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The Use of the Moss, *Calymperes Delessertii* Besch., as a Bioindicator to Airborne Heavy Metals

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Key words: Moss; *Calymperes Delessertii* Besch., heavy metals; bioindicator; atmospheric pollution.

ABSTRAK

Satu kajian yang lengkap tentang penumpukan logam berat yang terdiri daripada udara oleh lumut Calymperes delessertii *Besch. telah dijalankan. Logam berat yang dikaji adalah Zn, Cd, Ni, Fe, Mn, Pb dan Cu. Kesesuaian lumut ini sebagai satu penunjuk terhadap logam-logam ini juga dibincangkan.*

ABSTRACT

A detailed study on the accumulation of aerial heavy metals by the moss, Calymperes delessertii *Besch. was conducted. Heavy metals studied were Zn, Cd, Ni, Fe, Mn, Pb and Cu. The suitability of the moss as a bioindicator to these aerial metals was also discussed.*

INTRODUCTION

The use of mosses for monitoring effluent dispersal of heavy metals has been investigated by several workers (Ruhling and Tyler, 1970; Goodman and Roberts, 1971; Little and Martin 1974; Barclay-Estrup and Rinne, 1978). Its use for monitoring regional and local variations in heavy metal concentration was reported by Groet (1976), Schakelette and Connor (1973) and Martinez and co-workers (1971). Also reported is its use as a guide to mineralisation (Ward and co-workers, 1977).

Recently Lee and co-workers (1983) reported on the heavy metals of some Malaysian mosses. It was found that mosses from urban areas had a higher Pb concentration than those from rural areas. Similar trends in the variations of Pb in mosses were reported by Groet (1976) and Barclay-Estrup and Rinne (1975). Cu generally followed the same trend as Pb although it was less well defined. No clear trend was observed for the variation of Zn, Cd, Ni, Fe and Mn for mosses from different areas.

This paper reports on a more detailed study on the accumulation of aerial heavy metals by the moss, *Calymperes delessertii* Besh. 'Unpolluted' mosses were placed at Kuala Lumpur city (heavy traffic) and Universiti Pertanian Malaysia campus, Serdang (light traffic) and their heavy metal contents were monitored continuously over a period of ten weeks.

METHODS AND MATERIALS

The moss, *Calymperes delessertii* Besch. was collected from a remote oil palm estate some distance from Universiti Pertanian Malaysia. There was no known industrial activity in its vicinity.

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The 'unpolluted' mosses were placed in wooden frames of dimension 30 × 20 cm^2 with nylon meshing forming the bases. Care was taken to minimize overlapping of mosses so that they were all exposed to the atmosphere. They were suspended at a height of 0.8 m above the ground in three locations. They were the Merdeka Roundabout, Kuala Lumpur (site A), Bank Negara Roundabout, Kuala Lumpur (site B) and Universiti Pertanian Malaysia campus (site C). Both sites A and B are some 20 km from site C. Sites A and B represent areas of high traffic density whereas site C of low traffic density.

At the end of each exposure period (one week), mosses (about 10 g) were randomly collected from the wooden container from each site. They were mixed to form a composite mixture. They were then kept in polyethylene bags and labelled and cleaned immediately upon reaching the laboratory. The mosses were separated from their substrates, rinsed twice with deionised water and dried at 75°C for 3 days according to the procedure of Ward and co-workers (1977).

Goodman and Roberts (1971) reported no appreciable difference between the metal contents of washed and unwashed samples of *Hypnum cupressifarme*.

The dry mosses were ground using a stainless steel mill. Samples (1 g) were digested using 20 cm^3 of a 4 : 1 mixture of concentrated nitric and perchloric acids. The residue was washed with 1% HNO_3 in deionised water, filtered and made up to 25 cm^3. A blank solution containing the acids was used as a control. All analyses were performed in duplicates. Zn, Cd, Cu, Pb, Ni, Fe and Mn were determined using a sequential scanning inductively coupled plasma emission spectrometer (ICP-ES; Labtest 710 – 2000).

RESULTS AND DISCUSSION

The concentrations of Zn, Cd, Cu, Pb, Ni, Fe and Mn in mosses at various exposure intervals for the three sites are shown in *Fig. 1, 2, 3, 4, 5, 6* and *7* respectively. Zn, Fe and Mn were highest in concentration while Cd was lowest. Pb, Cu and Ni had intermediate values.

