SHORT REPORTS

THE POTENTIAL OF USING *EICHHORNIA CRASSIPES* AND *IPOMOEA AQUATICA* AS BIOMONITORS IN ASSESSING HEAVY METAL POLLUTION IN THE MAE KHA CANAL AND THE MAE PING RIVER IN CHIANG MAI, NORTHERN THAILAND

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ABSTRACT

*Floating aquatic plants samples water hyacinth (*Eichhornia Crassipes*) and water morning glary (*Ipomoea Aquatica*) from the Mae Kha Canal and the Mae Ping River were collected at the ends of rainy and dry seasons in 1994. Plant samples were dried, ground , digested and finally analysed by atomic absorption spectrophotometry. The results showed that there is a great accumulation of Cd, Cu, Pb and Zn in both* Eichhornia crassipe *and* Ipomoea aquatica, *with a higher ratio in the former than in the latter.*

INTRODUCTION

The World Health Organization[1] classified cadimium and lead as members of the group of very toxic metals; copper as a member of the group of toxic, but essential metals, and zinc as a member of the gruop which is essential and toxic to a lesser extent. Urban waste discharge, as one of the major well known sources of these heavy metals to the sorrounding ecosystems, should certintally receive great concern.

Using plants as biomonitors in assessing heavy metal pollution has the following three main reasons. Firstly, trace amount of heavy metals are difficult by using water sample to determine, especially in the third world countries with mostly tranditional flame AAS machine. Secondly, plant analysis has three advantages: (1) dried plant meterials are eaiser to store and transport than water samples; (2) plant samples give an "integrated" record of pollution within a particular system; (3) plants can be harvested after a pulse of contaminated water has passed downstram; so it is possible to pinpoint pollution after it has happened[2]. Thirdly, plants are one kind of food source, either animals or human beings eat some plants directly. Therefore, it is very important to analyse metal concentrations in plants directly in order to safegrard the health of animals and humans.

Burton[3] reviewed the use of algae, bryophytes, pteridophytes, and angiosperms as biomonitors of the accumulation of heavy metals. There are various reports on water hyacinth, mostly done inside the laboratories, or planned from a water treatment point of view. For water morning glory, it is dificult to find literature concerning the analysis of heavy metal content and the application of it as indicators or monitors in assessing heavy metal pollution.

There is no published literature on heavy metal pollution to the Mae Kha Canal and the Mae Ping River. It is of great significance to try to assess heavy metal impact from the Chiang Mai City by using plants samples.

MATERIALS AND METHODS

Study site

Nine study sites were chosen in Chiang Mai, northern Thailand, of which five were on the Mae Ping River, three on the Mae Kha Canal, and one on Doi Suthep; the last serving as the control site. Figure 1 shows a map of the locations of the study sites.

Plant species

Two plant species were selected because of their abundance in both the Mae Kha Canal and the Mae Ping River. *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae), an aquatic floating monocotyledon Angiosperm, belongs to a small family of nine genera and about 35 species[4] . This plant is often used for pig feed and compost. Water morning glory or swamp cabbage, *Ipomoea aquatica* Forsk. (Convolvulaceae), an Angiosperm dicotyledon vine, can be found in wet sites such as swamps or canals. It is, in fact, both a terrestrial and aquatic plant[5] . In Thailand, it can be found everywhere all year round. People eat the shoots and young leaves in many ways. Voucher specimens for *Eichhornia crassipes* (Zhenbo 3) and *Ipomoea aquatica* (Zhenbo 1) have been deposited in the CMU Herbarium (Biology Department). Photo of living plants of the two species are shown in Figures 2-3.

Sampling

Samples were collected on two occasions, viz. the 3rd September and 27th December 1994, representing respectively the rainy and the dry season. Due to the flood, *Eichhornia crassipes* was collected at sites 2, 3, 4, 5 on both seasons. *Ipomoea aquatica* was collected at sites 2, 3, 4 for the rainy season and at sites 2, 3, 4, and 5 for the dry season.

Pretreatment and metal analysis

Plant samples were washed immediately on arrival at the laboratory using a sequence of tap water, distilled water, and deionized water. The samples were then put into an oven for drying at about 80°C until crisp. The samples were then broken up by hand and ground in a blender mill. Roots of water hyacinth were separated from other parts and treated separately.

