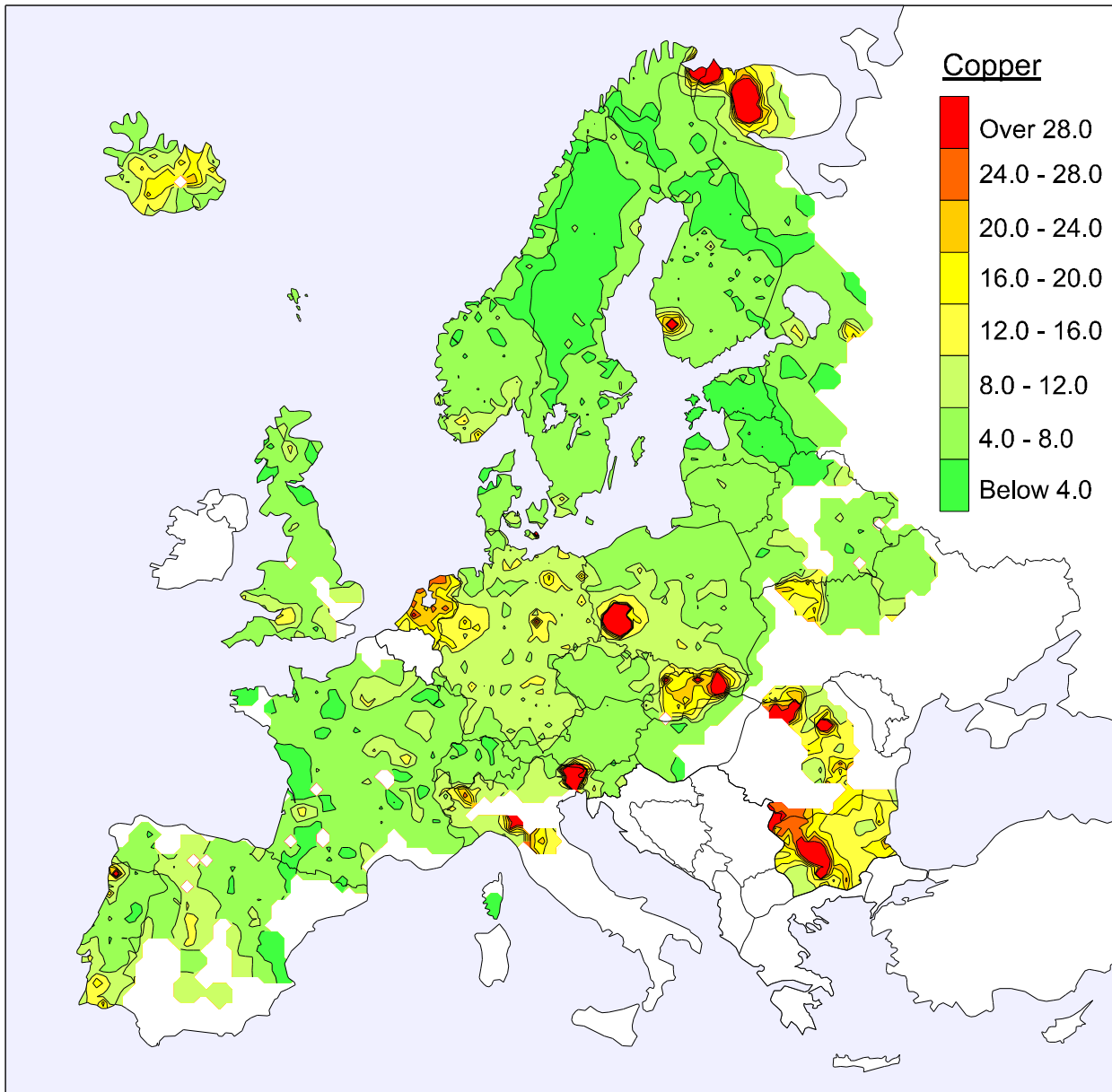
Mosses :

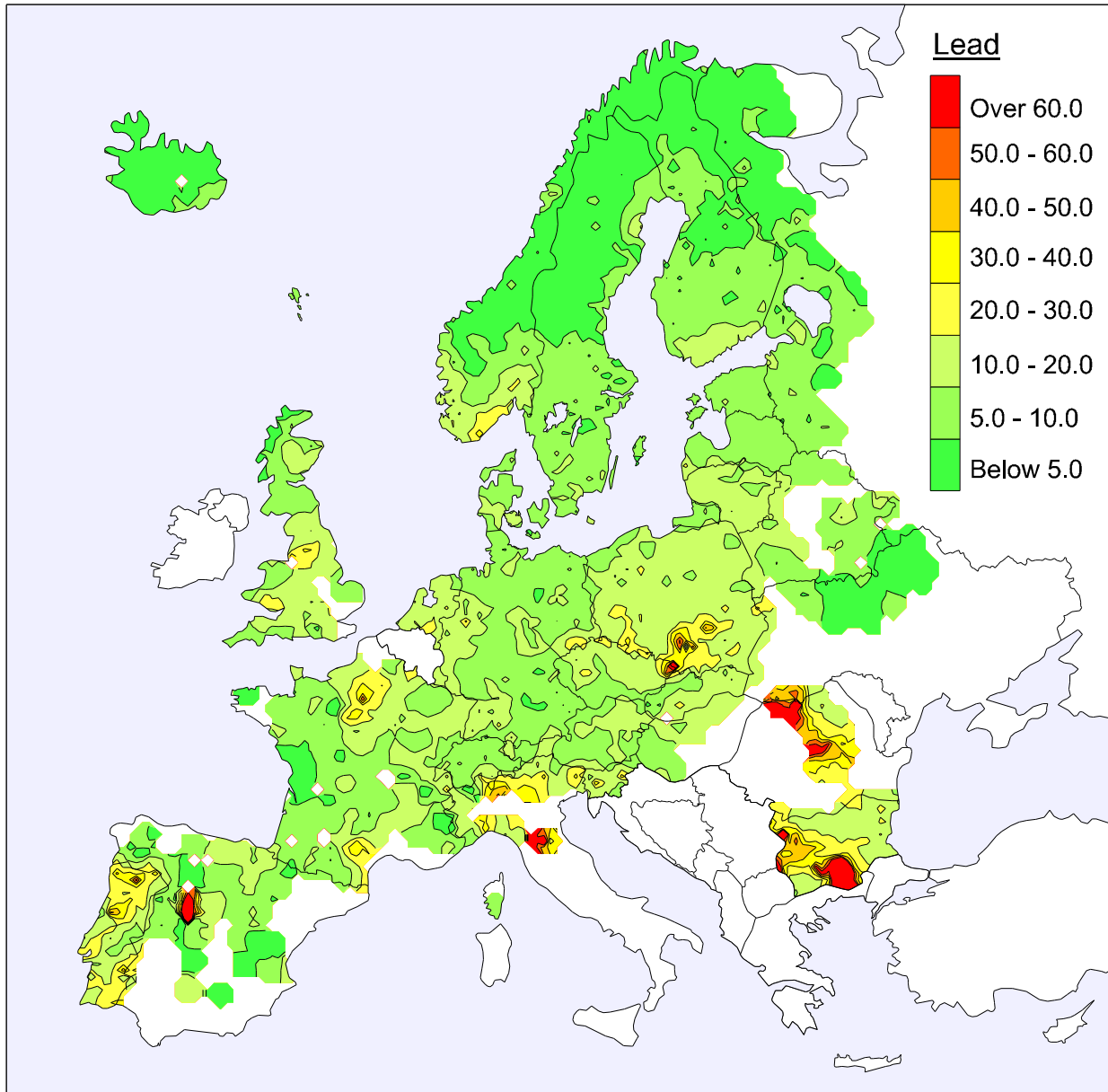
- have a high capacity to bind metals
- have no root system (unlike higher plants)
- are easy to sample
- are widely distributed
- concentrate metals 100-1000 times their levels in precipitation

Therefore they are useful and popular biomonitors of atmospheric metal deposition

History of moss biomonitoring surveys in Europe:

- 1968: Moss technique was first proposed
(Åke Rühling and Germund Tyler, Lund University, Sweden)
- 1975: First nationwide survey in Sweden
(Åke Rühling and Lena Skärby)
- 1977: First nationwide survey in Norway
(Eiliv Steinnes)
- 1985: First joint Nordic Survey (Denmark, Finland, Norway, Sweden)
(Åke Rühling, coordinator, [supported by Nordic Council of Ministers](#))
- 1990: Joint Nordic/Baltic survey (adding Iceland, Estonia, Latvia, Lithuania)
(Åke Rühling, coordinator)
- 1995: First European survey, 28 countries
(Åke Rühling and Eiliv Steinnes, coordinators)
- 2000: Second European survey, 28 countries
Coordinated by UN ICP Vegetation
- 2005: Third European survey, 28 countries
Coordinated by UN ICP Vegetation
- 2010: Fourth European survey, 27 countries
Coordinated by UN ICP Vegetation
- 2015: Fifth European survey, ? countries
to be coordinated by Marina Frontasyeva, JINR, Dubna





Metal deposition surveys in Norway:

Ca. 500 sites

Hylocomium splendens

Substitute: *Pleurozium schreberi*

1977, 1985, 1990, 1995, 2000, 2005, 2010

Analytical techniques used for trace element determinations 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, RE, Sm, Hg, Th, U

AAS: Ni, Cu, Cd, Pb

B. 1990, 1995, 2000

ICP-MS: **Li**, **Be**, **B**, Na, Mg, Al, **Ca**, Sc, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, **Ga**, As, Rb, **Sr**, **Y**, Mo, Cd, **In**, **Sn**, Sb, Cs, **Ba**, RE, (Hg), **Tl**, Pb, **Bi**, Th, U

