Pakistan Journal of Biological Sciences 2 (3): 186-189, 2002

Potential Use of *Colocasia esculentum* and *Panicum repens* as Bioindicators for Environmental Management of Linggi River, Malaysia

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Abstract: Concentrations of cadmium and lead in *Colocasia esculentum* and *Panicum repens* at four selected locations (Stations 1, 3, 4 and 5) along Linggi River, Malaysia were determined by Atomic Absorption Spectrophotometry (AAS) after digestion of the plant samples with dilute nitric acid. The concentrations of lead in both the *Colocasia esculentum* and *Panicum repens* were relatively higher ($p < 0.05$) than those of cadmium in the same species at all the stations along the Linggi River. The mean concentrations for cadmium and lead found in this study were 0.056 ± 0.017 mg/kg and 0.624 ± 0.173 mg/kg respectively. The upstream areas, in this case, being represented by Station 1 (Pantai) was relatively the least polluted in terms of cadmium and lead when compared to other stations along the river. The source of pollution for both metals came mainly from Station 3 (Seremban) and Station 4 (Mambau) where most of the factories and industries were located. *Colocasia esculentum* seemed more suitable as a bio-indicator for the study of cadmium and lead as compared to *Panicum repens,* because the former satisfied most of the bio-indicator criteria.

Key words: Plants, indicators, lead, cadmium, AAS, river

Introduction

In 1981, the Department of Environment (DOE) Malaysia listed the Linggi River as one of the most polluted rivers in Malaysia. The river is located at latitude 2°18′- 2°51′ N and at about 101°52 ′ E with altitude of between 6.3 and 1 174 m. The overall length of the river was about 82 km with a maximum width of 3 km (Khan, 1989). Water extracted from Linggi River was used for domestic, industrial, irrigation, fishery and agricultural purposes.

Water pollution of Linggi River was due to discharges of domestic wastes mainly from urban areas of Seremban, Mambau, Rantau and Pedas. Other sources of pollution were effluents from palm oil and rubber factories in Seremban which were located near the Linggi River. In addition, effluents from other types of factories such as for food processing and electronic products; discharges from automobile and metal workshops, and sawmills also contributed to the Linggi River water pollution. Public transportation vehicles especially buses, taxis, vans, cars and motorcycles emitted gases which contributed to the air pollution. The livestock farming of cattles, sheep and pigs along the Linggi River were also sources of pollution of Linggi River. Another possible source of pollution was the excess usage of chemical fertilizers and pesticides for agricultural purposes in areas near the Linggi River.

Some examples of research work in Malaysia which explored the potentiality of plants and animals to be used as bio-indicators are the study of metals in seaweeds and molluscs of East Malaysia (Mokhtar *et al.*, 1997a) and the determination of vanadium in tunicates of East Malaysia (Mokhtar *et al.*, 1997b).

This study was carried out to determine the concentrations of cadmium and lead in the *Colocasia esculentum* and *Panicum repens*, two plant species that could be found growing at various points along the Linggi River stretch. The roots and leaves of these plant species were analyzed for cadmium and lead in order to evaluate their potential use as pollution indicators.

The objectives of this study were to: determine the concentrations of cadmium and lead in the *Colocasia esculentum* and *Panicum repens*, collected at various points along Linggi River, observe the trend for cadmium and lead concentrations in the two plant species along the Linggi River, compare concentrations of cadmium and lead in the two types of plants those in water and sediments from the same river and evaluate the suitability of *Colocasia esculentum* and *Panicum repens* as bioindicators in estimating the level of cadmium and lead pollution.

The findings of this study was envisaged to be useful for the management of water quality of Linggi River and for comparisons with other rivers in Malaysia.

Materials and Methods

Fig. 1 shows the location of stations for sampling of plants in this study which coincided with the stations for water and sediment samplings which had been carried out by other members of the research team led by Mazlin Mokhtar. The plants of this study were found at four of the six water quality monitoring stations i.e., at Station 1 (Pantai), 3 (Seremban town centre), 4 (Mambau) and 5 (Rantau). These plants were not found at Stations 2 and 6. However, for the purposes of comparison with results of sediment and water, the numbering of sampling stations in this study was kept the same as those for sediment and water samples.

