Atmospheric Environment 102 (2015) 130–135

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Influence of the physicochemical characteristics of pollutants on their uptake in moss

Z. Varela [a,*], J.A. Fernández [b], C. Real [b], A. Carballeira [a], J.R. Aboal [a]

[a] Área de Ecología, Departamento de Biología Celular y Ecología, Facultad de Biología, Univ. Santiago de Compostela, 15782 Santiago de Compostela, Spain
[b] Área de Ecología, Departamento de Biología Celular y Ecología, Escuela Politécnica Superior, University Santiago de Compostela, 27002 Lugo, Spain

HIGHLIGHTS

- Physicochemical characteristics of elements determine their uptake in moss.
- Factor analysis identifies groups depend on elements binding properties.
- Ionic and covalent nature of elements determines the radicals which they bind to.

ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form
25 November 2014
Accepted 27 November 2014
Available online 27 November 2014

Keywords:
Biomonitoring
Factor analysis
Heavy metals
Pseudoscleropodium purum

ABSTRACT

Bryophytes are commonly used as biomonitors to estimate the atmospheric deposition of heavy metals and metalloids. However, the tissue concentrations of these elements in moss do not always accurately reflect atmospheric levels. The aim of the present study was to investigate whether element uptake in moss is affected by the physicochemical characteristics of the elements. Factor analysis was used to identify any patterns of covariance in the accumulation of elements in samples of the moss *Pseudoscleropodium purum* collected from the surroundings of different factories and from control sites. The variation in the concentrations of elements was similar in moss from both types of sites and was related to the binding properties of the elements. This suggests that the physicochemical characteristics of the elements determine the uptake of metals and metalloids from the atmosphere. Therefore, in studies that use multiple correlations among elements as indicators of a common origin of contaminants, erroneous conclusions may be reached by overlooking the adsorption properties of the moss.

1. Introduction

Since the moss biomonitoring technique was first reported (Rühling and Tyler, 1968), bryophytes have been widely used as biomonitors to estimate the atmospheric deposition of heavy metals and metalloids. However, the concentrations of elements in moss samples do not always accurately reflect the atmospheric deposition of these elements (Aboal et al., 2010): the tissue burdens will not only depend on the amount of a particular contaminant in the atmosphere, but also on the physicochemical characteristics of the contaminants and the uptake processes.

Although numerous biomonitoring studies have been carried out with moss, relatively little is known about the specific physicochemical mechanisms involved in the bioadsorption processes, in comparison with those in other organisms (algae, bacteria, fungus, plants; González and Pokrovsky, 2014). In fact, there are no reports in the available literature about how the physicochemical characteristics of contaminants and of the uptake processes in mosses might affect the bioconcentration of different atmospheric contaminants. Aspects such as the amount of a contaminant emitted by factory and the type of emission (gaseous or particulate, particle size, etc.) may have important effects on the uptake process. The physicochemical processes in mosses include aspects such as the affinity of contaminants for cation exchange sites (Nieboer and Richardson, 1980), competition by metals or metalloids for cation exchange sites (Couto et al., 2004) and synergistic uptake of contaminants (Sun et al., 2009).

Therefore, the objective of the present study was to determine whether the uptake of elements by moss is influenced by the physicochemical properties of the elements. Factor analysis was carried out with the aim of identifying any patterns of covariance in

* Corresponding author.
E-mail address: zulema.varela@usc.es (Z. Varela).

http://dx.doi.org/10.1016/j.atmosenv.2014.11.061
1352-2310/

the bioconcentration of elements in moss samples collected from the surroundings of different factories and from control sites. The working hypothesis of the study is that as these types of samples are subjected to different levels and types of contaminants, different patterns will be observed if caused directly by the inputs of atmospheric contaminants, but that if there is some underlying intrinsic process in the moss capable of interfering the distribution of elements, then similar uptake patterns will be observed in both types of samples.

