

Distributions of heavy metal in the surface sediments of mangrove from west coast of Peninsular Malaysia

Kumar Krishnan^{1,2}, Elias Saion¹, M.K. Halimah¹, Yap CK³ and Muhd Suhaimi Hamzah⁴

¹Department of Physics, Faculty of Science, Universiti Putra Malaysia, Selangor, Malaysia

²Inti International University, Nilai, Darul Khusus, Negeri Sembilan, Malaysia

³Department of Biology, Faculty of Science, Universiti Putra Malaysia, Selangor, Malaysia

⁴Malaysian Institute Technology Research (MINT), Selangor, Malaysia

ABSTRACT

A study is carried out on the concentrations of heavy metal of arsenic (As), copper (Cu), lead (Pb) and zinc (Zn) present in surface sediments from 10 locations throughout west coast Malaysia. Instrumental neutron activation analysis (INAA) and Atomic Absorption Spectroscopy (AAS) method was used to determine element concentrations in the entire samples. Samples were dried and crushed to powdery form before preparation for INAA and AAS. As calibration and quality control procedures, blank samples, standard reference material IAEA-Soil-7 and SL-1 were analyzed same conditions as the samples. The mean concentrations of As, Cu, Pb and Zn on sediment samples ranged from 8.75 to 44.60, 5.70 to 69.45, 13.16 to 34.52 and 34.17 to 348.10 mg/kg respectively. The enrichment factor value of sediments varied from 0.21 – 9.18. Degree of contamination (Cd) and modified degree of contamination (mCd) of all the heavy metal fall in the range between 2.81 – 7.74 and 0.70 – 1.94 respectively. Sediments of the Juru (L5) are contaminated by Zn, while the sediment from Lukut (L8) and Kampung Panchor (L6) was heavily contaminated by As.

Keywords: Heavy metal, Spectrometry, Enrichment, Contamination factor, Neutron activation.

1. INTRODUCTION

Mangrove ecosystems are coastal forests categories as a high primary marine productivity, which found in sheltered coastlines, estuaries, river banks or deltas in tropical countries. The mangrove forests are best developed and coldest temperature of 20°C and fairly maintained a constant temperature throughout the whole year. Mangroves are salt-tolerant evergreen trees and grow according to the climate, salinity of the water and topography. The soft substrate is predominantly made of clay and silt rather than sand. Since nutrients often adsorbed onto muddy sediment particles, the inputs of mangrove-derived organic matter into intertidal and river estuaries are important for a variety of fish and shellfish, including many commercial species [1], [2]. Fish and many marine species use the spaces under the mass of prop roots of mangrove trees as a 'delivery rooms,' of offspring and habitat for their growing period before moving to the open sea. Due to unplanned and uncontrolled urbanization and rapid growth of industrial economics around many cities and coastal area the level of pollution degradation is unpredictable. Out of many pollutants, heavy metals such as Pb, As, Cu and Zn are a major concern because of their persistent and bio-accumulative nature. The level of contamination may extend its hazardous effect to aquatic life, system and human health, especially to human consumers of seafood, by bioaccumulation in the food chain. Cu is an essential element which exists in several enzymes in human to maintain metabolic functions and needed in small amount. Higher uptake of Cu can cause serious effects such as irritation of the eyes, mouth and nose and abdominal pain that is associated with nausea, stomach cramping, vomiting, diarrhea, and even death. Carcinogen such as a arsenic and can cause cancer of the internal organs. Lead can affect every organ and system in the body, especially for adults can result in decreased performance in the nervous system, blood pressure and anemia. Even though Zn also essential for the human body, but high levels of Zn can interrupt metabolism of protein and can cause respiratory disorders. In Malaysia, human activities are the main result of anthropogenic sources which resulting in increased heavy metal concentrations and indirectly cause contamination of living organisms in ecosystem [4], [5]. It was noted that a number of the studies on heavy metals have been focused on the west coast of Peninsular Malaysia due to huge economic growth and activities, human population and agriculture are concentrated in this coastal area [6]. Surface sediment is the last destination to settle down for all kinds of pollution that comes from human activities as a result of a variety of problems in the ecosystem [3]. Therefore, it is important to analyze sediment to identify the level of pollution in mangrove areas. The research on the sediment is one of the excellent tools for verifying the source of the effects on the depositional environments over a long period of time (history) [7]. Most of the pollutants leave their fingerprints in sediments and analysis of sediment offers certain advantages compared with water analysis. The metal concentrations in sediments fluctuate over time and it was observed the rate of change is much lower than that of the water [8], [9]. Therefore, the top layers about few centimeters in depth of the sediments reflect degree of contamination. Hence, the current study was undertaken to estimate the distribution patterns of heavy metal and concentrations in surface sediments of mangrove area to evaluate the present trend of pollution patterns. By normalizing the metals detected to iron, the enrichment factor (EF) of each metal was assessed thereby determining the extent to which the sediments have been