The correlation coefficients of the various elements in the mosses with exposure time are shown in Table 1.

TABLE 1
Correlations between heavy metal concentrations in the moss and exposure times at various sites

Element	Site A	Site B	Site C
Zn	– 0.05	– 0.29	– 0.17
Cd	0.67	0.35	0.49
Cu	0.76*	0.81*	0.90**
Pb	0.98**	0.95**	0.95**
Ni	0.68	0.95**	0.59
Fe	0.07	0.85**	0.57
Mn	0.55	0.21	0.90**

Level of significance:

* $p < 0.01$

** $p < 0.001$

Zinc

Zinc concentration increased initially, reaching a maximum between 4 to 6 weeks. However, thereafter there was a decrease. The final concentrations were lower than those of the 'unpolluted' mosses. Ruhling and Tyler (1970) in their investigation of woodland moss, *Hylоco-nium Splenden,* showed the sorption and retention of heavy metals to be in the order of Cu, Pb, > Ni > Co > Zn, Mn. It has also been shown that the uptake of heavy metals is mainly a process of passive ion exchange. In 'dusty' areas uptake is presumably dominated by surface absorption via aerial transport of the particulates (Ward *et al.*, 1980). Should the moss, *Calympe-res delessertii* Besh. show a similar order of sorption and retention of metal ions, it would explain the decrease of Zn after the initial increase. As the concentration of other metal ions like Pb, Cu, Ca, K, Mn and Na started to build up, they would stop the active sorption process by Zn which was present. Hence, this moss does not appear to be a suitable bioindicator for monitoring aerial Zn on a long term basis.

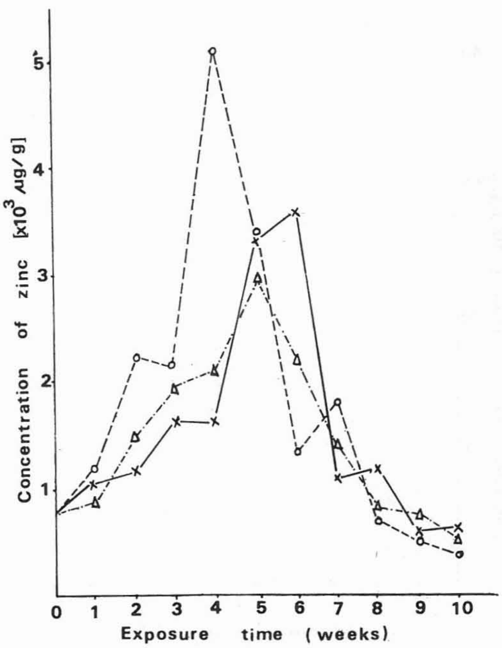

Fig. 1. Concentration of zinc in the moss at sites A (x), B (o) and C (Δ).

Cadmium

No significant correlation could be established between the metal with exposure at all three sites. Generally, the metal content increased with exposure. However, the pattern of increase appears random.

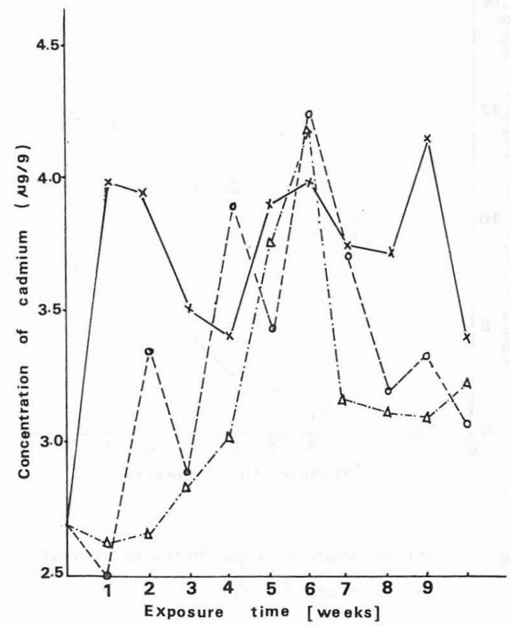

Fig. 2. Concentration of cadmium in the moss at sites A (x), B (o) and C (Δ).

