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Aquatic Plants As Phytoindicator For Heavy Metals Contaminant In Polluted Freshwater Bodies

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Abstract

Over the past decade, ecologists have tried to determine how changes in species composition and diversity affect ecosystem structure and function. Until recently, the majorities of these studies have been conducted in terrestrial ecosystems and have not taken into account environmental variability. Nowadays, humans tend to neglect water as part of main sources in our daily life. As time goes by, with few exceptions, water has always been a natural resource that people take for granted. The idea of this research is to understand how aquatic plants can be used to detect and act as an indicator for polluted freshwater bodies. In this study, sixteen water samples were collected from four different places (Selangor, Perak, Pahang and Kelantan) where six different aquatic plant species were abundance and dominant. All the water samples were analyzed for six types of heavy metals which are iron (Fe), lead (Pb), copper (Cu), zinc (Zn), and nickel (Ni) and manganese (Mn). All six different aquatic plant species which are Eichhornia crassipes, Hydrilla verticillata, Cabomba fuscata, Salvinia natans, Nelumbo nucifera and Pistia stratiotes exhibiting highly significant differences between aquatic plant species widespread, locations and the heavy metals content. This clearly demonstrates that freshwater environment with abundance of invasive macrophyte species can have an important influence and indication on the accumulation of heavy metals content. The importance of the interaction components emphasises that the changes in heavy metals composition are complex and the responses are not consistent across all aquatic plant species. Examination of the summarised data revealed that, of the 6 macrophyte species analysed at all different locations, all exhibits as potential ecological indicator for unhealthy aquatic ecosystems or as phytoindicator for heavy metal contaminants either at low or high level contamination.

Keywords— Aquatic Plants, Phytoindicator, Heavy Metals, Freshwater Bodies.

Introduction

Malaysia was facing environmental issues since rapid development of tin mining about 100 years ago then followed by other traditional industries such as natural rubber and palm oil production. Wastewater from these industries caused severe pollution of rivers and seas. In early 1970s, pollution caused by industrial wastewater and other wastes became very

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obvious in Malaysia due to the rapid industrialization which were supported by foreign investment (Sari & Wan Omar, 2008; Shuhaimi-Othman, Lim, & Mushrifah, 2007). According to the Malaysia Environmental Quality Report (P. K. Rai, 2009), the estimated number of water pollution load in Malaysia for 2011 was 1,393,528 kg/day comprising especially of sewage treatment plants, agro-based industries, manufacturing industries and animal farms. About 77 percent of the total number of sources was domestic sewage facilities (1,067,235) followed by pig farming (202,293kg/day or 14 percent), agro-based industries (73,664 kg/day or 5 percentand manufacturing industries (50, 336 kg/day or 4 percent). Of the total number of effluent sources identified, Klang River Basin (Federal Territory of Kuala Lumpur and State of Selangor) had the highest number (238,226 kg/day), followed by Perak River Basin (73,708 kg/day), Landat River Basin (70,266 kg/day), Jawi River Basin (31,674 kg/day) and Skudai River Basin had the least number (26, 130 kg/day).