enriched with particular metal and area. Also the modified degree of contamination (mCd) of metal contaminants was as well determined to assess the pollution status of the sediments under study.

2. EXPERIMENTAL

Study area and sampling procedure

This present study was conducted in mangrove area along river estuaries in the west coast areas of West Malaysia (~ 800 km) at seven locations covered from latitude: N 05° 20' 24.7" to N 01° 15' 58" and longitude: E 100°24'25.2" to E 103°30'39" as shown in Table 1 and Figure 1.

ID	Location Name	GPS Reading	Description of nearby activities
L1	Tok Muda, Kapar,	N03° 7' 30.9"	Residential Area, Hydroelectric
		E101°20'27.7"	
	Selangor	"	Power Plant
L2	Sungai Sepang Besar,	N 02° 56'16.9"	Residential Area, Intertidal Area
	Selangor	E 101°45' 9.4"	
L3	Sungai Pasir Gudang, Johor	E 103°57' 26"	Residential Area, Shipping Area
		N 01° 24'3.99"	Intertidal Area
L4	Kuala Gula, Perak	N 04° 55' 58"	Fishing Village, Tourism Spot,
		E100°27'33.6"	
		"	Fish cage, shrimp pond
L5	Juru, Penang	N 05° 20'24.7"	Fishing Village, Residential Area
		E100°24'25.2"	Industrial Area
		"	
L6	Kampung Panchor,	N 04° 31'33.4"	Fishing Village, Tourism Spot
	Pantai Remis, Perak	E100°39'17.5"	Fishcage, shrimp pond
L7	Sungai Kim Kim, Johor	N 01° 26'40.2"	Residential Area, Shipping Area
		E103°58'14.2"	Intertidal Area
L8	Lukut, Port Dickson,	N 02° 34'49.4"	Residential Area, Shipping Area
	Negeri Sembilan	E101°47'53.9"	Industrial Area
L9	Pulau Kukup, Johor	N01° 19'18.7"	Residential Area, Shipment Area
		E103°25'30.6"	Fish cage, shrimp pond
L10	Tanjung Pia, Johor	N 01° 15' 58"	Residential Area, Shipping Area
		E 103°30' 39"	Tourism spot

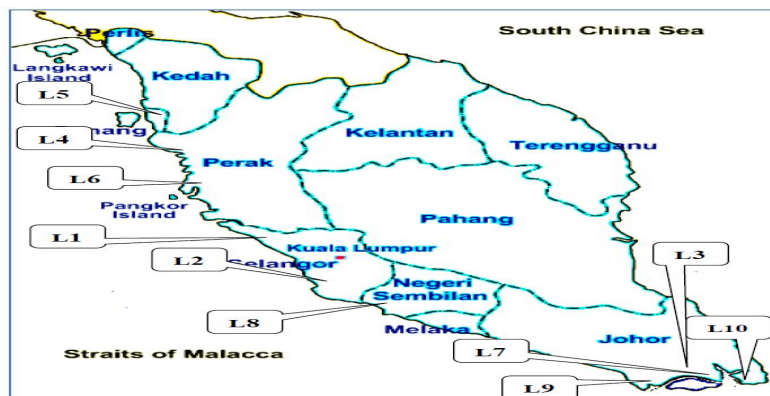


Figure 1 : Location of the surface mangrove sediment sampling stations

A collection of sampling was in January 2011 until December 2011 from the mangrove areas. All the locations of the present study are exposed to the different types of anthropogenic sources such as an agriculture, aquaculture, industrial, development, tourism, shipping port, hydroelectric plant and etc. The sampling map and descriptions of the sampling locations are shown in Table 1.