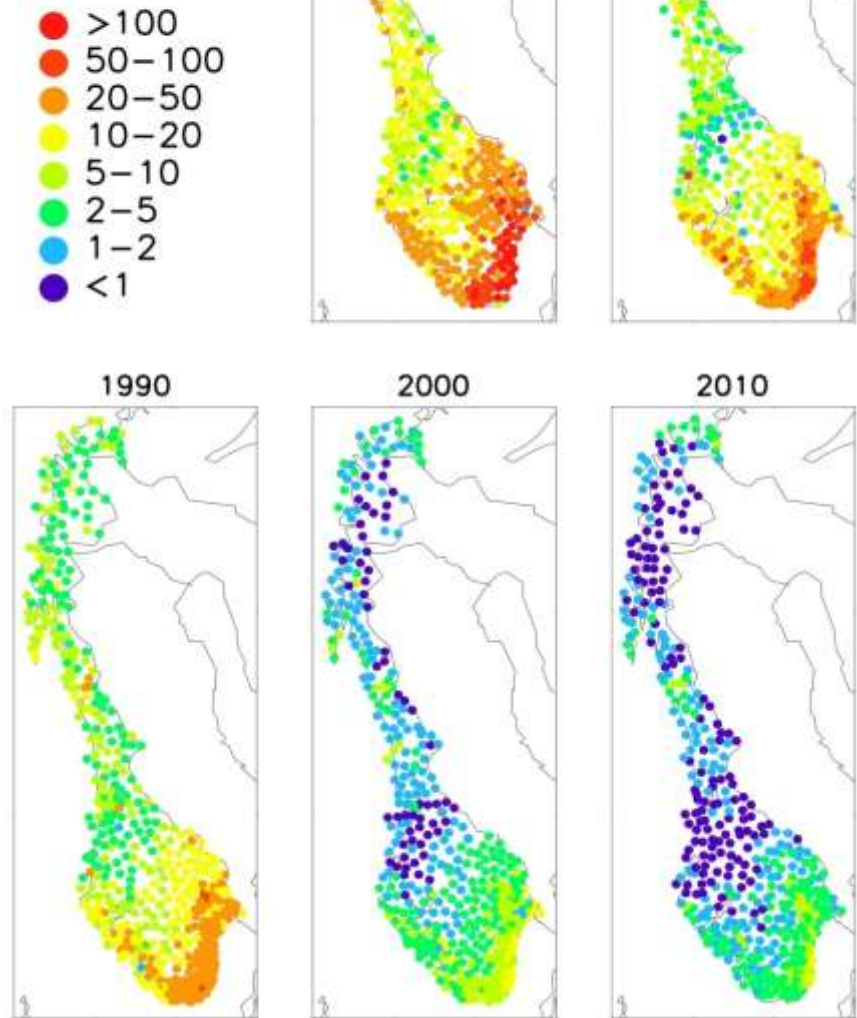
AFS: **Hg**

Priority elements– European moss survey:

V, Cr, Fe, Ni, Cu, Zn, As, Cd, Hg, Pb

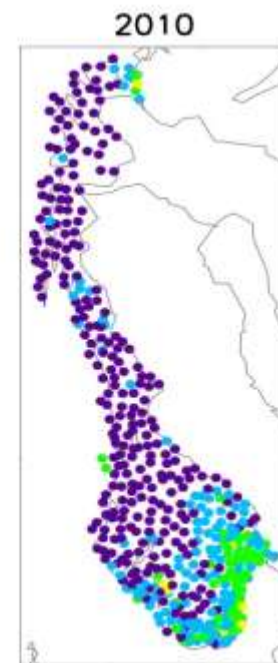
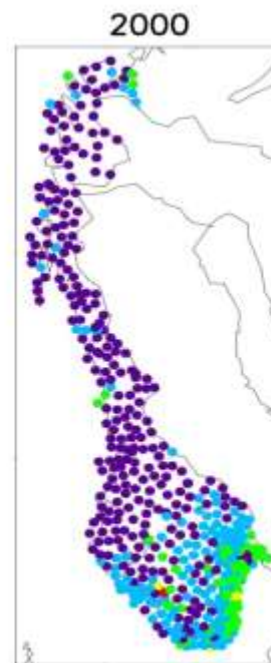
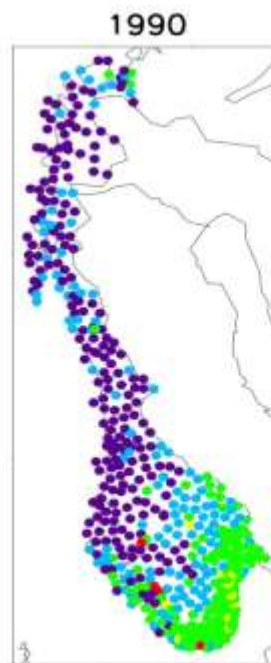
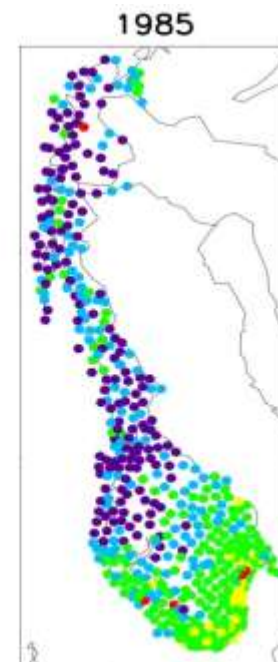
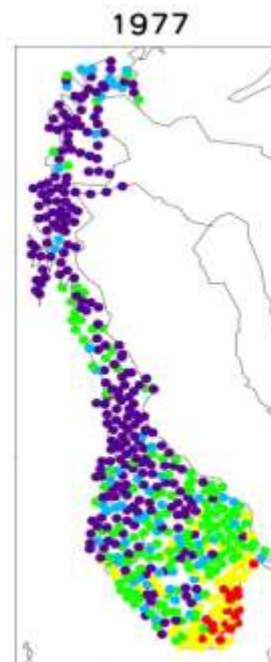
Pb in moss in Norway (μg^{-1}):

Temporal trends 1977-2010

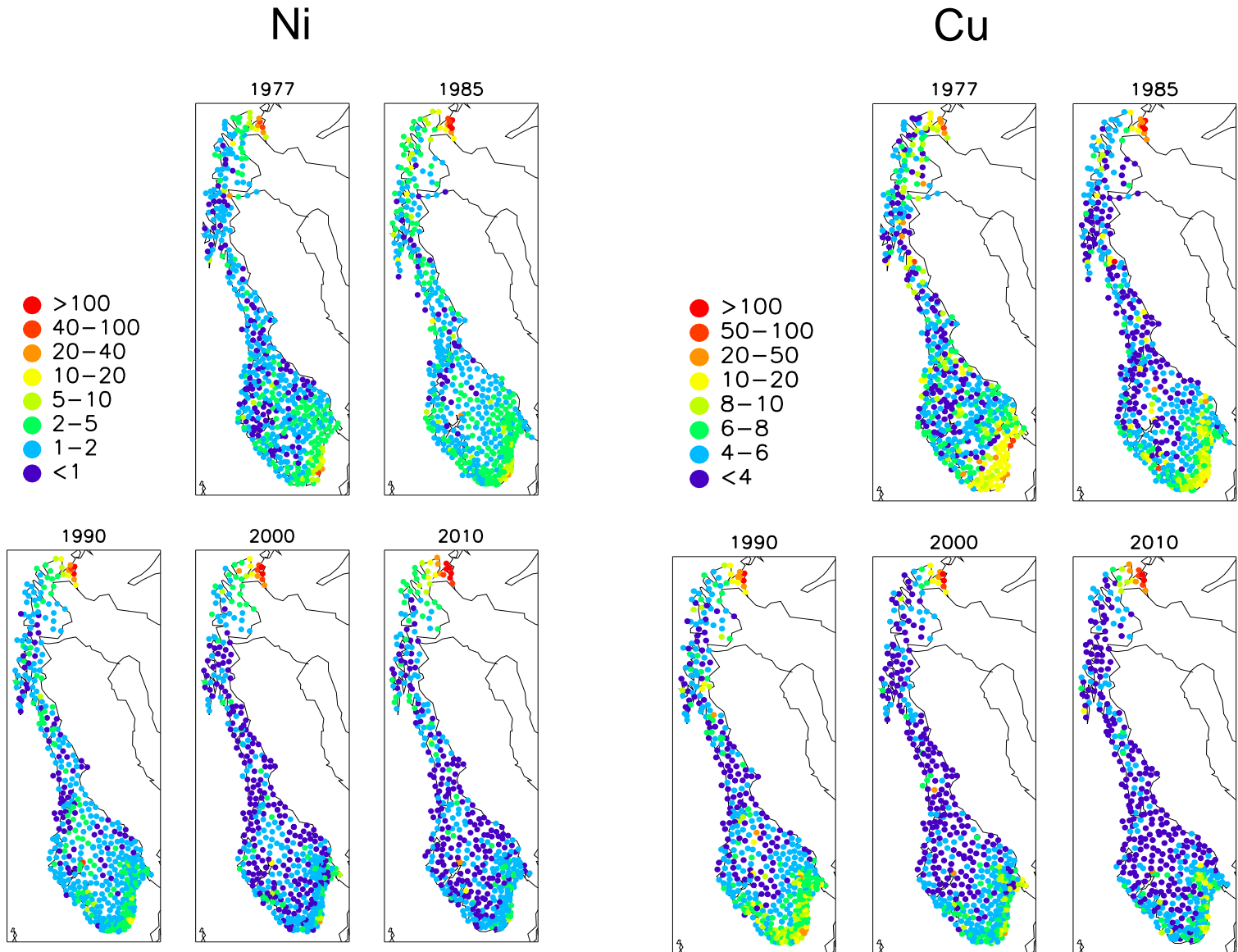


Cd in moss in Norway (μg^{-1}):

