Heavy Metals Pollution and Ecological Risk Assessment in Surface Sediments of West Coast of Peninsular Malaysia

Tijjani Rufa'i Buhari and Ahmad Ismail

Abstract—**In this study, Surface sediments from six sampling sites in the west coast of Peninsular Malaysia were analysed for heavy metals (Cu, Zn, Pb, Cd and Ni) to evaluate the pollution status and ecological risk assessment. Sediment samples were collected in triplicates from six sampling sites in the study area. Direct aqua – regia method was employed to analyse the total metal concentrations in the sediment samples. The filtrates obtained from the sediments, were determined for heavy metals by using an air –air acetylene flame atomic absorption spectrophotometer (AAS) Perkin Elmer Analyst 800. The results showed that Zn and Cd reveal considerable contamination, and almost all the sampling sites were of moderate degree of contamination. The calculated; Potential Ecological Risk Index (RI) ranged from low to moderate, the Sediment Quality Guideline Quotient (SQG-Q), for all the sampling sites falls into impact level category 2; indicating moderate impact potential for observing adverse biological effects. All the studied metals except Zn were found below effective range-median (ERM). The present study reveals that surface sediments from west coast of Peninsular Malaysia were exposed to heavy metals pollution; Zn and Cd were observed as metals of Ecotoxicological significant in the present study.**

Index Terms—**Surface sediments, heavy metals, pollution, ecological risk, west coast of Peninsular Malaysia.**

I. INTRODUCTION

The concentrations of heavy metals in surface sediments of west coast of Peninsular Malaysia has been studied extensively and were reported in previous studies by many authors [1]-[4]. Results from these studies have revealed elevated levels of Cu, Zn, Pb and Cd in the study areas. Coastal and estuarine regions are the important sinks for many persistent pollutants and they accumulate in the organisms and bottom sediments [5]. Pollution of aquatic ecosystems by heavy metals is an important environmental problem [6] because of its permanent disturbances in marine ecosystems, leading to environmental and ecological degradation [7].

Heavy metals are accumulated in marine sediments, where they are incorporated in several biological and chemical cycles, affecting the water column and biota. Anthropogenic impacts including; industrial discharges, domestic sewage, non-point source, runoff and atmospheric precipitation are the main sources of toxic heavy metals that enter aquatic ecosystems [8], [9]. Studies conducted by Ismail and Ramli [2], Morton and Blackmore [10] and Ip *et al.* [11] have shown that trace metal pollution occurs in sediments from coastal areas which are near actively operated industries, urban centers and agriculture [2], [10] and [11]. Yap and Chew [12] have also reported significant higher concentration of metal in sediments collected from active urban area potentially receiving domestic wastes and vehicular runoff in Peninsular Malaysia [12].

Coastal pollution has been increasing significantly over the recent years and is found compounding environmental problems in many developing countries [13]. Elevated levels of heavy metals were reported from the sediments of Straits of Johore [14] and Straits of Malacca [4] in Peninsular Malaysia that indicates anthropogenic in put in these areas. As in many developing countries, Malaysian coastal zone has experienced severe deterioration as a result of pollution. Many researches concerning heavy metals concentrations in the surface sediments of west coast Peninsular Malaysia were reported by [4], [15], [16], but there is a gap with regards to heavy metals toxicity and ecological risks implications in this area.

The objectives of the present study were: 1- to determine the concentration and distribution of heavy metals in the surface sediments of west coast of Peninsular Malaysia and 2- to evaluate the studied metals toxicity and their ecological risks implications.

II. MATERIALS AND METHODS

Samplings were conducted in August 2008 to June 2010. A total of six sampling sites were selected for surface sediments in the west coast of Peninsular Malaysia (Fig. 1). The coordinates of sampling sites were recorded with Global positioning system (Garmin OREGON 45OT 850MB waterproof GPS). Description of each sampling site was given in Table I. Top 3-5 cm surface sediments [4] and [17] were collected in triplicates from three different points within a certain area (approximately 1 meter radius) from each sampling site using plastic scoop and placed in separate labelled polyethylene plastic bags. Each sediment sample was instantly placed in ice and transported to the laboratory until further analysis.