Samples were then completely dried by putting them into an oven at 105°C for 10 hours. About three grams of each sample were accurately weighed into a 250 ml conical flask and 30 ml 65% nitric acid were added to each sample which then was left to pre-digest overnight. Samples were heated nearly to dryness on a hot plate at a temperature of 75-85°C. Then 15 ml of oxidant soultion (HNO_3:H_2O_2=1:2) were added to each sample. The samples were heated again on a hot plate until nearly dry. The samples were filtered on acid washed filter paper (Whatman no. 42) and the solutions were collected in 50 ml volumetric flasks[6].

For quality control purpose, a mixed standard addition curve was used since it was found that external standard calibration gave very different results from those obtained through standard addition.

Measurement were made on a Perkin-Elmer 2380 Flame AAS machine.

RESULT AND DISCUSSION

1. Enrichment of metals by plants (parts) from water

Commonly the results are expressed in terms of the enrichment ratio rather than an absolute concentration[2]. Table 1 shows the enrichment ratios for the 4 elements, and it explains that plant metal ocntents were much higher than in water samples, indicating biological accumulation of the metals in aquatic ecosystems.

Table 1 Enrichment Ratio (Conc. of Metals in Plant Samples vs in Water Samles).

Sample	Cd			Cu			Pb			Zn		
No.	R/W	BP/W	MG/W	R/W	BP/W	MG/W	R/W	BP/W	MG/W	R/W	BP/W	MG/W
1	26720	22980	15780	5023	2354	2028	3106	3464	3324	10038	3044	7357
2	27140	18520	14920	4791		2010	1789	3404	3289	8798		6463
3	10262	9408	6638	3679	549	1632	1649	2719	2763	12878	3146	7687
4	9127	8480	6040	4264	550	1777	1649	2767	2737	13351	3304	7540
5	12771	16300	13500	883	480	1359	4500	3004	3012	4215	1845	2406
6	17543	17986	14000	842	436	1398	5360	3567	3160	4336	1811	2449
7	16767	11978		9153	6014		3666	2332		106447	31789	
8	17511	15944		9510	6728		3392	2080		108830	32214	
9	15783	11217	6767	8644	3139	2875	7342	2907	1382	7092	2948	1101
10	15783	11933	9650		2875	2629		2919	1400		2930	
11	22000	21900	16367	13772	3364	2030	3899	2770	1532	7545	1903	737
12	23833	22367	15000	12287	3235	2022	4117	2907	1544	7415	1961	746
13	1891	1453	1146	19686	3691	2717	5612	9586	3517	2860	1190	738
14	1891	1351	1242		4016	2748		11494	3546		1204	744
15	52400	35600	16467	40198	14479	6126	7520	6831	2314	76935	31416	17604
16	51033	23367	15000	41491	14375	6606	7542			77165		18882
Mean	19299	15674	9532	10889	4143	2372	6946	4183	2234	27994	8047	4653

Note: W: Water
R: Root
BP: Blade and petioles of Eichhornia crassipes
WG: Ipomoea aquatica

2. Comparison of enrichment by metals

Figure 4 shows the relationship between metal concentrations in water and the enrichment ratio for Cd and Pb (also Table 2). Very good linear relationships were found for Cu and Zn when C(water) and C(plant)/C(water) were converted into Log_{10} value (Figure 5).

Table 2 Regression equations for Log_{10} enrichment ratio and enrichment ratio plotted against Log_{10} metals or metals in water from which the plants were collected, based on the data to construct Figure 4 and 5

