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Heavy Metals in some Malaysian Mosses

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RINGKASAN

Enam puluh lima jenis sampel lumut dikumpulkan secara rawak dari kawasan Kuala Lumpur dan di sekitarnya. Sampel-sampel ini dianalisiskan untuk Zn, Pb, Cd, Cu, Ni, Fe dan Mn. Kecenderongan tertentu diperhatikan untuk perubahan kepekatan Pb lumut-lumut. Perubahan dalam logam lain tidak mengikut kecenderongan yang jelas. Nilai latar belakang bagi logam-logam ini kecuali Fe pada umumnya dapat dibandingkan dengan nilai yang telah dilaporkan. Kajian pertalian antara logam-logam dilakukan dan keputusan menunjukkan adanya pertalian yang positif dan penting antara Pb, Cd, Cu, Fe dan Mn. Kesesuaian untuk menggunakan lumut-lumut sebagai penunjuk pencemaran adalah dibincangkan.

SUMMARY

Sixty-five moss samples were collected randomly from areas in and around Kuala Lumpur and analysed for Zn, Pb, Cd, Cu, Ni, Fe and Mn. A definite trend was observed for the variation of Pb concentration in mosses. The variations for the other metals were, however, not clearly defined. The background values for these metals were generally comparable to previously reported values except Fe which was high. Correlation studies among the metals were performed and the results indicated positive significant correlations among Pb, Cd, Cu, Fe and Mn. The suitability of using mosses as pollution indicators is discussed.

INTRODUCTION

The monitoring of atmospheric pollution is of great importance. Various direct means of monitoring heavy metals in the atmosphere are available (Hendrikson, 1962). However, most of these methods, though yielding accurate and quantitative estimations, are rather expensive and cumbersome. The use of biological materials as metal indicators, on the other hand, has been reported to be a relatively cheap, simple and reliable method (Goodman and Roberts, 1971; Little and Martin, 1964). The use of mosses in this respect has been reported to be advantageous over that of vascular plants (Groet, 1976).

Ruhling and Tyler (1968, 1970, 1971) studied the distribution of heavy metals in mosses and vascular plants. *Holocomium splendens* was found to be a sensitive indicator for heavy metal pollution. Groet (1976) investigated the heavy metal levels in *Leucobryum glaucum* (Hedw) Angtr. extr. and other mosses and found that the heavy metal concentrations were generally higher in the more industrialized areas.

Ward *et al* (1977) studied the concentrations of heavy metals in bryophytes. They found that near the ore treatment plant, the metal concentrations were higher in the mosses than in their substrates, indicating foliar uptake of airborne contaminants.

Barclay-Estrup and Rinne (1978, 1980) reported that the concentrations of both lead and zinc in two feather mosses were higher in the urban than the rural areas. They found that the metal concentrations in *Pleurozium schreberi* decreased with increasing distance from the city.

In the study of seventeen moss species, Onianawa and Egumjomi (1983) found that lead values for mosses from the rural areas of the country were significantly lower than those of the

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city. No definite trend was, however, observed for all the other trace metals analysed.

The distribution of heavy metals in Malaysian mosses has not been investigated. The present study is the first attempt to determine the variations in heavy metals in mosses in the city of Kuala Lumpur as well as some areas nearby, and to assess the suitability of using mosses as pollution indicators.

METHODS AND MATERIALS

Sixty-five samples of mosses consisting of 24 species were collected randomly from November 1981–December 1981, and from October 1982–February, 1983. The mosses were collected from areas which include Kuala Lumpur, the capital of Malaysia, Selangor (Petaling Jaya, Shah Alam, Serdang), Negeri Sembilan (Pasoh Forest Reserve), Perak (Tanjung Malim) and Pahang (Genting Highlands and Cameron Highlands). *Fig. 1* shows the locations of these areas. Depending on the natural habitat of the mosses collected, associated substrate samples of soil or bark were collected wherever possible.

Fig. 1. Map of part of Peninsular Malaysia showing sampling locations.

On arrival in the laboratory, the mosses were manually separated from their substrates, washed till no soil adhesion could be seen, rinsed with deionised water and dried at 75°C for three days. The substrate materials were similarly treated. The dried samples were ground using a stainless steel grinder. One gram of the ground sample was digested with a 4:1 mixture of concentrated nitric and perchloric acids. The residue was redissolved in 1% nitric acid and made up to 25 cm^3. (Little and Martin, 1972). A blank treated in the same way was used as a control. Duplicates were carried out for all the samples.