Temporal trends 1977-2010



Concentrations of metals in moss in Norway 1977 - 2010



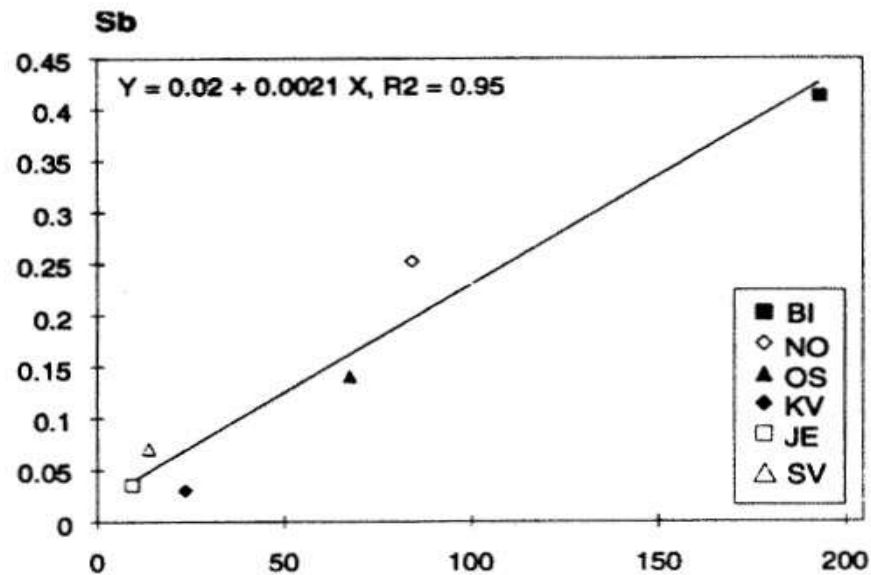
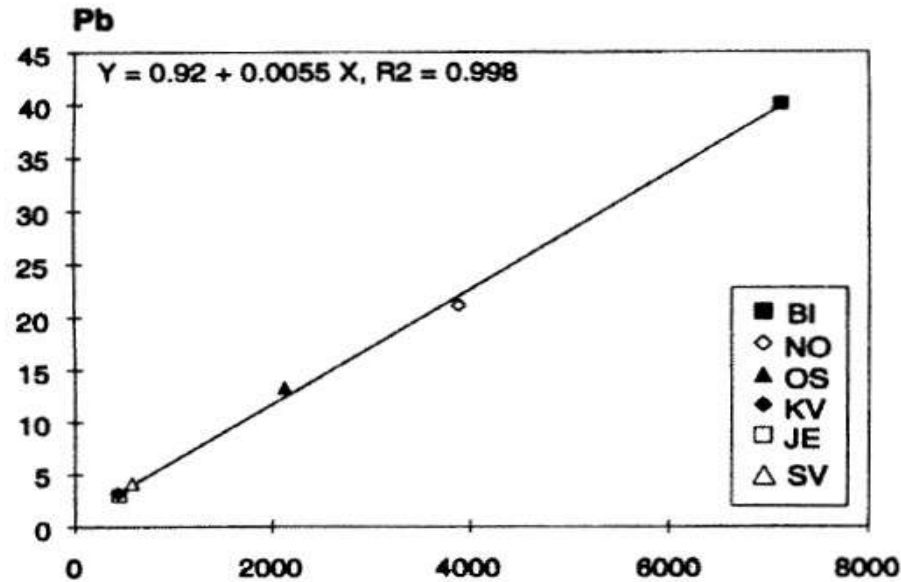
1990 moss samples in Norway: Factor loadings

Factor No	1	2	3	4	5	6	7	8
Expl. Var. %	28.8	15.0	10.3	7.0	6.6	4.5	4.2	3.5
Li		0.67						
B				0.81				
Na				0.74				
Mg				0.88				
Al		0.67						
Ca				0.61				
V	0.78							
Cr						0.85		
Mn								0.61
Fe						0.88		
Co			0.93					
Ni			0.98					
Cu			0.97					
Zn					0.91			
Ga		0.58						
As	0.64		0.56					
Rb							0.81	
Sr								
Y		0.82						
Mo	0.87							
Cd					0.87			
Sb	0.88							
Cs							0.82	
Ba								0.86
La		0.85						
Hg					0.71			
Tl	0.61							
Pb	0.88							
Bi	0.90							
Th		0.78						
U		0.70						

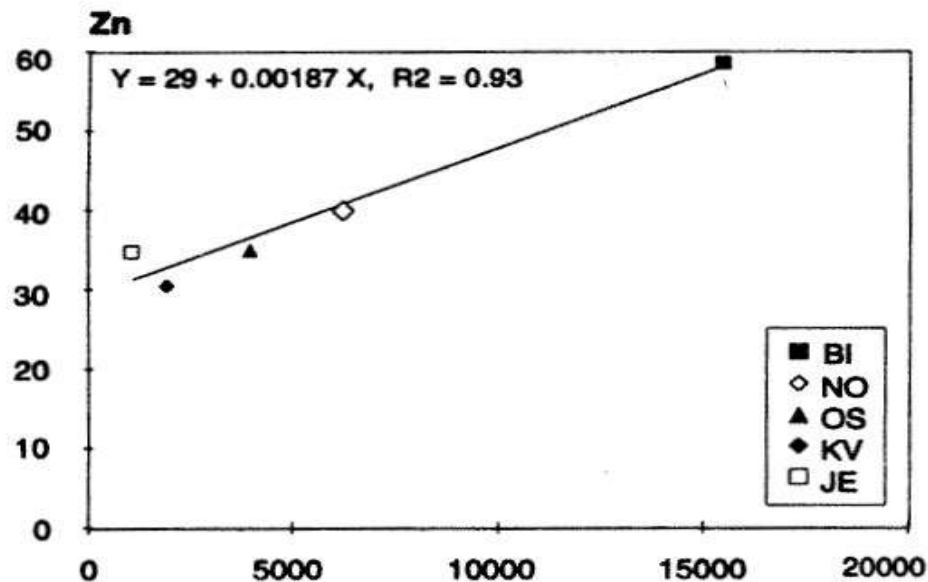
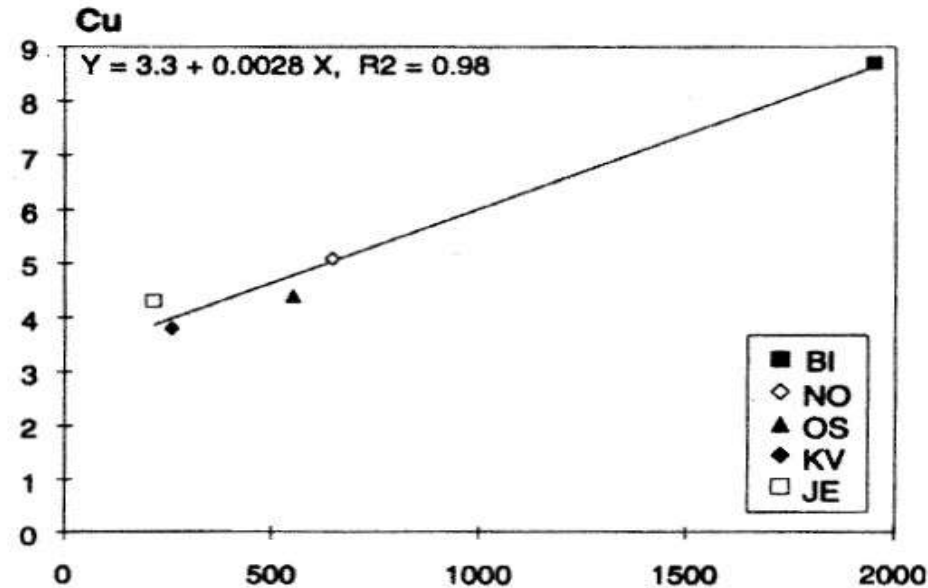
Station network Calibration moss/deposition 1990



Calibration of concentration in moss ($\mu\text{g/g}$) against bulk deposition ($\mu\text{g/m}^2$)



Calibration of concentration in moss ($\mu\text{g/g}$) against bulk deposition ($\mu\text{g/m}^2$)

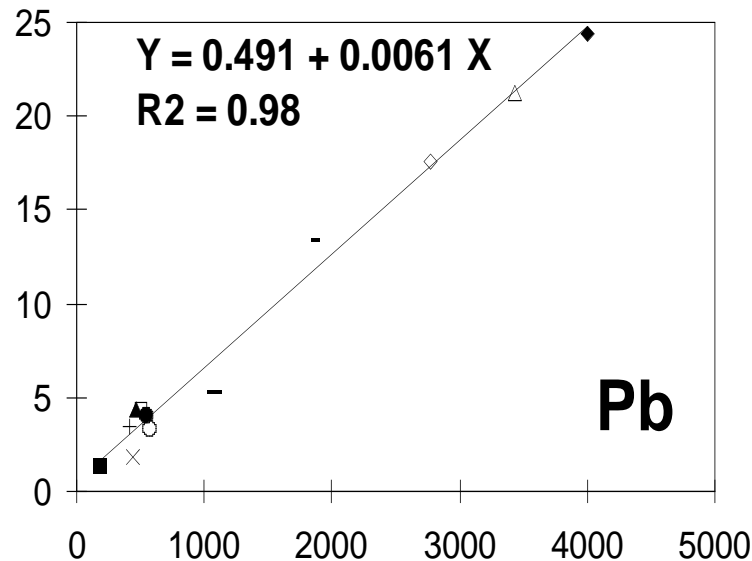


Sites for collection of precipitation samples 1993-1995 (T. Berg and E. Steinnes, Environ. Pollut. 98, 61-71 (1997))

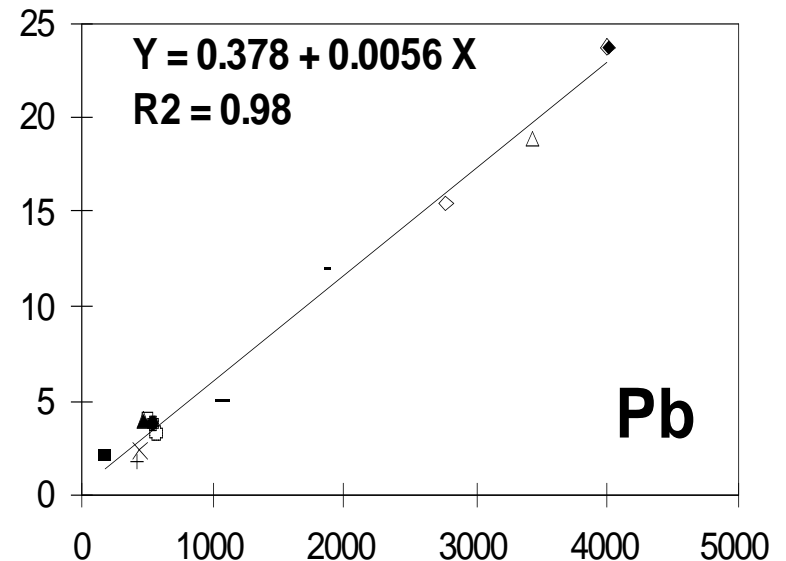


Concentrations of Pb in *Hylocomium splendens* and *Pleurozium schreberi* ($\mu\text{g g}^{-1}$) versus atmospheric bulk deposition ($\mu\text{g m}^{-2}$)

H. Sp.

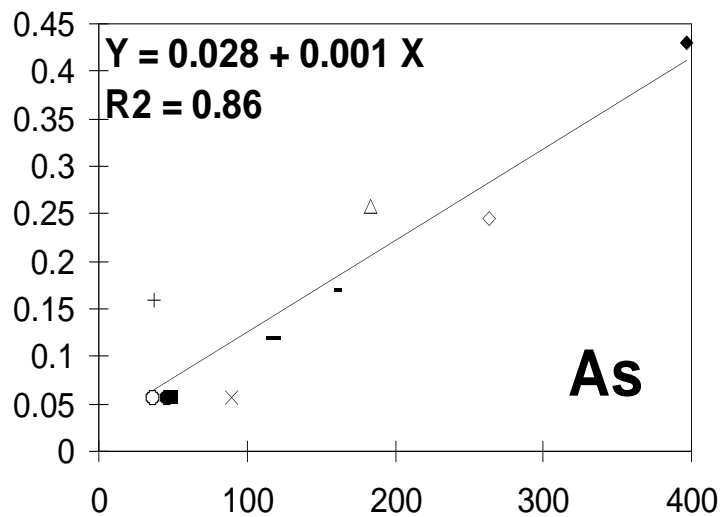


Pl. Sch.