Water pollution used to be primarily a local problem, with identifiable sources of pollution by liquid waste. Up to a few decades ago most of the wastes discharged to waters came from animal and human excreta and other organic components from industry. However, due to the increasing of urbanization, this issue has expanded (P. K. Rai, 2009). The use of hazardous chemicals in manufacturing industries and agriculture cause severe water pollution as waste from these industries goes directly into nearby rivers, lakes and ponds. This not only affects the quality of water but also pose danger to several endangered aquatic species (P. Rai, Mishra, & Tripathi, 2010). Hence, water pollution is a negligible issue and there is an increasing concern about heavy metals contamination in river system. Heavy metals are discharged directly into surface water with little or no treatment. Some of them are needs to human body, but mostly they give harm to environment as they cannot be degraded or destroyed. When they interfere directly to aquatic environment, at certain concentrations they can lead to poisoning (S, 2014). The most important heavy metals from the point of view of water pollution are Zn, Cu, Pb, Cd, Hg, Ni and Cr. Some of these metals (e.g. Cu, Ni, Cr and Zn) are essential trace metals to living organisms, but become toxic at higher concentrations. Others, such as Pb and Cd have no known biological function but are toxic elements (Rahman et al., 1993). For instance, Pb, one of the more persistent metals, was estimated to have a soil retention time of 150–5000 years and was reported to maintain high concentration for as long as 150 years after sludge application to soil (Shaharuddin et al., 2012). In conjunction with this, these metals gradually reduce organism abundance and which may modify important ecosystem functions for example, decomposition rates, oxygen dynamics and nutrient cycling (Fleeger, Carman, & Nisbet, 2003). The application of aquatic plant to treat heavy metals in aquatic environment is a way in achieving environmental friendly. They are a good adsorption capacity, selective adsorption of heavy metal ions, low cost, free availability and easy regeneration. Aquatic plants have abilities in reducing pollutants levels in water bodies, absorbing toxic substances like cadmium (Cd), lead (Pb), mercury (Hg), nickel (Ni), copper (Cu) and many more at concentration between 4000 and 20 000 times those in water (Yang, Feng, He, & Stoffella, 2005). In this paper, selected aquatic plants have been used to prove whether they can be used as phytoindicator for unhealthy aquatic ecosystem.

Materials and Methods

Site and Sample Collection

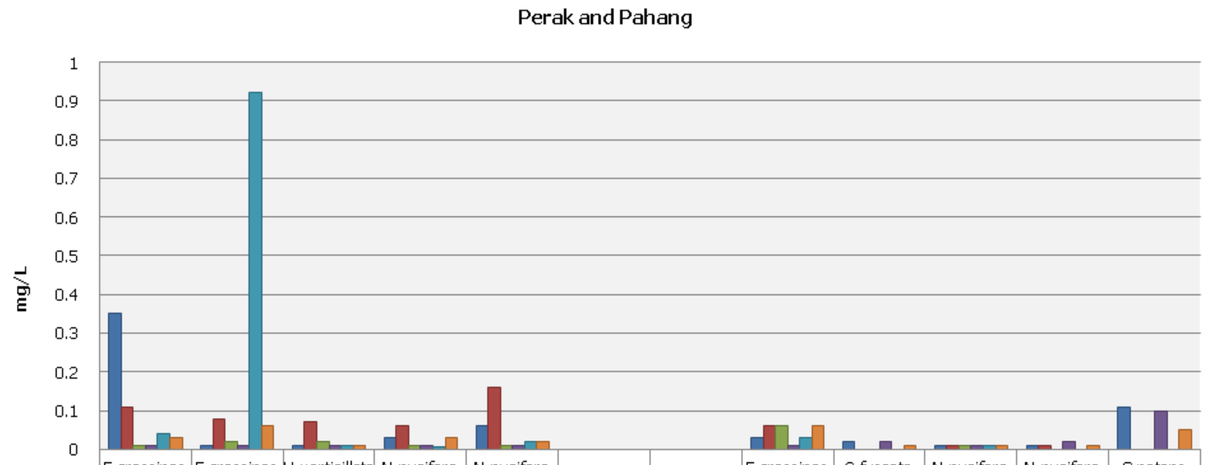
Four states were selected in this study; they are Perak, Pahang, Selangor and Kelantan. Ten water samples were collected in triplicate from about 10cm below the water surface using 500ml HDPE bottles (Sujaul Islam, Ismail, Muhammad Barzani, Sahibin, & Mohd Ekhwan, 2012).Collected samples were preserved in the dark and cool box during sampling and transported to the laboratory for analysis following standard procedure (Association, Association, Federation, & Federation, 1995). The samples were analyzed in laboratory for measuring selected ex-situ parameters in accordance with APHA and HACH standard methods of analysis (Hossain M.A., 2013).

