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## ASSESSMENT OF HEAVY METAL CONTAMINATION AT WEST AND EAST COASTAL AREA OF PENINSULAR MALAYSIA

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### Abstract

Five heavy metal elements [Pb(II), Cr(VI), Ni(II), Zn(II) and Cu(II)] in the sediment of the two coastal areas had been analysed of the mid-east and mid-west of Peninsular Malaysia in the year of 2012. This is to assess and monitor contamination of heavy metal at mangrove area in the state of Negeri Sembilan, Melaka and Pahang. Overall and individual analyses on the heavy metals showed the concentration of the named heavy metals were not at alarming stage. All analysed elements were found to be much lower than the international guideline provided by the Chinese (EPA-China), Canadian (CEPA) and American (US-EPA). Quantitative assessment using *Enrichment Factor* shows that all analysed elements were to found be within the degree of background concentration.

**Keywords:** Enrichment factor, Port Dickson, Kuantan, South China Sea, Strait of Malacca, Mangrove Forest Area

### Abstrak

Lima elemen logam berat [Pb(II), Cr(VI), Ni(II), Zn(II) dan Cu(II)] dalam sedimen kawasan persisiran pantai di pertengahan pantai timur dan barat telah dianalisis pada tahun 2012. Ia nya bertujuan untuk menilai dan memantau kontaminasi logam berat di kawasan bakau di Negeri Sembilan, Melaka dan Pahang. Analisis individu dan keseluruhan bagi logam berat menunjukkan aras kepekatan logam berat yang dinamakan adalah tidak membimbangkan. Kesemua analisis elemen didapati adalah jauh lebih rendah daripada garis panduan yang dikeluarkan oleh negara China, Kanada dan Amerika Syarikat. Penilaian kuantitatif dengan menggunakan *Enrichment Factor* menunjukkan elemen yang dianalisis berada pada paras kepekatan semulajadi.

**Katakunci:** *Enrichment factor*, Port Dickson, Kuantan, Laut China Selatan, Selat Melaka, Kawasan Hutan Bakau

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## INTRODUCTION

Peninsular Malaysia is surrounded by Strait of Malacca as part of Andaman Sea for the west coast area, and South China Sea for the east coast area. The shoreline for Peninsular Malaysia comprised of 1972 km, while for Sabah and Sarawak, the shoreline is at 1802 km, and 1035, respectively (Midun, 1988). Degradation of coastal area with reference to its stability and also environmental quality are continuously monitored. Several causes of coastal destruction have been listed to be the coastal erosion, ill-planned development, land reclamation, uncontrolled marine sand mining, environmental degradation, and coastal resources utilisation (Seang & Latif, 2002). Despite of effort for constant monitoring by the authority, contamination of coastal area in Malaysia is yet to be controlled nor completely reported. Numbers of stakeholders for the western coastal area are more than what we (Malaysian) have for the east coast of Peninsular Malaysia. The three states, Malaysia, Singapore and Indonesia have formed the Malacca Strait Council, and joint-forces with Japan and Korea since 1968 to provide the navigational safety

together with remedies against pollution in the strait (Goh & Cleary, 2005). While for South China Sea, it sees more dispute rather than collaborative work on the area (Schofield & Storey, 2011). It is hoped that by alarming the stakeholders on the environmental degradation of coastal shall bestow better geopolitical stability at the region. Coastal degradation should be taken as one of the threats. United Nations Conference on Environment and Development (UNCED) in Rio De Janeiro when this subject has been conferred, has recommended that the Integrated Coastal Zone Management (ICZM) be implemented in order to minimise conflicts and to provide for optimal sustainable resource use (Seang & Latif, 2002).

This study was carried out to report the degree of contamination for both coastal areas with the heavy metals. Selected areas are to be consisted of mangrove plants which could entrap most of the pollutants either point-source nor non-point source in sediment. Most studies were being carried out at heavily industrialized area such as Port Klang (Tavakoly *et al.*, 2013), Pulau Pinang (Minhat, *et al.*, 2013). Study of heavy metal in sediment have

been carried out throughout the world targeting area with high anthropogenic activities such as in India (Rokade, 2009), China (Shuai-Long *et al.*, 2013), Madagascar (Hervé *et al.*, 2010), Indonesia (Takarina *et al.*, 2004), Italy (Bertolotto *et al.*, 2005) and several other parts in the world. Interestingly, a study for the sediment of Strait of Malacca also had been conducted as well (Saion *et al.*, 2007). Presence of heavy metals in the coastal sediment indicates contamination by *ex situ* pollutant or also the alteration of natural geochemical cycles of the monitored metals (Galloway, 1972). Selected areas are to represent both coastal areas of Peninsular Malaysia for the presence of heavy metals in their sediment. Hypothetically, the contamination source could be originated from the river flow passing through industrial areas along the west coast of Peninsular, and also the exploration and refinery of crude oil, and industrial activity at the east coast.

