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Assessment of Accumulation of some Heavy Metals in Mosses of Idukki District, Kerala (Western Ghats, India)

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Abstract

Bryophytes constitute an important proportion of the vegetation in the Western Ghats. Recent developmental activities cause an increase in the metal contaminants in the environment which ultimately accumulate in the plant system. Mosses have been used as indicator to monitor level of environmental pollution. In the present study, eighteen moss species and their soil substrata were analyzed to evaluate the accumulation capacity of heavy metals in mosses of different sites of Idukki District of Kerala. Statistically metal concentrations showed significant differences (p=5%) in interspecies, while the accumulation capacity of *Campylopodium khasianum* was higher than others. The substratum showed highest content of Cr followed by Ni and Pb in all the five selected sampling sites. All the mosses showed high accumulation of Cr (III) as compared to other metals (Cd, Cu, Pb, Ni) irrespective of their sampling sites. Among 18 mosses, *Campylopodium khasianum* was found to accumulate highest content of Cr, Cd, Ni and Pb, indicating that this moss can be used to reclaim soil contaminated with these metals.

1. Introduction

Western Ghats is recognized among 34 known hot spots of biodiversity in the world. The region represents a major part of tropical evergreen forests comprising high taxonomic diversity and endemism. Variable topography, climatic conditions and high moisture content in various pockets support the luxuriant growth of mosses and liverworts. These constitute an important serial stage of the forest community in the disturbed as well as undisturbed habitats.

Idukki district in Kerala state represents an important pocket of high bryophyte diversity. The region is an important destination on the tourist map. The huge influx of tourists and the developmental activities have been making the flora of the region under threat. Large areas of the region have been converted into tea gardens and spice orchards where many agrochemicals containing organic, inorganic and metal pollutants have been used. Tea plants growing in South India have been known to accumulate metal contents of Zn, Cu, Pb and Cd (Seenivasan *et al*., 2008). These metal ions are mainly accumulated by passive ion exchange in mosses. The metals spread fast into the adjacent areas by runoff and other anthropogenic activities causing environmental pollution.

Mosses have long been used as agents for monitoring metal pollution. Because of their high surface:volume ratio, the simple anatomy, absence of cuticle and ectohydric nature, they accumulate metals in their tissues (Sun *et al*., 2007). They may show an elemental composition which reflects over the long term, the dissolved gases, particulate matter and metal ions of the atmosphere, and thus can be considered important biomonitors of environmental pollution. The absorption and tolerance levels of mosses are higher in comparison to other groups of plants. They retain pollutants in higher quantities and prevent recycling of such metal pollutants over a period of time. An analysis and estimation of metals in their tissues give an idea about the overall quality of the environment. Therefore, in the present study, dominant mosses were collected from Idukki district and analysed for accumulation of five metals Pb, Cd, Cu, Cr and Ni in the tissues and substratum of eighteen moss species from different sampling sites to assess the levels of metal pollution.

2. Materials and Methods

Eighteen species of mosses along with their substrata were collected from different sites of Idukki district of Kerala, India during months of October and November (Fig. 1). They were identified as *Bryhnia novae-angliae, Ctenidium lychnites*, *Mnium thomsonii*, *Funaria hygrometrica, Hyophila involuta*, *H. spathulata, Anomobryum brachymenioides, A. cymbifolium, Bryum pseudotriquetrum*, *B. argenteum* var *Lanatum*,