Laboratory Analysis (ex situ parameters)

All the samples collected from the field were kept in a refrigerator at a temperature between 1ºC-4ºC in order to minimize activities and metabolism of organism in the water, also to insure the preservation of the samples (Water, 2009). Addition of 2.5ml chloroform in 500ml of samples was done in order to preserve them. Quantification of heavy metals was based upon calibration curves of standard solutions of respective heavy metals. These calibration curves were determined several times during the metal analysis was controlled by including triplicate samples in analytical batches and blanks. The relative standard deviation of the mean of triplicate measurements were <5. Each of samples was filtered with a syringe through filter paper with a pore size of 0.2 mm (Orange® Scientific, Gyro disc CA-PC). The heavy metals analyzed were Fe, Cu, Zn, Ni, Mn and Pb and they were measured in accordance with Atomic Absorption Spectrometer Flame (ASS) at specified wavelengths.

Results and Discussion

Only five aquatic plants species were found in Perak and Pahang, including *Eichhornia crassipes, Hydrilla verticillata, Nelumbo nucifera, Cabomba fuscata* and *Salvinia natans.* The highest concentration of Mn recorded at Perak was 0.92 mg/L and concentration of Fe was 0.35 mg/L, both by *Eichhornia crassipes* which is much higher than that in Pahang. Meanwhile the presence of Pb was detected by *Nelumbo nucifera* at 0.16 mg/L, which is again much higher compare in Pahang. Compared to Perak, among all four examined species at Pahang, *Eichhornia crassipes* and *Nelumbo nucifera* are able to detect all five measured metals. However, only *Salvinia natans* is able to accumulate highest concentration of Fe (0.11 mg/L) and Cu (0.01 mg/L). The arrangement according to their accumulation for both states, the following order was observed for six elements are as follows: Mn > Fe > Pb > Cu> Ni > Zn. The increase in Mn concentrations in the plants may be the result of the industrial waste waters inflow from the smelter, as well as the inflows from other rivers. It also may lead to plant nutrients imbalances (Australia). The result shown above indicated that metal accumulation was higher in floating plants (*Eichhornia crassipes, Nelumbo nucifera* and *Salvinia natans*) than in rooted plants for both states. Based on Interim National Water Quality Standards for Malaysia (INWQS), both freshwater bodies at Perak and Pahang are categorized under Class I and III (Department of Environment, 2011).



	E.crassipes	E.crassipes	H.verticillata	N.nucifera	N.nucifera			E.crassipes	C.fuscata	N.nucifera	N.nucifera	S.natans
Fe	0.35	0.01	0.01	0.03	0.06		0	0.03	0.02	0.01	0.01	0.11
Pb	0.11	0.08	0.07	0.062	0.16		0	0.06	0.000	0.01	0.01	0.000
Zn	0.01	0.02	0.02	0.01	0.01		0	0.06	0.000	0.01	0.00	0.000
Cu	0.01	0.01	0.01	0.01	0.01		0	0.01	0.02	0.01	0.02	0.1
Mn	0.04	0.92	0.01	0.006	0.02		0	0.03	0.000	0.01	0.00	0.000
Ni	0.03	0.06	0.01	0.03	0.02		0	0.06	0.01	0.01	0.01	0.05

Figure 1.0: Concentrations of study heavy metals by collected aquatic plants at Perak and Pahang

Figure 1.1: Salvinia natans (Floating Seaweed)

Figure 1.2: Eichhornia crassipes (Mart.) Solms (Water Hyacinth)

Figure 1.3: Nelumbo nucifera (Water Lotus)

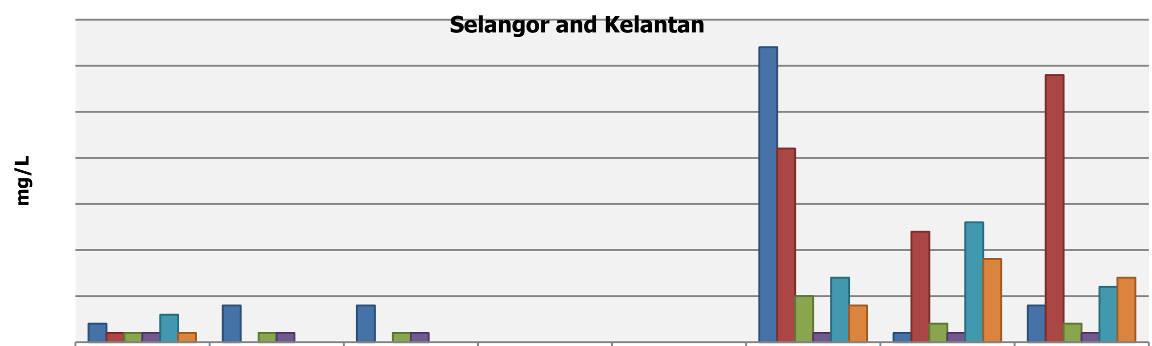
Figure 1.4: Cabomba furcata (Forked Fanwort)