Analytical method

In the current study, four replicate experiments in all samples of the analysis samples were weighted approximately 150 mg for short irradiation and 200 mg for long irradiation. The certified IAEA-Soil-7 was used as a multi-element comparator. As calibration and quality control procedures, blank samples, standard reference material IAEA-Soil-7 and SL-1 were irradiated by using pneumatic transport facility with thermal neutron flux of $3\text{-}4 \times 10^{12} \text{ n cm}^{-2}\text{s}^{-1}$ at the MINT TRIGA Mark II research reactor operated at 750 kW. For short irradiation, the samples were radiated for 1 minute and counting times 5 and 20 minutes after a cooling time of 20 minutes and 24 hours respectively. The samples were irradiated for 6 hours and counted for 1 hour after a cooling time of 3-4 and 21-28 days for long irradiation [10]. Alternately AAS method used to determine the concentration of those elements that are poorly detected by INAA method shown from their recovery results. All the glassware and plastic containers used for the collection, transportation, and laboratory analysis were acid-washed with 10% concentrated of nitric acid, HNO₃ (AnalaR grade; BDH 69%) to prevent and minimize any possibility of contamination. About 0.50 g of each dried and powdery sample was digested with HNO₃ (AnalaR grade; BDH 69%) and perchloric acid, HClO₄ (AnalaR grade; BDH 60%) combined in the ratio of 4:1. The sediment, standard and blank samples were placed into a hot block digester and digestion tube at low temperature (40 °C) for first 1 hour and then were completely digested at high temperature (140 °C) for at least 3 hours [11]. At the end of the digestion process, the resulting solution obtained is diluted with 40 ml of double distilled water and then were filtered out through a Whatman™ No. 1 filter paper Cat No 1001 090 (diameter: 90 mm) into a clean and dried, acid-washed polyethylene container. Then they were determined the concentrations by using Perkin Elmer Model AAnalyst 800 an air-acetylene Flame Furnace Atomic Absorption Spectrophotometer (AAS). All the samples were analyzed in three replicates. The quality and analytical procedures for the sediment were checked with standard Certified Reference Material (CRM) Soil – 7 and SL-1.

3. RESULTS AND DISCUSSION

The analytical results for the CRM and measured values of Soil-7 and SL-1 are shown in Table 2. The recoveries between the measured and certified in AAS and INAA method are within the range of acceptable. The recoveries in both methods for all of the certified reference material are in the range 82.1– 110.6 %.

Table 2 The analysis of the standard reference material and comparison with certified values of SL-1 and SOIL-7. *denotes standard reference from SOIL 7

Element	As	*Cu	*Pb	Zn
Certified value	27.6	11	60	223
Measured values by INAA	25.45	-	-	246.69
Recovery	92.2	-	-	110.6
Measured values by AAS	-	11.14	49.25	-
Recovery	-	101.3	82.1	-

Table 3: Concentration of heavy metal (mg/kg) in the surface mangrove

Location	As	Cu	Pb	Zn
L1	9.10 ± 1.78 (7.22, 11.49)	5.70±0.69 (4.98,6.37)	27.04±5.50 (23.14,30.93)	59.80±4.34 (53.89,63.99)
	16.95 ± 1.68 (14.57,18.34)	11.14±0.04 (11.11,11.19)	15.41±7.51 (10.35,24.04)	91.78±7.24 (85.08,101.35)
L3	21.72 ± 0.46 (21.09,22.08)	14.99±1.30 (13.68,16.28)	25.54±7.08 (17.86,31.81)	69.94±7.07 (62.67,79.60)
	8.75 ± 0.70 (7.91, 9.63)	13.94±2.09 (11.82,16.00)	27.16±3.71 (23.71,31.08)	82.34±9.51 (71.05,91.88)
L5	10.50 ± 0.98 (9.15,11.47)	69.45±0.17 (69.31,69.63)	34.52±9.41 (27.64,45.25)	348.10±11.44 (335.24,360.71)
	22.89 ± 9.30 (15.51,36.34)	10.25±0.49 (9.76,10.74)	13.16±3.74 (9.048,16.38)	34.17±3.56 (31.90,39.40)
L7	24.714 ± 0.69 (24.22,25.73)	18.68±1.04 (17.63,19.72)	27.73±7.84 (21.00,36.34)	81.77±2.65 (78.67,85.06)
	44.60 ± 1.22 (43.33,46.20)	17.75±1.68 (16.10,19.46)	21.85±6.39 (17.21,29.13)	70.63±2.31 (67.32,72.65)
L9	11.21 ± 0.81 (10.24,12.22)	8.05±1.08 (6.97,9.14)	24.41±8.01 (18.55,33.54)	83.08±6.84 (75.74,92.07)
	11.72 ± 0.31 (11.30,12.05)	6.47±1.90 (4.57,8.38)	21.30±5.65 (17.47,27.79)	72.35±7.69 (62.40,79.46)