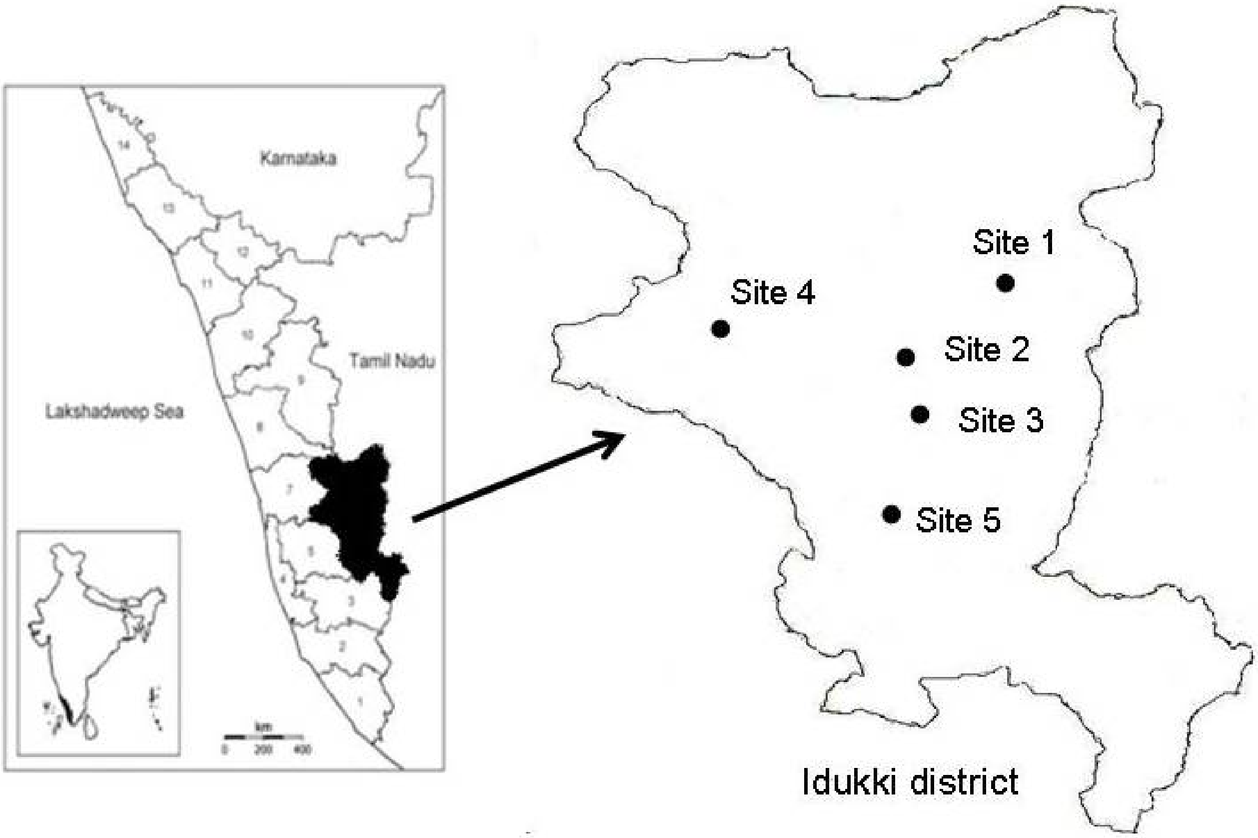

Fig. 1: The location of sampling sites in Idukki district of Kerala, India

Rhodobryum roseum, Atrichum undulatum, Pogonatum flexicaule, *Anisothecium molliculum*, *Dicranum gymnostomum*, *Campylopodium khasianum*, *Campylopus durelli* and *Ceratodon stenocarpus* using moss floras (Gangulee, 1969-1980; Chopra, 1975). The precise areas and localities of collection, altitude, growth form, substratum and other edaphic parameters were recorded on the spot (Table 1). They were cleaned, washed, dried at room temperature. Both the dried moss and the soil forming the substratum were digested with nitric acid and perchloric acid (6:1) and the estimation of the heavy metals was done by AAS (Model AAS ZEEnit 60/65) (Allen, 1989).

The data were recorded in triplicate and subjected to one way ANOVA. The values are expressed as mean ± standard deviation (SD). The comparison between the mean values was made by *Post Hoc* Tukey HSD (Honestly Significant Different) test at $p \leq 0.05$ using SPSS statistical software version 10.0. Bars with similar scripts are non-significantly ($p \leq 0.05$) different mean values.