Equation	r^2	n
Cd(ratio, WHR) = 28482.02 - 71810.2*Cd(water)	0.418	16
Cd(ratio,WHBP) = 21526.71 - 52468.49*Cd(water)	0.593	16
Cd(ratio, WMG) = 14881.18 - 34456.53*Cd(water)	0.735	15
Log Cu(ratio, WHR) = 0.467 - 1.488*LogCu(water)	0.644	16
Log Cu(ratio, WHBP) = 4.358 - 1.755*LogCu(water)	0.817	16
Log Cu(ratio, WMG) = 3.788 - 0.742*LogCu(water)	0.864	15
Pb(ratio, WHR) = 14747.69 - 3594.533*Pb(water)	0.302	16
Pb(ratio, WHBP) = 11282.92 - 3914.812*Pb(water)	0.831	16
Pb(ratio, WMG) = 3801.187 - 751.194*Pb(water)	0.317	15
Log Zn(ratio,WHR) = 5.139 - 0.882*Log Zn(water)	0.827	16
Log Zn(ratio, WHBP) = 4.685 - 0.889*Log Zn(water)	0.901	16
Log Zn(ratio, WMG) = 4.356 - 0.702*Log Zn(water)	0.469	15

Where: r^2, coefficient of determination of regression
n, number of samples

No matter what model can be fitted to Figure 4 and 5, it can be seen that the enrichment ratio tends to decrease as the aqueous concentration increases. This is presumably due to the decreased availability of sites to bind metals as the concentration increases[2].

3. Comparison of enrichment of metals

The enrichment ratio or concentration factor is a useful tool in comparison of accumulation of different metals although they may occur at different ambient concentrations[2].

Figure 6 shows the average accumulation ratios of the four elements in the two plant species. It is seen that the highest accumulation occurred in the root of *Eichhornia crassipes* followed by in the blade and petioles of *Eichhornia crassipes* and *Ipomoea aquatica*. The accumulation of the four elements in the plant species (parts) follow different sequences. In the root of *Eichhornia crassipes*, the ratio ranking of enrichment is Zn > Cd > Cu > Pb, in blade and petiole Cd > Zn > Pb >Cu, in *Ipomoea aquatica* Cd > Zn > Cu > Pb. It is noted here that Cd, a highly toxic element, is also the element which is most likely to be accumulated by these two plant species. Since Zn is an essential element for the growth of plants, it is not a surprise that a very high accumulation factor was found for Zn in both plant species.

4. The justification of using plant meterials as monitors in assessing metal pollution

Eichhornia crassipes and *Ipomoea aquatica* can both concentrate metals which makes it easier to determine metal content in cases where the metal content in water is very low and a good facility with a low enough detection limit is not available. The use of a complicated method and detrimental chemicals can be avoided through analysing plant tissue.