Samplings were done on 14 August, 4 September and 6 October 1998. *Colocasia esculentum* and *Panicum repens* were selected for this study based on the criteria as outlined by Anton (1994) i.e., widely distributed, easy to sample, having the same niche at their habitats and could easily be found along the Linggi River. The plant samples were taken at Stations 1, 3, 4 and 5 by pulling out the whole plant out of the soil with roots intact. Sketches of the two species of plants used in this study are shown in Fig. 2.

Sample preparation: In the laboratory, samples were rinsed thoroughly with distilled water. The roots and leaves were cut using stainless steel knives which were earlier rinsed with distilled water. The roots and leaves were dried in an oven at 48 °C for 48 hours (i.e., until the weight became constant). The sample was then crushed using an electronic grinder. The pulverized sample was digested in nitric acid solutions by using the microwave oven (CEM MDS 81-D).

Sample digestion and determination of metal by atomic absorption spectrophotometry (AAS): Digestion was done in a microwave oven as suggested by APHA (1992). The pulverized sample (1 g) was weighed accurately, poured into a teflon bottle and 20 ml nitric acid solution (1:1) was added to the bottle. The teflon bottle was screw-capped using the MDS 81-D capping station and digestion was carried out in the microwave oven. The digested sample solution was then filtered through a 0.45 um cellulose acetate membrane filter. The filtrate was collected in a 100ml volumetric flask, diluted with distilled water to the mark and analyzed using the AAS. Triplicate analysis were done and the AAS was calibrated using standard solutions.

Data analysis: Data obtained were analyzed using ANOVA, t-test and correlation test. The statistical analysis were made easier with the use of the Microsoft Excel software.

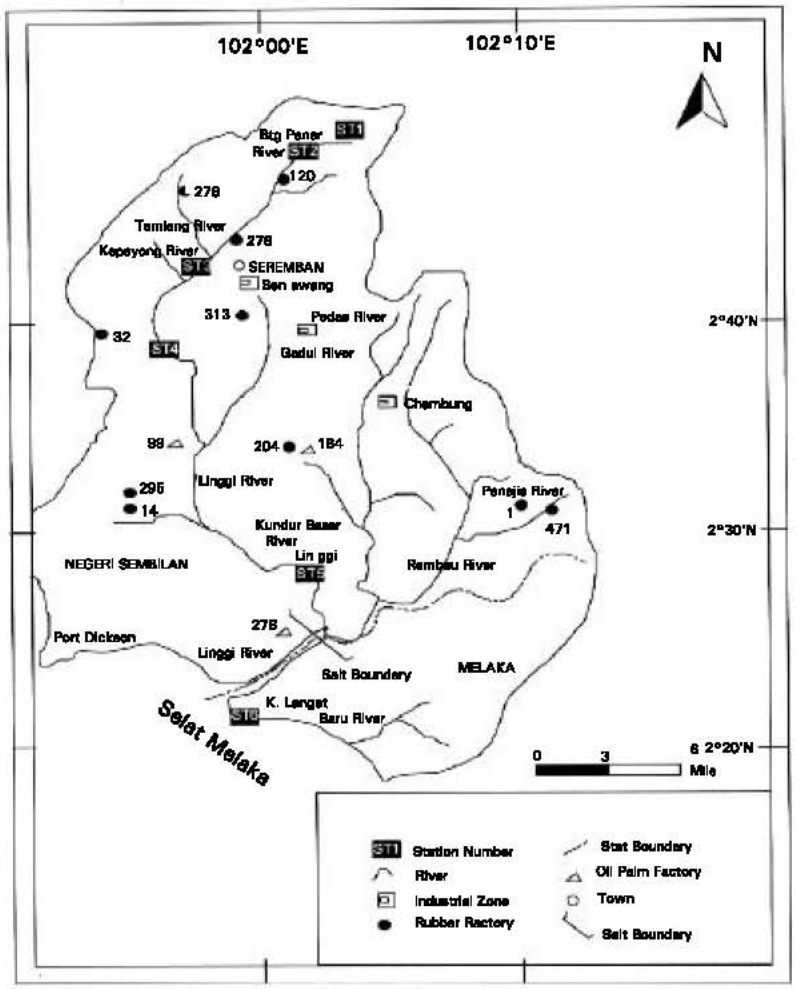
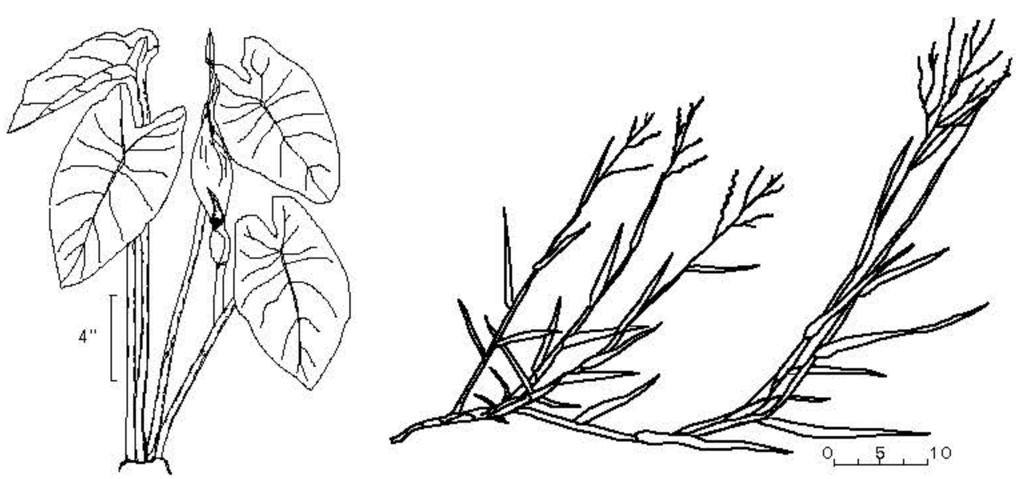