### AIM AND OBJECTIVES

This study is aiming to report the quantitative assessment heavy metal concentration in both of costal area for Peninsular Malaysia due to the unnatural geochemical cycle, which could refers to either anthropogenic or natural disaster, i.e. earthquake or tsunami. It is usual that what is not measured will not be monitored. This is when the

possibility of the certain environmental pollution would go unnoticed in time because such pollutant was not measured at the beginning, therefore it is improbable that such parameters to be monitored throughout the time. In this study, selective elements were used to represent heavy metals as part of environmental pollution monitoring program for coastal area.

### MATERIALS AND METHODS

This study involved series of field visit collecting sediment samples for the analysis of heavy metal composition. The analysis was carried out in University of Malaya laboratory.

#### Sampling Location

Five mangrove forest areas were selected from mid-west coast and mid-east coast of Peninsular Malaysia as for sampling location. Sediment sampling was done from February 2012 until October 2012 during low tide Figure 1 shows the location of sampling sites for both west and east coast of Peninsular Malaysia for the assessment of heavy metal contamination. Repetition of sampling would be carried out when the initial analysis has indicated heavy metal pollution would have taken place. Meanwhile Table 1 shows the latitude and longitude of sampling sites.

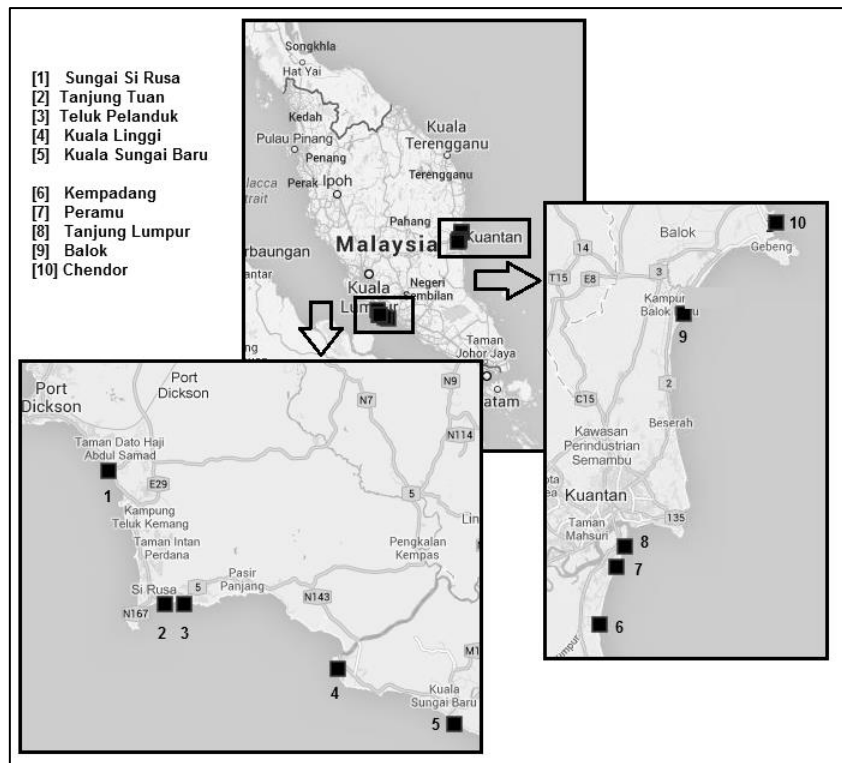


Figure 1. Sampling Sites for West and East Coast of Peninsular Malaysia

In mid-west coast area, the study was conducted at the coastal with mangrove forest of Negeri Sembilan and Malacca. Sampling sites spread from N2.3°, E102.0° to N2.5°, E101.8°. Manufacturing, tourism, agricultural and construction sector are among important sectors in Negeri Sembilan which contribute half of the state's gross domestic products (DOS, 2013). While, Malacca state is located in the southern region of Peninsular Malaysia and bordered Negeri Sembilan to the north and State of Johor to the south. All sites face

Straits of Malacca which are sheltered by Sumatera Island. Mangroves forest for southern west coastal usually can be found at river banks and estuaries. Selected mangrove site in west coast were surrounded heavily with many anthropogenic activities such as construction site in Teluk Pelanduk, fishing and boating activities in Sg. Si Rusa and Linggi, near to recreational and resort activities in Tanjung Tuan and near to power and other industrial processing plants in Kuala Sg. Baru.

