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Lead adsorption capacity of some moss species used for heavy metal analysis

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ABSTRACT

Mosses, covering about 23,000 species of all land plants in the world, have been widely used as an indicator of heavy metal pollution in many studies. A crucial part in these researches is to regularize the adsorption capacities of different moss species obtained from different regions to objectively compare the pollution levels. In this study, we have first analyzed the lead adsorption capacities of six different moss species by means of using column filled with Amberlite XAD-2000 resin method. The adsorption capacities of the studied six mosses are found in descending order as *Eurhynchium striatum*, *Hypnum cupressiforme*, *Pleurozium schreberi*, *Eurhynchium striatulum*, *Homalothecium sericeum* and *Thuidium tamariscinum*. Then, we have regularized the Pb adsorption levels for the moss species obtained from different regions along one of the important coast highway in Turkey, namely Sarp-Samsun highway, with respect to the determined adsorption capacities.

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1. Introduction

Due to rapid urbanization and industrial development in recent years, atmospheric pollution has caused serious deterioration of the terrestrial environment in many countries. Biomonitoring is a technique using organisms or biomaterials to obtain information on certain characteristics of the biosphere (Wolterbeek, 2002; Kardel et al., 2012). Mosses have been well studied as tools for the biomonitoring of the atmospheric pollution (Lee et al., 2005; Koz et al., 2012; Persch and Schroeder, 2006).

Mosses are used as sensitive bioindicators of heavy metal contamination and have several advantages as indicators organisms: (1) they have no epidermis or cuticle, therefore, their cell walls are easily penetrable for metal ions; (2) they have no organs for uptake of minerals from substrate, they obtain them mainly from precipitation; (3) mosses show the concentrations of the most metals as a function of the amount of atmospheric deposition (Grodzinska and Szarek-Lukaszewska, 2001; Uyar et al., 2007; Sharma, 2009).

The main sources of lead are the combustion of lead gasoline, waste incineration and industry. Lead pollution is correlated with urbanization and density of population. Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults (Commission of the European Communities, 2001; ATSDR, 2009).

In this study, we analyze the lead adsorption capacity of six different mosses species which are used as biomonitors for the determination of environmental pollution by using AAS spectrometry. The six species, namely, *Homalothecium sericeum*, *Thuidium tamariscinum*, *Eurhynchium striatulum*, *Eurhynchium striatum*, *Hypnum cupressiforme* and *Pleurozium schreberi* are selected from *Pleurocarpous* style (i.e. in the form of carpet mosses) which are mostly utilized in analysis studies as they have larger leaf surfaces compared to other species such as *Acrocarpous*. The moss samples are gathered on July 2006 from different regions along one of the important coast highway in Turkey, Sarp-Samsun highway (Koz et al., 2008), and the analysis is performed on June 2007. Then, we perform a normalization process on the heavy metal concentration results obtained at different regions with respect to the adsorption capacities of the moss species. With such an analysis and a normalization procedure, we first aim to reveal the order of the adsorption capacities of six moss species and to relate these capacities to their anatomic and morphological structures. Second, we could regularly compare the environmental pollution at different regions by using the different moss species existing at those regions.

2. Materials and methods

2.1. Instruments, reagents and solutions

A Unicam AA-929 flame atomic adsorption spectrophotometer (FAAS) equipped with single element hollow cathode lamps and an air/acetylene burner were used for the determination of trace

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Table 1
Instrumental parameters for the measurements of the working elements by FAAS and microwave digestion program applied for the moss samples.

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Flow rate of acetylene ($L\,min^{-1}$)
Instrumental parameters of FAAS				
Pb	217.0	0.5	6.0	1.1

Step	Time (min)	Power (W)	Pressure (bar)	Temperature (°C)
Microwave digestion program				
1	6	250	45	180
2	6	450	45	200
3	6	650	45	220
4	6	250	45	220
Vent (min)	3	–	–	–

Table 2
Analysis of certified reference material.

Element	IAEA-336 Moss[a]		
	Certified value ($\mu g\,g^{-1}$)	Found value ($\mu g\,g^{-1}$)	Error (%)
Pb	(4.9)[b]	5.1 ± 0.4	+4.1

[a] 1.00 g of Moss CRM was taken, and after digestion in microwave irradiation according to Table 1, the method was applied. Final volume was 10 mL.
[b] The value in parenthesis is not certified.

metals. D_2-lamp was also operated in FAAS for background correction. The instrumental parameters were those recommended by the manufacturer, and summarized in Table 1. Milestone Ethos D microwave oven with closed vessel and 1450 psi maximum pressure was used for digestion of moss samples in Duran et al. (2007).