Fig. 1: Location of water sampling stations along the Linggi River; plant specimen for this study were sampled at stations 1,3,4 and 5 only.



Colocasia esculentum *Penicum repens*

Fig. 2 : Sketches of *Colocasia esculentum* and *Panicum repens*

Results and Discussion

The trend in cadmium and lead contents in the plants: The results of this study showed that the lead contents are relatively higher than the cadmium in the roots and leaves of *Colocasia esculentum* and *Panicum repens*. Possible sources of lead in the plants were water from the river and atmospheric lead which accumulated in stomas of the plants. Air particulates with adsorbed lead that were emitted by automobiles or factories were also sources of lead pollution.

The roots and leaves of *Colocasia esculentum* collected from Station 4 accumulated the most quantity of lead and cadmium. Station 1 was relatively the least polluted as shown by the least amount of both metals in roots and leaves (Table 1). The relatively highest concentration of lead in *Panicum repens* was found in the samples collected at Station 3 (0.580 ± 0.211 mg kg^{-1}), followed by those from Station 4 (0.446 ± 0.171 mg kg^{-1}), Station 5 (0.258 ± 0.123 mg kg^{-1}) and Station 1 (0.073 ± 0.171 mg kg^{-1}). The relatively highest cadmium concentration was found in samples from Station 4 (0.45 ± 0.006 mg kg^{-1}). Like in leaves of *Panicum repens*, the highest amounts of lead and cadmium were found in samples collected at Station 4 i.e., 0.042 ± 0.003 and 0.341 ± 0.124 mg kg^{-1}, respectively. Lead and cadmium in roots and leaves of both species were relatively the lowest at Station 1, which was located at the upper stretch of Linggi River called Pantai, which has not been exposed to much anthropogenic activities. Root-Cd and leaves-Cd in both plant species at Station 1 ranged from 0.001 ± 0.001 to 0.003 ± 0.002 mg/kg. Root-Pb and leaves-Pb in both plant species ranged from 0.033 ± 0.030 mg/kg to 0.075 ± 0.021 mg/kg.