Copper

Cu uptake by the moss shows a significant correlation with exposure; at site A a positive correlation of 0.76 ($p < 0.01$), site B, 0.81 ($p < 0.01$) and site C, 0.90 ($p < 0.001$). At two sites, A and B, the mosses did not have the same rate of sorption. This suggests variability of copper in the environment. Ruhling and Tyler (1970) suggested that the sorbed Cu ions formed a very stable complex with the moss tissues and hence were not readily leached out.

The continuous increase of Cu with time suggests the suitability of this moss as an indicator to atmospheric Cu levels.

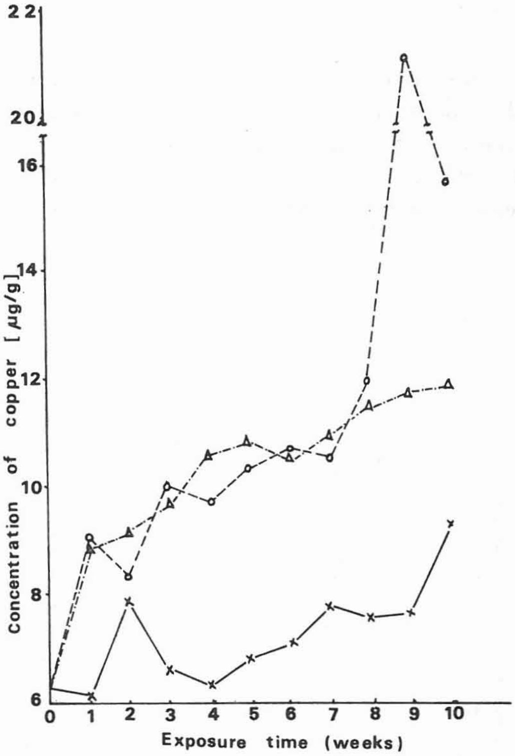

Fig. 3. Concentration of copper in the moss at sites A (x), B (o) and C (Δ).

Lead

Significant correlations of Pb in the moss with exposure are observed at all three sites; site A, 0.98; site B, 0.95; site C, 0.95, all at the significant level of $p < 0.001$. The average rate of sorption of Pb by the mosses on a weekly basis at sites A, B and C were 120.8, 126.9 and 11.3 µg g^{-1}dry weight of the moss respectively. The rates of sorption at sites A and B are comparable. The greater increase of Pb in the moss at sites A and B (urban areas) correspond to the higher level of aerial Pb. As there are no known industrial plants emitting Pb in all three areas, motor vehicle exhausts could be regarded as the major source of lead pollution. Low and co-workers (1981) in their study of atmospheric Pb in Kuala Lumpur and Universiti Pertanian Malaysia campus reported a higher concentration of atmospheric lead in Kuala Lumpur (6.5 µg m^{-3}) than at Universiti Pertanian Malaysia campus 0.25 µg m^{-3}). The present study confirm the earlier findings. Pb was reported to form a highly stable organochelate with mosses (Mellor and Mallye 1948).

Ruhling and Tyler (1968) reported that some mosses were good indicators for Pb accumulation. Martinez and co-workers (1971) reported that Spanish mosses found in the vicinity of busy highways contained a high level of Pb suggesting a high aerial Pb environment. Mosses that were most distant from travelled roads had the lowest Pb content. They also established that the Pb was incorporated in the tissues. Using electron scattering properties of Pb, Skaar (1973) and co-workers were able to establish that lead was accumulated within the nuclei of moss leaf cells.

It appears that this moss, *Calymperes delessertii* Besch. is a good bioindicator of atmospheric lead.

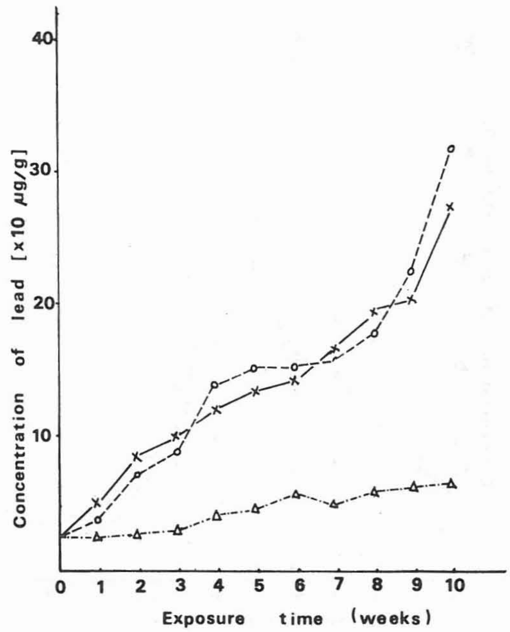

Fig. 4. Concentraton of lead in the moss at sites A (x), B (o) and C (Δ).

