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THE USE OF *Ipomoea Pes-Caprae* PLANT SPECIES TO MONITOR METAL POLLUTIONS OF THE COASTAL SOIL

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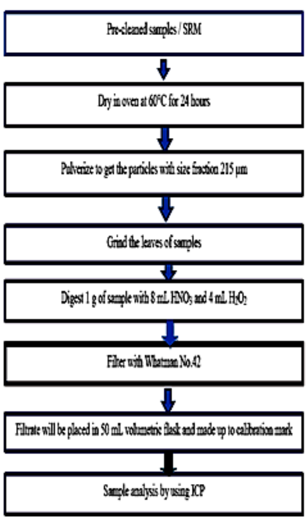
Graphical abstract



Abstract

In this study, biomonitoring technique was applied to evaluate metals pollution at selected beach site. *Ipomoea pes-caprae* species were used to monitor the concentration level of lead (Pb), aluminum (Al), iron (Fe), barium (Ba), and zinc (Zn). Besides studying the ability and effectiveness of this plant as biological indicators of metal pollution in beach areas, the study also aimed to characterize the possible contributors of the metals in the area. The selected plants were collected along the coastal areas of Balok, in Kuantan, Pahang Malaysia. The study area is directly connected to the fish landing jetty of the local residents. The samples were collected at six sampling stations along the polluted shoreline area in two seasons, pre-monsoon and post-monsoon; and were duplicated. The metal content in the *Ipomoea pes-caprae* was considered as the indicator of environmental pollution in the coastal area. Significant differences of metal concentrations were found in samples collected from different sampling stations with certain levels. A comparison of the metal contents to the control samples clearly proved that the area has been polluted with the studied metals. In general, lower metals concentrations were found in post-monsoon samples compared to pre-monsoon samples. The concentration of metal Al was found to be the highest in the plant samples; The plant samples were contained the highest concentration of metal Al; followed by Fe, Zn, Ba, and Pb. Based on the EF values, it is strongly suggested that all the metals uptake were via the root system. The results of the PCA clearly indicated that the elements of Al, Fe, and Ba were contributed by the soil origin; meanwhile the elements of Pb and Zn were correlated to anthropogenic sources.

Keywords: Bio-monitoring, *Ipomoea Pes-Caprae*, heavy metals, enrichment factor, principal components analysis

1.0 INTRODUCTION

Coastal area is susceptible to various environmental problems that can result in degradation of natural resources [1]. The area is among the most important places for human inhabitant and could be considered the ultimate receptacle of anthropogenic pollutants [2]. Many persistent pollutants are sinks and accumulated in the bottom sediment in this area [3]. Balok River in Kuantan, Malaysia is one of the important rivers flows across the international industrial site of Gebeng. Most of the factories activities in this area are under a direct connection to this river. In certain conditions, especially during the rainy season, the wastewater will overflow from the waste ponds and entering the main river stream. The presence of some industrial waste in the water body will disrupt the water quality of the affected river. There are various types of organic and inorganic pollutants that potentially being released by industries, including heavy metals. The river water that flows from the headwaters to the beach site is expected to deposit some metal contaminants around the estuary and coastal side of the river. Therefore, a study should be carried out in the coastal area in order to evaluate the levels of heavy metals that possibly have been carried away from its origin (upstream the river) and finally deposited in the area. It is important to know the pollution levels of the area because it has a direct effect on the fishing activities of the local residents. Bio-indicator is a biological organism used to indicate the state of the environment [4]. Main bio-monitor, including plants, fish and invertebrates might have dissimilar reactions to metal exposures like storage, uptake and release capacities. These special characteristics can be used to evaluate the consequence of ecosystem and human health risk [5]. Marine organisms like algae and mollusc as bio-indicators are a very common bio-indicators to assess aquatic pollution. This is because they are able to collect trace metal up to one thousand times higher concentration compared to the corresponding concentration in seawater. The use of biological species in the monitoring of marine environmental quality allows the evaluation of the biologically available levels of contaminants in the ecosystem or the effect of contaminants on living organisms [6]. Ipomoea pes-caprae species, which also knew as beach morning-glory is a herbaceous vine that grows wild on ocean shores [7]. This plant reaches a height of four to six inches, but the stems may creep along the ground to a length of 75 feet. Ipomoea (Convolvulaceae) consists of more than 200 species that extensively distributed in tropical and subtropical countries [8]. This plant has long trailing stems, a very fast growth rate, being among the earliest species to colonize newly deposited dunes and contributing in the initial stabilization of sand [9]. Additionally, this species is a perennial beach plant that forms large patches just above the high-tide line on coastal beaches and dunes and highly exposed to salt-spray and inundation by either salt or fresh water [10]. Hence, there is a probability that metal contaminants flow from the river to seawater was absorbed into this plant. Therefore, it is expected that this plant can serve as a good bio-indicator to study the level of metal pollution around the coastal area. The aims of the study were to evaluate the capability of Ipomoea pes-caprae plant species as a possible bio-monitor of metal pollution in coastal areas and to observe the possible way of the metals uptake into the plant bio-indicator.

