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Environmental Science and Pollution Research

ISSN 0944-1344
Volume 23
Number 22

Environ Sci Pollut Res (2016)
23:22852-22870
DOI 10.1007/s11356-016-7502-7

Springer

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RESEARCH ARTICLE

Multivariate extraction of dominant geochemical markers for deposition of 69 elements in the Bregalnica River basin, Republic of Macedonia (moss biomonitoring)

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Received: 9 February 2016 / Accepted: 22 August 2016 / Published online: 27 August 2016

Abstract Atmospheric deposition was investigated using the terrestrial moss species *Hypnum cupressiforme* (Hedw.) and *Homolothecium lutescens* (Hedw.) in the Bregalnica River basin, Republic of Macedonia. Long-term emission occurs in this area due to the hydrothermal exploitation of Pb–Zn deposits (*Sasa* and *Zletovo* mines) and copper ore exploitation and floatation (Bučim mine). Determination of the chemical elements was conducted using atomic emission spectrometry with inductively coupled plasma (ICP-AES) and mass spectrometry with inductively coupled plasma (ICP-MS). A combination of multivariate techniques (PCA, FA and CA) was applied for data processing and identification of element association with lithogenic/anthropogenic origin. Seven dominant factors were extracted from the total of 69 analysed elements. Spatial distribution maps were constructed for the determination and localisation of smaller areas with higher contents of certain anthropogenic elements. In this way, the influences of selected human activities on local air pollution can be determined. The summarised data show quantification of the element distributions. This not only allows the determination of the distribution of hazardous elements but also presents complete characterisation of element deposition in the environs of mines.

Keywords Air pollution · Moss · Biomonitoring · Atomic emission spectrometry with inductively coupled plasma · Mass spectrometry with inductively coupled plasma · Multivariate assessment · Spatial distribution · Bregalnica River basin

Responsible editor: Céline Guéguen

Electronic supplementary material The online version of this article (doi:10.1007/s11356-016-7502-7) contains supplementary material, which is available to authorized users.

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Introduction

Environmental pollution at hazardous levels for living organisms presents a global problem and a challenge for a macrocase monitoring. Some sub-disciplines have been developed over time in order to consider realistic environmental conditions. Arguably, the understanding of atmospheric pollution is one of the most emergent areas of environmental science (Fernández et al., 2015). Atmospheric pollution represents solutions or suspensions of minute amounts of harmful compounds in the air (Vallero 2014). The degree and extent of environmental changes over the last decades have given a new urgency and relevance to the detection and understanding of environmental changes due to human activities, which have altered global biogeochemical cycling of heavy metals and other pollutants (Athar and Vohora 1995; Acton 2013). Monitoring of toxic air pollutant is needed in order to understand their spatial and temporal distribution and ultimately to minimise their harmful effects. In addition, to direct physical and chemical methods of air pollution monitoring, bioindication has also been used to evaluate air pollution risk (Aboal et al. 2010; Ares et al. 2012; Vallero, 2014).