Bull. Environ. Contam. Toxicol. (1985) 35:430–438

Bulletin of Environmental Contamination and Toxicology

Potential Use of a Roadside Fern (*Pteris vittata*) to Biomonitor Pb and Other Aerial Metal Deposition

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Lead, widely used as antiknock additives in gasoline in many parts of the world, is released from vehicular exhausts and contaminates the roadside environment (Smith 1976). Such contamination of Pb may account for 1 to 10 percent of the total mass of suspended particulates in urban atmospheres (Nriagu 1978). Since Pb is toxic and may be present in high levels it presents health risks to the urban population (Bryce-Smith 1971). Further the Pb-containing particulates often settle onto roadside vegetation by sedimentation, impaction and interception resulting in high Pb content in the vegetation. The concentrations of Pb in such plants in turn are often used to demonstrate the extent of aerial deposition of Pb along roadsides. Plant materials employed in such studies are varied and included leaf (Kovacs et al. 1982) and bark of trees (Osibanjo and Ajayi 1980), grass (Motto et al. 1970), moss (Onianwa and Egunyomi 1983) and lichen (Laaksovirta et al. 1976). Some studies have also been made on the contamination of other metals such as manganese, iron, zinc, copper and cadmium (Smith 1973; Ward et al. 1977; Kovacs et al. 1982). These metals are present in vehicles and, as a result of wear and tear, are released into and contaminate the roadside (Lagerwerff and Specht 1970).

Hong Kong is a city with high traffic density of over 200 vehicles per kilometer of road. Further all gasoline sold here is leaded. Hence considerable contamination of Pb in the roadside environment is expected as has been shown in some recent studies (Ho 1979; Ho and Tai 1979, 1980). In our studies we found that some plants could be utilized as biomonitors of atmospheric Pb and other trace metals in the roadside environment. This paper reports on the Pb and other trace metal levels in the fern *Pteris vittata* growing along roadside and its possible use as biomonitor species for aerial deposition of metals.

MATERIALS AND METHODS

The fern *Pteris vitatta* L. was selected for this study because it is one of the most common indigenous species of plants capable of growing in highly urbanized areas in Hong Kong. In addition it can grow, with the minimum amount of soil substrate, in a variety of habitats including steep slopes and stone walls. Composite frond samples of fern were collected in March, 1979 from 44 roadside sites in the Island of Hong Kong covering a range of annual average daily traffic (AADT) from 320 to 51,240 vehicles per day and a mean and median AADT values of 13,850 and 13,610 respectively. In order to have the samples as comparable as possible all the sampling locations were within 3 m from the road curb and with a height of less than 2 m from the road surface. Further all the samples were taken in two consecutive days and with no rain fallen for at least 5 days prior to the sampling dates.

Each plant sample was oven-dried for 48 h at 90°C. After drying, the samples were ground to fine powder by a microhammer mill to pass through a 1 mm aperture screen. Previous tests indicated that contamination of trace metals resulting from the milling process was insignificant. Each individual ground sample was thoroughly mixed before subsamples of about 0.7 g each were accurately weighed. Metals were then extracted from each subsample by boiling it in 15 ml of 4 *M* nitric acid for 30 minutes. At least three replicated subsamples were made from each sample. The extract was filtered and the filtrate was made up to 25 ml with distilled water. Reagent blanks were prepared by carrying out the whole procedure, but in the absence of the sample. The amounts of Pb, Mn, Fe, Zn, Cu and Cd in solution were determined by atomic absorption spectrometry (Instrumentation Laboratory 651) with background correction and acetylene as fuel. The concentrations of metals in the filtrate were blank-adjusted and the metal contents in the fern samples were computed and expressed as μg metal per g dry sample. The mean maximum deviations in the metal concentrations of the subsamples from the sample means were 6% for Pb, Fe and Cu; 7% for Mn and Zn; and 25% for Cd. Thus apart from Cd, variations in individual metal concentrations amongst the replicated subsamples were relatively small.

RESULTS AND DISCUSSION

The arithmetic mean, the median and the concentration range of the six metals in *Pteris* from the 44 sites are given in Table 1. The relatively high mean and median values, and the wide range of Pb found in *Pteris* testified to the overall high level of contamination of this metal in the roadside environment in Hong Kong. The highest Pb concentration of 937 μg/g was found at a site with an average traffic of 26,860 vehicles per day. Such high Pb content of around 1000 μg/g in plant materials is not uncommon in areas of high traffic and had been reported by other workers (e.g. Graham and Kalman 1974; Ward et al. 1977).