Generally, the concentration of lead and cadmium in roots and leaves were relatively higher in Station 4 (Mambau). This was supported by data on cadmium and lead concentrations in sediment and water (Table 5). Station 4 was situated near a road in Mambau town. Sources of pollution here were pollutants from upper stream areas and effluents from sawmills, rubber and mattress factories near the river at Station 4. Concentrations of cadmium and lead in effluents were relatively the highest in Senawang area (Mokhtar *et al.*, unpublished results). Senawang river flows into Linggi River and brought the pollutants with it. This flowed through Stations 3 and 4 of this study. The polluted air also contributed to accumulation of these metals in the studied plant tissues. According to Mansfield (1976), pollutants which were accumulated on surfaces of leaves could be absorbed through the leaves and transported to other tissues.

Comparisons of cadmium and lead content in plants, water and sediments: The amount of cadmium and lead in the sediments of Stations 1 to 5 (private communication with Mokhtar *et al.*) were generally higher than those found in the roots of *Colocasia esculentum* and *Panicum repens* ($P<0.05$) species. However, the amounts of the same metals were found to be relatively lower in the leaves of both species.

The concentration of cadmium in water (Mokhtar *et al.*, unpublished results) were relatively higher than those in the roots and leaves for both species collected at Stations 3 and 4. The amounts of cadmium in both the roots and leaves for both species that had been collected at Station 5 (Rantau) were found to be relatively higher than compared to those found in water. The concentrations of lead in the sediment were found to be 100 times higher than those found in the plant species studied. According to Kabata-Pendias and Pendias (1985), the normal levels of lead in plants are in the range of 0.2 and 20.0 mg kg^{-1}.

The linear correlation test between leaves-roots, cadmium-lead and *Colocasia esculentum*- *Panicum repens*: The results of this study showed that the accumulation of cadmium in the roots and leaves of *Colocasia esculentum* and *Panicum repens* were quite balanced. However, the lead accumulation in the roots and leaves of *Panicum repens* were not balanced. The results of the linear correlation test showed that the absorption of cadmium and lead from the environment by the leaves of both species studied were linear. The leaves of *Colocasia esculentum* were relatively more sensitive and capable in accumulating cadmium and lead from the environment in a linear form as compared to thits roots, or even to the roots and leaves of *Panicum repens*.

The Cd in roots and leaves of *Colocasia esculentum* and *Panicum repens* were highest at Station 4 (Tables 1, 2). This observation was consistent with the levels of Pb in roots and leaves of *Colocasia esculentum* which were highest also at Station 4 and second highest at Station 4 in term of lead in *Panicum repens*. All of these results were also consistent with the results of Table 5 where the concentrations of Cd and Pb were highest or second highest in the water and sediment samples.

The comparisons of the results of the study with the bio-indicator criteria suggested by Anton (1994) show that the *Colocasia esculentum* and *Panicum repens* had fulfilled most of the criteria.

Table 1: Cadmium content in *Colocasia esculentum*

Station	Cd concentration (mg kg^{-1})			
	Root		Leaves	
	Range	Average	Range	Average
1	ND-0.005	0.002 ± 0.003	ND-0.002	0.001 ± 0.001
3	0.035-0.045	0.040 ± 0.005	0.015-0.029	0.022 ± 0.007
4	0.044-0.076	0.056 ± 0.017	0.035-0.047	0.040 ± 0.006
5	0.021-0.026	0.024 ± 0.003	0.012-0.024	0.017 ± 0.006

ND: not detected i.e. below limit of detection (0.001 mg/kg)

Table 2: Cadmium content in *Panicum repens*

Station	Cd concentration (mg kg^{-1})			
	Root		Leaves	
	Range	Average	Range	Average
1	0.002-0.005	0.003 ± 0.002	0.002-0.003	0.002 ± 0.001
3	0.013-0.034	0.027 ± 0.012	0.010-0.029	0.017 ± 0.010
4	0.038-0.050	0.045 ± 0.006	0.039-0.045	0.042 ± 0.003
5	0.021-0.040	0.031 ± 0.010	0.020-0.030	0.024 ± 0.005