Sediment samples were dried in the laboratory using an air-circulating oven to a constant dry weight at 80^{0}C. The

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dried sediment samples were crushed to powder by using a porcelain mortar and pestle then sieved vigorously to produce homogeneity [17], through a 63μm stainless steel aperture

sieve. For analyses of total heavy metals concentrations (Cu, Zn, Pb, Cd and Ni) in the sediment sample, direct aqua-regia method was employed as described by Ismail [17].
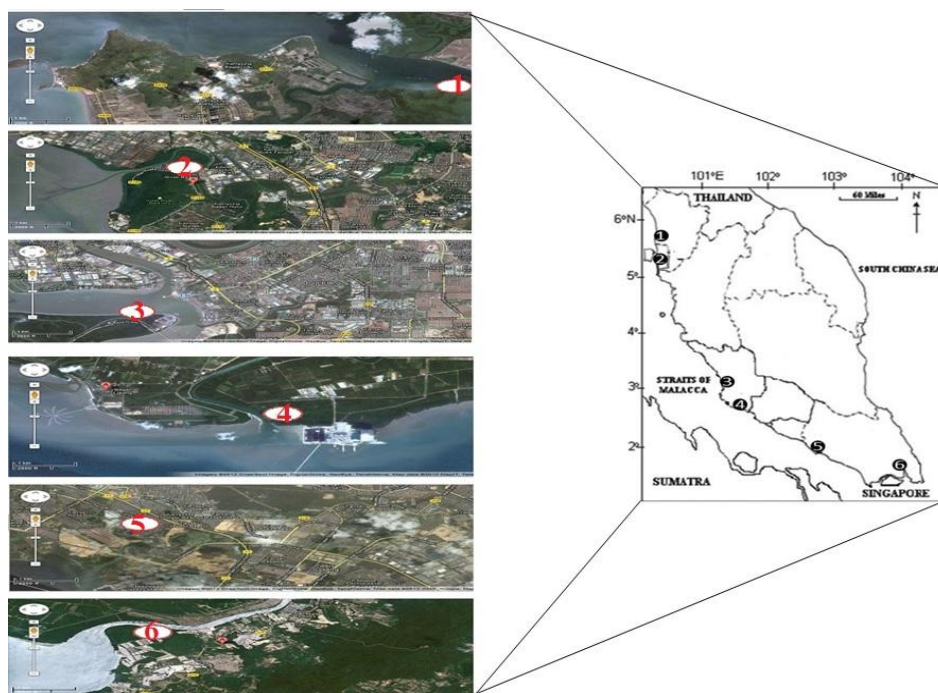

Fig. 1. Map of west coast of Peninsular Malaysia showing sampling sites: 1, 2, 3, 4, 5 and 6.

TABLE I: DESCRIPTION OF SAMPLING SITES IN THE WEST COAST OF PENINSULAR MALAYSIA

S/No	Sampling site	Coordinates	Site description
1.	Sengantang Garam, Kedah	N 05° 39.552' E 100° 23.983'	Jetty, aqua cultural area and paddy field
2.	Kuala Juru, Penang	N 05° 19.683' E 100° 22.949'	Industrial area
3.	Sungai Puluh, Klang	N 03° 04.786' E 101° 23.903'	Jetty receiving domestic wastes and industrial area
4.	BaganLalang, Selangor	N 02° 36.669' E 101° 41.100'	Recreational and agricultural areas
5.	Minyak Beku, Johor	N 01° 47.746' E102° 53.395'	Jetty receiving domestic wastes and shipping activities
6.	Sungai Tiga, Johor	N 01° 25.841' E 104° 00.281'	Jetty, agricultural and oil plantation

About 0.5-1.0 g of each dried sediment sample was weighed and digested in a combination of concentrated nitric acid (AnalaR grade, BDH 69%) and per chloric acid (AnalaR BDH 60%) in the ratio of 4:1, first at low temperature (40℃) for 1 hour and then increased to 140℃ for at least 3 hours [17]. Later, the digested samples were diluted to 40 mL with double distilled water. After filtration, the prepared samples were determined for Cu, Zn, Pb, Cd and Ni using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin-Elmer Model AAnalyst 800. The data were presented in μg/g dry weight.