Figure 1.5: Hydrilla verticillata (Water Thyme)

Trace metal concentration found in *Eichhornia crassipes* are shown in Figure 2.0, Fe concentrations were significantly higher in plants collected from Kelantan than Perak. The same figure shown by Pb concentrations was tolerated most by *Salvinia natans* at value 0.29 mg/L and again much higher than Selangor. Meanwhile, at Selangor, found only *Hydrilla verticillata* was able to detect all measured heavy metals compared than other species.

These values suggest the potential of *Hydrilla verticillata* to take up and accumulate the most in Selangor. There were no great variations in the concentration of each metal in the collected sample at Selangor compared to Kelantan, which were generally low. As a whole for both sites, metals concentrations were in the order of: Fe > Pb > Mn> Ni > Zn > Cu. Based on Interim National Water Quality Standards for Malaysia (INWQS) (Department of Environment, 2011), both freshwater bodies at Selangor and Kelantan are categorized under Class I and III.

Generally, the accumulation of metals by plants mainly depends on the available concentration of metals in the water, time of exposure, competition and/or toxicity metals (Abdel-Shafy, Hegemann, & Teiner, 1994). The effect of a simultaneous presence of several metals on the uptake of any metal was dependant on the plant species and metal involved. Thus, it was expected that the level of metals in plants located in Kelantan would be higher than in Perak, followed by Pahang and Selangor.



	H.verticillata	P.stratiotes	E.crassipes			E.crassipes	E.crassipes	S.natans
Fe	0.02	0.04	0.04		0	0.32	0.01	0.04
Pb	0.01	0.000	0.000		0	0.21	0.12	0.29
Zn	0.01	0.01	0.01		0	0.05	0.02	0.02
Cu	0.01	0.01	0.01		0	0.01	0.01	0.01
Mn	0.03	0.000	0.000		0	0.07	0.13	0.06
Ni	0.01	0.000	0.000		0	0.04	0.09	0.07

Figure 2.0: Concentrations of study heavy metals by collected aquatic plants at Selangor and Kelantan

Figure 2.1: Hydrilla verticillata (Water Thyme)

Figure 2.2: Eichhornia crassipes (Mart.) Solms (Water Hyacinth)

Figure 2.3: Pistia stratoites (Water lettuce)

Figure 2.3: Pistia stratoites (Water lettuce)

Table 1: *Analysis Of Heavy Metals Content (Fe, Pb, Zn, Cu, Mn, Ni) In Water Samples Dominated By Six Aquatic Plant Species at Sixteen Different Sites of Freshwater Bodies at Perak, Pahang, Selangor And Kelantan*

Locality	Species	Mean value (±sd, n = 10) of heavy metals concentration (mg/l)					
		Fe	Pb	Zn	Cu	Mn	Ni
Perak	*Eichhorniacrassipes*	0.149±0.35 (Class I)	0.022±0.11 (Class III)	0.002±0.01 (Class I)	0.001±0.01 (Class I)	0.016±0.04 (Class I)	0.01±0.03 (Class I)
	Eichhorniacrassipes	0.002±0.01 (Class I)	0.03±0.08 (Class III)	0.003±0.02 (Class I)	0.001±0.01 (Class I)	0.015±0.92 (Class V)	0.01±0.06 (Class IIB)
	Hydrilla verticillata	0.002±0.01 (Class I)	0.23±0.07 (Class III)	0.009±0.02 (Class I)	0.002±0.01 (Class I)	0.003±0.01 (Class I)	0.026±0.01 (Class I)
	Nelumbo nucifera	0.018±0.03	0.01±0.062	0.005±0.01	0.001±0.01	0.008±0.06	0.008±0.03