Table 3: Lead content in *Colocasia esculentum*

Station	Cd concentration (mg kg^{-1})			
	Root		Leaves	
	Range	Average	Range	Average
1	0.051-0.092	0.075 ± 0.021	0.071-0.084	0.078 ± 0.007
3	0.294-0.391	0.356 ± 0.054	0.298-0.453	0.359 ± 0.082
4	0.440-0.782	0.624 ± 0.173	0.400-0.762	0.615 ± 0.190
5	0.296-0.671	0.432 ± 0.207	0.281-0.312	0.296 ± 0.016

Table 4: Lead content in *Panicum repens*

Station	Cd concentration (mg kg^{-1})			
	Root		Leaves	
	Range	Average	Range	Average
1	0.058-0.091	0.073 ± 0.017	ND-0.058	0.033 ± 0.030
3	0.454-0.824	0.580 ± 0.211	0.150-0.403	0.251 ± 0.134
4	0.256-0.588	0.446 ± 0.171	0.200-0.435	0.341 ± 0.124
5	0.153-0.394	0.258 ± 0.123	0.160-0.322	0.227 ± 0.084

ND: not detected i.e. below the limit of detection (0.001 mg/kg)

Table 5: Concentration of Cd and Pb in the water and sediment samples

Station	Concentration in water and sediment			
	Cadmium		Lead	
	Water (mg l^{-1})	Sediment (mg kg^{-1})	Water (mg/l)	Sediment (mg kg^{-1})
1	0.0005 ± 0.0010	0.3405 ± 0.2254	0.0425 ± 0.0285	42.8 ± 4.1
3	0.0455 ± 0.0910	0.1666 ± 0.0635	0.0115 ± 0.0192	20.1 ± 6.8
4	0.0968 ± 0.1134	0.3346 ± 0.1701	0.0318 ± 0.0226	23.6 ± 6.6
5	0.0000 ± 0.0001	0.2638 ± 0.1481	0.0218 ± 0.0155	33.6 ± 12.8

Leaves of *Colocasia esculentum* was found to a very likely sample to be used as indicator of metal pollution, specifically for cadmium and lead. The two plants also fulfilled criteria for selecting plants for heavy metal monitoring as suggested by Phang *et al*. (1993), viz. (I) the organism should accumulate the pollutant without being killed or rendered incapable of sustained growth and reproduction, (ii) the organism should exhibit a high bioconcentration factor for metals, (iii) a simple correlation should exist between the metal content of the organism and the metal content in the seawater, and (iv) all organisms in the survey should exhibit the same correlation between their metal contents and those in the environment, at all locations studied.

The concentrations of lead in both the *Colocasia esculentum* and *Panicum repens* were relatively higher ($P<0.05$) than those of cadmium in the same species at all the stations along the Linggi River. The concentrations of both metals were still below the recommended toxicity levels of 5-30 mg kg^{-1} for cadmium and 30-300 mg kg^{-1} for lead (Alloway, 1995). The mean concentrations for cadmium and lead found in this study were 0.056 ± 0.017 mg kg^{-1} and 0.624 ± 0.173 mg kg^{-1} respectively. The upstream areas, in this case, being represented by Station 1 (Pantai) was relatively the least polluted in terms of cadmium and lead when compared to other areas along the river. The source of pollution for both metals came mainly from Station 3 (Seremban) and Station 4 (Mambau) where most of the factories and industries were located. In addition, the nearby Senawang River that carried effluents from factories flowed into Linggi River and added to pollution of the river. The pollution could also be due to emission from exhaust tail pipes of automobiles which contain metal oxides especially lead oxide.

Colocasia esculentum is perhaps more suitable as a bio-indicator for the study of cadmium and lead as compared to *Panicum repens*, because the former satisfied most of the bio-indicator criteria as suggested by Anton (1994) and Phang *et al*. (1993). Further analysis on the relationships between concentrations of metals in the plants and those in the soil is recommended. This would give a better picture on the extraction of metals from soil by plants where the latter obtained their nutrients and trace elements from the soil. Future studies may look into other characteristics of plants such as its genetics variability or its ability to be cultured.

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