3. Results

Of 18 moss species studied, *Campylopodium khasianum*, *Bryhnia novae-angliae*, *Mnium thomsonii*, *Anomobryum brachymenioides, A. cymbifolium* and *Hyophila involuta* were observed to have better metal tolerance potential than others. The order of metal tolerance observed was (i) Cd, *Campylopodium khasianum* > *Mnium thomsonii* > *Anomobryum brachymenioides* > *Anomobryum cymbifolium*; (ii) Cr(III), *Campylopodium khasianum* > *Anomobryum brachymenioides* > *Mnium thomsonii* > *Anomobryum cymbifolium*; (iii) Cu, *Anisothecium molliculum* = *Hyophila involuta* > *Pogonatum flexicaule* > *Dicranum gymnostomum* > *Campylopodium khasianum*; (iv) Pb, *Campylopodium khasianum* > *Bryhnia novae-angliae* > *Pogonatum flexicaule* > *Anisothecium molliculum* = *Hyophila involuta* and (5) Ni, *Campylopodium khasianum* > *Anomobryum brachymenioides* > *Mnium thomsonii* > *Anomobryum cymbifolium*.

In the soil substratum, Cr (III) content was maximum following Ni. The amount of Cr (III) was more

Table 1: Concentration of heavy metals in the soil samples of studied sites

Site Name and altitude (m)	Taxon	Growth Form	pH	Mean Concentration of heavy metals in the substratum of moss samples (µg g^{-1} dry weight of soil)				
				Cd	Cr(III)	Cu	Pb	Ni
Mattupatti (Site 1) 1700	*Bryhnia novae-angliae*	Mat	6.5	57.02 ± 9.038	369.70 ± 34.10	117.72± 11.97	84.551 ± 0.045	261.80± 20.18
	Ctenidium lychnites	Mat	7.6					
	Mnium thomsonii	Mat	6.4					
Munnar (Site 2) 1600	*Funaria hygrometrica*	Turf	5.6	72.81 ± 18.60	340.86 ± 24.41	116.77± 19.51	183.80 ± 77.79	325.50± 112.30
	Hyophila involuta	Turf	6.1					
	Anomobryum brachymenioides	Turf	5.8					
	Anomobryum cymbifolium	Turf	6.5					
	Bryum pseudotriquetrum	Turf	7.8					
	Bryum argenteum var. lanatum	Turf	8.0					
	Rhodobryum roseum	Turf	6.6					
	Atrichum undulatum	Turf	6.5					
Attukadu (Site 3) 1500	*Pogonatum flexicaule*	Turf	6.5	88.48 ± 0.29	378.18 ± 0.404	74.88 ± 0.608	261.65 ± 0.101	266. 51± 0.377
Athirapally (Site 4) 1200	*Anisothecium molliculum*	Turf	6.1	88.51 ± 2.18	355.00 ± 30.20	96.22 ± 19.53	199.96 ± 87.37	250.58 ± 34.20
	Hyophila spathulata	Turf	6.5					
	Dicranum gymnostomum	Weft	6.5					
	Campylopodium khasianum	Turf	5.1					
	Campylopus durelli	Cushion	5.8					
Adimali (Site 5) 1300	*Ceratodon stenocarpus*	Cushion	7.2	93.04 ± 0.049	333.56 ± 0.087	80.29 ± 0.262	126.08 ± 0.029	459.81 ± 0.025

or less same irrespective of the selected sampling sites in Idukki region, Kerala. The order of metals in the substratum was as follows: Site 1: Cr > Ni > Cu > Pb > Cd; Site 2: Cr > Ni > Pb > Cu > Cd; Site 3: Cr > Ni > Pb > Cd > Cu; Site 4: Cr > Ni > Pb > Cu > Cd; Site 5: Ni > Cr > Pb > Cd > Cu.

4. Discussion

Bryophytes have been widely used as bioaccumulators to monitor the extent of pollutants- such as trace metals and radionuclides in the environment (Zechmeister *et al*., 2003). Ectohydric nature of mosses is an advantage to use them as bioindicators of heavy metal contamination. The present investigation was carried out to assess the level of accumulated metals in mosses and their contamination in the substratum of Munnar region of Idukki district which is a tea plantation site and tourist attraction zone.

The present study demonstrated that the soil of sampling sites are contaminated with metals- Cu, Cr (III), Pb, Ni and Cd. The consistent application of various fungicides, industrial activities, transport and other developmental activities may be the reasons for high levels of these metals (Karak and Bhagat, 2010). Irrespective of the selected sampling sites, Cr (III) concentration was found to be highest in most of the mosses and their substrata. Usually, Cr occurs in two forms, Cr (III) and Cr (VI), and plant uptake is in both the forms. Seenivasan *et al.* (2008) found that Cr (III) content was highest in black tea samples collected from Munnar. Cr (III) is considered as a local contaminant which comes through the CTC rollers factories located in that region of Kerala. These CTC rollers are made of stainless steel containing chromium (17% w/w) that are used for the manufacturing of CTC processed black teas.