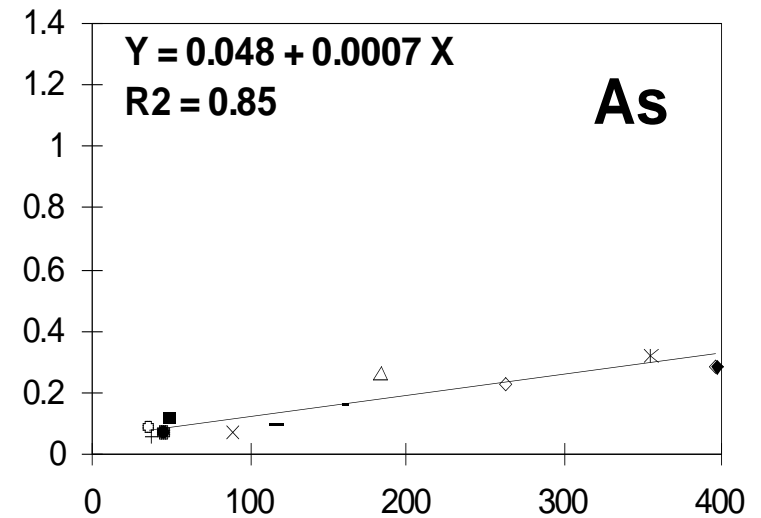


Concentrations of As in *Hylocomium splendens* and *Pleurozium schreberi* ($\mu\text{g g}^{-1}$) versus atmospheric bulk deposition ($\mu\text{g m}^{-2}$)

H. Sp.

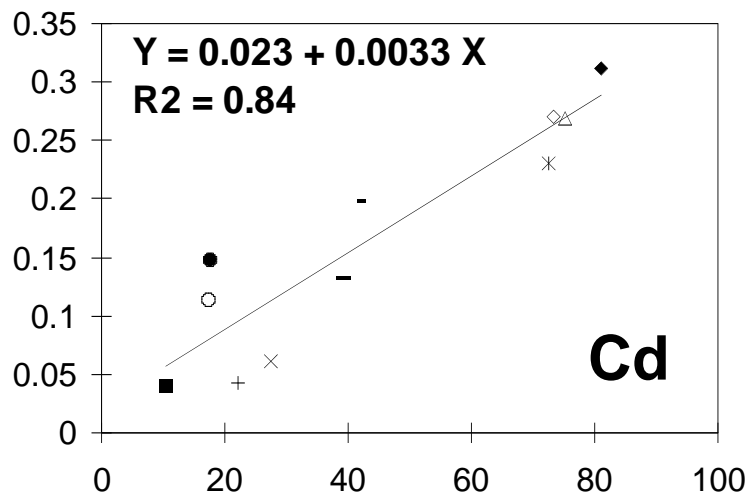


Pl. Sch.

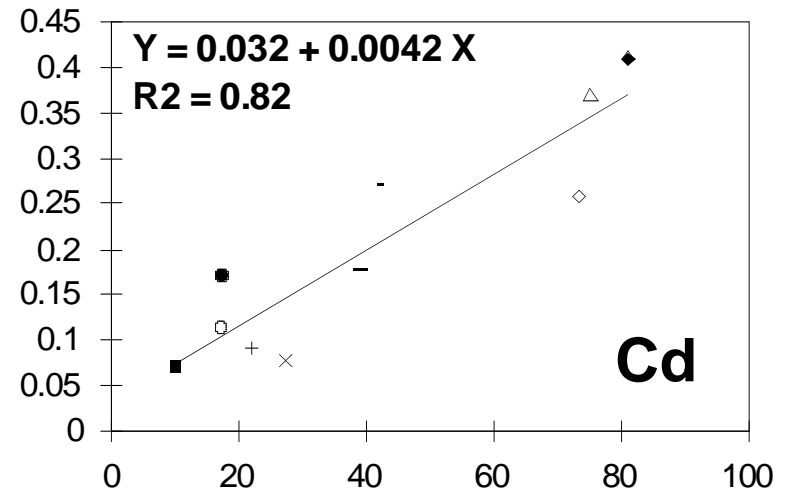


Concentrations of Cd in *Hylocomium splendens* and *Pleurozium schreberi* ($\mu\text{g g}^{-1}$) versus atmospheric bulk deposition ($\mu\text{g m}^{-2}$)

H. Sp.



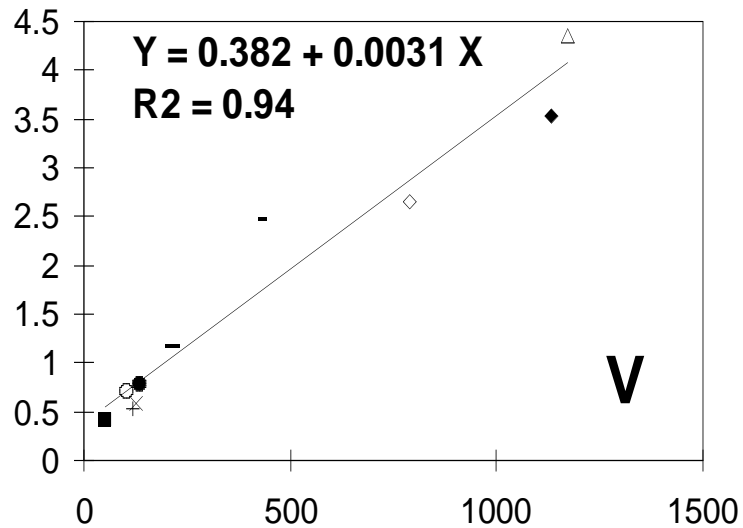
Pl. Sch.



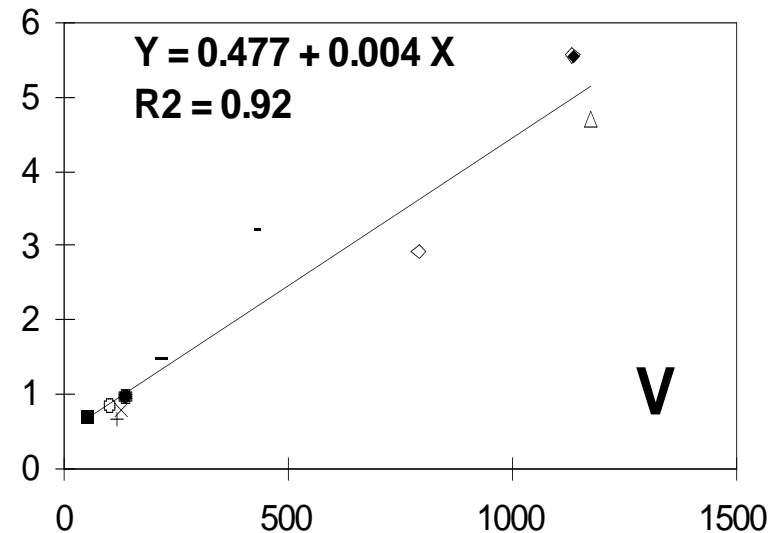
The scatter in the lower end is mainly due to very low levels of Cd in precipitation samples

Concentrations of V in *Hylocomium splendens* and *Pleurozium schreberi* ($\mu\text{g g}^{-1}$) versus atmospheric bulk deposition ($\mu\text{g m}^{-2}$)

H. Sp.

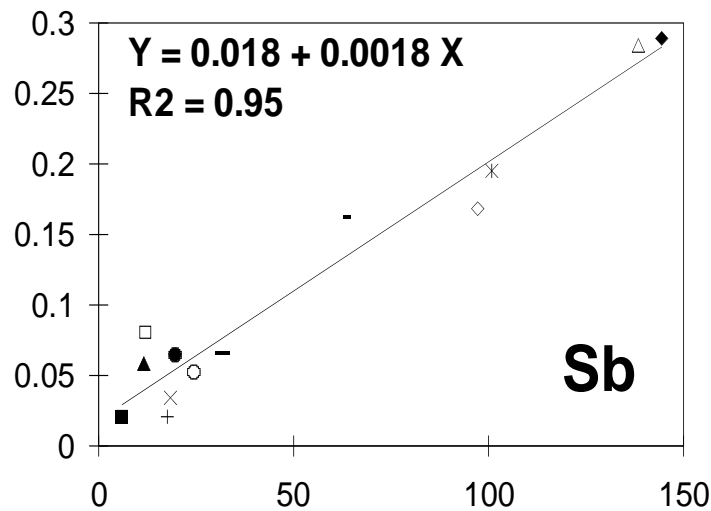


Pl. Sch.

