Jurnal
Teknologi

Full Paper

ASSESSMENT OF AQUATIC ECOSYSTEM STATUS USING MACROPHYTE SPECIES AS KEY TOOLS INDICATOR FOR HEAVY METAL POLLUTION

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Article history
Received
5 August 2015
Received in revised form
21 November 2015
Accepted
28 November 2015

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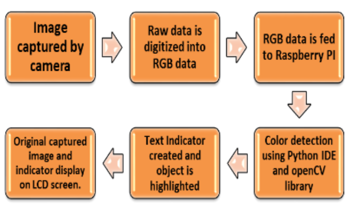
Graphical abstract



Abstract

Aquatic plants or macrophytes are beneficial to fresh water bodies because they produce oxygen, which assists with overall fresh water bodies functioning, and provide food and shelter for aquatic living organisms. A lack of aquatic plants in a freshwater bodies system where they are expected to occur may suggest a reduced population of macro and micro fauna. In addition, the absence of macrophytes may also indicate water quality problems as a result of excessive turbidity, herbicides, or salinization. However, an over abundance of macrophytes can result from high nutrient levels and may interfere with freshwater bodies processing, recreational activities and detract from the aesthetic appeal of the system. In this study, sixteen water samples were collected from four different places (Selangor, Perak, Pahang and Kelantan) where six different macrophytes species were abundance and dominant. All the water samples were analyzed by using Atomic absorption spectroscopy (AAS) for six types of heavy metals which are iron (Fe), lead (Pb), copper (Cu), zinc (Zn), nickel (Ni) and manganese (Mn). All six different macrophytes species which are *Eichhorniacrassipes, Hydrillaverticillata, Cabombafuscata, Salvinianatans, Nelumbonucifera*and *Pistiastratiotes*exhibiting highly significant differences (*P*< 0.0001) 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. Therefore, macrophyte is an effective tool in responding heavy metal in low level environmental contamination that might otherwise be difficult to detect.

Keywords: Macrophytes, phytoindicator, heavy metal, water pollution

1.0 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 obvious in Malaysia due to the rapid industrialization which were supported by foreign investment [1, 2]. According to the Malaysia Environmental Quality Report [3], 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 percent) and 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).

The heavy metal pollutants in aquatic environment from many resources either natural or anthropogenic activities in industrial, domestic and agricultural become worldwide problem. Trace metals are very significant because many of these metals are essential nutrients when in lower concentrations but they become toxic if their concentrations achieved certain limits [4]. Heavy metals are the most abundant and persistent environmental inorganic pollutants. Unlike other pollutants, metals cannot be degraded but the cleanup usually requires their removal. Some heavy metals may transform into the persistent metallic compounds with high toxicity, which can be bio-accumulated in the organisms, magnified in the food chain, thus threatening human health [5]. Therefore, ecological engineering offers a simple, cheap and energy efficient method of treating polluted water and wastewater.

Phytoindicator is a branch of phytotechnology which use plant to specifytoxic contaminants from the environment. Plants can take up various pollutants including heavy metal, nutrients (nitrate, ammonium, phosphorus), metalloids, petrochemical compounds (fuels, solvents), pesticides and soluble radionuclides [6, 7, 8]. The use of indicators and indices for the evaluation and assessment of the environmental status of diverse ecosystems is becoming a widespread procedure to analyze the various and often complex components of a system. Indicators can be handled as information tools, as they represent an objective system of information and evaluation, when properly selected, and the methodology of their determination and use can be uniformly specified and agreed upon. [9]. Aquaticmacrophytecan be excellent phytoindicator because they respond to nutrients, light, toxic, contaminants, metals, herbicides, turbidity, water level change and salt [10]. Aquatic macrophytes also can take up excessive nutrients and also play a crucial role in creating a favourable environment for a variety of chemical, biological and physical processes that contribute to the nutrient removal and degradation of organic compounds [11].

Aquatic macrophytes are those physiologically adapted to surviving in permanent or semi-permanent aquatic ecosystems. They can be identified in free-floating, submeged or emergent. Aquatic macrophytes have special fundamental property that make them attractive limnological indicators, which is they react slowly and progressively to changes of nutrient condition, in contrast with bacteria and microalgae over several years [12]. In fact, Aquatic species are one of the plants that have high potential for the phytoremediation of water contaminated with heavy metal [13, 14, 15, 16, 17, 18, 19]. Some species have expressive ability of bioconcentration, and therefore, increased accumulation of nutrients and heavy metals [20]. High concentrations in plant tissues of some elements may be the result of substantial availability of those elements in the surrounding environment. In this way, aquatic plants can be used as indicatorsfor detecting early warning of excessive heavy metals input to aquatic ecosystem to prevent serious heavy metal pollution.

