Science of the Total Environment 565 (2016) 249–257

Contents lists available at ScienceDirect

Science of the Total Environment

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

Contribution of atmospheric deposition to tissue concentrations of mercury in aquatic bryophytes

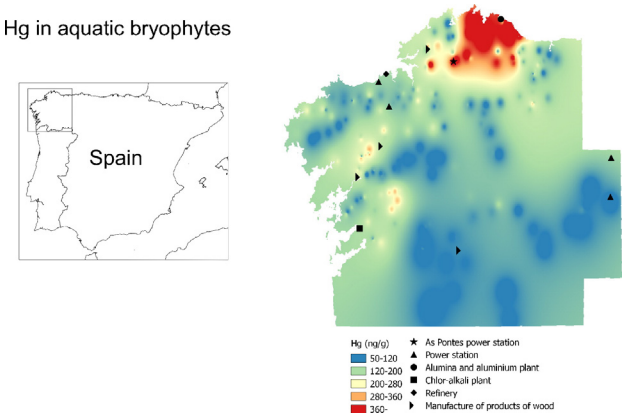
Rubén Villares [a,*], Santiago Díaz [b], Jesús López [c], Maria Dolores Vázquez [a], Alejo Carballeira [b]

[a] Departamento de Biología Celular y Ecología, Escuela Politécnica Superior, Universidade de Santiago de Compostela, 27002 Lugo, Spain
[b] Departamento de Biología Celular y Ecología, Facultad de Biología, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain
[c] Departamento de Ecología y Biología Animal, Facultad de Ciencias, Universidade de Vigo, 36310 Vigo, Spain

HIGHLIGHTS

- Significant levels of Hg in aquatic bryophytes were detected.
- Atmospheric deposition from a coal fired power plant was the probable source.
- A spatial interpolation technique ignoring the catchment borders appears suitable.
- Atmospheric deposition should be taken into account in aquatic pollution.
- An environmental specimen bank allowed a retrospective study.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 January 2016
Received in revised form 13 April 2016
Accepted 22 April 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Biomonitoring
Interpolation
Power station
Environmental specimen bank

ABSTRACT

In this biomonitoring study, we measured the temporal variations in concentrations of mercury in samples of aquatic bryophytes from rivers in a region that received large inputs of the metal via atmospheric deposition. In the first year of sampling, the presence of an important source of atmospheric deposition of Hg (a lignite-fired power plant) led, during the rainy season, to elevated concentrations of the metal in catchments situated downwind of the prevailing winds. High concentrations of the metal were even detected in samples from apparently clean rivers in isolated mountain sites within the downwind catchments. Substitution of the type of fuel (high quality imported carbon instead of brown coal) used in the power plant greatly reduced Hg emissions in subsequent years. Application of spatial interpolation techniques to dense monitoring networks with aquatic bryophytes, without taking into consideration the catchment borders, appears suitable for studying extensive atmospheric pollution derived from a large scale source of contamination. This study also demonstrates the importance of environmental specimen banks in retrospective studies of contamination, as they enable posterior analysis of contaminants that for various reasons cannot be analyzed at the time of sampling.

* Corresponding author.
E-mail address: ruben.villares@usc.es (R. Villares).

http://dx.doi.org/10.1016/j.scitotenv.2016.04.159
0048-9697/

1. Introduction

Aquatic mosses have been used for several decades to biomonitor metal contamination (e.g. Empain, 1973; Burton and Peterson, 1979; Mouvet, 1985). The technique is based on the fact that mosses concentrate aquatic contaminants in their tissues, thus facilitating analysis of the contaminants. Mosses have a particularly high capacity to accumulate Hg (Díaz et al., 2012). The technique also enables detection of sporadic contamination that would otherwise only be detected if water sampling coincided with such events (Cesa et al., 2006). Another advantage is that, by definition, these biomonitors only assimilate the bioavailable fraction of contaminants, which is difficult to determine via chemical analysis of water samples.

Studies of contamination in rivers usually centre on catchments in the search for possible sources of contamination. However, some contaminants with low volatilization temperatures, such as Hg, are readily dispersed via the atmosphere and may then precipitate and enter waterways. Spatial interpolation techniques are often applied when terrestrial mosses are used to biomonitor atmospheric contamination (e.g. Fernández et al., 2000; Figueira et al., 2002; Nickel et al., 2014). In the present study, we moved away from the usual catchment approach used in river pollution studies and applied a spatial interpolation technique that ignored the catchment borders. We believe that the technique may be of practical use for monitoring contamination by Hg, which is readily dispersed in the atmosphere.

