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Trace element data for surface soil and moss in Norway analyzed by PMF and PCA with optional CLR transformation

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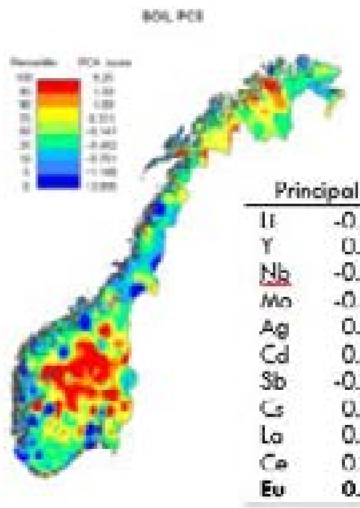
Statement of the Problem: Classical principal component analysis (PCA) is useful to separate anthropogenic and geogenic sources of trace elements in surface soil and moss. However, while mass input (µg/g) of trace elements can be determined by positive matrix factorization (PMF), this cannot readily be done by PCA. Also, classical PCA can be sensitive to minor changes in input data. We considered here datasets for 464 stations in mainland Norway and more than 21 trace elements including Pb, Cd, Ag, As, and Hg and several rare earth elements. PMF scores for individual stations were plotted, and PCA with CLR transformation was tested to check robustness and to see if significant factors were missed.

Methodology & Theoretical Orientation: Surface soil and moss *(Hylocomium splendens)* samples were collected all over mainland Norway from open air sites. Chemical and statistical analyses were conducted as described previously.

Findings: PMF factor contributions (scores) of anthropogenic factors from dated moss samples with high levels of Pb, Cd, Cr, Co, As, Hg at Svanvik near the Russian border confirm the influence of a Russian copper - nickel smelter. A much smaller increase is seen in the soil samples. Using CLR transformation with PCA, increased robustness is reflected by the fact that all five factors each have near-equivalent PMF factors, which is not the case for PCA without CLR transformation. However, scores are noisy and have significant negatives. Classical PCA on soil samples produces an Ag, Hg factor at Ulefoss, along with a distinct Eu factor free of Ag and Hg (PC5), both not seen with the CLR transformation.

Conclusion & Significance: PMF and PCA factor scores at individual stations such as Svanvik or Ulefoss can be an important adjunct to score maps in identifying pollution sources and PCA with CLR transformation provide more robust factors, however, at the possible expense of missing significant and more distinct factors.



Principal component loadings

Li	-0.02	Dy	0.06
Y	0.06	W	0.06
Nb	-0.19	Tl	0.15
Mn	-0.42	Pb	-0.15
Ag	0.02	U	-0.19
Cd	0.03	Cr	0.10
Sb	-0.08	Co	0.23
Cs	0.10	Ga	0.15
La	0.01	As	-0.12
Ce	0.02	Hg	0.02
Eu	**0.82**		

Figure 1. PC5 loadings and scores for natural surface soil of Norway using non-CLR transformed PCA, highlighting europium contributions.

Recent Publications:

1. Christensen E R, Steinnes E and Eggen OA (2018) Anthropogenic and geogenic mass input of trace elements to moss and natural surface soil in Norway. Science of the Total Environment 613-614:371-378.
2. Nygård T, Steinnes E and Røyset O (2012) Distribution of 32 elements in organic surface soil: contributions from atmospheric transport of pollutants and natural sources. Water, Air, and Soil Pollution 223:699- 713.
3. Schaug J, Rambæk J P, Steinnes E and Henry R C (1990) Multivariate analysis of trace element data from moss samples used to monitor atmospheric deposition. Atmospheric Environment 24(10):2625-2631.
4. Sadeghi M, Petrosino P, Ladenberger A, Albanese S, Andersson M, Morris G, Lima A, De Vivo B and The GMAS Project Team (2013) Ce, La, and Y concentrations in agricultural and grazing-land soils of Europe. Journal of Geochemical Exploration 133:202-213.
5. Rusu A-M, James Chimonides P D, Jones G C, Garcia-Sanchez R and William Purvis O (2006) Multi-element including rare earth content of lichens, bark, soils, and waste following industrial closure. Environmental Science and Technology 40:4599-4604.

Biography

Erik R Christensen is a distinguished Professor Emeritus of Environmental Engineering. He has edited a book on contaminated aquatic sediments and co-authored the book *Physical and Chemical Processes in the Aquatic Environment* (Wiley, 2014) with An Li. He has been an Associate Editor for the *Journal of Great Lakes Research* and the ASCE *Journal of Environmental Engineering*, and published over 90 peer reviewed journal articles. He is a fellow of the American Society of Civil Engineers.

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