Analyses of Zn, Pb, Cd, Cu, Ni, Fe and Mn on all the samples were carried out using a sequential inductively coupled plasma emission spectrometer (Labtest Plasmascan 710–2100).

To check the accuracy of the analysis, determinations were made of the metal contents of NBS standard reference material No. 1571 (Orchard leaves). The material, in duplicate, was treated in the same manner as the moss samples. The obtained concentrations for all metals except Mn and Fe fell within accpetable limits (Table 1). The low values of Mn and Fe cannot be explained at this juncture.

RESULTS AND DISCUSSIONS

Variations of heavy metal concentrations

There are three areas where the mosses were collected. Area I (Kuala Lumpur) has the highest traffic density. Area II comprises Petaling Jaya, a satellite town 8 km from Kuala Lumpur; Shah Alam, a new state capital 24 km east of Kuala Lumpur and a University and Research Complex at Serdang, 20 km south of Kuala Lumpur. Area III includes the Pasoh Forest Reserve in Negeri Sembilan, Tanjung Malim in Perak and Cameron

TABLE 1
Analysis of National Bureau Standards (NBS)
No. 1571 (Orchard leaves)

Metal	Zn	Pb	Cd	Cu	Ni	Fe	Mn
Certified value	25 ± 3	45 ± 2.0	0.11 ± 0.01	12.0 ± 1.0	1.3 ± 0.2	300 ± 20	91 ± 4
Observed value[1]	27 ± 0.3	47 ± 0.2	0.12 ± 0.00	12.1 ± 0.4	1.1 ± 0.3	253.5 ± 0.5	77.3 ± 1.2

[1] The values are means and S.D.s of the duplicate analyses.

Highlands as well as Genting Highlands in Pahang. The traffic density in these areas is generally in the order of Kuala Lumpur > Petaling Jaya > Shah Alam > Serdang > Area III. The heavy metal concentrations in mosses in areas I, II and III are shown in Tables 2, 3 and 4 respectively.

There is a clear distribution pattern for Pb, irrespective of the species type and the age of the mosses. With the exception of residential areas, Pb concentration ranged from 131 to 1634 $\mu g\ g^{-1}$ in Kuala Lumpur. The range was 88–308 $\mu g\ g^{-1}$ in Petaling Jaya, 23–98 $\mu g\ g^{-1}$ in Shah Alam, 17–69 $\mu g\ g^{-1}$ in Serdang with the exception of the sample at the Tennis Court, Universiti Pertanian Malaysia, 13–17 $\mu g\ g^{-1}$ in Pasoh Forest Reserve, 47–56 $\mu g\ g^{-1}$ in Genting Forest, 17–54 $\mu g\ g^{-1}$ in Cameron Highlands and 19–22 $\mu g\ g^{-1}$ in Tanjung Malim. These values clearly show that there is a definite distribution pattern for Pb in mosses, depending on the traffic density of the areas.

When specific species of the mosses are considered, the same trend is shown. Pb concentration for *Hyophilla involuta* ranged from 172–1118 $\mu g\ g^{-1}$ in Kuala Lumpur and 54–88 $\mu g\ g^{-1}$ in Selangor. For *Barbula indica,* it was 412–1315 $\mu g\ g^{-1}$ in Kuala Lumpur and 44–93 $\mu g\ g^{-1}$ in other areas. Similar trends in the variation of Pb concentration had been reported for *Leucobryum glaucum* (Groet, 1976) and *Pleurozium schreberi* and *Hylocomium splendens* (Barclay-Estrup and Rinne, 1978). Mosses, thus, appear to be a good indicator of Pb pollution in the atmosphere.

No clear trend was observed for the variation of Zn, Cd, Ni, Fe and Mn in the mosses. Cu generally followed the same trend as Pb although it was not as well defined. Low and *et al.*, (1983) demonstrated in a 10-week moss-bag experiment that the uptake of Zn, Cd, Ni, Fe and Mn initially increased with exposure time, but subsequently decreased. Pb and, to a lesser extent Cu, were the two metals whose concentrations in the mosses increased with increasing exposure time. This could be due to the fact that Pb was more effectively sorbed by the mosses (Ruhling and Tyler, 1970). Lead was reported to form a more stable organochelate with mosses than the other metals (Mellor and Mallye, 1947, 1948). Mosses, therefore, could not be used to monitor Zn, Cd, Ni, Fe and Mn levels on a long term basis.

Analysis of heavy metals in the substrates gave wide variations. No meaningful deductions could be drawn from the results.