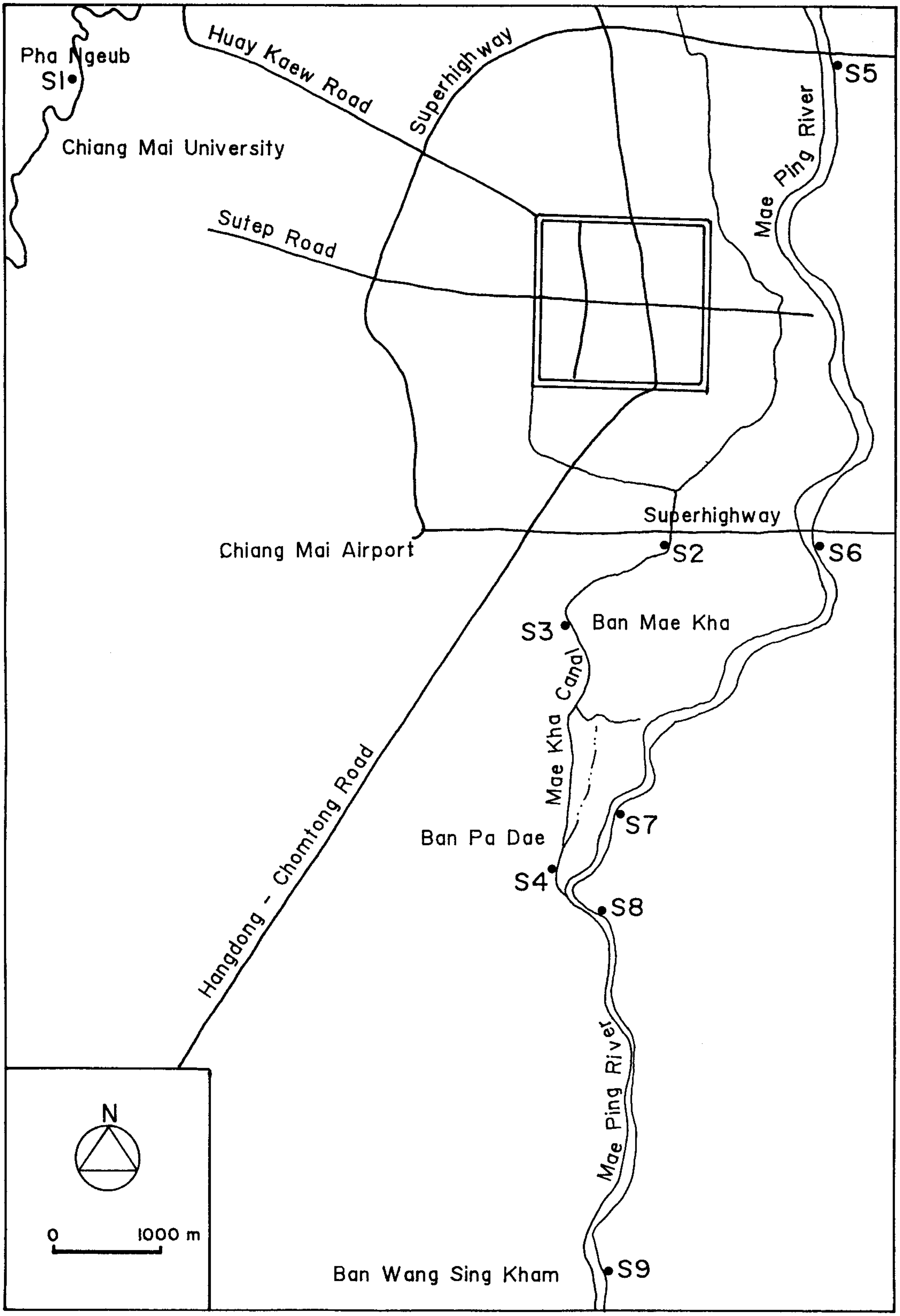


Fig. 1 Map showing the loations of the study sites.