2. Material and methods

Extensive sampling of aquatic bryophytes for use as biomonitors of metal pollution in inland waters was carried out for the first time in the study region in 1990. Samples of the mosses *Fontinalis antipyretica* Hedw., *Platyhypnidium riparioides* (Hedw.) Dixon, *Brachythecium rivulare* Schimp., *Fissidens polyphyllus* Wilson ex Bruch & Schimp., and the liverwort *Scapania undulata* (L.) Dum were collected at 218 sampling sites (SS) (Fig. 1). A total of 424 moss samples were collected, as various species were often collected at each SS. Although the Hg contents of the samples were not determined at the time, due to a lack of appropriate equipment, the samples were stored in the Galician Environmental Specimen Bank. Other sampling surveys were carried out in the same area in 2001 and 2003 (for a detailed description of this new aquatic biomonitoring network, see Vázquez et al., 2007). Briefly, in 2001, samples of *Fontinalis squamosa* Hedw., *F. antipyretica* and *P. riparioides* were collected at 89 SS. In 2003, the network was extended and sampling was concentrated on a single genus, and specimens of

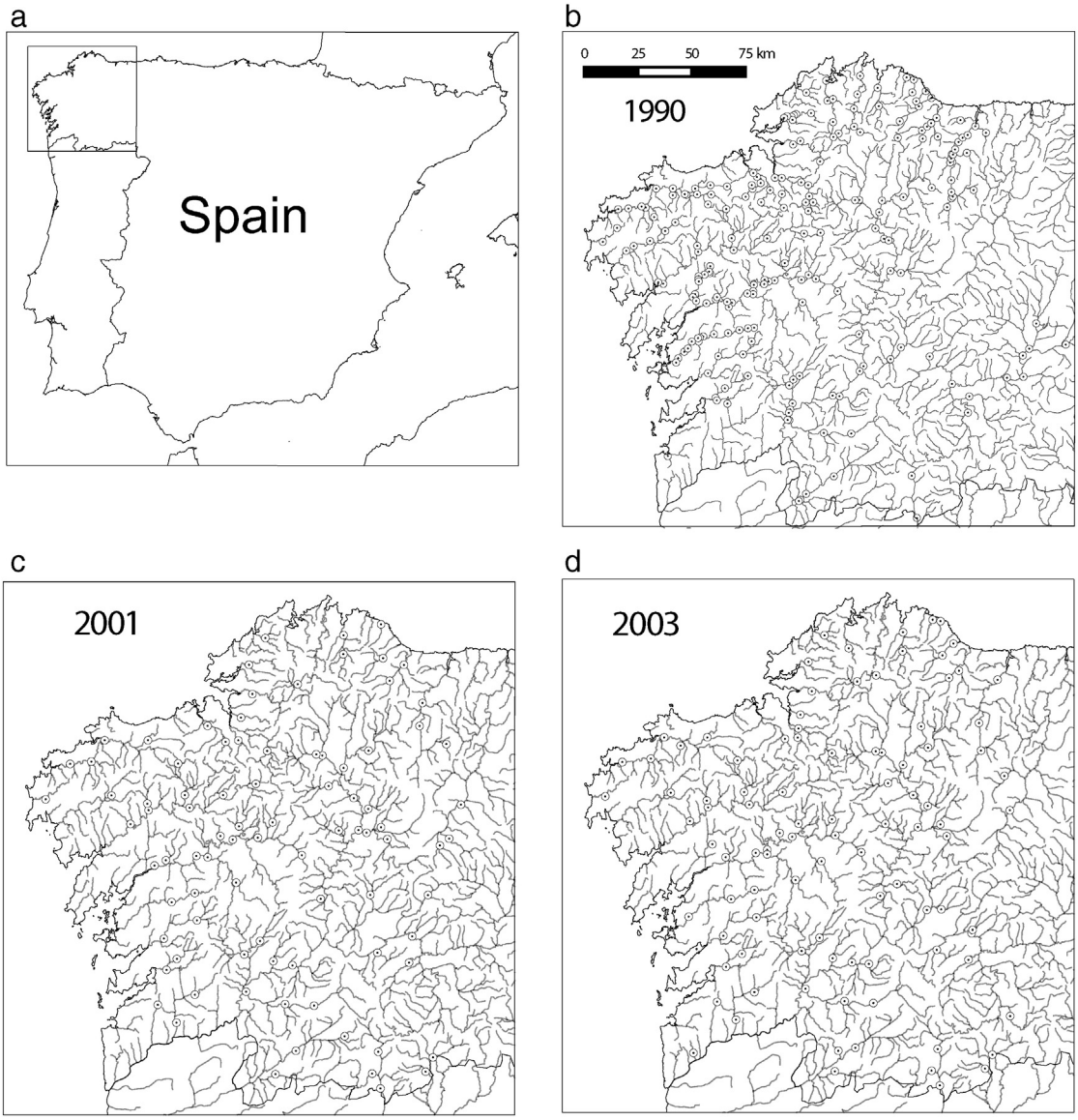


Fig. 1. Location of the sampling sites.