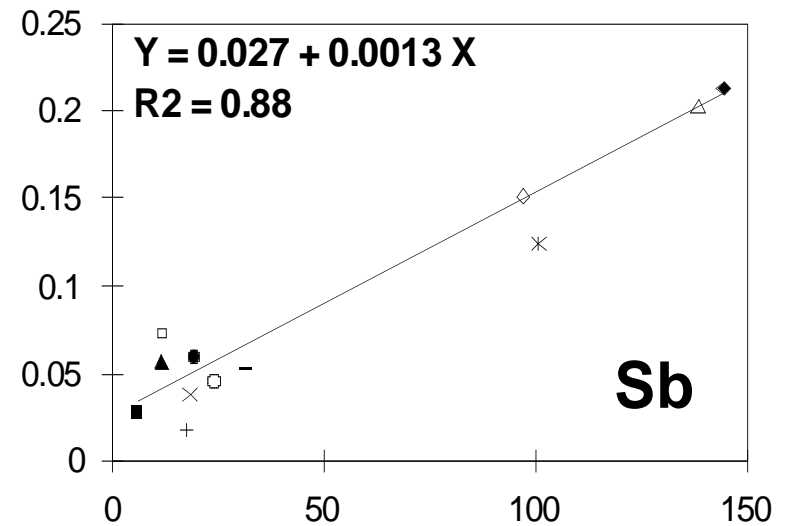


Concentrations of Sb in *Hylocomium splendens* and *Pleurozium schreberi* ($\mu\text{g g}^{-1}$) versus atmospheric bulk deposition ($\mu\text{g m}^{-2}$)

H. Sp.



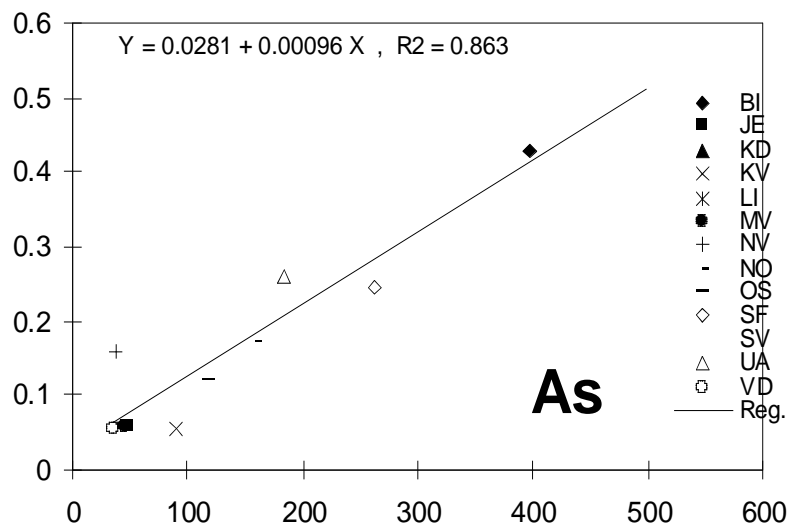
Pl. Sch.



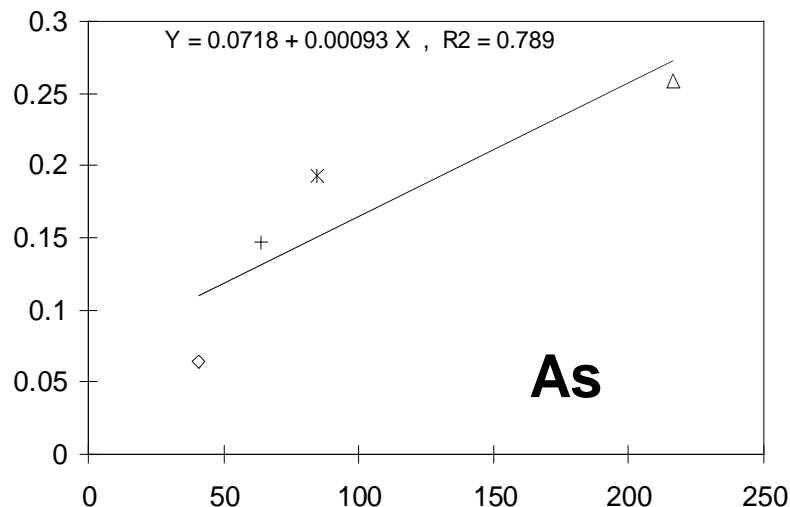
Calibration moss/deposition using data from different Nordic countries

T. Berg, A. Hjellbrekke, Å. Rühling, E. Steinnes, E. Kubin, M.M. Larsen and J. Piispanen:
Absolute deposition maps of heavy metals for the Nordic countries based on moss surveys.
Report TemaNord 2003:505, Nordic Council of Ministers, Copenhagen 2003.

Denmark + Norway



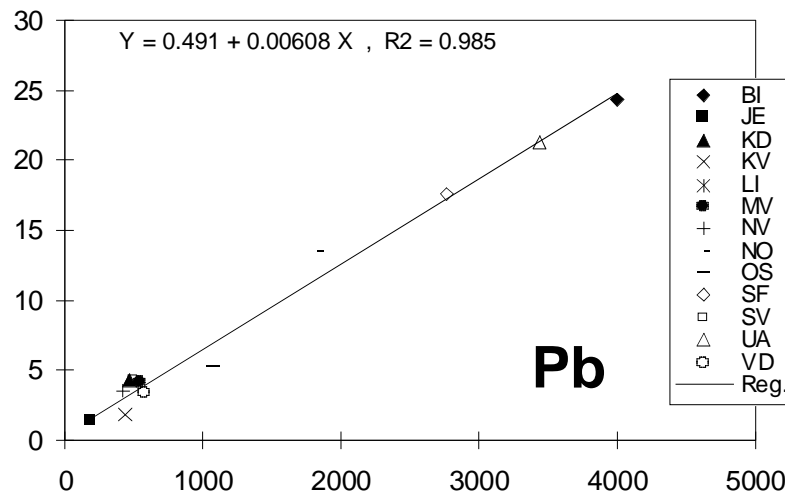
Finland + Sweden



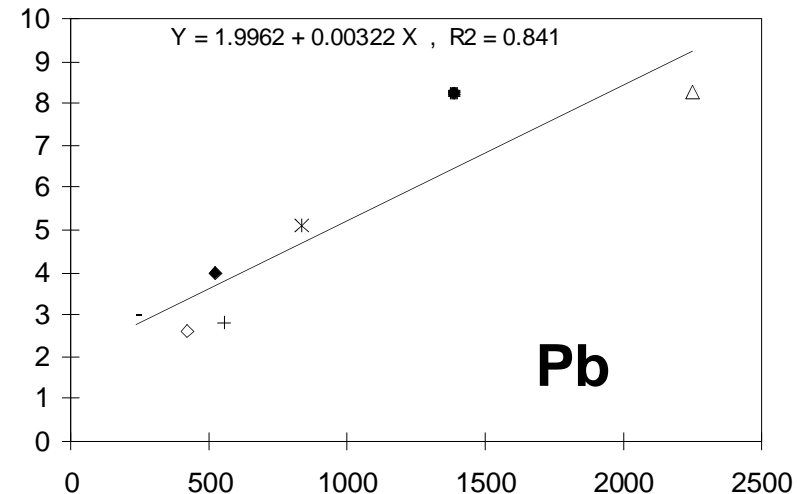
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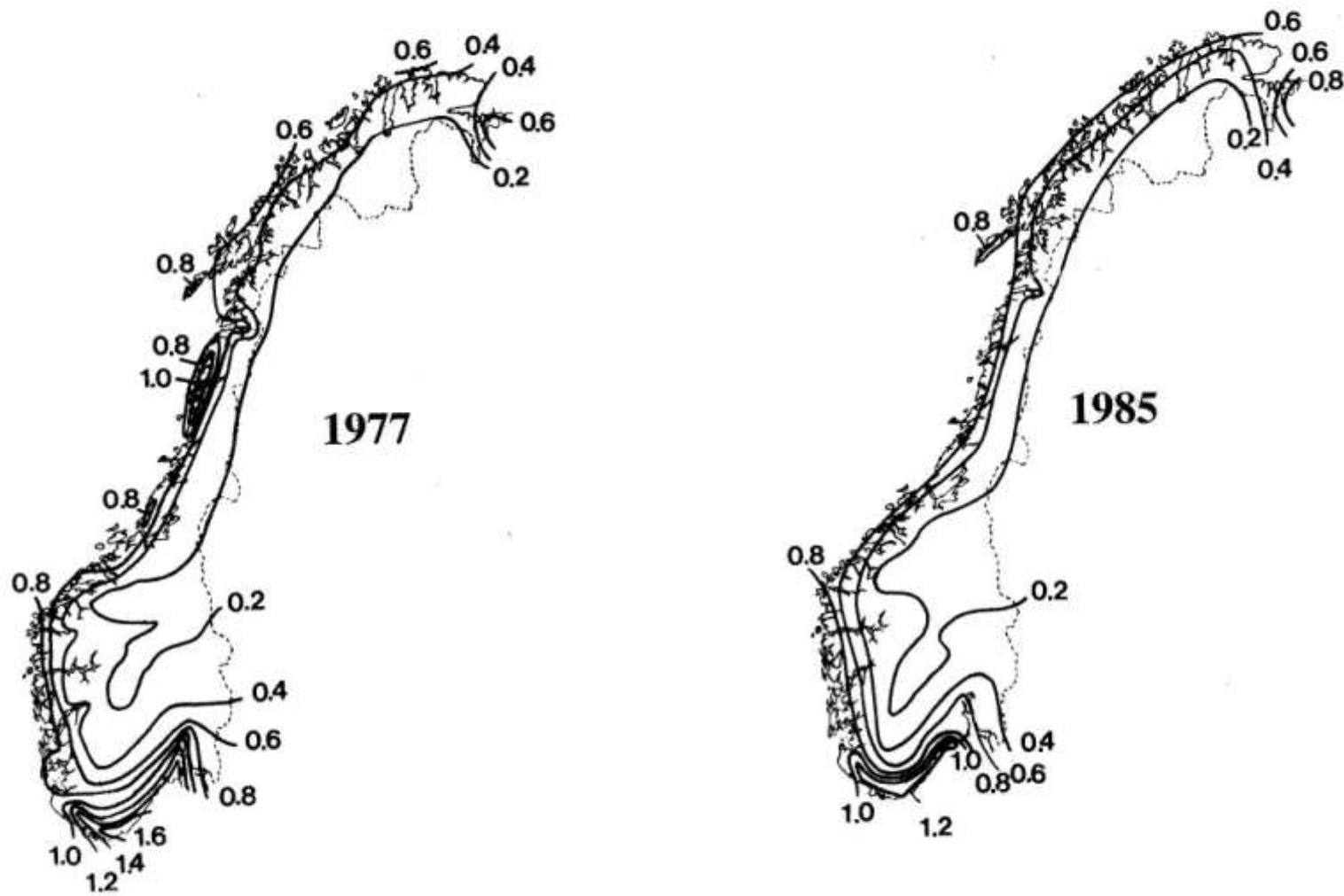
Denmark + Norway