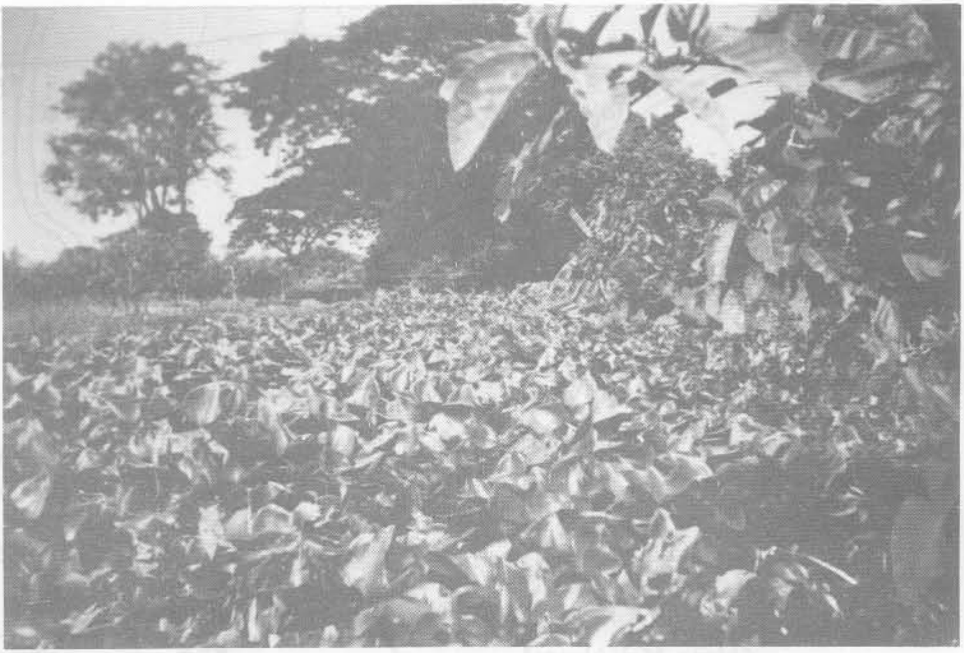
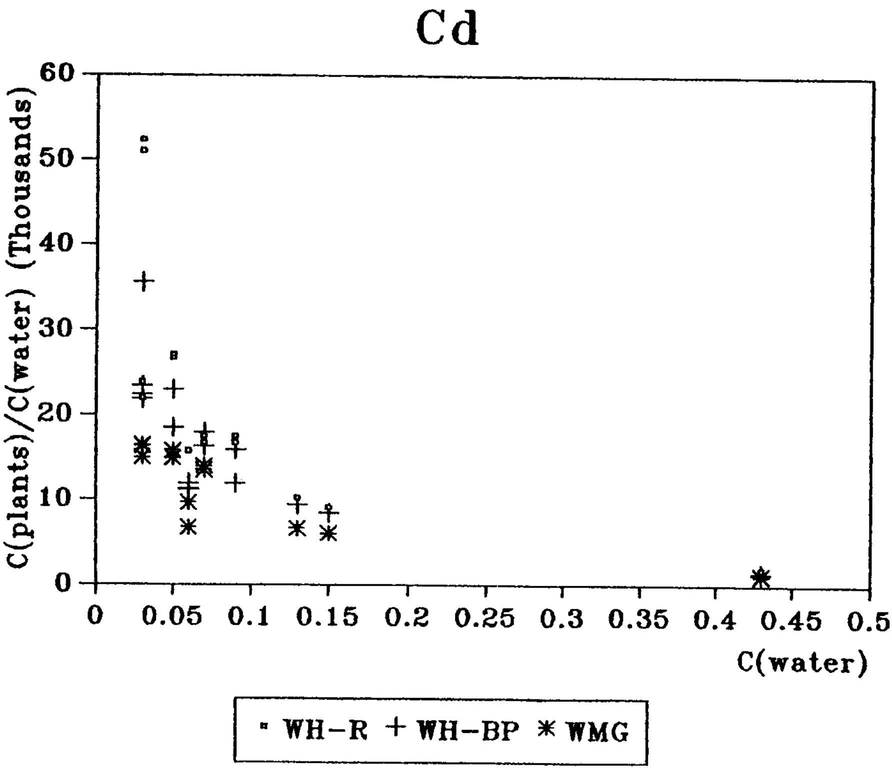


Fig. 2 Photo of water hyacinth (*Eichhornia crassipes*).

Fig. 3 Photo of water morning glory (*Ipomoea aquatica*).