**Table 1.** Latitude and Longitude of Sampling Sites [1-10] for the Assessment of Heavy Metal Contamination in the Sediment

Location	State	Latitude (North)	Longitude (East)
[1] Sungai Si Rusa	Negeri Sembilan	2° 29' 51.40"	101° 50' 23.38"
[2] Tanjung Tuan	Negeri Sembilan	2° 25' 8.16"	101° 52' 30.34"
[3] Teluk Pelanduk	Negeri Sembilan	2° 25' 9.55"	101° 52' 59.42"
[4] Kuala Linggi	Negeri Sembilan	2° 22' 54.33"	101° 58' 14.59"
[5] Kuala Sungai Baru	Melaka	2° 21' 1.03"	101° 02' 15.30"
[6] Kempadang	Pahang	3° 45' 5.89"	103° 19' 32.16"
[7] Peramu	Pahang	3° 47' 4.67"	103° 20' 8.16"
[8] Tanjung Lumpur	Pahang	3° 47' 47.61"	103° 20' 24.69"
[9] Pantai Balok	Pahang	3° 55' 46.53"	103° 22' 26.59"
[10] Chendor	Pahang	4° 03' 46.27"	103° 23' 37.46"

In mid-east coastal area, study was conducted in State of Pahang. Sampling sites spread from N 2.7°, E 101.9° to N 4.1°, E 103.3°. Pahang is the largest state in Peninsula Malaysia with the mangrove area located mostly in three districts which is Kuantan, Rompin and Pekan (DOS, 2013). These sites are also located in anthropogenic activities area such as recreational center, fishing market and boating activities such as in Kempadang, Tg. Lumpur and Pantai Balok, as well as conversion of land into dumping site of daily waste by the villagers in Chendor and Peramu area. There is also fresh food processing factory located adjacent to Peramu mangrove area with the industrial wastes discharge directly into the mangrove area. Adding up to the anthropogenic activity, there is also on-going oil and gas activities at eastern block of Pahang (Danny, 2009).

**Sampling and Heavy Metal Analysis Techniques**

Triplicates sample of soil from the top surface sediment with the depth of 1 – 10 cm were taken at each sampling site. All samples were collected with shovel and kept in sterile Falcon tube. Samples were conserved in cooler box for further analysis at laboratory. Then, the samples were dried in the oven at 80°C for two days. Dried samples were crushed using Fritish crusher machine to get fine

sediment and transferred to the Wykeham Farrace siever machine to separate the sediment size. The sediment with equal or less than 63 mirometer size was collected for acid digestion method using 65% HNO3: 37% HCl in a ratio of 4:2 on the hot plate until clear fume evolved. Sediment ≤ 63 micrometer was chosen because fine sediment with that size can restrain more than total sediment (Fortsner & Solomons, 1980).

The solution was cooled at room temperature for 10min and filtered using Whatman No.1 Qualitative filter paper. Each filtrate was diluted with distilled water up to 50ml in a 250ml Erlenmeyer flask. Concentration of five elements: [Pb(II), Cr(VI), Cu(II), Zn(II) and Ni(II)] were analysed to represent heavy metals contamination with the use of Atomic Absorption Spectrophotometer (AAS) instrument.

**RESULTS AND DISCUSSION**

As mentioned earlier, five heavy metal elements were used to report the contamination assessment of the selected mangrove areas for both coastal lines. Presence of Cu(II), Zn(II), Cd(II) and Pb(II) show that the alteration of natural geochemical cycle (Galloway, 1972). Mangrove forest area is selected to be the sampling sites as they are to be

strategic locations that link marine and terrestrial ecosystem made them suitable station for the settlement and accumulation of heavy metal from surrounding area for long period.

Previous studies also supported the circumstance because mangrove surface sediment possesses variable physical and chemical properties such as the sediment particles size and type which consist of sand, clay or silt as well as its ability to become anaerobic and reduced with high sulphide and organic matter content thus it can hold and retain water-borne heavy metal which are introduced into coastal area by river discharge from lithogenic and anthropogenic sources or surface run-off (Pekey, 2006; Praveena *et al.*, 2008; Tam & Wong, 2000).