Finland + Sweden

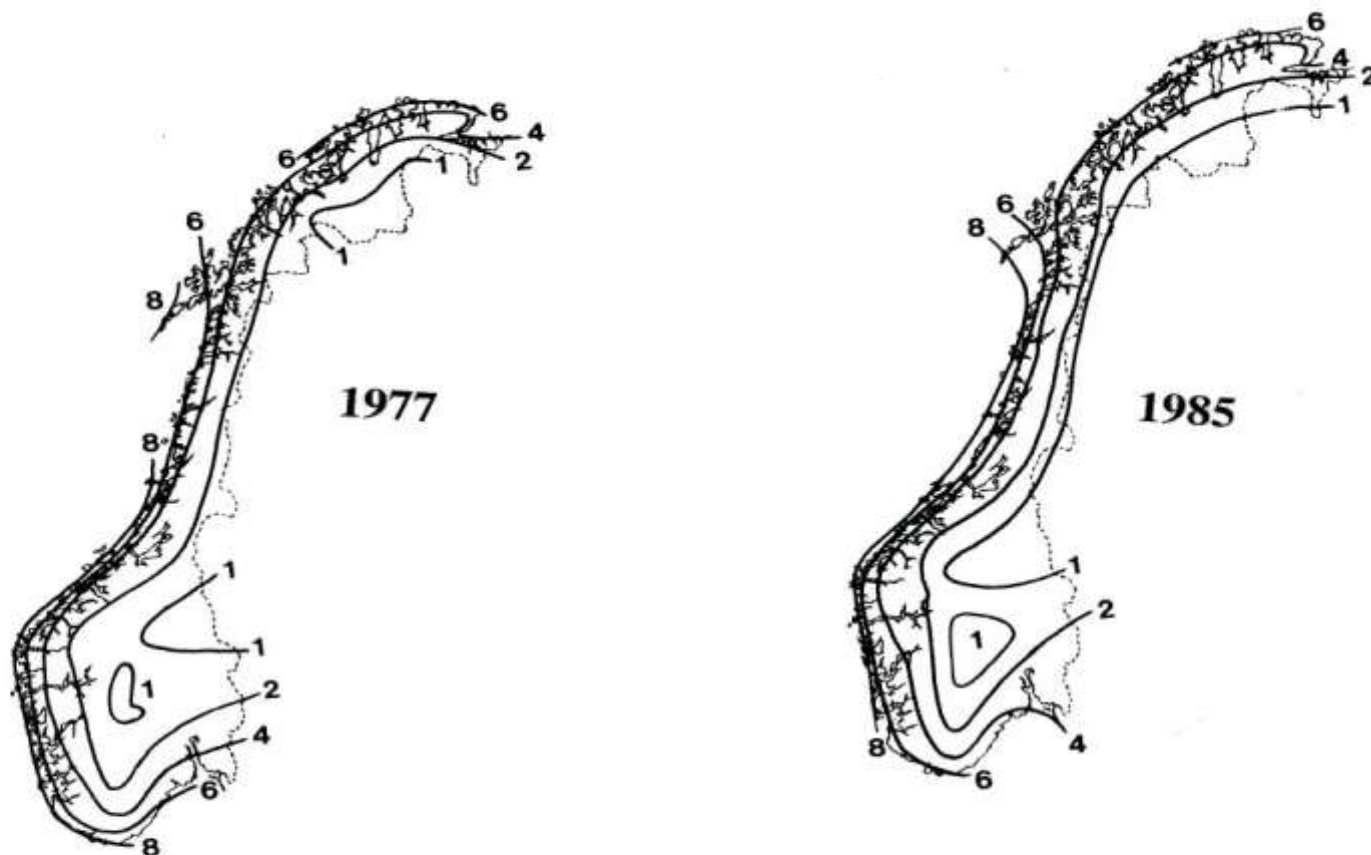


National moss survey



Se (ppm)

National moss survey



I (ppm)

Relative influence from different sources to the elemental composition of mosses in rural and remote areas

Element	Air pollution	Marine factor	Local factor	Soil factor
Al				+++
V	++			+
Cr	+			++
Mn		- -	+++	
Fe	+			+++
Ni	++			++
Cu	++		+	
Zn	++	-	++	
As	+++	-		+
Se	++	++		
Sr		+++		
Cd	++		+	
Sb	+++			
Hg	++			+(?)
Pb	+++			

How to secure the **quality** of future moss surveys?

- A. Standard reference materials should always be analyzed along with the moss samples.
- B. In case of new moss species inter-calibration should be done versus *Pleurozium schreberi* or *Hylocomium splendens*.
- C. Contributions from factors other than air pollution to the element contents in moss should be identified and assessed if possible.

A. Reference samples recommended for the 2015 moss survey:

- Moss reference samples issued by the Finnish Forest Research Institute.

Recommended values exist for the 10 elements of priority in the European moss survey and 13 additional elements:

E. Steinnes, Å. Rühling, H. Lippo and A. Mäkinen: "Reference materials for large-scale metal deposition surveys". Accred. Qual. Assur. 2, 243-249 (1997).

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B. Need for inter-calibration of moss species:

- I. Relative efficiency for priority elements should be checked for newly introduced moss species, preferably versus *Pleurozium schreberi* or *Hylocomium splendens*.
- II. If *Pleurozium schreberi* or *Hylocomium splendens* does not exist in a new survey area, calibration of a new moss species may be done via some other species independently calibrated against one of the two above species.
- III. It has been assumed that *Pleurozium schreberi* and *Hylocomium splendens* have the same efficiency for capturing of elements from air and precipitation. Previous research (Berg & Steinnes, 1997) indicates that they may have a significantly different efficiency for some elements. This should be re-checked.

C. Contribution from factors other than air pollution to the element contents in moss*:

1. Uptake of element from the soil or other growth substrate.
2. Supply from natural sources of elements in the atmosphere.
3. Leaching of element from the moss due to competition with element from natural sources

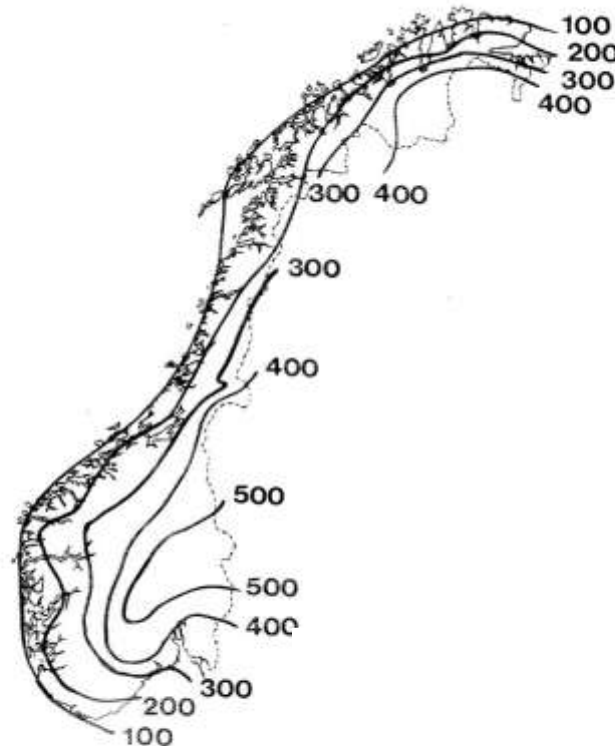
**See E. Steinnes: "A critical evaluation of the use of naturally growing moss to monitor the deposition of atmospheric metals". Sci. Total Environ. 160/161, 243-249 (1995).*

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Data from the 1977 moss survey in Norway:

