

## Comparison of response of moss, lichens and attic dust to geology and atmospheric pollution from copper mine

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**Abstract** Different sampling media (moss, lichen and attic dust) were used for monitoring the distribution of 15 elements, including certain trace elements, in the vicinity of an intensively exploited copper mine in the east of the Republic of Macedonia. Moss species (*Hypnum cupressiforme* and *Campothecium lutescens*), epiphytic lichens (*Hypogymnia physodes* and *Evernia prunastri*) and attic dust were collected for comparative analysis for monitoring air pollution. In both cases (lithological and anthropogenic affected areas) for the distribution of elements, the sampling media follows the expression capabilities: attic dust > moss > lichens. Enrichment factors M/L—moss vs. lichen, for plant response to elements distribution and D/L—attic dust vs. lichen, for historical response of elements distribution were significant for Cu and Ni, which were singled out as the main markers for anthropogenic and geogenic distribution. The factor analysis highlighted geogenic (F1: Ni-Cr-Cd-Fe-Al-K-Mn-Zn) and anthropogenic (F2: As-Cu-Pb) association of elements from three types of media samples. For anthropogenic affected areas, *T* value and *F* value for Cu content were significant at  $p < 0.05$  and higher enrichment factors were obtained for lichen, moss and attic dust media (3.8, 5.0 and 5.7,

respectively). Spatial distribution for element deposition (with emphasis on Cu and Ni) is not disturbed by the significant differences in the sampling media matrix. Treated sample materials (attic dust, moss, lichen) are shown to be useful in determining an anthropogenic impact, as well as the chemical properties or geological background on orographic diverse terrain in the presence of complex geological structure.

**Keywords** Attic dust · Bučim copper mine · Macedonia · Lichen · Moss · Spatial distribution

### Introduction

The environmental fate of heavy metals absorbed on to dust particles is of growing concern when addressing environmental issues for mine and processing plants environs (Pacyna et al. 2007). The complexity of the contamination sources and the large amounts of waste tailings produced is of high priority when investigating the contamination levels and the mechanisms that rule their distribution and deposition in the local environment (Järup 2003; Vallero 2008; Ashraf et al. 2011). Different media sampling is used for monitoring the possible air pollution by heavy metals around metal emission sources. Long-term and long-distance monitoring are sensitive for different types of sampling media and stability and responsiveness with respect to environmental and pollution conditions, present limitations for implementing air pollution monitoring (Artiola et al. 2004). The ability of moss and lichen to accumulate trace substances present in the lower atmosphere is well known and their potential as biomonitors of environmental pollution by heavy metals has been documented by numerous studies (Branquinho et al. 1999;

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