Nickel, Iron and Manganese

For Ni and Fe, the metal contents in the moss could be significantly correlated with exposure at site B only.

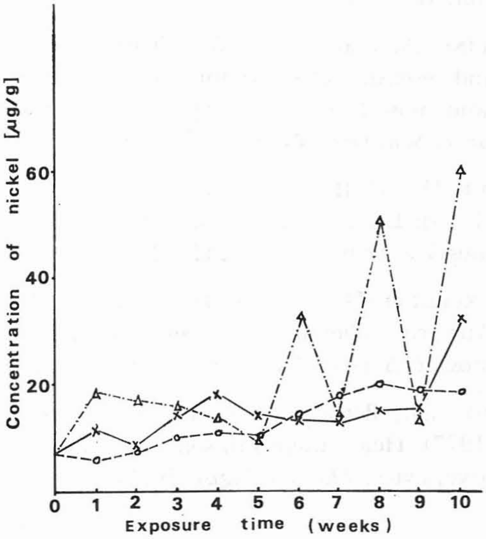

Fig. 5. Concentration of nickel in the moss at sites A (x), B (o) and C (Δ).

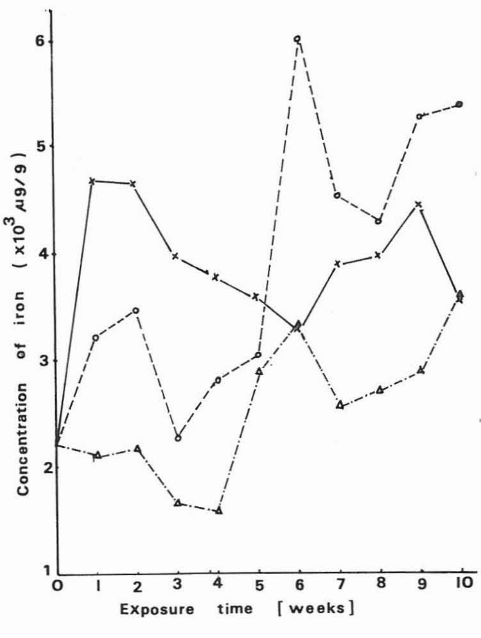

Fig. 6. Concentration of iron in the moss at sites A (x), B (o) and C (Δ).

For Mn, significant correlation between the metal in the moss and exposure interval was established at site C only.

Reasons for such variability in the uptake of these metals by the moss are not clear. However it does indicate that the moss could not be used to monitor these metals in the atmosphere.

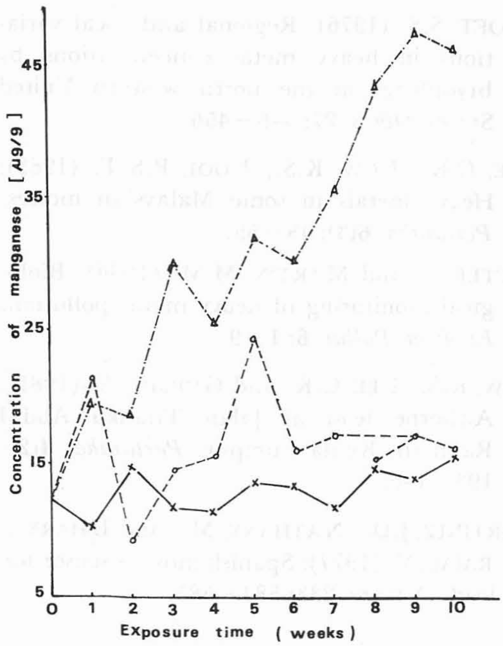

Fig. 7. Concentration of manganese in the moss at sites A (x), B (o) and C (Δ).

CONCLUSION

The moss, *Calymperes delessertii* Besch. appears to be a good bioindicator for monitoring aerial Pb and to a lesser extent Cu. It is not satisfactory for Zn, Cd, Ni, Fe dan Mn. If the metal concentrations in the mosses could be quantitatively related to the total metal content in the air, this convenient and yet inexpensive approach would be useful in the study of metal hazards to crops, live stock and man. Once such a relationship has been established, the moss technique would be much preferred to direct air sampling.

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