Ni was found to be the second highest in concentration in the soil. Nickel is a toxic element mainly coming through the foliar and soil application of low quality fertilizers and micro nutrients. Franklin et al. (2005) reported that potassic fertilizers contained 2.7 to 16 mg kg^{-1} nickel as impurity, while commercial phosphatic fertilizers contained 19 to 24 mg kg^{-1} Ni. Therefore, the agro inputs used in tea fields are the main

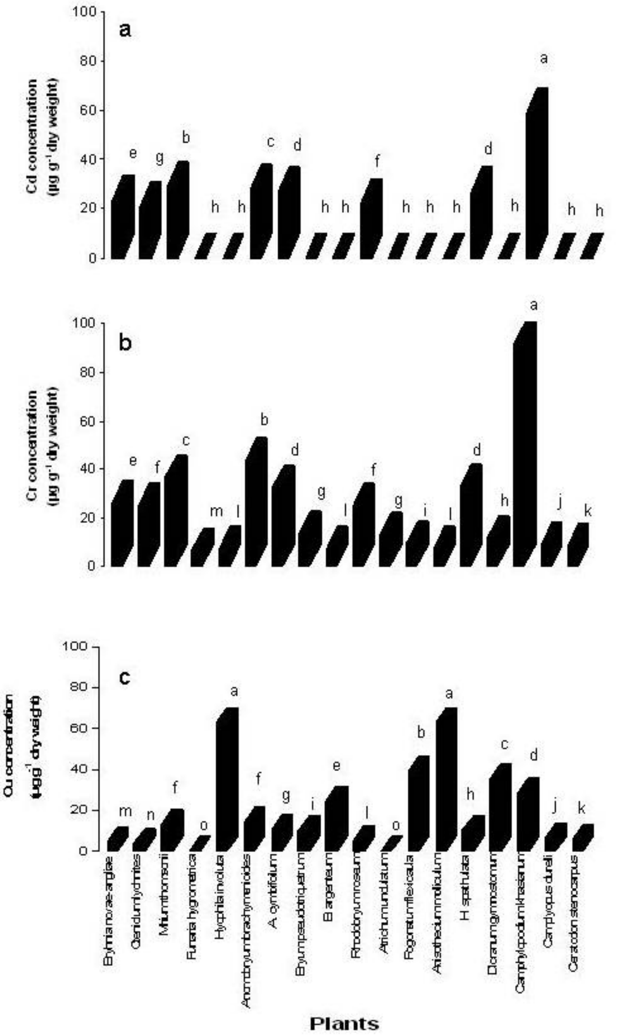

Fig. 2: Concentration (µg/g) of heavy metal (a) Cd (b) Cr (c) Cu in different mosses collected from five sampling sites of Idukki district. Small letters (a,b,c) on the bars represent the amount of concentration of metals

source of metal contamination in the tea plantation area as well as in the adjoining areas.

The concentration of Pb was 3rd in order of their amount in soil in four of the selected sampling sites. Jin *et al.* (2005) found that higher concentration of Pb in tea gardens adjacent to Hangzhou city was because of the contamination of atmosphere with emissions from transportation and industrial activities. Atmospheric deposition is also an important source of Pb in tea leaves (Han et al. 2007). The Pb in fertilizer may be another significant contributor to the annual inputs of Pb to soil (Nicholson et al., 1998).

Natesan and Ranganathan (1990) reported that the soil of tea gardens of Idukki region is also contaminated with Cd which is present in much higher concentration than the permissible limit of Indian standards. Phosphate fertilizer application is a significant contributor of trace elements, especially for Cd accumulation in cropped soils. According to Meeus et al. (2002), Cd from phosphate fertilizers constituted more than 50% of the total input in agricultural lands.