Background values for metals

Owing to the difficulty of obtaining true natural values for heavy metals in mosses, samples from remote and unpolluted areas were used to obtain data on 'near natural' or background values (Groet, 1976).

Table 5 lists the background values for the metals in the present study as well as some previously reported values for comparison. Generally the background values for Zn and Fe were higher in the Malaysian mosses. The background values for Pb was about-equal to that in Canada, South Scandinavia and New Zealand. It was, however, higher than that in North Scandinavia and Britain and lower than that in the Northeast USA. The background values for Cd and Cu were higher than those in Britain and Scandinavia but were about equal to those of the other countries. The Ni background value was higher than that in Canada and North Scandinavia and about equal to that in the other countries. For Mn, the background value was lower than that in Canada. The differences in values seem reasonable, taking into account that various species of mosses were studied.

Metal Correlation

A positive correlation was obtained for all metal except that between Ni and Fe (Table 6). Significant correlations were observed for Cd, Pb, Cu, Fe and Mn. Zn correlates significantly with Cd and Mn only. Ni correlates with Pb only. Rinne and Barclay (1980) reported significant positive correlations among Cd, Cu, Fe, Ni, Pb and Zn in *Pleurozium schreberi.* Groet (1976) observed significant positive correlations among Cr, Cu, Ni and Zn in *Leucobryum glaucum;* however, Cd correlated with Zn only. Ruhling and Tyler (1969) intercorrelated Cu, Zn, Ni and Pb in *Hypnum cuppressiforme* and reported positive correlations between Cu and Ni (0.61), Cu and Zn (0.36), Cu and Pb (0.49), but a lower correlation between Zn and Pb (0.29).

Correlation of heavy metals may be affected by emission sources (Groet, 1976), metrological conditions as well as the age and the species of the mosses (Grodzinska, 1978). In the present correlation study, all the mosses, irrespective of their age and species, were considered. This may explain some of the anomalies observed.

CONCLUSION

From the data gathered in this study it appears that Malaysian mosses are good indicators for Pb pollution in the atmosphere. However, the

TABLE 2
Concentration of heavy metals ($\mu g\ g^{-1}$ dry weight) in mosses in Kuala Lumpur

Sample Number	Location	Species	Zn	Pb	Cd	Cu	Ni	Fe	Mn
K1	Jalan Ampang	*Hyophilla involuta*	382.3	1118	5.8	62.6	20.6	3930	257.0
K2	Jalan Ampang	"	370.6	1079	7.3	69.8	21.3	9490	174.6
K3	Jalan Pekeliling	"	629.0	917.7	6.5	59.8	20.9	6800	114.7
K4	Jalan Brickfield	"	648.3	1037	4.7	77.8	15.8	5895	148.9
K5	Jalan Brickfield	"	550.1	708.9	2.9	103.1	8.6	3694	122.1
K6	Jalan Brickfield	"	311.4	429.3	2.8	41.2	12.4	1445	107.2
K7	St. Mary Cathedral	"	371.7	841.1	4.8	64.0	11.7	6797	201.3
K8	Jalan Belanda	"	305.9	535.4	3.2	49.5	17.5	5286	96.5
K9	Jalan Kuching	"	139.4	172.1	5.5	41.5	13.4	8833	76.2
K10	Court Hill	"	158.4	291.0	3.2	–	–	–	–
K11	Court Hill	"	197.6	311.4	1.2	52.6	6.2	2503	43.3
K12	General Hospital	"	619.0	468.0	5.9	33.0	5.7	5610	101.4
K13	Lake Garden	*Meiothecium microcarpum* Harv.) Mitt.	88.5	131.7	1.4	36.6	6.1	2342	40.5
K14	Jalan Brickfield	"	257.9	142.0	.08	69.5	19.4	5186	95.4
K15	Residential (city centre)	"	634.0	215.9	3.0	21.9	45.6	3330	34.6
K16	Edinburgh Circle	*Meiothecium* sp.	673.0	1697	3.4	25.8	43.1	3410	25.6
K17	Jalan Raja Muda	*Berbula indica*	1008	1315	5.2	56.9	25.3	5370	134.4
K18	Jalan Tunku Abdul Rahman (T.A.R)	"	1881	411.9	7.5	43.5	19.7	4610	175.3
K19	Road Junction of Jalan T.A.R., Jalan Raja Laut.	"	504.0	483.5	4.6	36.7	56.1	4340	108.2
K30	Residential (outside city)	*Barbula* sp.	38.9	35.6	3.2	9.9	9.7	8489	23.3
K21	Jalan Pekeliling	*Calymperes dozyanum*	726.6	407.9	3.0	25.3	29.9	2190	61.3
K22	Residential (outside city)	*Calyperes* sp.	479.0	63.4	1.9	9.8	43.8	860	49.3
K23	Jalan Duta	*Isopterygium minutirameum* (C.M.) Jaeg.	227.2	328.6	4.0	75.7	19.7	6610	66.6
K24	Jalan Brickfield	*Syrrhopodon* sp.	241.1	322.2	1.1	44.2	16.1	1450	63.3
K25	Jalan Sungai Besi	*Bryum coronatum* Schwaerr.	757.0	588.4	7.1	52.9	20.9	7200	99.4
K26	Jalan Pekeliling	*Splachnobryum oorschotii* (Lac.) C. Mall.	896.0	1634	6.6	74.5	19.3	6750	128.2