Apart from Fe, *Pteris* contained lesser amounts of Mn, Zn, Cu and Cd than Pb (Table 1). Further, similar concentration ranges of Mn (Osibanjo and Ajayi 1980), Zn and Cu (Smith 1973; Ward et al. 1977), and Cd (Lagerwerff and Specht 1970) have been reported in plants in other studies. The levels of Fe in the fern samples were rather high and reflected the considerable amount of aerial deposition of dust particles on the plant. Roadside dust particles contain a very

Table 1. The arithmetic mean, median and concentration range values (μg/g) of metals in *Pteris* spp.

	Mean	Median	Range
Pb	281	216	16-937
Mn	90	76	12-308
Fe	2590	1750	210-19150
Zn	149	122	34-562
Cu	34	24	7-176
Cd	0.28	0.19	0.09-1.65

high level of Fe (Hopke et al. 1980) thereby elevating the Fe contents in the fern samples. (Indeed our unpublished results showed that a high percentage of Fe in roadside plants could be removed by washing with distilled water or by natural rain.) Similarly very high Fe levels in roadside mosses were observed by Onianwa and Egunyomi (1983). From Table 1, it is also apparent that the distribution of the metals in the sample was skewed towards the lower concentrations. This is indicated by the median value of each metal being about 25% lower than the arithmetic mean.

The relationships between the log concentrations of the metals in the fern samples and the log traffic volume are given in Figures 1 and 2. The correlation coefficient (r) in each case was calculated and tested for its significance. The results showed that the log concentrations of the six metals were positively correlated with the log traffic volume (Fig. 1 and 2). For Pb, Fe, Mn, Zn and Cu the correlations were significant at the 0.1% level whereas it was significant at 2% level for Cd. The slope of the fitted regression line was steepest for Pb, then in a descending order followed by Fe, Cu, Zn, Mn and Cd. A steeper regression slope would indicate a greater degree of contamination of the metal with increase in traffic volume. Thus from the graphs it is apparent that there were relatively greater contaminations in roadside fern by metals such as Pb, Fe and Cu when compared with Mn and Cd. In agreement with this study Ward et al. (1977), working on 17 sites along the Auckland Motorway in New Zealand, found statistically significant relationship (significance calculated from Spearman rank correlation coefficients) between elemental composition (Pb, Zn, Cu, Cd) in vegetation and traffic density. Although many workers found that the level of Pb contamination in roadside vegetation tended to be greater with the increase in traffic volume, the relationship was not always as clear-cut or quantitative as indicated in this study (e.g. Motto et al. 1970; Goldsmith et al. 1976; Havre and Underdal 1976). For Fe, Mn, Zn, Cu and Cd relatively few studies have been made and results available indicated that their levels in roadside vegetation were higher in location with higher traffic (e.g. Lagerwerff and Specht 1970; Burton and John 1977; Mankovska 1978).

Regional distribution of Pb and Fe levels in *Pteris* from all the 44 sites in Hong Kong Island are presented in Figure 3. Here the

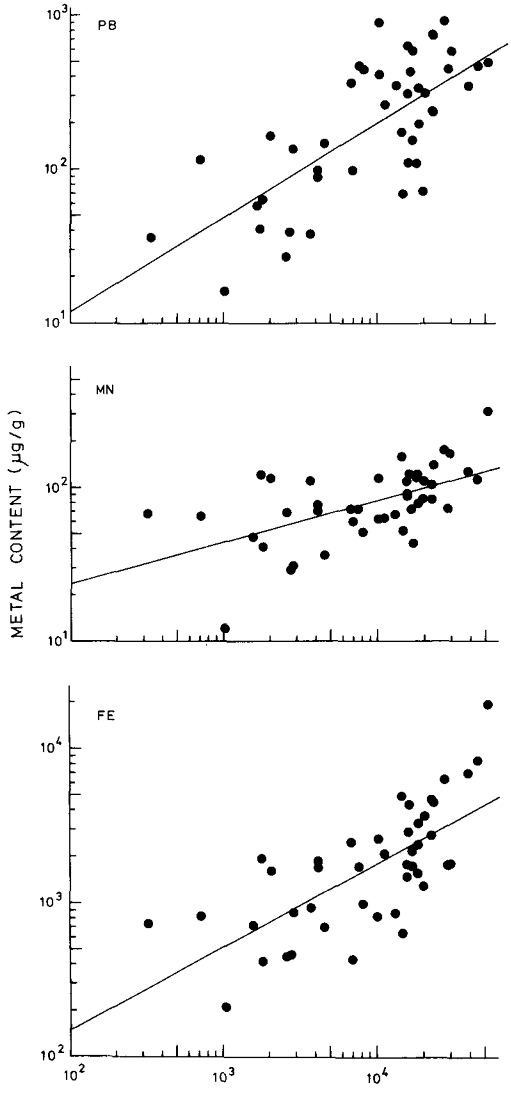

Figure 1. Correlation plots between log traffic volume and log Pb, Mn and Fe levels in roadside fern. Pb: r=0.717, $P<0.001$; Mn: r=0.563, $P<0.001$; Fe: r=0.707, $P<0.001$.

