SHORT COMMUNICATION

HEAVY METAL ACCUMULATION BY THREE SPECIES OF MOSSES IN SHILLONG, NORTH-EASTERN INDIA

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Abstract. Comparisons were made of the accumulation of cadmium, copper, manganese, lead, and zinc in *Plagiothecium denticulatum, Bryum argenteum* and *Sphagnum* sp. in Shillong, Meghalaya State, Northeastern India. Samples of *P. denticulatum* and *B. argenteum* were collected inside Shillong city (urban) and its immediately adjacent outskirts (suburban), while *Sphagnum* sp. was collected from a suburban site only. Lead and copper levels were higher in *P. denticulatum*, while *Sphagnum* sp. accumulated higher amounts of zinc, manganese, and cadmium. An urban-suburban gradient was evident for lead and zinc in *P. denticulatum*, and for cadmium in *B. argenteum*, while a reverse trend could be discerned for manganese in *P. denticulatum*. Besides vehicles and minor industries, quarry dust was likely to be an important source of manganese, copper, and zinc.

Mosses and other bryophytes have been shown to be efficient accumulators of heavy metals, because the effective absence of a vascular system in these plants necessitates a relatively unrestricted exchange of solutes between the atmosphere and the living plant tissues (Livett, 1988). The usefulness of moss analysis in determining heavy metal concentrations in different geographic areas has been demonstrated by several studies (Rühling and Tyler, 1970, 1971, 1973; Groet, 1976; Grodzinska, 1978; Barclay-Estrup and Rinne, 1978; Rinne and Barclay-Estrup, 1980). However, heavy metal accumulation in Indian species of mosses remains poorly documented. This paper presents the results of a preliminary investigation of the concentrations of cadmium, copper, manganese, lead, and zinc in three species of mosses, *Plagiothecium denticulatum, Bryum argenteum*, and *Sphagnum* sp. from Shillong, North-eastern India. As Shillong does not have any major industries, the main objectives of this investigation were to assess the role played by various non-point pollution sources in heavy metal contamination of environment, as well as to evaluate the suitability of the three moss species as indicators of metal concentrations. Furthermore, Barclay-Estrup and Rinne (1978) have shown that significant differences could exist between lead and zinc levels in mosses collected inside a city and from its immediate outskirts. As Shillong is a small hill city with most of its vehiculat traffic and commercial and minor industrial activities confined to a relatively small area, it is of interest to see whether the level and pattern of metal accumulation is different in mosses growing in the

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commercial area from those growing in areas virtually devoid of commercial and industrial activities, but located not more than 1–2 km away from the former.

All the collection sites were in Shillong city (lat. 25°34′N; long. 91° 52′E), Meghalaya State, North-eastern India, which at about 1500 m a.s.l., lies at the base of the Laitkor range of hills, the latter with a mean altitude of 1900 m a.s.l. (Figure 1). It receives an average annual rainfall of about 2000 mm. The rocks in the area are mostly quartzites with intrusions of granites, metamorphosed basic rocks called 'khasi greenstones', phyllites, and others (Mazumder, 1986). A large number of stone and sand quarries are operative in Shillong and its neighbouring areas, the locations of some of which are shown in Figure 1. *P. denticulatum* and *B. argenteum* were collected in August 1992 from 4 sites located within the commercial area of the city (designated urban), and from another 4 sites in its immediate outkirts, within a 1-2 km radius of the centre of the commercial area (designated suburban). *Sphagnum* sp. was collected from one suburban site only, where it was found found to grow on the edges of a forest about 2 km away from the centre of Shillong city (Figure 1). *P. denticulatum* was found to grow profusely on stones and cemented surfaces, while *B. argenteum* was particularly abundant on asbestos roofs. A total of 8 replicate samples each of *P. denticulatum* and *B. argenteum* were collected from urban as well as suburban sites, while 4 replicate samples of *Sphagnum* sp. were collected from the single suburban site where this species was found. The samples were air-dried for 48 hr, carefully hand-sorted to remove any extraneous materials, and oven-dried at 40 °C for another 48 hr. Only the green parts of *P. denticulatum* and *B. argenteum*, and the 'feathery' branches of *Sphagnum* sp. were subjected to acid digestion ($4HNO_3$: 1 $HClO_4$). The residues were dissolved in 2 mL HNO_3 and the volume brought to 20 mL with deionized water. Metals were analyzed in a Perkin Elmer 2380 atomic absorption spectrophotometer. Peak heights were compared with those of standard solutions, and metal concentrations calculated as $\mu g\ g^{-1}$ dry weight of moss tissue.