During the period of AAS metal analysis, a quality control sample was routinely included for every 5–10 samples. Procedural blanks and quality control samples made from standard solutions for Cu, Zn, Pb, Cd and Ni were analyzed after every 5-10 samples to ensure the sensitivity and recovery of the instrument used. The procedures of quality assurance (QA) and quality control (QC) were employed to ensure the validity of the analytical data [18]. All plastics and glassware used were washed with detergent, Deacon 90, rinsed with double-distilled water and soaked in 10% HNO3 for at least 24 h, then rinsed with double-distilled water and allowed to dry at room temperature. The QA and QC were controlled by procedural blanks, sample replicates and certified reference

material (CRM). The quality of the method was checked with a certified reference material (CRM) for Soil from International Atomic Energy Agency (IAEA), Soil-5, Vienna; Austria and Dogfish liver DOLT-3 from National Research Council Canada (NRCC) were analysed. These were checked to accuracy of the digestion method with the certified values supplied by the IAEA and NRCC. To ensure the sensitivity of the Atomic Absorption Spectrophotometer (AAS) and generate calibration curves against which sample concentrations were calculated. The results of similar digested samples analyzed for Cu, Zn, Pb, Cd and Ni by the flame AAS Perkin Elmer A Analyst 800 showed acceptable recoveries of the metals. About 94-107% for soil and 87-110 for dogfish liver, recoveries of these metals were listed in Table II. The percentages of recoveries for the heavy metal analyses were 97 – 107 (Table II).

All statistical analyses of data were carried out using SPSS statistical package programs version 17 and graphs were plotted with Microsoft EXCEL 2007. Data were tested for the basic assumptions of normality and homogeneity of variance in exploratory data analysis in SPSS 17.

The assessment of sediment contamination was performed based on Hakanson's procedures [19]; the contamination factor is the ratio between the mean concentration of single

metal in the surface sediment and the background level as a general reference and could be calculated from the equation as:

$$Cif = Ci / Cin$$

where Ci is the mean concentration of an individual metal examined and Cin is the baseline or background value of the individual metal. Lowest metals concentrations in sediment from the sampling sites were used as background value in this study.

TABLE II: COMPARISON OF ANALYTICAL RESULT OF CRM SOIL-5 AND DOLT-3 WITH CERTIFIED CONCENTRATIONS USING AAS PERKIN ELMER A ANALYST 800 (N=3)

Heavy metal	CRM	Certified value(μg/g)	Measured value(μg/g)	Recovery (%)
Cu	Soil-5	77.1±4.7	75.62±5.0	99
	DOLT-3	31.2±1.0	29.8±2.7	96
Zn	Soil-5	368.0±8.20	362.9±15.6	100
	DOLT-3	86.6±2.4	83.8±3.5	97
Pb	Soil-5	129.0±26.0	124.8±22.0	97
	DOLT-3	0.32±0.05	0.38±0.09	109
Cd	Soil-5	1.5±0.0	1.56±0.03	101
	DOLT-3	19.4±0.6	20.5±0.4	105
Ni	Soil-5	13±0.00	12.85±1.02	107

Cif is defined according to the following categories: $Cif < 1$ low contamination factor; $1 \leq Cif < 3$ moderate contamination factor; $3 \leq Cif < 6$ considerable contamination factors; $Cif \geq 6$ very high contamination factor.

Degree of contamination (Cd) is defined as the sum of contamination factors for all metals in the surface sediments: $Cd = (Cif)$

The following terminologies were used to describe the degree of contamination: $Cd < 7$ low degree of contamination; $7 \leq Cd < 14$ moderate degree of contamination; $14 \leq Cd < 28$ considerable degree of contamination; $Cd \geq$ very high degree of contamination.

Potential ecological risk index (RI) was introduced originally by Hakanson [19], to assess the degree of heavy metal pollution in sediment, according to the toxicity of heavy metals and the response of the environment:

$$RI = \Sigma\ Er\ i$$

RI is the potential ecological risk index for all the heavy metals in the sediments, which is the sum of $Er\ i$.

$$Er\ i = Tr\ i\ Cf\ i$$

where: $Er\ i$ is the potential ecological risk index of an individual metal, $Tr\ i$ is the metal toxic response factor given by Hakanson [19] as (Zn=1, Pb=Cu=Ni=5, Cd=30) $Cf\ i$ is the metal pollution factor.

$$Cif = Ci / Cin$$

where: Ci is the concentration of metals in the sediment, and Cin is the background value of metals in the sediments. Hakanson [19] has defined five and four categories of $Er\ i$ and RI respectively and was used by Wu *et al*. [20] as shown in Table III.