2.0 EXPERIMENTAL

2.1 Sampling Site

Balok beach is around 15km north of Kuantan city in Pahang, Malaysia and also known as great windsurfing places. The beach is located close to the Kuantan Port in the north, and directly received the outflows of Balok river water, which was expected to receive the discharged waste water from the surrounding industries. In addition, the area is situated next to the fishing villages and commercial tourism development site. The beach area, which is bound by the South China Sea, occupies the northern tropic and is influenced by monsoons climate, which knew as the southwest monsoon (summer) and the northeast monsoon (winter). The study area was experiencing seasonal wind of the north east monsoon that prevailed from October to February. The total of six sampling sites which were evenly distributed along the beach side was chosen.

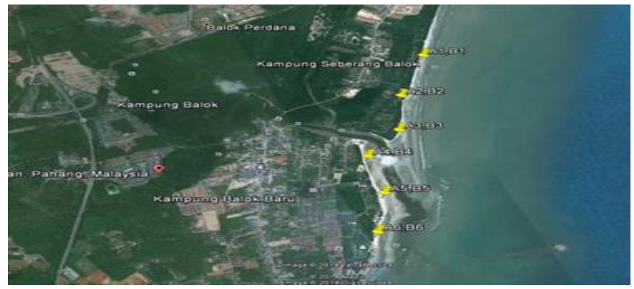


Figure 1 The positions of the six sampling sites distributed along beach side of South China Sea

The exact positions of the six sampling sites are illustrated as in Figure 1. The distance between each sampling station was about 500 meters. The same plants sample was also collected in another beach as a control sample.

2.2 Sample Collection

The plant samples were collected in two different seasons; pre-monsoon or the Southwest monsoon (September 2013) and during the post-monsoon (northeast monsoon) in March 2014. About two kilograms of the plant sample (without the flower) were collected. The green parts of the plant sample were immediately stored in a closed plastic bag to avoid any contaminants from the surrounding air and then transferred to the experimental laboratory for further analysis. Figure 2 shows the physical structure of the plant sample used in this study.

Figure 2 The physical structure of the *Ipomoea pes-caprae* plant

2.3 Sample Treatment and Analysis

The cleaned plant samples were dried in an oven at 60°C for 24 hours. The dried samples were ground into powder form and were sieved to get the particles with a homogeneous size fraction. To analyze the total metal content of the sample, one gram of sample material was digested by the application of a mixture of acids and assisted by microwave digester. One gram of ground plant material was soaked with 10 ml of HNO3 in the digestion vessel and left to react for about 30 minutes. Hydrogen Peroxide, H2O2 (2.5 ml) is added to the mixture and swirled. When the frothy reaction fills 75% of the digestion vessel, it is capped and the vent tube is mounted. The carousel of capped vessels is placed in the oven at 95% power for 2.25 minutes for each sample. After the cooling process, the digested sample's solution was then filtered through filter paper and the final solution was transferred into a 50 ml volumetric flask and later was added with deionized water to the calibration mark. The mixture is analyzed by the inductively coupled plasma optical emission spectrometry, ICP-OES. The accuracy of the method was validated through certified standard reference material NIST No. 1575 (pine needle) which was treated and analyzed using the same procedure as for the real samples. The percent recoveries of all the studied elements are in the range of 85 % to 90 %.