Concentrations of Cd, Cu, Mn, Pb, and Zn in *P. denticulatum* and *B. argenteum* in both urban and suburban sites, and in *Sphagnum* sp. in a single suburban site, are shown in Table I. Table I also shows the comparisons among the three species, as well as between the urban and suburban sites, as revealed by oneway ANOVA and Duncan's Muliple-Range tests. Vehicular emissions are likely to be the major contributor of lead, as leaded gasolone is still used in India. Tyre rubber wear (Hewitt and Candy, 1990) as well as minor industries could be possible sources for zinc and cadmium, while copper, manganese, and partly, cadmium contaminations could occur from fungicides and fertilizers used in the agricultural plots strewn around Shillong city. Besides, both dry and wet depositions of fine dust blown from stone and sand quarries which often expose granite and 'khasi greenstone' layers, could be possible mechanisms for the deposition of manganese (1035.87 ± 343.33 p.p.m. in granite), copper and zinc (221 ± 82, and 61 ± 16 p.p.m., respectively, in khasi greenstone) (Mazumder, 1986; Mishra, personal communication) in Shillong.

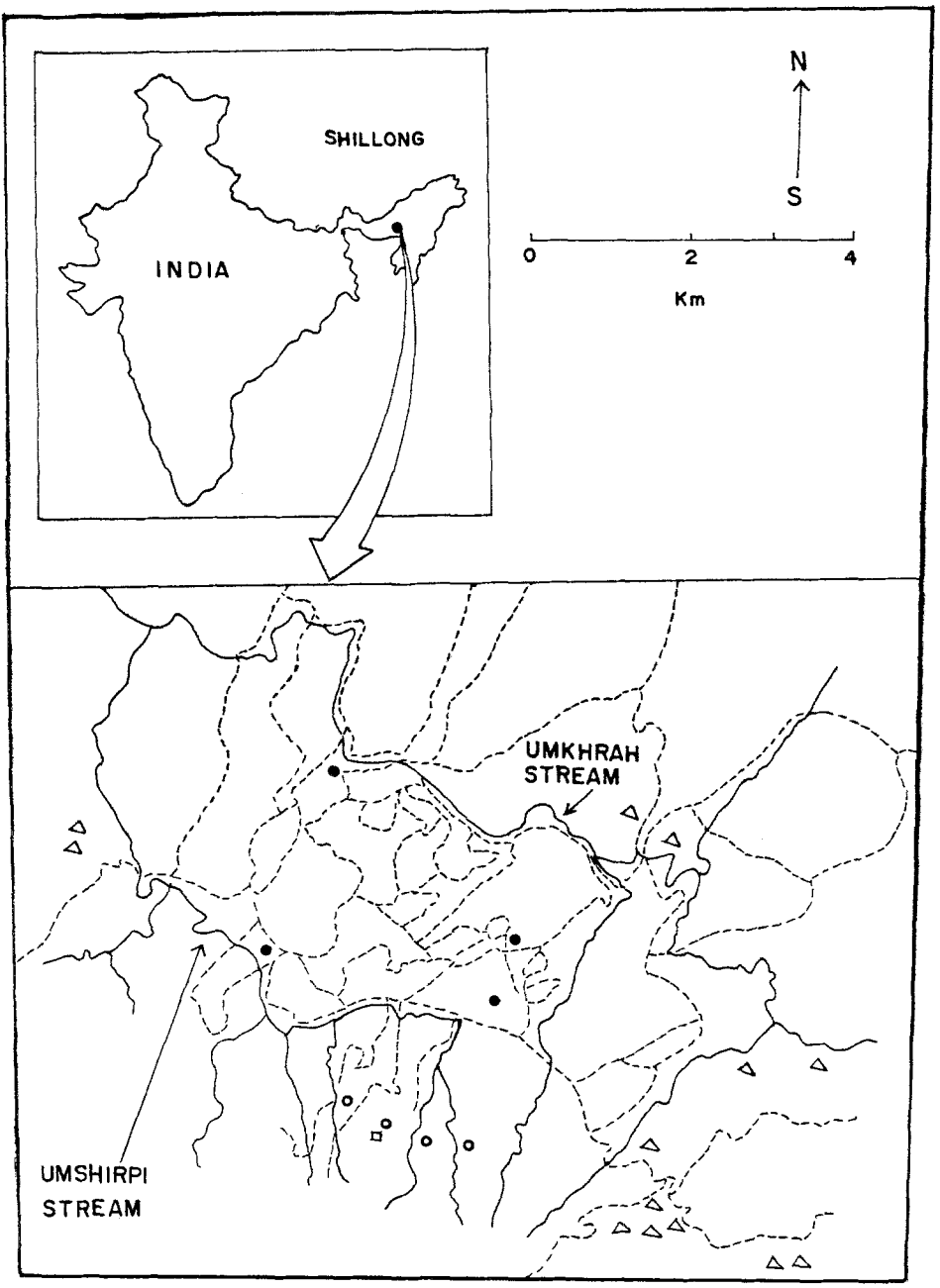

Fig. 1. Map of Shillong showing the waterways (solid lines), major traffic arteries (dotted lines), urban (closed circles) and suburban (open circles) collection sites for *P. denticulatum* and *B. argenteum*, suburban collection site form *Sphagnum* sp. (square), and major stone and sand quarries (triangles).