TABLE III: RISK GRADES INDICES AND GRADES OF POTENTIAL ECOLOGICAL RISK OF HEAVY METAL POLLUTION [20]

Eri	Risk grade	RI	Risk grade
<40	Low potential ecological risk	<150	Low potential ecological risk
40-80	Moderate potential ecological risk	150-300	Moderate potential ecological risk
80-160	Considerable potential ecological risk	300-600	High potential ecological risk
160-320	High potential ecological risk	≥600	Significantly high potential ecological risk
≥320	Significantly high potential ecological risk		

Mean Sediment Quality Guidelines - Quotient (SQG-Q) is an index that works as a central tendency indicator of adverse biological effects due to mixture of chemicals in different concentrations. The Mean SQG-quotient was calculated for each sampling site, using the following equations [21]:

$$SQG\text{-}Q = \Sigma ni = 1\ PEL\text{-}Q/n$$

$$PEL\text{-}Q = C/PEL$$

where: PEL-Q is probable effect level quotient, C is heavy metal concentration at each sampling site, PEL is probable effect level of each heavy metal and n is the number of heavy metals or contaminant used. The PEL values used in this study were: Cu=108, Zn=271, Pb=112, Cd=4.21 and Ni=42.1 [22].

According to MacDonald *et al*. [23] each sampling site can be assigned to one of the following impact level categories:

Category 1: SQG-$Q \leq 0.1$ unimpacted: lowest potential for observing adverse biological effects; Category 2: $0.1< SQG$-$Q <1$: moderate impact potential for observing adverse biological effects; Category 3: SQG-$Q \geq 1$: highly impacted potential for observing adverse biological effects.

Sediment Quality Guidelines (SQG) of effect range-low (ERL) and effect range-median (ERM) derived from the database of Long *et al*. [24] (Table III) was used to assess the level of toxicity of heavy metals in the surface sediments.

Metal concentrations below the ERL value, indicates effects on biota would rarely be observed, concentrations equal to the ERL but below the ERM, biota could occasionally be affected by the pollutant, whereas at concentrations equal to or above the ERM, effects would be expected to occur frequently.

III. RESULTS AND CONCLUSION

A. Heavy Metal Concentrations in the Surface Sediment

The mean concentration and standard error (SE) of heavy metals in the surface sediments from six sampling sites in the west coast of Peninsular Malaysia were presented in Table IV. The mean range total concentrations of Cu, Zn, Pb, Cd and Ni

in the surface sediment from the six sites ranged from 12.79 - 65.39, 60.83 - 442.19, 8.46 - 53.73, 0.60 - 1.65 and 10.09 - 29.25 μg/g dry weight, respectively. Statistical analysis showed that the metal concentrations of Cu, Zn, Pb, Cd and Ni were significantly different ($p < 0.05$) between the sampling sites.

Average shale was used as reference baseline in this study to provide elemental background concentration. The concentration of Cu at Site 2 was higher than the reference baseline of average shale. The concentrations of Zn, Cd and Pb were above the reference baseline of average shale except Pb at Site 4. High metal concentrations might suggest metals contamination in the area. The total concentrations of Ni were found below the average shale baseline value suggesting low concentration of this metal expected to pose contamination.

TABLE IV: THE MEAN CONCENTRATION AND STANDARD ERROR (SE) OF HEAVY METALS IN THE SURFACE SEDIMENTS FROM SIX SAMPLING SITES IN THE WEST COAST OF PENINSULAR MALAYSIA

Sampling site	Cu	Zn	Pb	Cd	Ni
1	34.79±0.19	60.83±1.74	27.78±1.41	1.25±0.04	13.11±0.16
2	65.39±0.70	442.19±4.13	29.97±0.36	1.24±0.08	29.25±0.08
3	35.48±0.64	256.50±2.40	34.22±0.23	1.37±0.06	26.42±0.24
4	12.79±0.57	75.38±1.63	8.46±0.83	0.60±0.05	10.09±0.54
5	37.64±0.95	241.87±0.78	53.73±0.18	1.65±0.11	21.18±0.48
6	13.90±0.03	117.38±0.99	28.28±0.11	1.40±0.14	11.89±0.29
Non-polluted [a]	<25	<90	<40	-	<20
Moderately polluted [a]	25-50	90-200	40-60	-	20-50
Heavily polluted [a]	>50	>200	>60	>6	>50
Average Shale [b]	45	95	20	0.30	68
ERL [c]	34	150	46.7	1.2	20.9
ERM [c]	270	410	218	9.6	51.6