The results obtained for the mean and range concentrations of heavy metal in the sediment samples that collected from west coast Malaysia are presented in Table 3. The total concentrations of As, Cu, Pb and Zn on sediment samples ranged from 8.75 to 44.60, 5.70 to 69.45, 13.16 to 34.52 and 34.17 to 348.10 mg/kg respectively. The mean concentration of As was ranging between 8.75 and 44.6 mg/kg. The highest mean concentration of As was found in L8 and the lowest was found in L4. Overall mean concentration of As in the mangrove surface sediment of West Malaysia about 18.22 mg/kg. As compared with USEPA guidelines (PEL indicators) for As (3.0 mg/kg), As result obtained from these studies was higher than the limit set by USEPA. The mean concentrations of Cu in (mg/kg, dry weight) have ranged from 5.7 to 69.5. Most of the sites showed the concentration of Cu was lower except one site (L5, Juru, Penang). The highest concentration of Cu in surface sediments was found in sampling location L5 (69.5 mg/kg) and lowest at the L1 (5.7 mg/kg). As compared to other studies, the concentrations of Cu in the present study were lower than those reported for polluted drainage sediments (Cu: 1019 mg/kg) and the intertidal sediments (Cu: 0.40-315 mg/kg), in the west coast of Peninsular Malaysia. On the other hand, compared with the marine sediments, the concentrations of Cu in this study were higher than the offshore sediments in the Straits of Malacca (Cu: 0.25-13.8 mg/kg, and in the Dumai coast, Indonesia (Cu: 1.61-13.8 mg/kg) [12], [13], [14] and [15]. The results for Pb levels in mangrove surface sediments are given in Table 3. Pb levels in mangrove surface sediments ranged from 13.16 mg/kg at L6 to 34.52 mg/kg at L5. Overall mean concentration of Pb in mangrove surface sediment of West Malaysia about 23.81 mg/kg. Compared with USEPA guidelines (PEL Indicators) for Pb (40 mg/kg), all the studied areas in west Malaysia were lower than USEPA limit. The mean concentrations of Zn were ranging between 34.17 and 348.10 mg/kg. The highest mean concentration of Zn was found in L5 and lowest was found in L6. Overall mean concentration of Zn in mangrove surface sediment of West Malaysia about 99.40 mg/kg. As compared with USEPA guidelines (PEL indicators) for Zn (81.0 mg/kg), Zn result obtained from these studies was higher than the limit set by USEPA.

Enrichment Factor (EF)

Enrichment factor is most useful tools to determine whether anthropogenic contamination based on the calculation of the normalization of each heavy metal concentration to Al or Fe because of its high natural concentration and minimum anthropogenic contamination. Many researchers used Fe successfully to normalize metals contamination in river and coastal sediments [16], [17]. Fe has been used as a normalizer to determine EF because it is the most abundant and

common element in the earth's crust and free of contamination in the current study. The EF for Fe-normalized data is defined by:

$$EF_{metal} = \frac{\left(\frac{M_{exp}}{Fe_{exp}} \right)_{sample}}{\left(\frac{M_{ref}}{Fe_{ref}} \right)_{shale}}$$

Where M_{exp} is referring to the concentration of element in the experimental sample, F_{exp} is the concentration of Fe in the experimental sample, M_{ref} is the concentration of abundant and common element in the average shale and F_{ref} is the concentration of Fe in the average shale. In the current study, average shale, Fe was used as background reading in the average shale [18]. This element ratio's indicates [19]:

EF < 1	no enrichment
EF < 3	minor enrichment
3 < EF < 5	moderate enrichment
5 < EF < 10	moderately severe enrichment
10 < EF < 25	severe enrichment
25 < EF < 50	very severe enrichment
EF > 50	extremely severe enrichment

The EF values for all sampling sites are given in Table 4. By choosing Fe as a normalizing element, most of the sampling site showed EF values lower than 1.0 for the Cu in most of the studied location except in L5 and L6. On the other hand, Pb showed minor to moderate enrichment for all the studied area. These could be due to anthropogenic activities which discharge chemical wastes, lead acid batteries, gasoline additives, and domestic sewage directly to the environment. For the As, it was found that the EF showed moderate, severe enrichment especially in L6 and L8. Timber frame structures and buildings are common in L6, Kampung Panchor (fisherman village). Therefore As could possibly be enriched by leachates from chromated copper arsenate, which is used to treat the woods. On the other hand, a higher EF of As at L8, Lukut, Port Dickson is attributed to the presence of petroleum refinery complexes nearby sampling location. A part of that, L5, Juru has a higher EF factor for Zn compared other sampling sites. As reported by other study, these could be due Juru River received discharge of waste product from several small rivers that flow through urban areas which are active with human activities [23]. Generally it can be seen clearly in Figure 2, sites at Juru, Penang (L5) and Kampong Panchor, Perak (L6) had exceeded the EF value of 1.0 for all the heavy, which suggested that a significant portion of heavy metal is derived from non-crustal materials or non-natural weathering processes due to anthropogenic source [20]. Based on the description of nearby activities in Table 1, the enrichment factor of location L5 and L6 high may be due to excretion of fish waste products, death and decomposition from fish farming which will influence the mangrove sediments. On the other hand other activities such as loading and unloading fishes from the fisherman and cleaning of boats and maintenance maybe also contribute an enrichment factor is higher than other sampling location. As reported by other studies, there are many factors linked to destructive of mangrove area. Human activities such as a tourism, agriculture, aquaculture and urban sprawl are the main drivers linked to the destruction of mangrove area. Uneaten fish feed, fish waste and any organic material that produced by fish farming activities also caused destruction in mangrove area and varies between regions [21],[22].

Table 4 : Enrichment factor of copper in the surface mangrove sediment

Location	As	Cu	Pb	Zn
L1	2.36	0.43	4.57	2.13
L2	2.81	0.53	1.66	2.08
L3	3.45	0.69	2.64	1.52
L4	1.22	0.56	2.46	1.57
L5	1.1	2.11	2.36	5
L6	9.18	1.19	3.43	1.88
L7	3.14	0.68	2.29	1.42
L8	8.06	0.93	2.57	1.75
L9	1.5	0.31	2.13	1.52
L10	1.31	0.21	1.55	1.11

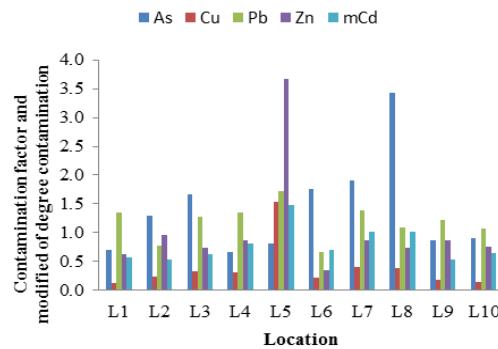


Figure 2 : Enrichment of As, Cu, Pb and Zn

Modified degree of contamination (mCd) calculated based on the contamination factor (Cf) each pollutant [24]. At least five surficial sediment samples required and then averaged to produce a mean pollutant concentration. Cf can be evaluated based on the equation below:

$$Cf = \frac{C_{sample}}{C_{background}}$$

The following terminology was used to describe the level of contamination

$Cf < 1$	low contamination factor
$1 < Cf < 3$	moderate contamination factor
$3 < Cf < 6$	considerable contamination factor
$Cf > 6$	very high contamination factor

where C_{sample} and $C_{background}$ refer to the mean concentration of an element in the contaminated sediments and average shale respectively.