TABLE I

Metal concentrations (mean ± SD) in *P. denticulatum, B. argenteum* (8 samples), and *Sphagnum* sp. (4 samples), in urban and suburban sites in Shillong, and comparisons of metal levels among species/sites, as revealed by one-way ANOVA and Duncan's Multiple-Range tests

Metal	Concentrations in $\mu g\ g^{-1}$ (±SD)					F. value	Rankings[a]
	P. denticulatum		*B. argenteum*		*Sphagnum* sp.		
	Urban (1)	Suburban (2)	Urban (3)	Suburban (4)	Suburban (5)		
Cd	1.25±0.1	1.08±0.1	1.98±013	1.3±0.15	2.01±0.98	3.79*	5,3>1,2,4
Cu	45.38±11.83	37.73±9.2	30.7±7.5	24.68±6.3	25.18±6.62	4.26**	1>3,4,5
Mn	397.19±27.2	503.6±25.1	308.54±14.7	333.17.±16.1	639.08±60.7	67.01***	5>2>1>3,4
Pb	66.38±7.6	52.27±11.1	40.74±10.55	35.07±7.3	28.42±9.35	10.4***	1>2,3,4,5
Zn	40.05±6.71	24.36±6.13	15.28±4.6	14.97±3.94	92.34±9.72	98.09***	5>1>2,3,4

* $P = 0.05$.

** $P = 0.025$.

*** $P = 0.001$.

[a] Rankings based on Duncan's Multiple-Range tests.

Table I reveals that *P. denticulatum* and *B. argenteum*, and *Sphagnum* sp. to some extent, appear to be fairly good indicators for copper. Rühling and Tyler (1970) observed a high affinity for this metal in mosses. *Sphagnum* sp., on the other hand, seems to reflect zinc and cadmium depositions much better than the other two species. *P. denticulatum* also appears to be suitable for indicating lead, while manganese is efficiently accumulated by all the three species, the decreasing order being: *Sphagnum* sp., *P. denticulatum*, and *B. argenteum.*

When metal contents of urban and suburban samples of *P. denticulatum* and *B. argenteum* are compared, an urban-suburban gradient is evident for lead and zinc in *P. denticulatum*, and for cadmium in *B. argenteum*, but not evident for copper in either species. Manganese contents, in contrast, were significantly elevated in the suburban samples of *P. denticulatum.* As mentioned earlier, *Sphagnum* sp., which was found in a suburban site only, also exhibited a high manganese content. Similar results for manganese were obtained in several studies, where its high accumulations were associated with low levels of other metals in mosses and lichens. It is possible that the adsorption of manganese is decreased in the presence of higher amounts of other metals (Johnsen and Rasmussen, 1977; Grodzinska, 1978; Rinne and Barclay-Estrup, 1980). The reason for this decreased adsorption is likely to be related to the relative instability of organic chelates with manganese (Mallor and maley, 1947, 1948; Rinne and Barclay-Estrup, 1980).

Metal levels in Shillong mosses can not at present be compared with those from other parts of India as there are no other studies, but when compared with data available for other species from Scandinavia, North-eastern United States, and parts of Canada (Rühling and Tyler, 1970, 1971, 1973; Groet, 1976; Barclay-Estrup and Rinne, 1978; Rinne and Barclay-Estrup, 1980), the lead content of *P. denticulatum* is somewhat higher than those found in *Pleurozium schreberi* at sites around 30-50 km from city areas (Rinne and Barclay-Estrup, 1980), although less than those found in the North-eastern United States (Groet, 1976), and in Thunder Bay City, Ontario, Canada (Barclay-Estrup and Rinne, 1978). Zinc levels in *P. denticulatum* and *B. argenteum* are rather low, but that in *Sphagnum* sp. is somewhat higher than those found in the studies already mentioned. Likewise, copper and manganese contents of all the three mosses are significantly elevated compared to those found in the rural areas of Scandinavia and North America. Hence. these figures can be said to provide baseline data which will make comparisons possible with future studies both in Shillong and in other parts of India.

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References

Barclay-Estrup, P. and Rinne, R. J. K.: 1978, *Oikos***30**, 106.
Grodzinska, K.: 1978, *Water, Air, and Soil Pollut.***9**, 83.
Groet, S. S.: 1976, *Oikos***27**, 445.
Hewitt, C. N. and Candy, G. B. B.: 1990, *Environ. Pollut.***63**, 129.
Johnsen, I. and Rasmussen, L.: 1977, *Bryologist***80**, 625.
Livett, E. A.: 1988, in Advances in Ecological research 18, Begon, M., Fitter, A. H., Ford, E. D. and Macfayden, A., (eds.), Academic Press Ltd., London, p. 82.
Mazumder, S. K.: 1986, *Geological Survey of India records***117**, 1.
Mellor, D. P. and Maley, L.: 1947, *Nature, Lond.***159**, 370.
Mellor, D. P. and Maley, L.: 1948, *Nature, Lond.***161**, 436.
Rinne, R. J. K. and Barclay-Estrup, P.: 1980, *Oikos***34**, 59.
Rühling, A and Tyler, G.: 1970, *Oikos***21**, 92.
Rühling, A. and Tyler, G.: 1971, *J. Appl. Ecol.***8**, 497.
Rühling, A. and Tyler, G.: 1973, *Water, Air, and Soil Pollut.***2**, 445.