[a] US EPA [25]
[b] World average Shale [26]
[c] [24]

It was observed that the concentration of Cu, Zn and Ni were found higher at Site 2 than those at other sampling sites, indicating that the site is comparatively more polluted with these metals compared to other sampling sites. This might be attributed to different industries located at Prai Industrial area. In addition to discharge from Prai industrial area, domestic, agricultural and fishing activities might contribute the higher metals concentration at this Site. These industries discharged their effluents into the Juru River and the canals, which finally drain into the sea through a pump house [27]. The industries operating in the area as reported by [28] include: electronics; textiles; basic and fabricated metal products; food processing and canning; processing of agricultural products; feed mills; chemical plants; rubber based industry; timber based wood products; paper products and printing works; and transport equipment. It has been reported by Alkarkhi *et al.* [28] that sediments from this area were highly polluted with Fe, Zn and Cd. Arsenic, Cr, Cd, Zn, Cu, Hg, phosphate, ammonia, nitrate, sulphates, chloride and aluminium were also discharged as contaminants from these industries and other activities [29] Other main activities include ships' harbour with petroleum unloading and a red earth quarry, which extends right up to the coastline. In addition to these, some fishing villages situated in the area also contributed to the high anthropogenic input of heavy metals through Juru River, Semilang River and Jejawi River. Domestic sewage effluents were found as an important source of trace metals in previous studies [30], [31].

Pb and Cd concentrations were observed highest at Site 5, might be attributed to the anthropogenic input from domestic and jetty near the sampling site. In addition, Strait of Malacca and Batu Pahat Minyak Beku Ferry Terminal operating between the Peninsular Malaysia and the Indonesia also contributed high metals concentration to the sampling site. In general, the higher concentrations of metals at Site 2 and 5 could be explained by the proximity of these sites to high source of anthropogenic inputs from domestics, shipping and industrial area. Zhou *et al.* [32] has reported that sediments collected from Fo Tan in Hong Kong were mostly polluted by Cu, Zn, Ni, Cd and Cr because the site is located next to an industrial estate and these metals are commonly used in textile dyes, electroplating, galvanizing, battery manufacture, and plastic fabrication. The pattern of total metal concentrations in the sediment samples was in the decreasing order as: Zn > Cu > Pb >Ni >Cd.

B. Assessment of Sediment Contamination According to Sediment Quality Guidelines

Sediments from the sampling sites were assessed and categorised into different pollution levels based on the SQG of US EPA (Table IV). The contamination level of Cu and Zn in the sediments ranged between non-polluted, moderately polluted and heavily polluted. Sites 1, 3 and 5 were moderately polluted with Cu and Sites 2, 3 and 5 were heavily polluted with Zn at. Lead and Ni in the sediments were classified between non-polluted and moderately polluted, Lead was non – polluted at sites 1,2, 3, 4 and 6 and moderately polluted at Site 5. Ni was classified as non – polluted at sites 1, 4 and 6 and moderately polluted at sites 2, 3 and 6, among the sampling sites and only Site 5 was

moderately polluted with Pb while the remaining sampling sites were rated as non-polluted with Pb. The mean concentration of Ni showed 50% of the sites were non-polluted and the remaining halves were rated as moderately polluted. The contamination level of Cd indicated that none of the sampling site was found heavily polluted with Cd.

C. Assessment of Contamination Factor (Cif) and Degree of Contamination (Cd) in the Surface Sediments

The determination of contamination factor of heavy metals is an important aspect that indicates degree of risk of heavy metals to environment in relation with its retention time [33]. The contamination factors of heavy metals in the surface sediments based on average shale were presented in Fig. 2 a) and 2 b). The contamination factors of Cd were observed highest at all the sampling sites except at sampling site 2, were Cif of Zn was highest which correlated with highest concentration of Zn at the sampling site. A high contamination factor of heavy metal shows low retention time and high risk to the environment [33]. Previous studies in the west coast of peninsular Malaysia have shown elevated levels of Cd and Zn in the coastal areas adjacent to industrial estates and urban areas [34]-[36] and ports in the area [17], [18], [36] that might account for high CF of these metals.

The Cif values calculated indicated that all sites were low contaminated with Cu and Ni except Site 2 which was moderately contaminated with Cu. Considerable contamination of Zn was observed at Site 2 while Sites 4 and 1 showed low contamination of Zn.