The dynamic and distribution of heavy metal concentration in mangrove sediment usually affected by few mechanisms such as biological uptake, adsorption, mineralogical compound, hydrodynamic transport and mostly by the industrial discharge, effluent and shipping activities (Gopinath *et al.* 2010; Hart, 1982; Nobil *et al.*, Sivakumar, & Kannan, 2010 ). Nevertheless, result

and discussion in this study would engage on the concentration of heavy metals presence at the sampling area.

### Heavy Metal Analysis

It is important to investigate heavy metal concentration and distribution in the environment because most heavy metals such as Pb(II), Cu(II), Zn(II), As(V) are toxic and not biodegradable in nature thus it will affect human and ecosystem. Table 2 shows the mean concentration of selected elements at each sampling location. All individual elements was totalled up and averaged to represent findings of heavy metal contamination study at the west coast of Peninsular Malaysia. Meanwhile Table 3 shows the same representation of heavy metal study for the east coast of Peninsular Malaysia. Both tables show that the overall heavy metal composition in the sediment of the mangrove area at both coastal do not show the mathematical differences with the average of 0.5 and 0.6 ppm for west coast and east coast, respectively.

**Table 2:** Mean Concentration of Heavy Metal in Mangrove Surface Sediment of West Coast of Peninsular Malaysia (ppm)

Location Elements	Sungai Si Rusa	Tanjung Tuan	Teluk Pelanduk	Kuala Linggi	Kuala Sungai Baru	Average
Pb (II)	1.200	0.161	0.525	0.416	0.547	0.560
Cr (VI)	0.927	0.020	3.500	0.551	1.500	1.300
Cu (II)	0.082	0.131	0.219	0.296	0.154	0.176
Zn (II)	0.235	0.329	0.354	0.598	0.346	0.372
Ni(II)]	0.127	0.077	0.500	0.112	0.230	0.209
Total	2.571	0.718	5.098	1.973	2.777	
Average	0.514	0.144	1.020	0.395	0.555	0.525

**Table 3:** Mean Concentration of Heavy Metal in Mangrove Surface Sediment of East Coast of Peninsular Malaysia (ppm)

Location Elements	Kempadang	Peramu	Tanjung Lumpur	Pantai Balok	Chendor	Average
Pb (II)	0.198	0.382	0.350	0.210	0.326	0.293
Cr (VI)	0.707	0.829	1.100	0.586	0.238	0.692
Cu (II)	0.226	1.4	0.601	1.200	0.299	0.745
Zn (II)	0.870	1.2	1.100	0.735	1.390	1.059
Ni(II)	0.442	0.450	0.546	0.378	0.185	0.400
Total	2.443	4.261	3.697	3.109	2.438	
Average	0.489	0.852	0.739	0.622	0.488	0.638

Mangrove area at west coast, Teluk Pelanduk has the highest concentration of heavy metals while for the east coast area, Peramu has the highest concentration. The order of heavy metal concentration for west coast is as follow, Teluk Pelanduk > Kuala Sungai Baru > Sungai Si Rusa > Kuala Linggi > Tanjung Tuan ranging from 0.2 to 1.3 ppm while for east coast, Peramu > Tanjung Lumpur > Pantai Balok > Kempadang > Chendor ranging from 0.3 – 1.1 ppm.

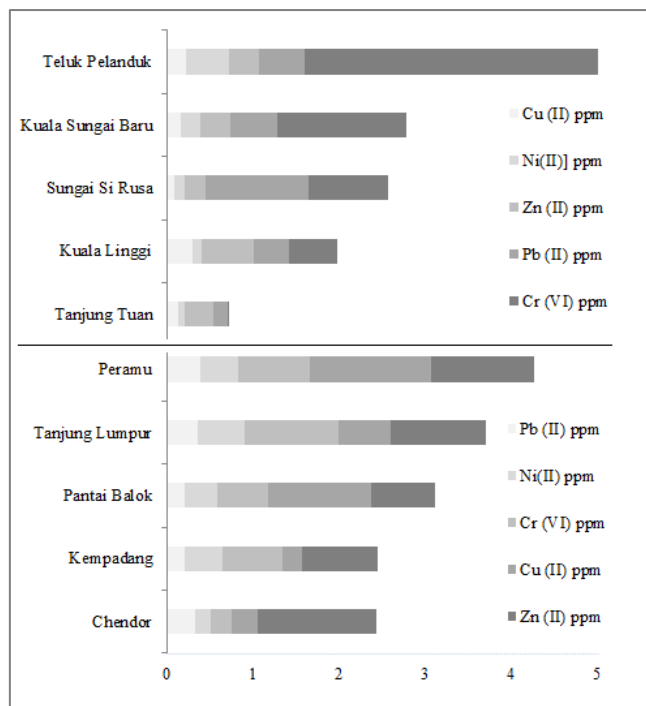
Overall analysis shows that the total analysed heavy metals in the sediment of both coastal did not exceed 5 ppm. These values are not alarming as they are below guidelines level. China has set the highest value for individual element of Zn to be at 150 ppm and the rest of other heavy metal elements are below than it (Shuai-Long *et al.*, 2013). While Garbarino *et al.* (1995) wrote that any heavy metal elements which have the concentration of more than 50 ppm in the sediment to be designated as a polluted area. These two guidelines values are used to support that the presence of heavy metal in both coastal of Peninsular Malaysia is not alarming despite of anthropogenic activity at all sampling areas.