Various aquatic macrophytes, such as aquatic floating macrophytesPistiastratiotesL. (water lettuce), Spirodelaintermedia W. Koch (duckweed) and Lemna minor L. (duckweed) present a high growth rate and have been applied for the removal of certain heavy metal like Cd, Cr and Pb. Moreover, aquatic plant synonym with nutrient bioindicator and removal. However,there are lacking information on qualitative and quantitative changes occurring in aquatic ecosystem related to heavy metal contaminants. In this study, the abundance of aquatic species signify what kind of heavy metal pollutant in aquatic ecosystem. These plants are chosen based on previous studies that documented their ability to survive in heavy metal pollution and the concentrations of metals in aquatic plants can be more than 100 000 times greater than in the associated water [21]. Therefore, certain aquatic plant species can be used as indicators of low level environmental contamination that might otherwise be difficult to identify.

2.0 SAMPLING AND METHODS

2.1 Sampling Site

4 different states in Malaysia have been chosen as a site study for collecting water samples. Those states are Selangor, Pahang, Kelantan and Perak. At the same 5 distinct locations have been identified with abundance of macrophytes within the state of Perak and Pahang. While, 3 distinct location have been recognize with domination of macrophytes in Perak and Kelantan. In the end, total of 16 different water bodies came along with distinct species of macrophyteshave been selected as our site study for water sampling.

2.2 Water Sampling

10 water samples were collected in triplicate in 1 litre plastic containers at selected sites using standard methods of collection. Water samples then were stored at 40°C and preservation of samples were done by the addition of 2.5ml chloroform in 500 ml of water for further analysis of various heavy metals (Fe, Pb, Ni, Cu, Zn and Mn).

2.3 Laboratory Testing

The experiments were sequentially replicated to evaluate the variations.All water samples were read its concentration of heavy metals Fe, Pb, Ni, Cu, Zn and Mn respectively.Heavy metals concentration in different water samples were determined by Perkin-Elmer flame Atomic Absorption Spectrometer (AAS). Operational conditions were adjusted in accordance with the manufacturer guidelines to yield optimal determination. 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. Standard methods for the examination of water and waste water, APHA 1995 were used for analyzing various parameters of polluted freshwater bodies [22].

3.0 RESULTS AND DISCUSSION

Six different aquatic plant species which are *E.crassipes, H.verticillata,C. fuscata, S. natans, N. Nucifera*and *P.stratiotes*were analysed for iron, lead, nickel, copper, mangan, zinc from four different locations which are Perak, Pahang, Selangor and Kelantan. Analysis of variance on each of 16 locations data (Table 1) confirmed the previous findings by exhibiting highly significant differences ($P< 0.0001$) between the all aquatic plant species widespread and the heavy metals (iron, lead, nickel, copper, mangan, and zinc) 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 (Table 1) revealed that, of the 6 macrophytes species analysed at all 16 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. Environmental factor or influence is the strong reason for the inconsistency of different heavy metals content such as types of soil and pH at Perak. It appears that besides agricultural activities and industrial, types of soil is the main key player in determining type and level of contamination or pollution. In Selangor type of soil observed is acid sulphate, whereas in Pahang, Perak and Kelantan mostly clayey or laterite and sandy respectively. Clearly, further study is required to confirm this hypothesis.

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	*Eichhorniac rassipes*	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)
	Eichhorniac rassipes	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)
	Hydrillaverti cillata	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)
	Nelumbonu cifera	0.018±0.03 (Class I)	0.01±0.062 (Class III)	0.005±0.01 (Class I)	0.001±0.01 (Class I)	0.008±0.06 (Class I)	0.008±0.03 (Class I)
	Nelumbonu cifera	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)
ANOVA		****	****	****	****	****	****
Pahang	*Eichhorniac rassipes*	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)
	Cabombaf uscata	1.625±0.02 (Class IV)	ND	ND	1.627±0.02 (Class V)	ND	0.142±0.01 (Class III)
	Nelumbonu cifera	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)
	Nelumbonu cifera	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)
	Salvinianata ns	6.383±0.11 (Class V)	ND	ND	6.385±0.10 (Class V)	ND	0.095±0.05 (Class III)
ANOVA		****	****	****	****	****	****
Selangor	*Hydrillaverti cillata*	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)
	Pistiastratoit es	0.199±0.04 (Class I)	ND	0.023±0.01 (Class I)	0.002±0.01 (Class I)	ND	ND
	Eichhorniac rassipes	0.199±0.04 (Class I)	ND	0.023±0.01 (Class I)	0.002±0.01 (Class I)	ND	ND
ANOVA		****	****	****	****	****	****
Kelantan	*Eichhorniac rassipes*	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)
	Eichhorniac rassipes	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)
	Salvinianata ns	0.178±0.04 (Class I)	0.948±0.29 (Class III)	0.062±0.02 (Class I)	0.086±0.01 (Class III)	0.151±0.06 (Class III)	0.195±0.07 (Class III)
ANOVA		****	***	****	***	***	****

ND: not detected. ****Highly significant at P < 0.0001

4.0 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*andfor excess copper were *S.natans>C.fuscata>E.crassipes.* The best phytoindicator for excess mangan 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.*

Acknowledgement

The authors would like to thanks Ministry of Higher Education (MOHE) and International Islamic University Malaysia (IIUM) for the Research Grant RACE14-002-0008, FRGS13-052-0293 and NRGS13-002-0002.

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