The overall degree of sediment contamination (Cd) using the following formula:

$$Cd = \sum_{i=1}^k Cf_i$$

The Cd is referred to the degree of overall contamination in surface layers of the sediment. All n elements must be analyzed in order to calculate the value of Cd [25]. The following terminology used to describe the degree of contamination:

$Cd < 8$	low degree of contamination
$8 < Cd < 16$	moderate degree of contamination
$16 < Cd < 32$	considerable degree of contamination
$Cd > 32$	very high degree of contamination

The degree of contamination mCd calculated based on the equation below (ratio between the sum of all the contamination factors Cf of the number of analyzing elements) [26]:

$$mCd = \frac{\sum_{i=1}^k Cf_i}{n}$$

where n is the number of analyzed elements and (i) is i_{th} element and Cf is formula to calculate mCd.

$mCd < 1.5$	Nil to low degree of contamination
$1.5 \leq mCd < 2$	Low degree of contamination
$2 \leq mCd < 4$	Moderate degree of contamination
$4 \leq mCd < 8$	High degree of contamination
$8 \leq mCd < 16$	Very high degree of contamination
$16 \leq mCd < 32$	Extremely high degree of contamination
$mCd > 32$	Ultra high degree of contamination

Table 5 : Contamination factor, degree of contamination and modified degree contamination

Element	As	Cu	Pb	Zn	Cd	mCd
L1	0.7	0.13	1.35	0.63	2.81	0.7
L2	1.3	0.25	0.77	0.97	3.29	0.82
L3	1.67	0.33	1.28	0.74	4.02	1
L4	0.67	0.31	1.36	0.87	3.21	0.8
L5	0.81	1.54	1.73	3.66	7.74	1.94
L6	1.76	0.23	0.66	0.36	3.01	0.75
L7	1.9	0.42	1.39	0.86	4.56	1.14
L8	3.43	0.39	1.09	0.74	5.66	1.42
L9	0.86	0.18	1.22	0.87	3.14	0.78
L10	0.9	0.14	1.07	0.76	2.87	0.72

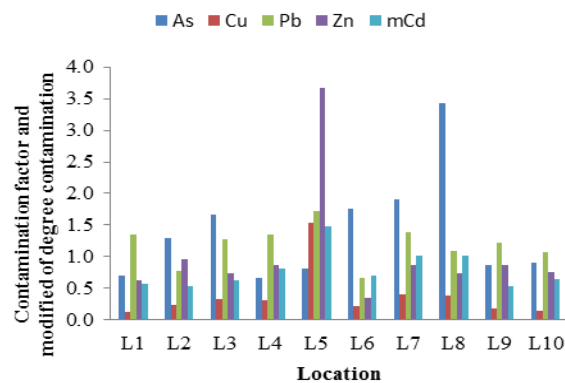


Figure 3 : modified degree contamination of As, Cu, Pb and Zn

The contamination factor (Cf) values were shown in Table 5. Contamination factors of all the heavy metal fall in the range of 0.13 - 1.90. The lowest of Cf (0.13) was found on Cu in L1 and the highest of Cf (1.90) was found on As in L7. Based on the result of Cf, it shows that most of sampling site can be categorized as a low and moderate contamination. Degree of contamination (Cd) and modified degree of contamination (mCd) of all the heavy metal fall in the range between 2.81 – 7.74 and 0.70 – 1.94 respectively. The highest and lowest of Cd and mCd was found in L5 and L1 respectively. Based on the degree of contamination and modified degree of contamination results, all the stations can be categorized as a low degree of contamination (Cd value < 8 and mCd < 2.0), this indicates that there are no serious anthropogenic pollution at most of the sites except in L5. These results supporting the L5 (Juru, Penang) is one the contaminated area as mentioned previously in other studies. In statistics, Spearman's rank correlation coefficient is a measure of statistical relationship between two variables (independent and the dependent variable). The sign of the Spearman correlation can be either positive, negative or zero. If both (independent and dependent variable) increase linearly, the Spearman correlation coefficient is positive. The Spearman correlation coefficient is negative when dependent variable decreases when dependent variable increases. A Spearman correlation of zero indicates that there is no tendency for dependent variable to either increase or decrease when the independent variable increases. The Spearman correlation increases in magnitude as independent variable and dependent variable become closer (becomes 1) to be perfectly monotonically functions of each other [27]. The values of correlation coefficients between element concentrations in surface sediments are given in Table 6. Correlations r for Cu and Pb (0.627), Cu and Zn (0.965) and Pb and Zn (0.649) shows high correlations between elements (P<0.01). Correlation coefficient results showed that the heavy metal might be originated from the common sources. No significant correlations (P>0.05) were observed between the accumulation of Cu and As, Pb and As and Zn and As indicated, that the concentrations of As in sediments was not directly influence by the same type of anthropogenic activities.