data are shown in terms of four intervals in concentrations. Similar presentations are made for Zn and Cu in Figure 4. Manganese and Cd are not included since the slopes of their correlation plots showed that these two metals did not contaminate the roadside ecosystem as much as the other four metals. From the maps it is apparent that roadside fern samples high in metal levels were mostly situated in built-up areas, especially on the northern and south-western part of the Island. Contrarily, fern materials taken from

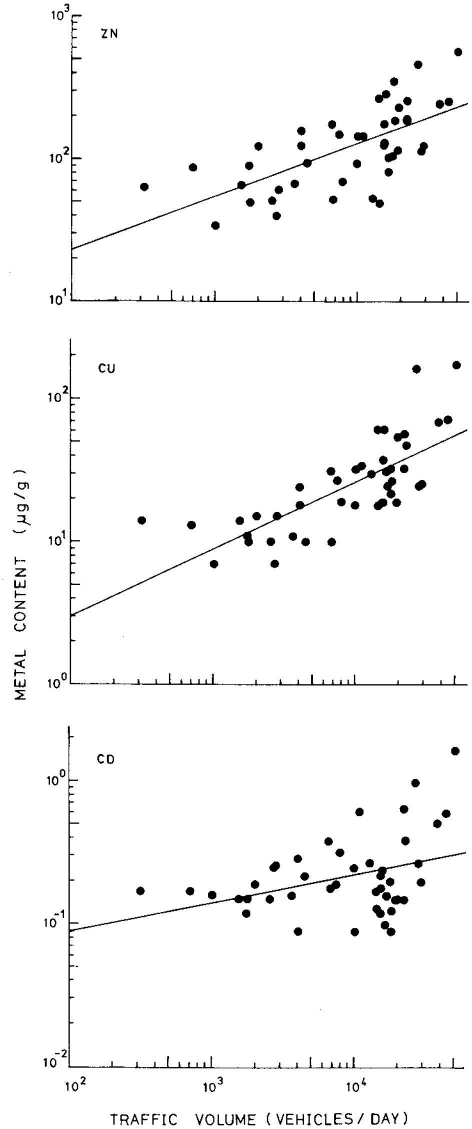

Figure 2. Correlation plots between log traffic volume and log Zn, Cu and Cd levels in roadside fern. Zn: r=0.650, P<0.001; Cu: r=0.774, P<0.001; Cd: r=0.383, P<0.02.

the south and south-eastern part of the Island had an overall lower levels of metals. Such regional differences in the metal levels in the fern reflected the extent of contamination of these metals in the roadside environment in different areas in the Island. Roads with heavy traffic were mostly situated in the northern built-up regions in Hong Kong Island, whereas those in the south-eastern part were mainly relatively light in traffic. The absence of sites in the central part of the Island was due to its hilly