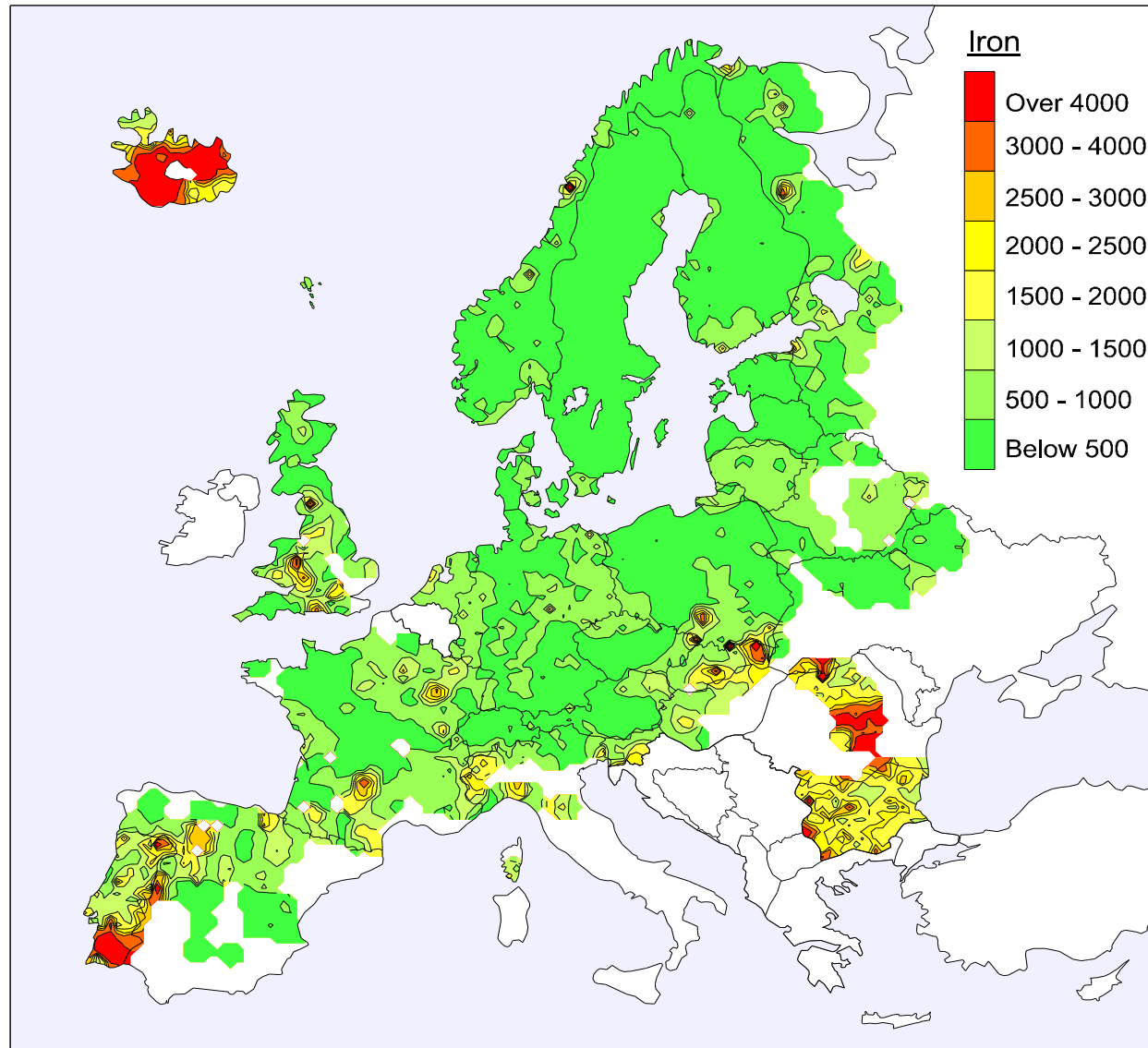
A. Mn uptake from the substrate

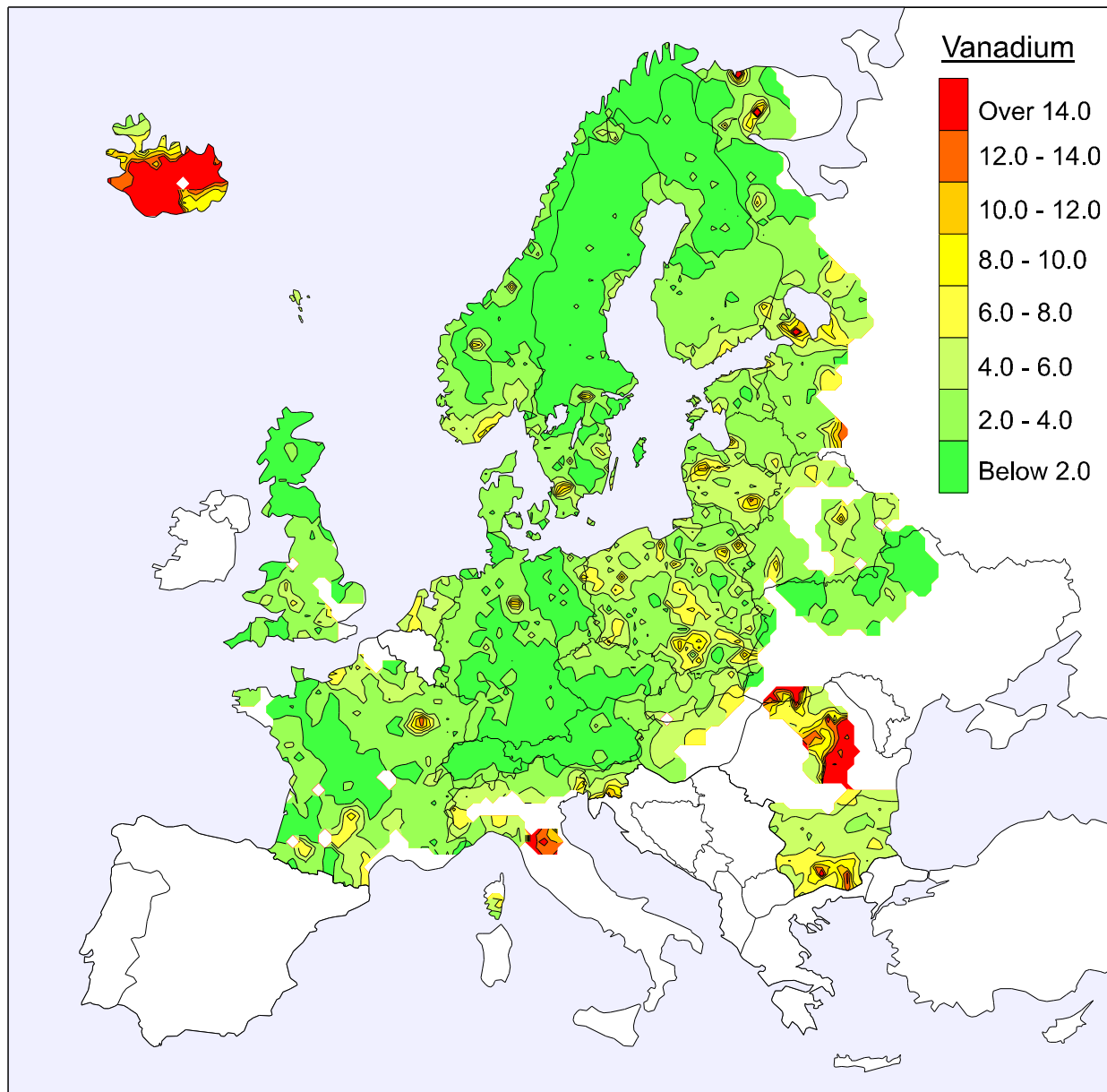
B. Exchange of Mn with marine cations



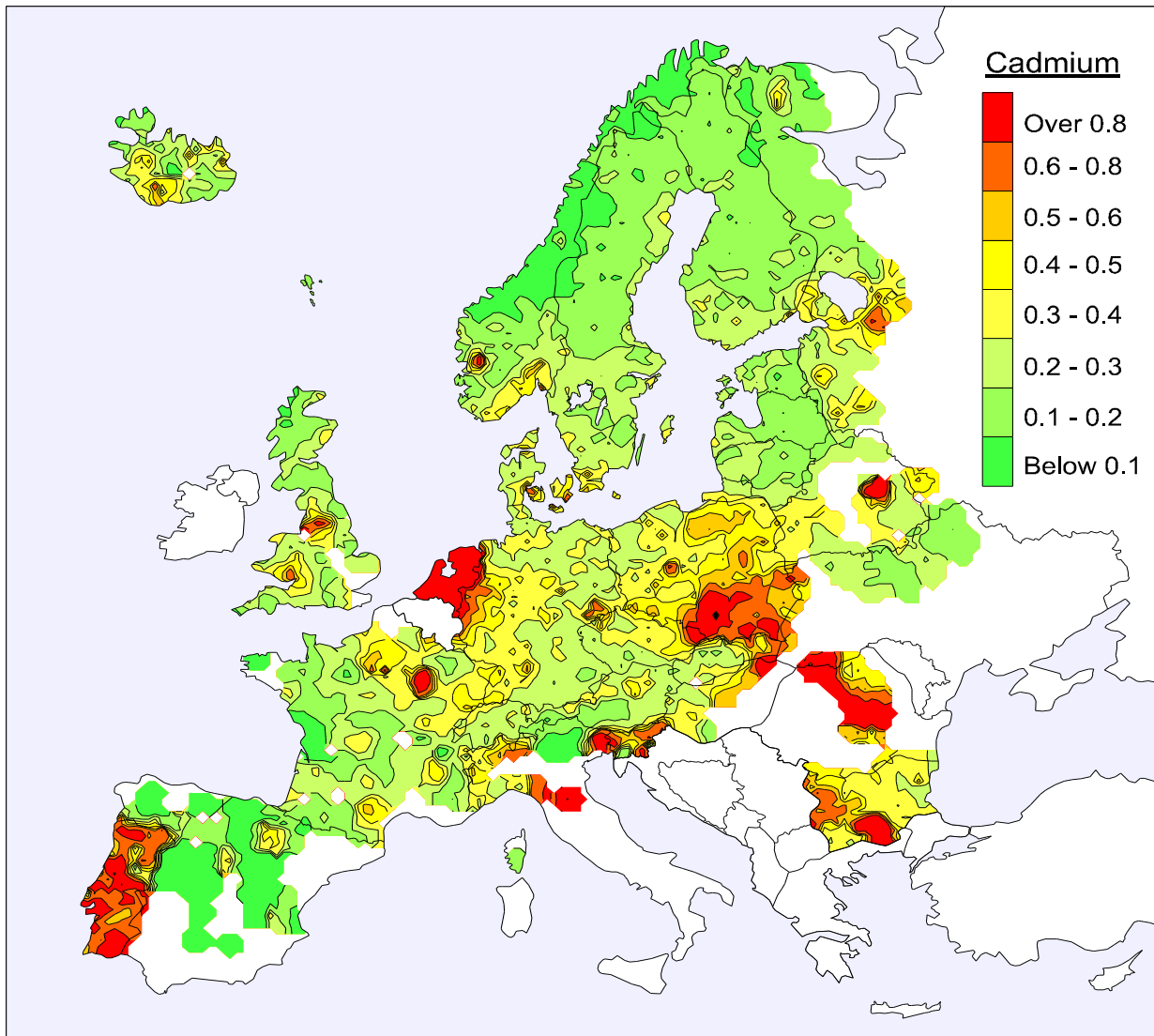
Mn ($\mu\text{g g}^{-1}$)

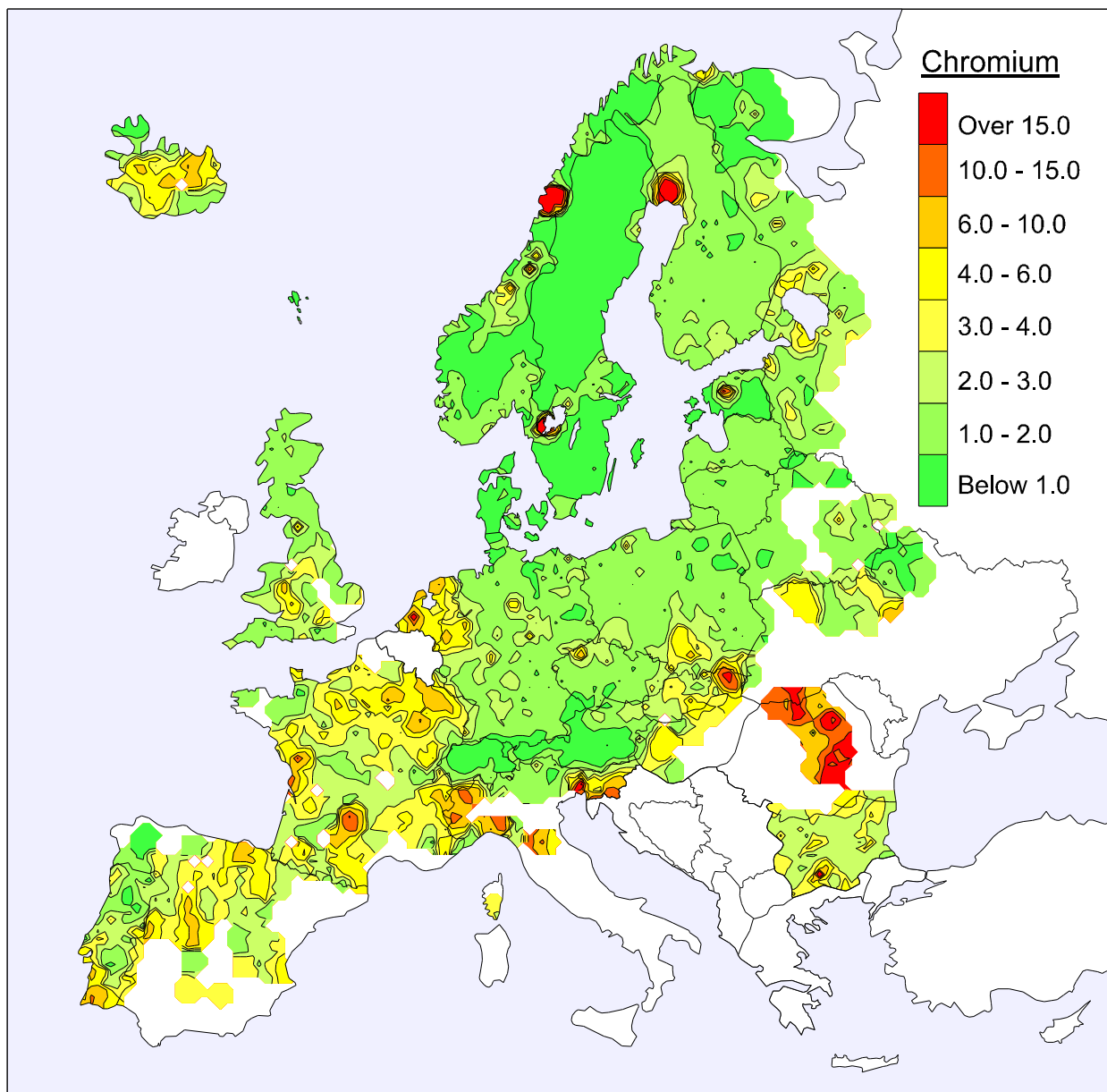
Iron in moss in Europe 1995 ($\mu\text{g g}^{-1}$): *Uniform high values in some areas due to soil contamination*