### Detailed Heavy Metals Analysis

Detailed illustration of analysed heavy metal concentration according to each breakdown of elements used for both east and west coast of Peninsular Malaysia are shown in Figure 2. The

breakdown of individual heavy metal elementary study showed inconsistent pattern of its presence. In general, it could be said that Zn (II) and Cr (VI) is the prevalent element that can be found in sediment for the mangrove of mid-east coast mid-west coast (exception for Tanjung Tuan), respectively.

Table 4 compares the element in heavy metal analysis in this study to the report by Tavakoly *et al.* (2013) and Saion *et al.* (2007) whom included the heavy metal element stated in several guidelines. Report by Xiaoyu *et al.* (2012) is also used for comparison with the guideline values given by the China Authority. The comparative mean of concentration between values obtained in this study, shows the contamination at the selected coastal area are not as bad as at Port Klang (Tavakoly *et al.*, 2013). Comparison with the larger area of Strait of Malacca for its sediment sampling (Saion *et al.*, 2007), shows the contamination at the coastal area is relatively lower. Information about heavy metal contamination at South East China Sea is yet to be obtained. Study by Tam and Wong (2000) showed that the heavy metal concentration in study were to be very much lower. They had found that three mangrove swamps in Deep Bay region which were seriously contaminated, with heavy metal concentrations in sediments around 80 ppm Cu, 240 ppm Zn, 40 ppm Cr, 30 ppm Ni, 3 ppm Cd and 80 ppm Pb.



**Figure 2.** Concentration Analysed Heavy Metals at Selection Locations of West and East Coastal Area of Peninsular Malaysia.

**Table 4.** Comparison of the Mean for Heavy Metal Concentration in the Sediment of East Coast and West Coast of Peninsular Malaysia with the Sediment of Strait of Malacca and International Guidelines

Area Element	East Coast	West Coast	PK *	SoM **	CAN GL **	ND GL **	USA-NYS GL **	CHI GL ***
Pb (II)	0.293 ± 0.084	0.560 ± 0.364	128	18.43	30.20	85	31	60
Cr (VI)	0.692 ± 0.317	1.300 ± 1.343	388	39.10	52.30	(-)	26	(-)
Cu (II)	0.745 ± 0.530	0.176 ± 0.083	118	17.46	18.70	36	16	35
Zn (II)	1.059 ± 0.261	0.372 ± 0.135	492	63.68	124	140	120	150
Ni(II)]	0.400 ± 0.134	0.209 ± 0.172	74	24.28	(-)	(-)	(-)	(-)

\* PK - Port Klang (Tavakoly et al., 2013)

\*\* SoM-Strait of Malacca; CAN GL - Canadian Guideline; ND GL - Netherland Guideline; USA-NYS GL - United State of America New York State Guideline (Saion et al., 2007)

\*\*\* CHI GL - China Guideline (Xiaoyu et al., 2012)

(-) Not available

### Enrichment Factor for Most Prevalent Heavy Metals

The usual statistical analysis on the concentration of heavy metals in the collected sediment by the use of mean and standard deviation were used to describe the presence of heavy metals in the area. Some of the data (high standard deviation values) have indicated that neither ANOVA nor Student-test can be used to determine the statistical differences between and within the coastal areas. For analysis purpose in order to assess the degree of heavy metal contamination, the comparative data can be determined using a few descriptive methods such as Enrichment Factor ( $E_f$ ), Geoaccumulation Index ( $I_{geo}$ ), Contamination Factor ( $C_f$ ) and Pollution Load Index ( $P_{Li}$ ). The named descriptions have been widely used in many studies.

$$f = \frac{\left[\left(\frac{\text{Metal}}{\text{Fe}}\right)\right]_{\text{sample}}}{\left[\left(\frac{\text{Metal}}{\text{Fe}}\right)\right]_{\text{background value}}} \quad \text{Eq. (1)}$$

Eq. 1 lists  $E_f$ , which was introduced by Simex and Helz (1981) and later used to describe the relative abundance of a selected environmental substance in the soil (Tam & Wong, 2000). It is also used to be compare with the substance in the bedrock (Hernandez et al., 2003) It is also used to compare current metal contamination with background area.