		(Class I)	(Class III)	(Class I)	(Class I)	(Class I)	(Class I)
	Nelumbo nucifera	0.062±0.06 (Class I)	0.022±0.16 (Class III)	0.005±0.01 (Class I)	0.003±0.01 (Class I)	0.008±0.02 (Class I)	0.006±0.02 (Class I)
Pahang	*Eichhorniacrassipes*	0.287±0.03 (Class I)	1.390±0.06 (Class III)	1.390±0.06 (Class I)	0.026±0.01 (Class III)	0.268±0.03 (Class V)	0.320±0.06 (Class V)
	Cabomba fuscata	1.625±0.02 (Class IV)	ND	ND	1.627±0.02 (Class V)	ND	0.142±0.01 (Class III)
	Nelumbo nucifera	0.013±0.01 (Class I)	0.083±0.01 (Class III)	0.018±0.01 (Class I)	0.004±0.01 (Class I)	0.083±0.01 (Class I)	0.022±0.01 (Class I)
	Nelumbo nucifera	0.707±0.01 (Class I)	0.030±0.01 (Class III)	ND	0.708±0.02 (Class V)	ND	0.020±0.01 (Class I)
	Salvinia natans	6.383±0.11 (Class V)	ND	ND	6.385±0.10 (Class V)	ND	0.095±0.05 (Class III)
Selangor	*Hydrilla verticillata*	0.134±0.02 (Class I)	0.023±0.01 (Class III)	0.007±0.01 (Class I)	0.026±0.01 (Class IIA)	0.004±0.03 (Class I)	0.078±0.01 (Class I)
	Pistia stratoites	0.199±0.04 (Class I)	ND	0.023±0.01 (Class I)	0.002±0.01 (Class I)	ND	ND
	Eichhorniacrassipes	0.199±0.04 (Class I)	ND	0.023±0.01 (Class I)	0.002±0.01 (Class I)	ND	ND
Kelantan	*Eichhorniacrassipes*	0.257±0.32 (Class I)	0.207±0.21 (Class III)	0.059±0.05 (Class I)	0.098±0.01 (Class III)	0.227±0.07 (Class IV)	0.080±0.04 (Class I)
	Eichhorniacrassipes	0.120±0.01 (Class I)	0.207±0.12 (Class III)	0.092±0.02 (Class I)	0.053±0.01 (Class III)	0.108±0.13 (Class III)	0.038±0.09 (Class I)
	Salvinia natans	0.178±0.04 (Class I	0.948±0.29 (Class	0.062±0.02 (Class I)	0.086±0.01 (Class	0.151±0.06 (Class	0.195±0.07 (Class

		)	III)		III)	III)	III)

Conclusion

The content of heavy metals (Fe, Mn, Zn, Cu, Ni, Pb) in water samples of dominant aquatic macrophytes from the freshwater bodies of Perak, Pahang, Selangor and Kelantan are varied in relation to plant species. Some species turned out to be more successful key tool indicator for certain elements, therefore showing high potential in possible use as environment phytoindicator. Therefore certain aquatic plant species can be used as key tool indicators of low level environmental contamination that might otherwise be difficult to detect. The effects of heavy metals, the macrophytes and locations established that every single species of macrophytes were determined with their own phytoindicator capabilities. The best phytoindicator for excess iron were C.*fuscata* > *S.natans* > *N.nucifera* whereas for excess lead were *E.crassipes* > *S.natans* > *N.nucifera.* On top of that, good phytoindicator for zinc were *E.crassipes* > *N.nucifera* > *S.natans and* for excess copper were *S.natans* > *C.fuscata* > *E.crassipes.* The best *phytoindicator* for excess manganese were *E.crassipes* > *S.natans* > *N.nucifera* and for nickel were *E.crassipes* > *S.natans* > *N.nucifera.* In conclusion, the most reliable phytoindicator for overall experiment were *E.crassipes, S.natans* and *N.nucifera.*

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