ATMOSPHERIC TRANSPORT OF METALS TO NORWAY 1975-2015

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Introduction

During the 1970s it became evident that "acid rain" due to long-range transport of polluted air from other parts of Europe was a major problem to freshwater fish in Norway. Analyses of moss samples in Sweden (Rühling and Tyler, 1971) and precipitation samples in southernmost Norway (Hanssen et al., 1980). confirmed that substantial amounts of heavy metals are supplied along with the acidifying sulfur and nitrogen components. This paper describes briefly research carried out to study the extent of metal pollution and following the temporal trends over the last 40 years.

Methods

Air concentrations of 20 elements were determined at the Birkenes stations in southern Norway over two periods in 1978-79 and 1985-86 and the results combined with air trajectories (Amundsen et al., 1992). Precipitation was monitored at three sites in different regions over the entire 40-yerar period and occasionally at a greater number of sites. Moss bio-monitoring of metal deposition was carried out at 470 sites all over the country every 5 years using the best available analytical techniques at any time (INAA/AAS 1977 -1985; ICPMS 1990 - 2015). Residual metal contamination was studied by corresponding sampling and analysis of natural surface soils according to a corresponding network. In the case of Pb stable isotope analysis was used to distinguish between contributions from air pollution and naturally occurring lead in the soils (Steinnes et al., 2005). Principal component factor analysis (Schaug et al., 1970) was used to separate contributions of metals from different source categories.

Results

Sector analysis of air concentration data showed that the main source areas pollution derived elements (*e.g.* V, Zn, As, Se, Cd, Sb, Pb) are to the southwest to southeast of Birkenes. Comparison of data from moss samples and precipitation at 12 different sites confirmed that concentrations in moss were generally proportional to atmospheric deposition at the same site (Berg and Steinnes, 1998). Atmospheric deposition of the above elements, as evident from repeated moss surveys, is generally about tenfold higher in the south than in areas farther north, but has decreased substantially over time (Steinnes et al., 2011), in the case of Pb to 5% of the 1977 level. The pollution-derived elements are also significantly enriched in the humic surface horizon of natural soils, most pronounced in the south of the country, as evident from repeated nationwide soil sampling campaigns (Steinnes et al., 1997; 2011). In the case of Pb the concentration in the surface soil horizon is tenfold higher in the south than in pristine areas in the north mainly because of differences in atmospheric deposition of Pb, as supported by stable Pb isotope analysis (Steinnes et al., 2005). Studies of peat cores from ombrotrophic bogs confirm the temporal and spatial trends evident from the other studies discussed.

In the far north-east some areas are substantially contaminated with Cu and Ni by pollution from nearby Russian industries. This trans boundary transport reached a maximum around 2005 and has continued since at the same level. Around 20 000 km of Norwegian land is affected.

Conclusion

With the exception of areas affected by smelters in Russia, the impact of long range atmospheric transport of metals from other countries has been substantially reduced over the last 30 years. Natural surface soils in the southern part of the country, however, remain to be considerably polluted from integrated deposition of metals (Pb, Zn, Cd, As, Sb, etc.) supplied mainly from trans boundary pollution and bound to humic substances. It has been claimed by some (Reimann et al., 2009) that the steep gradient evident in surface soil composition along a south-north gradient in southern Norway is due to natural conditions related to climate and vegetation. This view is not supported by results from a recent statistical study in Norway including the geographical distribution of ecological land classes (Nickel et al., 2014) where it is concluded that atmospheric transport is a main source of Pb and Cd accumulation in moss as well as in natural surface soil.

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