Ferum (Fe) acts as reference element to be used at the normalizer during the assessment. Other reference elements that could be used are Manganese (Mn) and aluminium (Al).  $E_f$  uses indices classification as the indicator which the value begins from less than zero (< 0) to more than forty (>40) as the indication for background concentration to extremely high enrichment. Table 5 lists the complete indices of classification according to  $E_f$  values. Determination of  $E_f$  value for this study would assist the interpretation of abundance heavy metal at the location.

Following the earlier study of heavy metal contamination in Port Klang by Tavakoly et al. (2013), Fe was used as the normalizer in this study, with the reference value of 6.2 as recommended by Rokade (2009). Analysis by  $E_f$  is shown in Table 6 which concludes that the presence of Zn (II) and Cr (VI), the two most prevalent elements in both coastal area are not alarming. Both elements show that they were within the degree of enrichment of their background concentration. By comparison to similar study by Tavakoly et al. (2013), whom found the  $E_f$  for Zn(II) and Cr(VI) were to be in between  $2 < EF < 5$ , indicating that the sediment of Port Klang Strait had moderate anthropogenic inputs of these heavy metals

**Table 5.** Classification for Degree of Enrichment according to its Indices (Rokade, 2009)

EF Indices	Degree of Enrichment
EF ≤ 1	Background concentration
EF 1-2	Depletion to minimal enrichment
EF 2-5	Moderate enrichment
EF 5-20	Significant enrichment
EF 20-40	Very high enrichment
EF > 40	Extremely high enrichment

**Table 6.** Analysis of Enrichment Factor for Prevalent Heavy Metal Element in the Mid-East and Mid-West Coast of Peninsular Malaysia

Location Elements	Kempadang	Peramu	Tanjung Lumpur	Pantai Balok	Chendor	Average
Zn (II)	0.870	1.2	1.100	0.735	1.390	1.059
$E_f$	0.14	0.19	0.18	0.12	0.22	0.17
Location Elements	Sungai Si Rusa	Tanjung Tuan	Teluk Pelanduk	Kuala Linggi	Kuala Sg. Baru	Average
Cr (VI)	0.927	0.020	3.500	0.551	1.500	1.300
$E_f$	0.15	0.00	0.56	0.09	0.24	0.21

### CONCLUSION

The average concentration of heavy metal [Pb (II), Cr (VI), Cu (II), Zn (II) and Ni(II)] at the sediment of coastal area for the mid-east and mid-west coast of Peninsular Malaysia in the year of 2012, were not at the alarming stage. Even at the individual analysis of heavy metal, their concentration were found to be very much lower than the international guideline provided by China, Canada and USA. These values are not expected to significantly change at present year of 2014, since there was no major anthropogenic activity has been reported at the sampling location. Detailed analysis using Enrichment factor ( $E_f$ ) also has supported this deduction.

Only the highest concentration of heavy metal, i.e. Zn in East Coast, and Cr in West Coast were analyzed using  $E_f$ . The rest of the other four heavy metals index followed the classification given by the analyzed  $E_f$  were to be less than one, i.e. Group  $E_f < 1$ . The other four values, the concentration were to have lower values. In addition, amongst the sampling locations, Peramu (east coast) and Teluk Pelanduk (west coast) were found to have the highest total concentration of heavy metals. Analyses with other indices were not carried since  $E_f$  alone has been a sufficient heavy metal pollution indicator.

Data collection for the accumulated heavy metals at the mangrove forest is suggested to be used for the

pollution monitoring because this area are known to possess multiple physical and chemical properties that can hold and retain heavy metals. Comparative data with other mangrove area such as in Hong Kong have shown the accumulation of heavy metal in such area would be high when the pollution incidents regularly occur. Therefore, with low concentration of heavy metals together with similar finding on  $E_f$  analysis indicated that no excessive heavy metal discharge to the environment in the studied area has taken place.

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