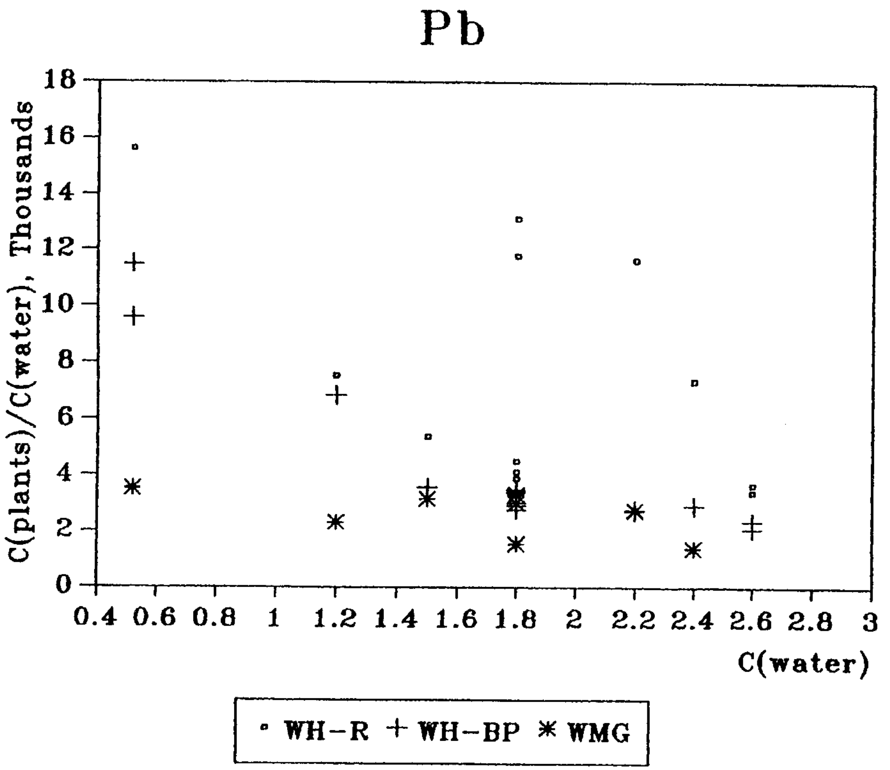
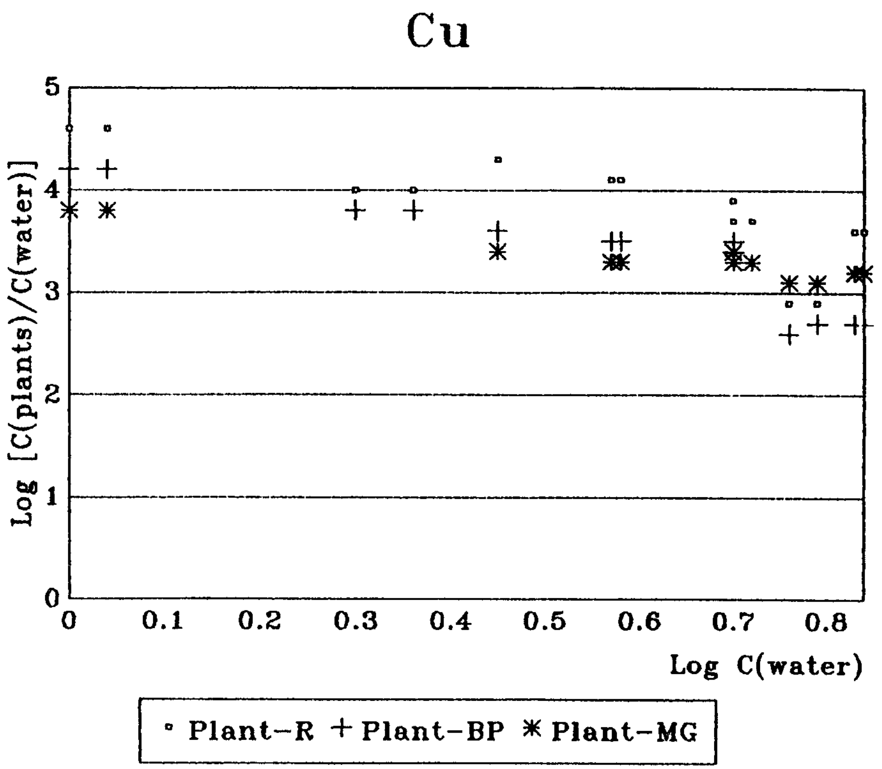


Fig. 4 Enrichment ratios of Cd and Pb.