The contamination factor for Pb and Cd revealed moderate and considerable contamination respectively at sites 1, 2, 3, 5 and 6. Low and moderate contaminations were observed for Pb and Cd respectively at Site 4. Lead recorded moderate contamination factor at sites 1, 2, 3, 5 and 6, and low contamination at Site 4. Cadmium shows a considerable contamination factor at Sites 1, 2, 3, 5 and while Site 4 showed moderate contamination. The values of degree of contamination (CF) were shown in Fig. 2.

The Cd values were moderate for all the sites except at Site 4 that showed low Cd. High Cd were observed at Sites 2, 5, and 3, which were assumed to be associated with domestic and/ industrial anthropogenic input and high concentration of metals observed at the sampling sites during the study. The highest Cd was detected at Site 2. It is therefore very necessary to monitor heavy metals concentration in Sites 2, 5 and 3.

D. Assessment of Ecological Impact in the Surface Sediments

1) Potential ecological risk index (RI)

Results of potential ecological risk (Er_i) of single metal and the potential ecological risk index (RI) of multi-metals were presented in Table V. The Eri for Cu, Zn, and Ni at all the Sites were less than 40. Therefore the risk grades were in low potential ecological risk. The Er_i values for Pb and Cd were generally above 40 from all Sites except at Site 4. The studied metals could be ranked by decreasing severity of ecological risk as: Cd > Pb > Cu > Ni > Zn, and according to the calculated RI, Cd was the most serious polluting metal in

the present study.

The potential ecological risk index (RI) accounting for the contamination caused by Cu, Zn, Pb, Cd and Ni indicated that Sites 5, 3 and 2 were exposed to moderate potential ecological risk while Sites 1, 6 and 4 were exposed to low potential ecological risk.
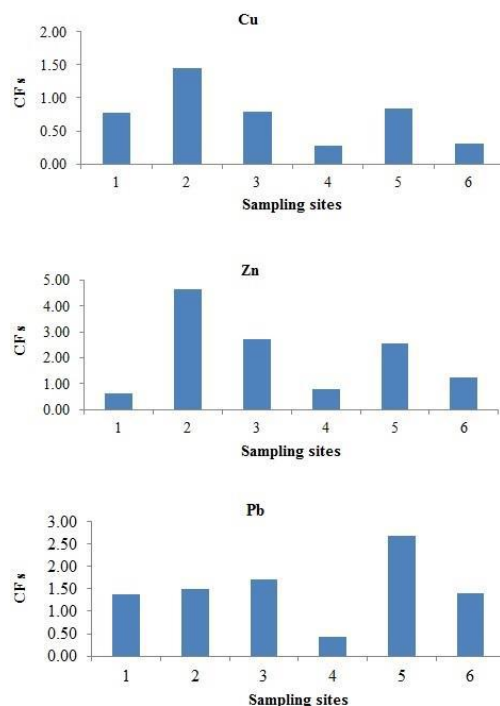

Fig. 2 a). Contamination factor (CFs) of Cu, Zn and Pb in surface sediments of west coast Peninsular Malaysia.
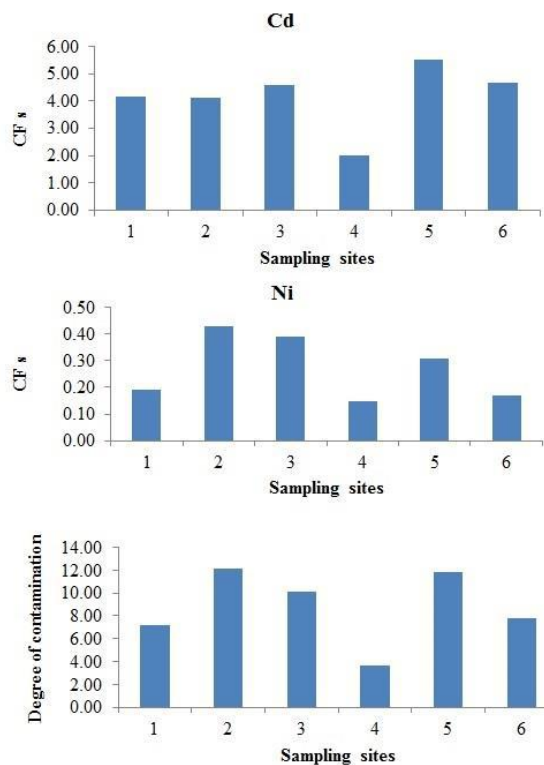

Fig. 2 b). Contamination factors (CFs) of Cd, Ni and degree of contamination in surface sediments of west coast Peninsular Malaysia.