3.0 RESULTS AND DISCUSSION

3.1 Heavy Metal Contents in *Ipomoea pescaprae*

The concentration of all the selected metals contained in the plant samples between sampling sites was summarized in Table 1. The results clearly demonstrate that the metal concentration was unevenly distributed over the study sites. The difference in the total concentration of metals in the plant samples could reflect the different emitters of the metals [11] and is depends on the differences of the metal contents deposited at a particular site by certain media. In general, selected plant samples contained the highest concentration of Al followed with Fe, Zn, Ba and Pb. All the samples contained higher concentrations of the studied metals compared to the background. The highest concentration of the studied metals was observed for Al, which in range between 2986.5 to 695.0 mg/kg dry weight. The high concentration of this element in the sample is already expected where Al is considered the most abundant natural element in the earth's crust, immobilized, and was not significantly affected by digenetic processes and strong redox effects in sediments. The existence of this element in the plant was not directly influenced by anthropogenic sources [12].

The second element that has shown significantly high concentration is Fe. This element is considered one of the essential microelements in the plant for its survival cycles. However, extreme high concentration of Fe in the plant will cause toxicity effects. The recommended concentration of Fe in plant was 150 ppm [13]. In this study, the maximum concentration of Fe was recorded as 508.3 mg/kg while the lowest was 77.4 mg/kg. The existence of Fe in the coastal plant samples can be related to the combustion process of fossil fuels, vehicles and fly ashes, which was transported widely through the air from its origin.

Table 1 Concentration of the studied elements contained in the samples (pre-monsoon and post-monsoon) collected at six sampling sites

		Element concentration, mg/kg				
	Stations	**Al**	**Ba**	**Fe**	**Pb**	**Zn**
Pre-monsoon	A1	1203.0	2.3	218.5	0.4	9.6
	A2	1618.5	3.1	294.4	0.7	20.8
	A2	1996.5	3.3	508.0	1.3	12.8
	A4	1657.5	4.1	280.3	0.8	16.2
	A5	2986.5	8.7	375.3	1.8	10.6
	A6	1574.5	2.5	305.3	1.2	9.9
	Mean	**1839.4**	**3.8**	**330.3**	**1.1**	**12.7**
Post-monsoon	B1	1433.5	5.1	438.5	4.4	37.3
	B2	1438.0	4.3	359.8	2.8	26.8
	B3	1455.5	2.4	482.7	5.2	16.2
	B4	695.0	3.3	242.2	2.3	23.0
	B5	767.0	1.8	206.5	1.0	19.6
	B6	289.8	1.6	77.4	0.2	21.8
	Mean	**1013.1**	**3.1**	**301.2**	**2.6**	**24.1**
	Control	**482.5**	**1.6**	**85.5**	**0.2**	**3.0**

Industrial emission and exhaust fume of motor vehicles were considered the main contributors of lead, Pb in the atmosphere [14], [15]. The particles of Pb will remain in the surrounding atmosphere for a period of time before finally deposited onto the various types of surface. The highest concentration of Pb was recorded as 5.2 mg/kg while 0.2 mg/kg was the lowest. In general, all the Pb concentrations measured in this study were lower than the recommended value which stated as 30 ug/g [16]. Zn, which is the other main essential micro-elements for the plant was measured between 9.9 to 20.8 mg/kg.

The critical value of this element in the plant is recommended at 15ug/g [17]. Plant with symptoms of Zn deficiency experiences a retarded elongation of cells [18]. Barium, Ba and its compounds are used for many important purposes. Barium sulfate is used by the oil and gas industries to make drilling muds. The barium compounds are used in the ceramic industry, insect and rat poisons, additives for oils and fuels. The highest concentration of the metal Ba measured in this study was 8.7 mg/kg and the lowest as 1.8 mg/kg. All the measured concentrations of Ba were a few times higher compared to the background values.

3.2 Correlation of Metal Contents Between Monsoons

In order to analyze the effect of the difference monsoon seasons on the heavy metal accumulation capacity of the selected plant, the comparison of the elemental mean concentrations between two different seasons are shown in Figure 3.

Northeast monsoon (post monsoon) normally brings heavy rainfall to the current coastal area sampling area, whereas the southwest monsoon normally signifies relatively drier weather. Both seasons can be clearly observed in the South China Sea. Their coastal areas are considered an active site where huge amount of organic and inorganic materials are introduced into the ocean system through river runoff, in situ primary production and artificial impact [19].