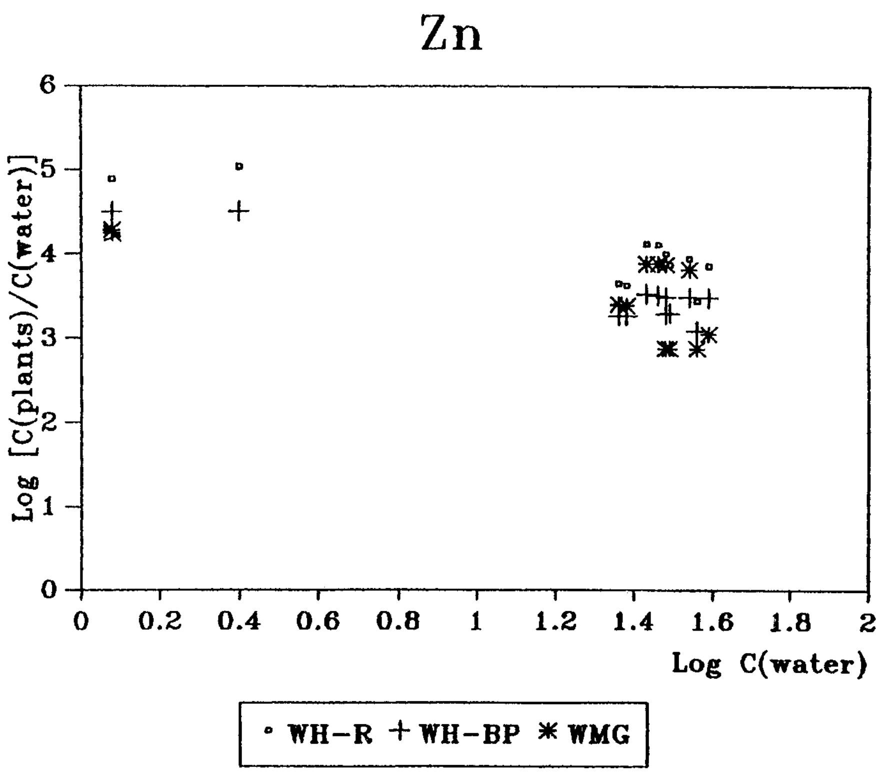


Fig. 5 Enrichment ratios of Cu and Zn.