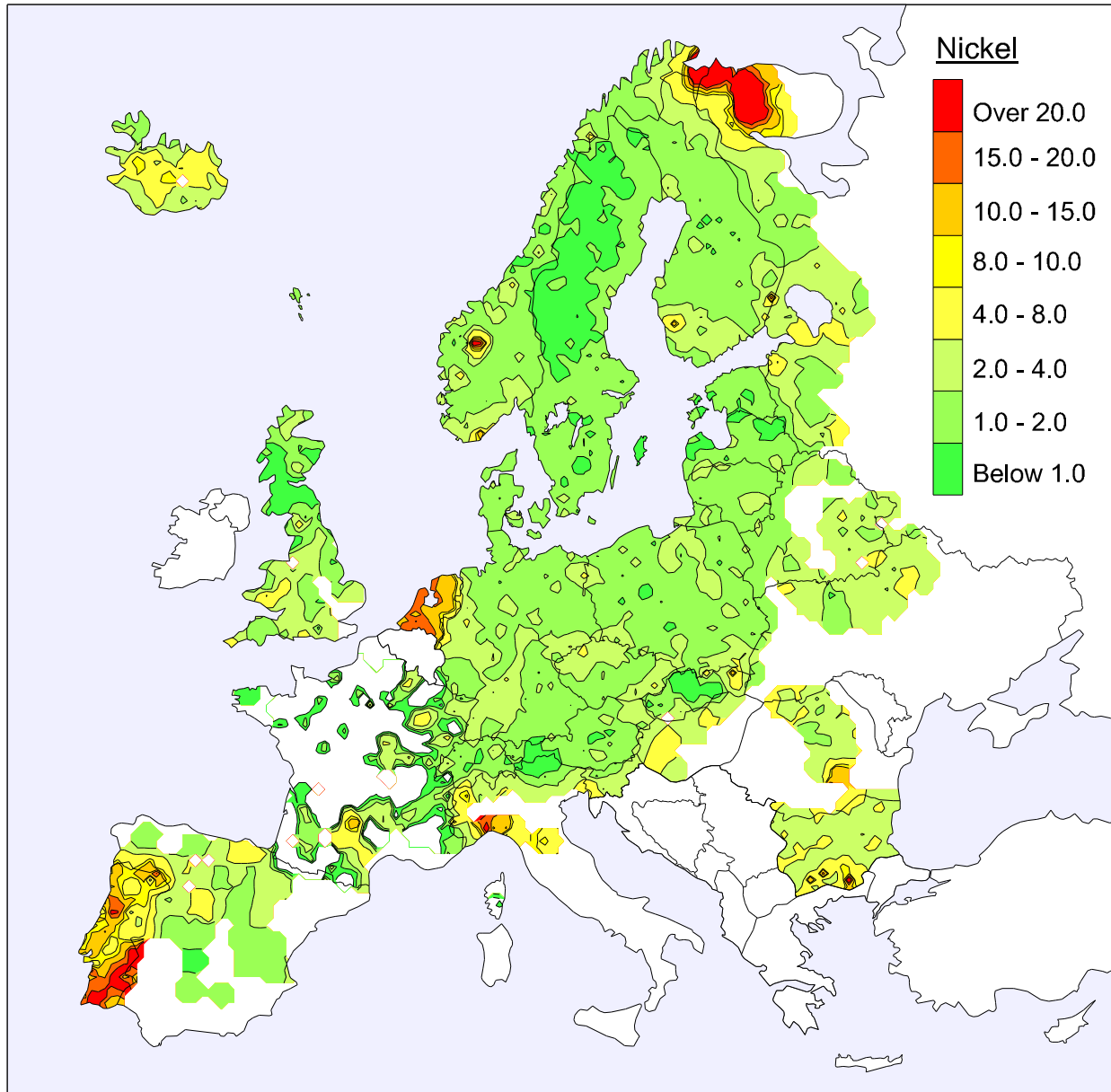




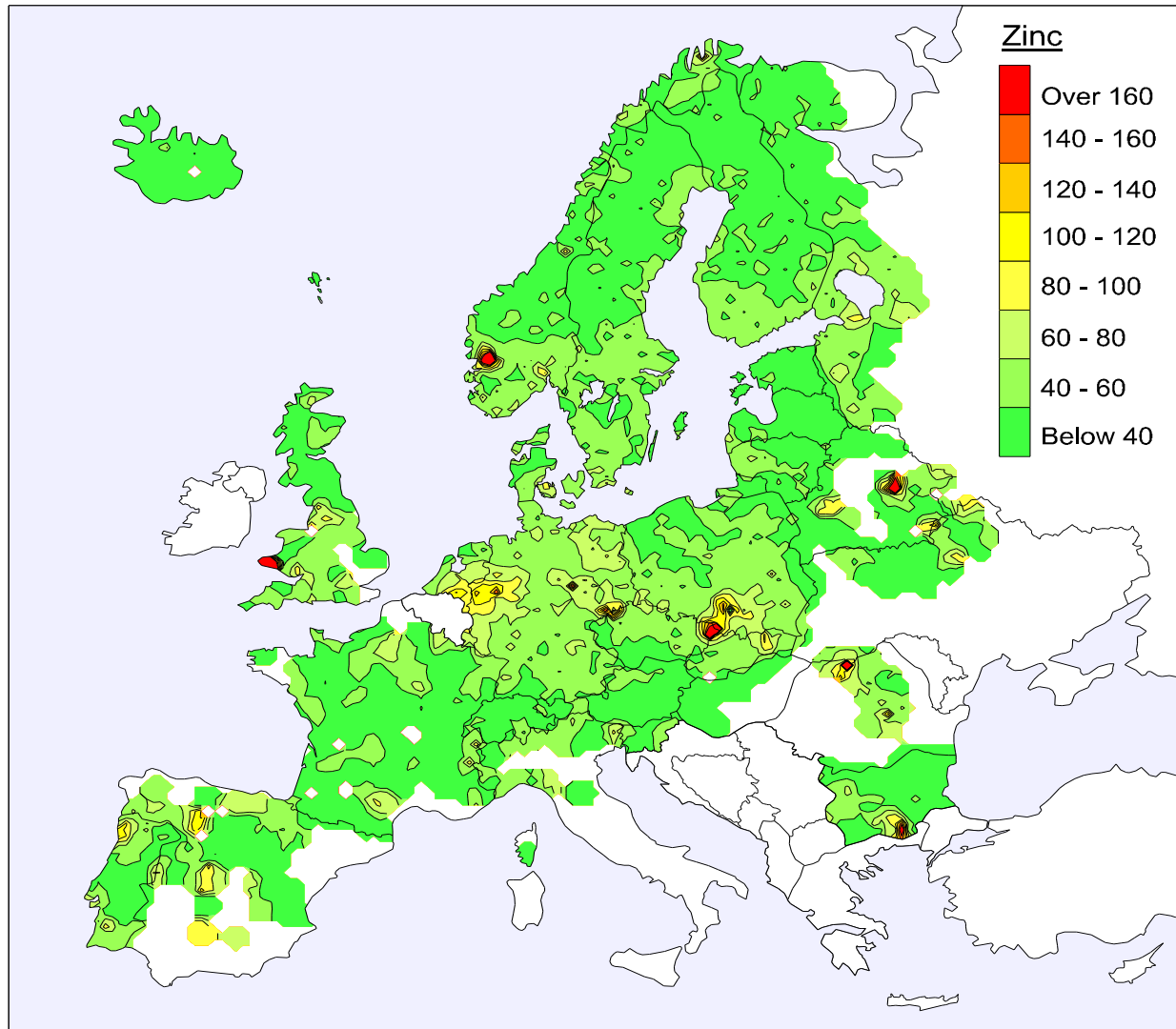
Example on differences across borders due to poor chemical analyses in one or both countries







Uniform Zn concentration in moss all over Europe
associated with nutrient uptake from the substrate



Participating countries in the European moss survey 2010

A closer look to the participants:

Sampling covering the entire or most of the country:

Albania, Austria, Belgium, Bulgaria, Croatia, Czech rep., Estonia, Finland, France, Iceland, Kosovo, Macedonia, Norway, Poland, Romania, Slovakia, Slovenia, Sweden, Switzerland, totally 20.

Sampling covering only part of the country's territory:

Belarus, Denmark (Faroe Islands), Italy, Russia, Spain, Serbia, Ukraina, totally 7.

Previously participating countries declining in 2010:

Germany, United Kingdom, Netherlands, Latvia, Lithuania, Portugal

Final conclusion:

Aboal et al:

“Atmospheric deposition of metals cannot be accurately estimated from the concentrations in moss tissues”

Present work:

Based on proper calibration, concentrations of given elements can be precisely transformed to bulk deposition values within a given region, excluding influence from local point sources.

Extension to larger territories such as the European continent may require separate calibrations in different regions.