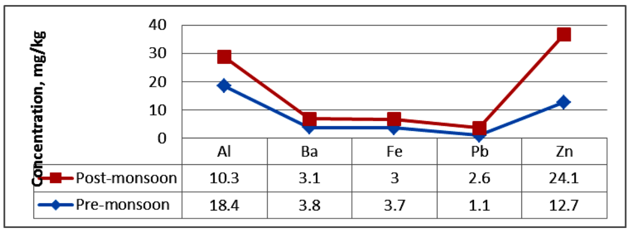


Figure 3 The mean of the metal concentrations of the studied elements in two difference seasons: pre- and post-monsoons

The plotted line chart based on the mean concentrations of the five studied elements (Figure 3) was clearly indicated that the mean concentrations of the studied elements were measured with some variations of both monsoons. The relatively high variations of the mean concentrations of the metal were observed for Al, Pb and Zn. The mean concentration of the metal Pb was recorded the biggest differences in the concentration data of the two monsoon seasons with almost 58 %. The variation of the metal contents accumulated in the plant samples clearly indicates that there are some factors that were indirectly influenced the capability of the selected plant samples to retain and absorb the minerals. These would include the capability of plant to absorb and retain minerals and resistance to weather changes and surrounding environment. This is of great importance when using plant as bio-monitors, since low variation within the same sampling point is a prerequisite. In comparison, the results of metal concentrations derived from the plant samples, for both monsoon seasons, the concentration of Al, Fe and Ba post-monsoon samples were found lower compared to the pre-monsoon samples. The reduction of metal concentrations in plants could be associated with the leaching process where parts of the metals were removed from the plants by the action of aqueous solutions, such as rain, dew, mist and fog [20]. Moreover, all the studied elements can be classified as micro-nutrients for plants which are considered none essential nutrients, where only small quantities are needed for plants to grow.

3.3 Enrichment Factor (EF)

In order to categorize the general origin or emitters of heavy-metal that was deposited in the study area, the enrichment factor (EF) values for each plant samples were calculated and summarized in Table 2. The interpretation of EF values is as follows:

- EF >10 indicates that the concentration of the metals observed in plant tissue could be originated from anthropogenic and natural events
- EF <10 indicates that the concentration of the metals observed in plant tissue is likely to be predominantly of pedological origin, derive from the soil substrate.

Based on the given definition and classification of the EF's, some important information, particularly relating to how the minerals can be absorbed into the plant system, either directly from ambient air through the surface of the plant leaves or through the root system, can be obtained.

Table 2 Enrichment Factors (EF's) with the corresponding standard deviations for five elements at six sampling stations

	Pre-monsoon					Post-monsoon			
Metals/ Stations	Al	Ba	Pb	Zn	**Metal/ stations**	Al	Ba	Pb	Zn
A1	1.0	0.6	0.9	1.3	**B1**	0.6	0.6	5.7	2.4
A2	1.0	0.6	1.4	2.1	**B2**	0.7	0.6	4.4	2.1
A3	0.7	0.4	1.5	0.7	**B3**	0.5	0.3	6.1	1.0
A4	1.1	0.8	1.5	1.6	**B4**	0.5	0.7	5.3	2.7
A5	1.4	1.2	2.7	0.8	**B5**	0.7	0.5	2.8	2.7
A6	0.9	0.4	2.2	0.9	**B6**	0.7	1.1	1.5	8.0
Mean	1.0 ± 0.2	0.7± 0.3	1.7 ± 0.5	1.2 ± 0.5	**Mean**	0.6 ± 0.1	0.6 ± 0.2	4.3 ± 1.5	3.2 ± 2.1

Assumption: Fe found in the plant samples is of terrestrial origin

The EF's values were varied by some levels among the analyzed elements. The EFs values of all the studied elements were calculated below 10, which indirectly give an indication that all the minerals that were absorbed by the plants, predominantly originated from the soil or the plant substrate (pedological origin). None of the studied elements absorbed by the plant can be directly associated to the surrounding ambient air pollutants. The anthropogenic pollutants probably could be indirectly influenced the levels of the minerals in plant after going through the deposition process. Based on the overall EF's values obtained in this study, the plant used in this study (Ipomoea pes-caprae) received their nutrients mainly through its true root system. There were, possibly, only a few parts of the micro-nutrients received by the plant directly from its ambient air through it leave.