TABLE 3
Concentration of heavy metals ($\mu g\ g^{-1}$ dry weight) in mosses in Selangor

Sample Number	Location	Species	Zn	Pb	Cd	Cu	Ni	Fe	Mn
	Petaling Jaya								
S1	Residential (next to playground)	*Hyophille involuta*	108.7	87.6	2.3	31.3	6.1	2586	38.9
S2	Town	*Philonotis hastata* (Duby) Sijk & Marg.	111.3	308.2	7.2	17.4	15.3	8029	47.4
S3	Playground	*Leucophanes octoblespharoides* Brid.	315.0	102.2	4.4	7.5	20.3	3700	16.4
	Shah Alam								
S4	Adjacent to electronic engineering factory	*Hyophille involuta*	1914	65.5	6.9	37.0	20.4	5140	56.7
S5	Ladang Sungai Rengam	*Octoblephan albdtum* Hedw.	314.0	24.2	3.1	9.6	14.6	4700	16.3
S6	As above	*Syrrhopodon cilliatus*	619.0	23.0	5.5	15.0	13.3	2780	18.2
S7	ITM	*Babula indica*	678.0	52.7	3.0	12.0	20.0	5160	19.2
S8	ITM	*Babula indica*	548.0	92.7	3.9	15.1	11.5	6980	65.1
S9	Adjacent to Highway.	*Calymperes* sp.	795.0	98.2	7.9	16.7	17.9	11370	37.3
	Serdang								
S10	Hydroponic unit, UPM	*Meiothecium microcarpum*	828.0	17.2	4.4	10.9	10.5	10570	78.4
S11	Foodtech, UPM.	" "	139.0	21.8	0.5	23.1	4.3	8517	24.9
S12	Tennis court, UPM	*Barbula indica*	1511	208.0	9.6	28.6	23.6	12280	213.2
S13	Coconut unit, UPM	*Isopterygium albescens* (Schwawgr.) Jaeg.	1074	25.3	2.8	19.3	6.9	2370	86.8
S14	Oil palm estate, UPM, near S13	" "	728.0	19.1	2.0	10.9	16.4	1710	48.0
S15	Oil palm estate, 10 m from highway to Kajang.	" "	68.6	40.4	2.1	15.8	8.1	1290	70.9
S16	Jalan Ladang, UPM	" "	110.3	45.3	3.9	12.3	17.5	4000	71.2
S17	Mardi Guard House	*Calymperes delesscittii* Besh.	158.0	21.6	1.8	14.9	16.1	1746	91.6
S18	Mardi Oil palm estate	*Syrrhopodon albovaginatus* Schwaegr.	149.9	27.2	2.3	55.3	17.1	3362	34.0
S19	Mardi Oil palm estate	*Isopterygzium minutirameum*	179.9	44.8	2.8	98.9	36.0	5659	35.3
S20	Junction between Serdang/ Belakong	" "	789.1	69.3	6.0	105.0	12.4	9458	106.7
S21	Same as 20	*Calymperes* sp.	152.8	62.5	2.4	19.2	3.2	1839	75.7
S22	Opposite to site 21	"	78.7	59.9	1.4	23.7	6.1	1343	22.4
	Puchong								
S23	Rubber estate	*Tazithelium ramicola* Broth.	139.5	44.6	2.7	23.7	10.5	4600	83.6
S24	Rubber estate	*Fissidens sylvaticus* Girff.	77.8	46.3	3.9	37.1	13.8	7181	36.8

*ITM – Institut Teknologi Mara.
UPM – Universiti Pertanian Malaysia.