2. Material and methods

2.1. Sampling

Samples of the moss *Pseudoscleropodium purum* (Hedw.) M. Fleisch were collected on at least two occasions between 1999 and 2008 from 33 control sites (Fernández et al., 2007) and 43 industrial sites (some of which were sampled on several occasions: Varela et al., 2014) in Galicia (NW Spain; Fig. 1). Information and annual production levels of each of the factories concerned are listed in supplementary material. Two sampling sites (SS) were established in the surroundings of each possible source of contamination following the method proposed by Fernández et al., 2007. Briefly, the SS were arranged along two polar radii from the focal point of emission. One transect followed the direction of the prevailing wind in Galicia (NE–SW) and the other was arranged perpendicular to this (NW–SE), with the aim of detecting any anisotropy in the dispersal of the contaminants. Samples were collected from one SS on each radius located as close as possible to the focal point of emission (supplementary material). Whenever possible, the samples were collected in open areas or small clearings in forests, although not next to trees, and areas close to main roads and centres of population were avoided (Carvajal et al., 2010). At each SS, approximately 30 subsamples of similar weight were combined to make a single composite sample. Whenever possible, the dimensions of the collection area were between 20 × 20 m and 50 × 50 m (Fernández et al., 2002; Aboal et al., 2006).

2.2. Chemical analysis

Prior to the analysis, samples were cleaned to remove adhered material; apical portions (3–4 cm long) were separated from the shoots and the material was homogenized and digested with HNO_3 in a microwave oven (CEM MDS2100). The concentrations of Al, Ba,

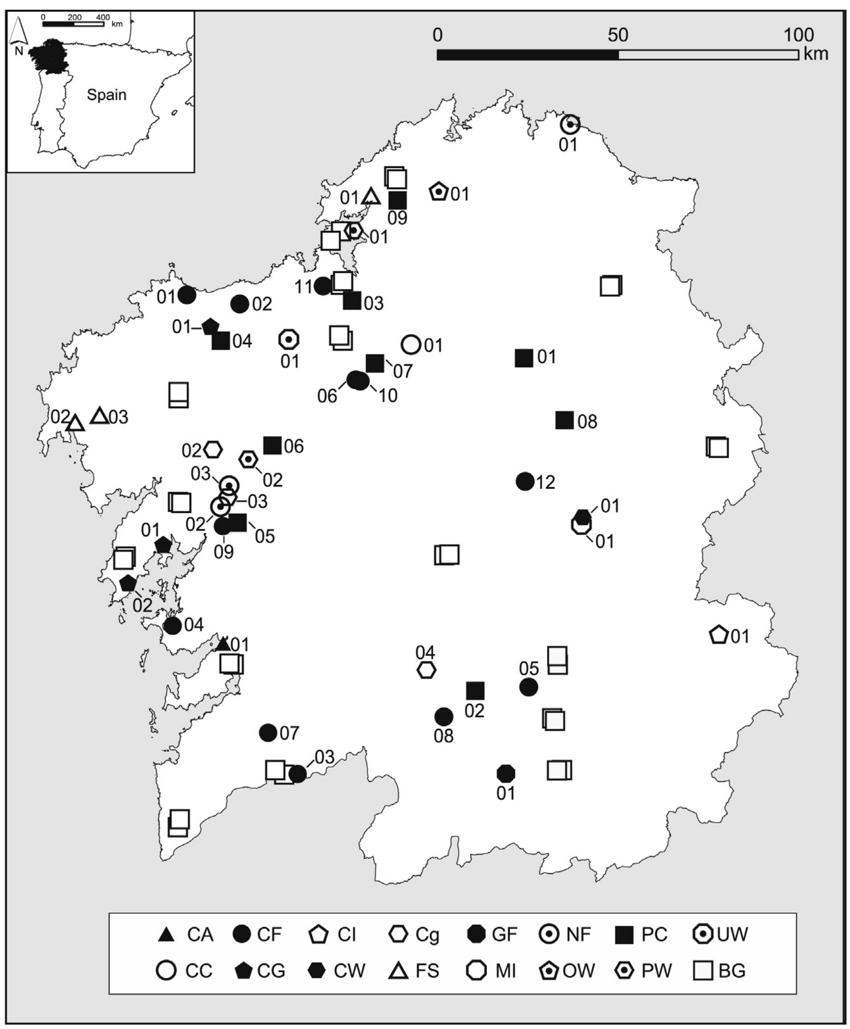

Fig. 1. Location of the moss *P. purum* SS in the surroundings of the different factories classified in several industrial sectors: chlor-alkali plants (CA), ceramic factories (CF), cogeneration plants (CG), chemical industries (CI), chemical industries with cogeneration (CC), cement works (CW), ferrous-smelters (FS), glass factories (GF), mineral industries (MI), non-ferrous smelters (NF), waste oil treatment (OW), paper and wood production with cogeneration (PC), paper and wood production (PW), urban waste incinerators (UW) and backgrounds sites (BG).