3.4 Multivariate Analysis of Metal Contents in Plant Samples

Principal Components Analysis (PCA) of the five metal concentrations in plant samples was employed in this study to provide a multivariate view of metal distribution in the study area. The use of this statistical analysis will reveal the possible origin of the detected metals and the similarities among sites that would be difficult by univariate and other simpler method of statistical analysis.

The eigenvalues and the explained variances of the principal Components (PC) are reported in Figure 4. On the basic of eigenvalues, the two principal components (PC1 and PC2) were significant in each case which explained 81.36 % of the total variation. The analysis based on the loadings confirms that all the metals are presented by these two PC.

Component	Eigenvalues			Extraction Sums of Squared Loadings			Component Matrix		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Element	1	2
1	2.49	49.72	49.72	2.49	49.72	49.72	Al	**0.97**	0.21
2	1.58	31.64	81.36	1.58	31.64	81.36	Ba	**0.82**	0.04
3	0.71	14.23	95.58				Fe	**0.77**	0.43
4	0.19	3.97	99.55				Pb	0.36	**0.86**
5	0.02	0.45	100.00				Zn	-0.25	**0.84**

Figure 4 Eigenvalues, explained and metal loadings variance of principal components (PC)

The first PC, which accounted for 49.72 % of the total variance, is mainly dominated by soil mineral elements, Al, Ba and Fe. The three elements were less enriched in the plant samples, which does not exceed the value of "2" on the EF scale. The lower EF values were recorded for samples taken during the post-monsoon compared to pre-monsoons. Compared with moss and lichen (which is often used in monitoring air pollutants) that receive minerals directly from the surrounding air, the results of EFs and PCA in this study strongly indicate that Ipomoea pes-caprae plant uptake some minerals, mostly through their root system. The second principal component, PC2 which was contributed 31.64 % of the total variance, were dominated by two elements, Pb and Zn. Based on the equally high factor loading in PC2 of the above elements, the existence of Pb in the group could be related to the anthropogenic sources, especially of oil and gas-related industries. It is reported that coal is an important source for Pb [21]. The concentration of Zn in the ecosystem probably originates from anthropogenic activities and soil origin. It is reported that excessive use of pesticides and fungicides may increase the enrichment of Zn in soil [22], [23]. These suggested that the enrichment of soil with Pb and Zn in the study area was much associated with the consumption of fossil as fuel and energy sources for the local industry.

4.0 CONCLUSION

It is generally known that the uses of biological materials as bio-indicator in the environmental study are considerably cheaper and reliable approach. Various types of plant such as lichen, mosses, bark and leaves of higher plants were used to obtain some information about the metal pollution in the environment. Generally, it is quite difficult to get the right type of plant species to be a good bio-indicator to monitor the pollution levels around the coastal area. The porous soil structure and high salinity levels of the sea water give some difficulty for plants to live along the coastal side. One of the plant species that can survive and widely grow along the coastal zone is Ipomoea pes-caprae. The plant has a simple structure which leaves and flowers grow on the roots that creeping along the coastal sand. The use of this plant as an alternative biological material in the environmental pollution monitoring study could provide a lot of information and indication related to pollution that sometimes cannot be derived from vascular plants. The results of this study have shown that Ipomoea pes-caprae can be analyzed in the same way as mosses and lichen in order to quantify numbers of element. The metal concentrations in Ipomoea pes-caprae from the study sites were found higher than those from the selected control area, which indirectly suggesting that the Ipomoea pes-caprae plant species can be expected to be an indicator of metal loading in the different ecosystem. The results of the study have proven that the plants are suitable to be used as an indicator of local ecosystem pollution. With the EF values in relatively low levels and supported by PCA results, it is highly possible that most of the needed minerals were taken in by the plant through its root system and it leaves. There were no significant differences of the metal concentrations among the ten sampling sites where the primary sources for Al, Ba and Fe were dominated by soil origin while Pb and Zn were dominated by anthropogenic sources. Based on the ability of this plant to provide a variety of information related to metal pollution as what has been observed in this study, it would be strongly suggested, by applying more detail study techniques, the Ipomoea pes-caprae could be considered one of the reliable biological indicators for environmental study.

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