Table 6: Correlation coefficients between element concentrations in surface sediments

	As	Cu	Pb	Zn
As	1			
Cu	-0.076	1		
Pb	-0.309	0.627	1	
Zn	-0.269	.965**	.649*	1

Correlation is significant at the 0.01 level (2-tailed).

Correlation is significant at the 0.05 level (2-tailed).

4. CONCLUSION

The influence of anthropogenic heavy metal pollutions in surface sediments of mangrove area, west coast Peninsular Malaysia were determined using enrichment factor (EF), contamination factor (Cf), degree of contamination (Cd) and modified degree of contamination (mCd). The results showed that the EF, Cd and mCd varied in the range (0.21 – 9.18), (2.81 – 7.74) and (0.70 – 1.94) respectively. The findings of this study showed that the EF, Cd and mCd of heavy metal varied in the range of all the sampling locations from low to moderate contamination. On the other hand the results of Cf, Cd and mCd indicate that there is no serious anthropogenic pollution at these sites. Although the concentration level of most of heavy metal in the surface sediments has not reached severe or high contamination level, however, it is highly recommended for further studies should be continuously done on the inputs of anthropogenic activities into mangrove area ecosystems. This is important to ensure that there is no hazardous effect of living organism in aquatic life system and human health, especially to human consumers of seafood.

Acknowledgement

The authors would like to thank the staff of the, Universiti Putra Malaysia, Inti International University, and Nuclear Agency Malaysia, who had contributed to this work.