The presence of Cu in the soil of sampling site of idukki region is because of the application of copper fungicides especially copper oxychloride to control blister blight disease caused by *Exobasidium vexans* (Seenivasan *et al.*, 2008). The frequent application of this fungicide throughout the monsoon season to prevent loss of yield due to pathogen is probably the main reason for its accumulation in the soils of tea gardens.

In our investigation, all the mosses showed high accumulation of Cr (III) as compared to other metals (Cd, Cu, Pb, Ni). The metals were found to be in high

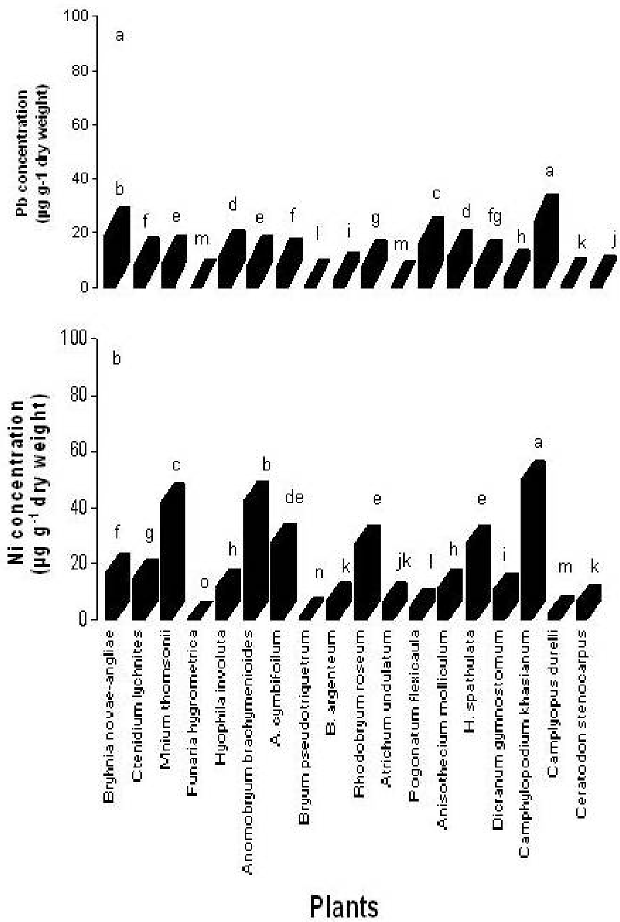

Fig. 3: Concentration (µg/g) of heavy metal (a) Pb (b) Ni in different mosses collected from five sampling sites of Idukki district. Small letters (a,b,c) on the bars represent amount of concentration of metals

concentration which is beyond the permissible limits (Singh *et al*., 2010). The observed difference in bioaccumulation of different metals in different mosses collected from the same sampling site must be due to the difference in their physiological, anatomical and morphological characteristics. In general, the mat forms have extensive branching system covering the ground surface and are directly attached to the soil surface. Turfs and cushions are robust growth forms, make extensive capillary system between their shoots enhancing their absorption capacity but their surface area is less. On the other hand, in weft forms the secondary stem remains away from the ground surface and hence the plants attached to the soil only by the main stem. Their cells are smaller in size and thick-walled which might be the reason for less accumulation of heavy metals in them from the substratum. The differences in binding affinity of the metals to the moss species could also be another factor contributing to variation in the accumulation pattern of the metals among different moss species. The metal accumulation potential of different species is correlated to their genotype also. Thus, the genetic make-up of the plant greatly influences its metal uptake potential (Ghatge *et al*., 2011). Among the 18 mosses, *Campylopodium khasianum* showed the highest accumulation for Cr, Pb, Ni and Cd. This might be due to its growth characters. *Campylopodium khasianum* is robust with wider leaves which provide greater surface area, the cells are larger in size and thin-walled, rhizoids are much branched, larger in numbers which firmly attach the plant to the substratum forming dense carpet. These features possibly are responsible for higher accumulation of all the studied metals.

5. Conclusions

Our study clearly reveals that the soil of Munnar region of Idukki district, Kerala has Cr (III) as one of the major metal soil contaminant as compared to Pb, Ni, Cu and Cd. The bioaccumulation potential of mosses for metals varies greatly and depends upon their tolerance to that particular metal. *Campylopodium khasianum* can be exploited as a better candidate to reclaim metal contaminated soils.

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