All chemicals obtained from Merck (Merck KGaA, Frankfurter Strasse 250, 64293 Darmstadt, Germany) and Fluka (Fluka Chemie GmbH, Industriestrasse 25, Buchs CH-9471, Switzerland) were of analytical reagent-grade, and all solutions were prepared in distilled/deionized water. IAEA-336 Moss standard was obtained from IAEA Laboratories at Seibersdorf and Vienna A-2444 Seibersdorf, Austria.

2.2. Method

1.00 g of fine powdered and dried moss samples were weighed into Teflon vessel and 7 mL of HNO_3, 2 mL of H_2O_2 and 1 mL HF were added. Then, the content of the vessel was digested by microwave irradiation. The residue was filtered off blue band filter paper and filtrate was diluted to 25.0 mL with distilled/deionized water. A blank digest was carried out in the same way. The final solutions were analyzed with FAAS for the determination of metals.

In order to determine the quality control data for chemical analysis standard reference material was analyzed. The results revealed good agreement between the observed values and certified values (Table 2).

2.3. Pb adsorption experiment

The moss species used in this research are collected from the regions free of human-induced pollution in Kümbet Plateau of Giresun province. The diagnosis of the moss species is performed by utilizing the main reference books on moss flora such as Bryology (Schofield, 2001), Die Moos-und Farnpflanzen Europas (Frey et al., 1995), The Moss Flora of Britain and Ireland (Smith, 2004) and Flora Dei Muschi D'Italia (Pedrotti, 2001). In order to investigate and compare the Pb adsorption capacity of moss species, six moss species (*H. sericeum* (Hedw.) B.S.G., *T. tamariscinum* (Hedw.) B.S.G., *E. striatulum* (Spruce) B.S.G., *E. striatum* (Hedw.) Schimp., *H. cupressiforme* Hedw., *P. schreberi* (Brid.) Mitt) were put in a 25 cm × 36 cm × 55 cm box. These moss species are frequently found in the studied area. The six species were first separated into four groups. While the first group is not given any Pb solutions, the second, third and fourth groups are given 0.005%, 0.05%, and 0.5% Pb solutions, respectively. This procedure was repeated once every 24 h for 10 days. Three different Pb concentrated solutions used during the experiments were prepared as follows:

(1) 0.5% Pb solution → 7.85 g $Pb(CH_3COO)_2$ + 1 L distilled water
(2) 0.05% Pb solution → 100 mL 0.5% $Pb(CH_3COO)_2$ + 1 L distilled water
(3) 0.005% Pb solution → 100 mL 0.05% $Pb(CH_3COO)_2$ + 1 L distilled water

100 mL of the prepared solutions were sprayed on the samples each day with the Atomiser equipment, which converts the liquid solutions into gas form. Then the samples were taken out of the box and put into an oven of 100 °C for 20 h for drying. The dried samples were ground in a spex mill. To reduce particle size effect, the powder obtained were sieved using a 400 mesh sieve and then stirred for 25 min to obtain a well mixed sample.

In our measurements the maximum relative errors due to the counting system for the detected elements were calculated as Pb < 7%.

3. Results and discussion

Table 3 indicates the moss samples that Pb solutions were given and the Pb absorption results for each of the mentioned group. According to this, the increase rate for *T. tamariscinum* is 6.41 times, whereas it is 11 times for *H. sericeum*, 46.85 times for *E. striatulum*, 56.37 times for *P. schreberi*, 115.83 times for *H. cupressiforme* and 162.43 times for *E. striatum*. As can be seen from the table, the adsorption capacity of the moss species follows a descending order as *E. striatum* > *H. cupressiforme* > *P. schreberi* > *E. striatulum* > *T. tamariscinum* > *H. sericeum*. However a comprehensive study is necessary to understand the nature of adsorption of Pb.

The moss species having the highest and lowest adsorption capacities are determined as *E. striatum* and *T. tamariscinum*, respectively, in our experiments. One of the important factors for the variation of concentrations with respect to the moss species is the size of the leaf surfaces. According to Table 3, while *E. striatum* has the widest leaf area, *H. cupressiforme* has the narrowest one among the utilized six moss species in the experiments. While *E. striatum* has the widest leaf, *H. cupressiforme* has the narrowest one among the utilized six moss species (Smith, 2004).

Table 4 gives the comparison of the obtained results with our previous study performed in 2008. Based on these results, we determine the concentration changes in our recent study regarding the moss analysis along the Sarp-Samsun coast highway, which summarizes the concentration levels for six moss species taken from different regions through the highway. Table 4 indicates the new calculated concentration levels in each region if *E. striatum* has been

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