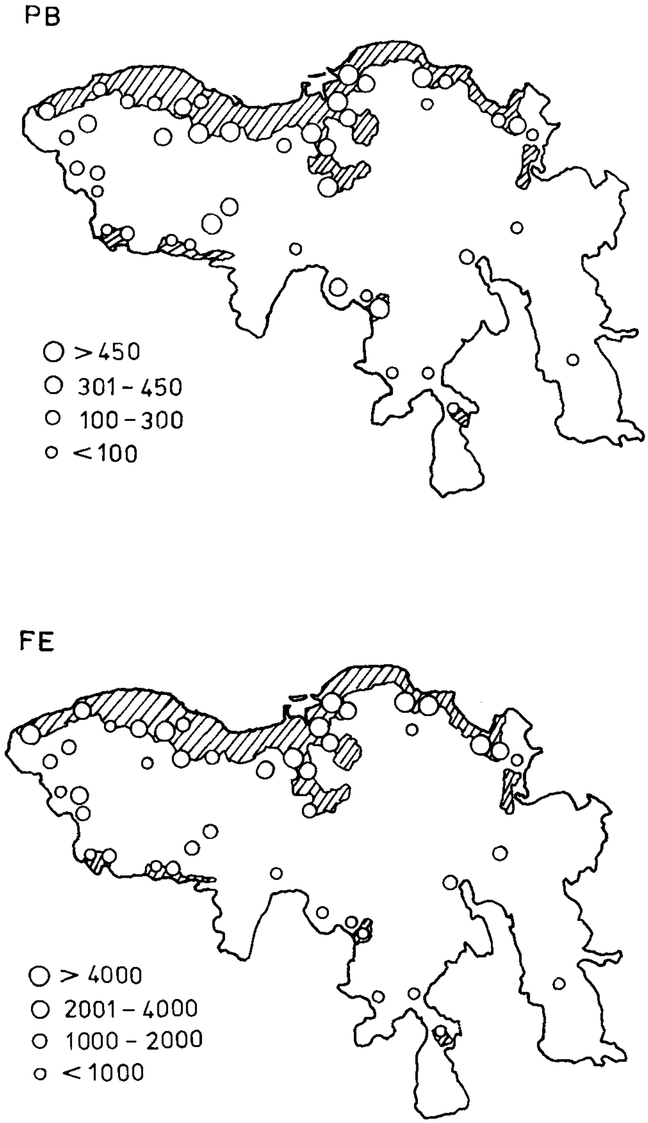

Figure 3. Regional distribution of Pb and Fe levels (μg/g dry weight) in roadside fern from 44 sites in Hong Kong Island. Data shown in terms of 4 intervals in concentrations. Built-up areas are hatched.

nature and a great portion of this region was Country Park areas where the relatively few roads present are barred to traffic.

Various plant materials, including those of lichen (Laaksovirta et al. 1976), moss (Onianwa and Egunyomi 1983), tree and litter (Schinner 1980) and bark (Laaksovirta et al. 1976; Osibanjo and Ajayi 1980) have been tested for their potential to monitor aerial deposition of metals. The suitability of these plant materials for

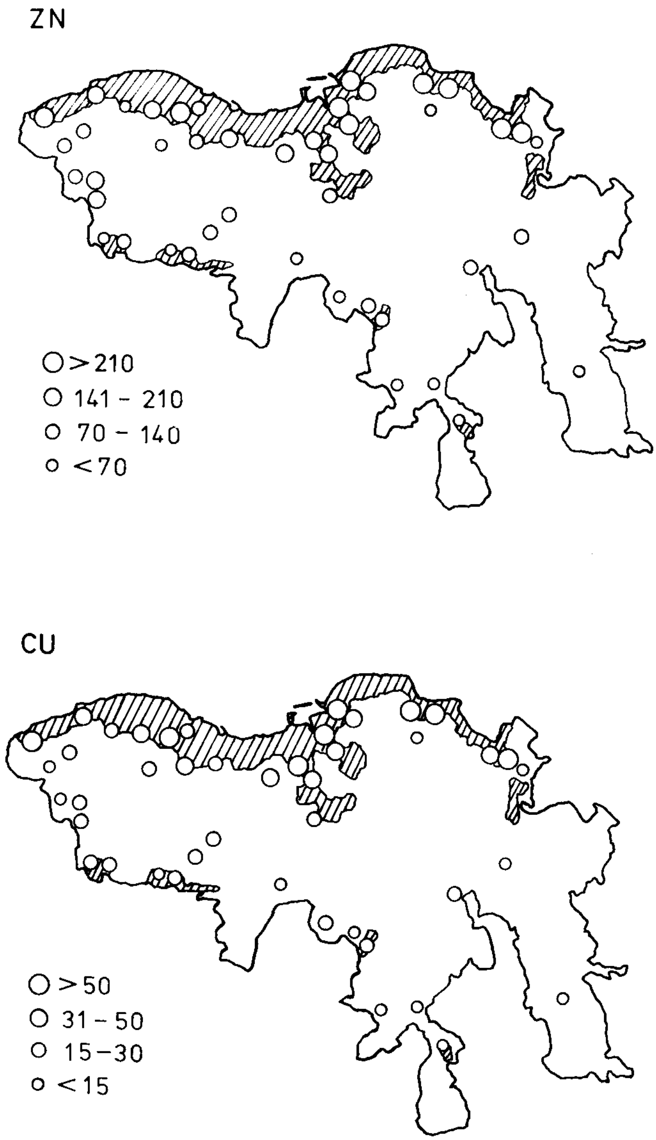

Figure 4. Regional distribution of Zn and Cu levels (μg/g dry weight) in roadside fern from 44 sites in Hong Kong Island. Data shown in terms of 4 intervals in concentrations. Built-up areas are hatched.

such use was found to vary. Thus Laaksovirta et al. (1976) found that Pb in lichen did not correlate with traffic, while, for bark, significant correlation ($r=0.76$, $P<0.001$) was found. Osibanjo and Ajayi (1980) also reported that bark from areas with relatively high traffic density was generally higher in Pb contents than that from areas with lower traffic density. However no such relationship was found for other metals in bark including Fe, Mn, Zn, Cu and Cd. Similarly for moss no defined gradient in Pb, Fe, Mn, Zn, Cu and Cd was ascertained from the samples collected from areas of different traffic densities (Onianwa and Egunyomi 1983). We believe that this is the first report on the use of roadside fern to monitor aerial deposition of Pb and other trace metals. The present study indicated that positive and significant correlations occurred between *Pteris* metal contents and traffic volume and this fern could be used as a monitor for atmospheric metal deposition.

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Received November 21, 1984; accepted December 6, 1984.