REFERENCES

- [1] Lacerda, L.D. Trace metals biogeochemistry and diffuse pollution in mangrove ecosystems. ISME Mangrove Ecosystems Occasional, 1998, papers 2 : 1-61.
- [2] Tomlinson, P.B. The botany of mangroves. Cambridge, UK, Cambridge University Press, 1986.
- [3] Abdullah, A. R.,Tahir, N. M., Tong, S. L., Hoque, T. M., Sulaiman, A. H., 1999. The GEF/UNDP/IMO Malacca Straits Demonstration Project: Sources of pollution. Mar. Pollut. Bull. 39, 229–233.
- [4] ANSARI, T. M., MAHBOOB, S., HANIF, T., ARIF, M. AND SALAM. A., Dry ashing or wet digestion? A comparative study for estimation of zinc and calcium in freshwater fish samples by atomic absorption spectrometry. J. chem. Soc. Pakistan, 2005, 27: 90–94.
- [5] TURKMEN, M., TURKMEN, A., TEPE, Y., TÖRE, Y. AND ATES, A., Determination of metals in fish species from Aegean and Mediterranean Seas. Fd. Chem., 2009, 113: 233–237.
- [6] Sericano, J.L.; Wade, T.L.; Jackson, T.J. Trace organic contamination in the Americas: An overview of the US national status and trends and the international mussel watch programmes. Mar. Pollut. Bull., 1995, 31: 214-225.
- [7] Vinodhini.R; M. Narayanan. Int. J. Environ. Sci. Tech.,5 (2), 2008, 179-182.
- [8] Boyden, C. R.; Aston, S. R.; Thornton, I. Tidal and seasonal variation of trace elements in two Cornish estuaries. Estuarine Coast Mar. Sci., 1979, 9 (3), 303-317.
- [9] Zvinowanda, C. M.; Okonkwo, J. O.; Shabalala, P. N.; Agyei, N.M. A novel adsorbent for heavy metal remediation in aqueous environments. Int. J. Environ. Sci. Tech; 2009, 6 (3), 425-434.
- [10] Kh. Rezaee. E. B. Saion. A. Khalik Wood. M. R. Abdi, Rare earth elements distribution in marine sediments of Malaysia coasts, JOURNAL OF RARE EARTHS, 2009, Vol. 27, No. 6, , p. 1066.
- [11] Yap, C.K., Ismail, A. & Tan, S.G. (2003). Accumulation, depuration and distribution of cadmium and zinc in the green-lipped mussel *Perna viridis* (L.) under laboratory conditions. Hydrobiologia, 498: 151-160.
- [12] Yap CK, Ismail A, Tan SG. Concentrations of Cu and Pb in the offshore and intertidal sediments of the west coast of Peninsular Malaysia. Environment International, 2002; 28: 467-79.
- [13] Yap CK, Ismail A, Tan SG. Cd and Zn concentrations in the straits of Malacca and intertidal sediments of the west coast of Peninsular Malaysia. Marine Pollution Bulletin, 2003; 46: 1341-58.
- [14] Amin B, Ismail A, Arshad A, Yap CK, Kamarudin MS. Anthropogenic impacts on heavy metal concentrations in the coastal sediments of Dumai, Indonesia. Environmental Monitoring and Assessment 2009; 148(1-4): 291-305.
- [15] Chee Kong YAP and Franklin Berandah EDWARD; Distribution of Heavy Metals in the Different Parts of *Cerithidea Obtusa* and the Relationships between Metal Distribution and Allometric Parameters of the Snail EnvironmentAsia 3(2) ,2010, 38-48.
- [16] Le Petit, G., Deschamps, J.P. and Nouchpramools, S. Trace Elements in Total Atmospheric Suspended Particles in a Suburban Area of Paris: A Study Carried Out by INAA , 2002.
- [17] Zhang L, Ye X, Feng H, Jing Y, Ouyang T, Yu X, Liang R, Chen W. Heavy metal contamination in western Xiamen Bay sediments and its vicinity, China. Marine Pollution Bulletin; 2007, 54: 974- 82.
- [18] Turekian KK, Wedepohl KH Distribution of the elements in some major units of the earth's crust. Bulletin of Geological Society of America; 1961, 72: 175–92.
- [19] Chen CW, Kao CM, Chen CF, Dong CD. Distribution and accumulation of heavy metals in sediments of Kaohsiung Harbor, Taiwan. Chemosphere; 2007, 66(8); 1431–40.
- [20] Valiela, I., Bowen, J. L. & York, J. K. Mangrove forests: one of the world's threatened major tropical environments. BioScience, 2001, 51, 807-815.

- [21] Ye, L., Ritz, D.A., Fenton, G.E., Lewis, M.E., Tracing the influence on sediments of organic waste from a salmon in farm using stable isotope analysis. *J. Exp. Mar. Biol. Ecol.* 1991, 145, 161–174.
- [22] Al-Shami, S., Rawi, C.S., Nor, S.A., Ahmad, A.H., & Ali, A. Morphological deformities in *Chironomus* spp. (Diptera: Chironomidae) larvae as a tool for impact assessment of anthropogenic and environmental stresses on three rivers in the Juru river system, Penang, Malaysia. *Environmental entomology*, 2010, 39, 210-22.
- [23] Yap, C.K., Edward, F.B. & Pang, B.H. A comparative study of distribution of heavy metal concentrations in *Pomacea insularum* collected from polluted and unpolluted sites of the freshwater ecosystem in Malaysia. *Wetland Science*, 2009a, 7(1): 75-82.
- [24] Abraham, G.M.S. Holocene. Sediments of Tamaki Estuary: Characterisation and Impact of Recent Human Activity on an Urban Estuary in Auckland, New Zealand. Ph.D. thesis, University of Auckland, Auckland, New Zealand, 2005, pp: 361.
- [25] Hakanson, L. Ecological Risk Index for Aquatic Control, a Sedimentological Approach. *Water Res.*, 1980, 14: 975-1001.
- [26] Liu, W.H., J.Z. Zhao, Z.Y. Ouyang, L. Solderland and G.H. Liu. Impacts of Sewage Irrigation on Heavy Metal Distribution and Contamination in Beijing, China. *Environ. Intl.*, 2005b, 32: 805-812.
- [27] Myers, Jerome L.; Well, Arnold D. *Research Design and Statistical Analysis* (2nd ed.). Lawrence Erlbaum; 2003, p. 508.