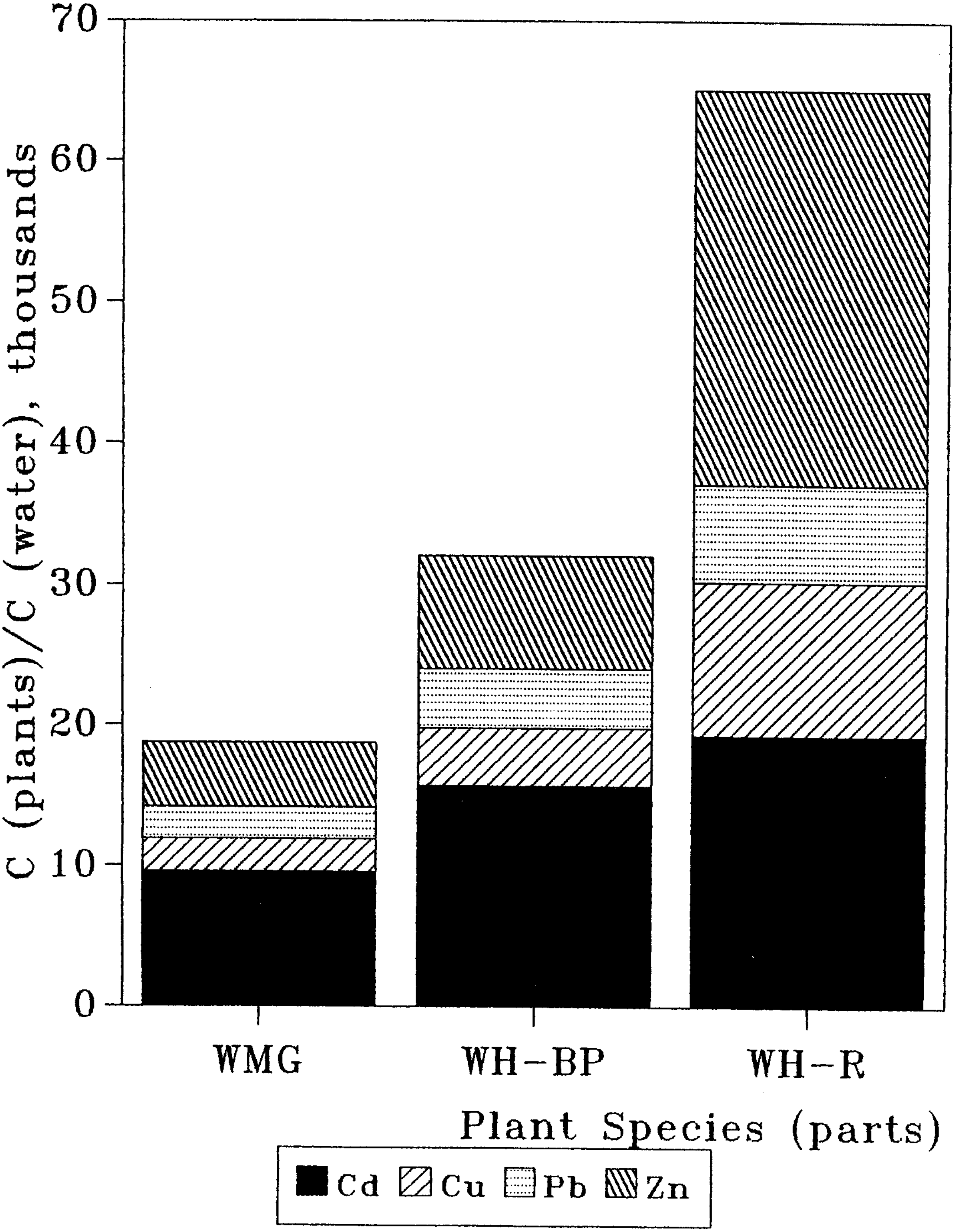


Fig. 6 Comparison of the average accumulation ratio of the four elements.

Since these two species of water plants accumulate heavy metals from water and a high content of metal discharge can be recorded, it is therefore a good idea to use them to monitor water discharge and enforce the pollution control regulations. Since this study was a kind of passive mornitoring, which collected plant samples naturally growing *in situ*, and also the data from this study itself are not enough, it is premature to conclude that these two plants can be used for monitoring water pollution.

They can serve as monitors in assessing the risk of heavy metal poisoning since *Eichhornia crassipes* is fed to pigs in some parts of the world, and *Ipomoea aquatica* is eaten by humans. However, there is no standard concerning the daily uptake of heavy metals by eating these plants.

In this study, empirical equations were developed for both *Eichhornia crassipes* and *Ipomoea aquatica* (Tables 2). It is supposed that these equations could be used for roughly estimating the metal concentration in water from the metal contents in water plants, *vice versa*. This allows use in spatially assessing heavy metal pollution. However, more work is needed.

CONCLUSION

There is a biological accumulation by *Eichhornia crassipes* and *Ipomoea aquatica*, of cadmium, copper, lead, and zinc. The roots of *Eichhornia crassipes*, which are always submerged, have a higher enrichment ratio than its blade and petiole. *Eichhornia crassipes* as a whole can accumulate more heavy metals than *Ipomoea aquatica*.

Since *Eichhornia crassipes* and *Ipomoea aquatica* can accumulate large amounts of heavy metals from water, and *Eichhornia crassipes* is usually fed to pigs while *Ipomoea aquatica* is eaten by humans, attention should be paid to their metal content and the amount of them fed to individual pigs and eaten by individual humans. Standards should be developed for the protection of aquatic living organisms, the whole ecosystem and human beings.

The accumulating characteristic of these two plant species makes them useful in removing heavy metals from the aquatic ecosystem, for purifying the water. Regular removal of the plant species from the Mae Kha Canal can be tried for the purpose of removing the heavy metals from the water systems.

More work is needed on the potential for using *Eichhornia crassipes* and *Ipomoea aquatica* as biomonitors in assessing heavy metal pollution. Some other species of angiosperms and other groups of species may also have the potential for monitoring heavy metal accumulation, such as algae, bryophytes and pteridophytes.

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REFERENCES

1. World Health Organization (WHO), 1973. Trace elements in human nutrition. Technical report No. 532. WHO, Geneva. pp. 5-56.
2. Kelly, Martyn, 1988. Mining and the Freshwater Environment. Elsevier Science Publishers LTD. New York. pp. 45-46.
3. Burton, M. A. S., 1986. Biological monitoring of environmental contaminants (plants). Monitoring and Assessment Research Center, King's College London, University of London. pp. 50-75.
4. Gopal, B. 1987. Water Hyacinth. Elsevier Science Publisher, Netherlands. pp. 50-150.
5. Maxwell, J.F. 1988. The vegetation of Doi Sutep-Pui national park, Chiang Mai Province, Thailand. Tigerpaper (FAO) 15:4, pp. 6-14.
6. Juntana, Renumat, 1987. Determinnation of lead, mercury, cadmium, zinc, copper and manganese in vegetables by atomic absorption spectrophotometry. Unpublished masters degree thesis in teaching Chemistry. Department of Chemistry. Faculty of Science. Chiang Mai University. 64 pp.