TABLE 4
Concentration of heavy metals ($\mu g\ g^{-1}$ dry weight) in mosses in Negeri Sembilan, Pahang and Perak

Sample Number	Location	Species	Zn	Pb	Cd	Cu	Ni	Fe	Mn
	Negeri Sembilan								
	Forest Reserve								
N1	Plot 1	*Syrrhopodon* sp.	179	13.6	1.3	7.3	4.0	2000	13.3
N2	Plot 2	”	171	12.6	1.3	20.4	15.6	2370	13.5
N3	Plot 3	”	179	15.6	1.5	13.5	19.9	3230	47.7
N4	Plot 4	”	176	16.5	1.4	7.6	17.0	2088	21.6
	Pahang								
P1	Genting Casino	*Barbula indica* (Schwaegr) Brid.	1521	648.5	4.4	33.1	12.7	4644	104.9
P2	Genting Casino	*Bryum argenteum* Hedw.	176.5	624.8	3.3	86.5	11.2	16113	106.9
P3	Genting Forest	*Pyrrhobryum spiniforme* (Hedw.) Mitt.	326.1	47.4	0.9	13.3	12.9	9064	–
P4	Genting Forest	*Trimegistia* sp.	380.5	56.1	1.9	10.4	18.8	7120	–
	Cameron Highland								
P5	Residential Bungalow	*Hyophilla involuta*	741.0	54.1	4.7	10.1	10.1	4120	110.7
P6	Research station	*Barbula indica* (Schwagr) Brid.	248.0	43.9	5.1	22.1	19.8	3940	84.6
P7	Jungle path	*Braunfelsia* sp.	442.0	17.2	1.7	8.0	26.6	3900	100.8
P8	Flower farm	*Philonofiz tumerianne* (Schwaegr) Mitt.	515.0	23.1	3.8	14.6	19.3	3470	100.6
P9	Hill slope	*Rhacopilum spectabile* Reinw and Hornsch.	804.0	34.3	3.4	11.3	17.3	4120	30.9
	Tanjong Malim, Perak								
P10	Oil palm estate	*Calymperes* sp.	626.0	22.0	1.8	7.5	20.3	3700	16.4
P11	Oil palm estate	*Octoblespharum albidum* Hedw.	589.0	18.8	1.6	10.4	14.3	7300	14.8

TABLE 5.
Comparison of Background Values of Heavy Metals

	Serdang (1) range)	Forest Reserve (1) (range)	Canada (2) range	Southern Scandinavia (3) range	Northern Scandinavia (3) range	North Eastern USA (4) mean	Britain (5) mean ± SD	New Zealand (6) mean ± SD
Species analyzed Element ($\mu g\ g^{-1}$)	*Isoptergium albescens*	*Sypohopodon* sp.	*Pleurozium schreberi*	*Hylocomium splendens*	*Hylocomium splendens*	*Leucobryum gloucum*	*Hypnum cupressiforme*	*Hypnum cupressiforme*
Zn	68.6–728.0	171–179	65–71	80–110	30–40	6.2	91 ± 17	17.2 ± 3.3
Pb	19.1–45.3	12.6–16.5	29–31	40–150	5–10	131.0	5.8 ± 8	10.6 ± 2.0
Cd	3.0– 3.9	1.3–1.5	0.5–0.6	0.8–1.5	0–1	0.89	1.4 ± 0.4	0.4 ± 0.21
Cu	10.9–19.3	7.3–20.4	6.6–8.8	8–12	5	9.6	13 ± 2	10.1 ± 2.4
Ni	8.1–16.4	4.0–19.9	2.0–3.4	3–8	1.5–2.0	9.4	8.3 ± 1.7	–
Fe	1290–12280	2000–3300	690–940	1000	500	–	–	–
Mn	48.0–213.3	13.3–47.7	290–320	–	–	–	–	–

References : (1) Results of present study
(2) Rinne and Barclay-Estrup, 1980.
(3) Ruhling and Tyler, 1973.
(4) Groet, 1976.
(5) Goodman and Roberts, 1971.
(6) Ward et al., 1977.

TABLE 6
Correlations between metals in mosses

Elements n	Cd 65	Pb 65	Cu 64	Ni 64	Fe 64	Mn 62
Zn	0.51**	0.18	0.04	0.21	0.15	0.27*
Cd		0.40**	0.27*	0.17	0.49**	0.55**
Pb			0.53**	0.26*	0.16	0.55**
Cu				0.02	0.31*	0.49**
Ni					−0.06	0.05
Fe						0.28*

Level of significance
*$P < 0.05$, ** $P < 0.001$

use of mosses as indicators for other metals requires a more detailed study of the displacement patterns among the metals.

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