The sampling sites (2, 3 and 5) that are associated with high anthropogenic activities shows high RI values mainly resulted from Pb and Cd. Cadmium and Pb produced the highest Eri among the studied metals therefore they should be considered

as the critical metals of concern with regards to ecological hazard in this study.

TABLE V: *ER I* AND *RI* HEAVY METALS IN THE SURFACE SEDIMENTS OF WEST COAST PENINSULAR MALAYSIA

Sampling site	PEL-Q					SQG-Q
	Cu	Zn	Pb	Cd	Ni	
1.	0.06	0.04	0.05	0.06	0.06	0.28
2.	0.12	0.33	0.05	0.06	0.14	0.70
3.	0.07	0.19	0.06	0.07	0.12	0.50
4.	0.02	0.06	0.02	0.03	0.05	0.17
5.	0.07	0.18	0.10	0.08	0.10	0.52
6.	0.03	0.09	0.05	0.07	0.06	0.28

Sediment quality guideline quotient (SQG-Q) and probable effect level quotient (PEL-Q) were presented in Table VI. The calculated SQG - Q from all sites falls into impact level category 2; indicating moderate impact potential for observing adverse biological effects a concentration level of metals at which negative effect or impact might be observed on living organism. Higher SQG – Q values were found at site with higher PEL – Q values of heavy metals. The highest SQG – Q value was observed at Site 2 which might be attributed to higher anthropogenic activities at this sampling site. A similar result was reported by Caeiro *et al*. [37] from Sado Estuary sediment were high impact potential for adverse biological effects was observed at hotspots areas found close to anthropogenic sources; at yeast factory and shipyard.

TABLE VI: PROBABLE EFFECT LEVEL QUOTIENT (PEL-Q) AND SEDIMENT QUALITY GUIDELINE QUOTIENT (SQG-Q) VALUES IN SURFACE SEDIMENTS OF WEST COAST OF PENINSULAR MALAYSIA

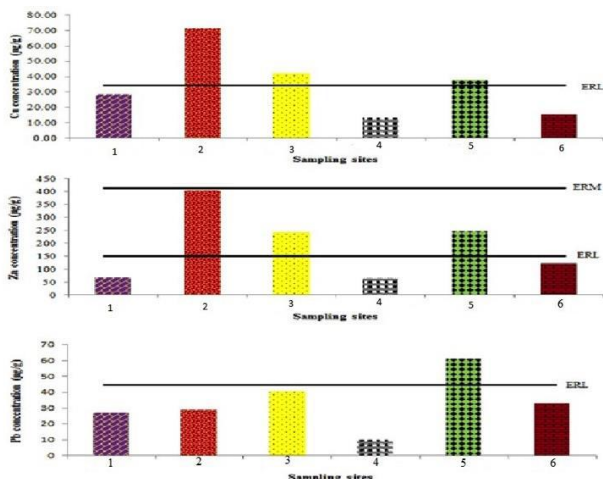| Sampling site	PEL-Q					SQG-Q
	Cu	Zn	Pb	Cd	Ni	
1.	0.06	0.04	0.05	0.06	0.06	0.28
2.	0.12	0.33	0.05	0.06	0.14	0.70
3.	0.07	0.19	0.06	0.07	0.12	0.50
4.	0.02	0.06	0.02	0.03	0.05	0.17
5.	0.07	0.18	0.10	0.08	0.10	0.52
6.	0.03	0.09	0.05	0.07	0.06	0.28

E. Assessment of Toxicity Level

Fig. 3 a). Comparison of Cu, Zn and Pb (µg/g d/w) in surface sediments of west coast of Peninsular Malaysia with their respective ERL and ERM values.

Sediment Quality Guidelines (SQG) of effect range-low (ERL) and Effect range-median (ERM) was used to assess the level of toxicity of heavy metals in the surface sediments. Comparison of Cu, Zn, Pb, Cd and Ni concentrations (µg/g d/w) in surface sediments of west coast of Peninsular Malaysia with their respective ERL and ERM values were presented in Fig. 3 a) and b).

The concentrations of Cu and Zn at Sites 2, 3 and 4, Pb at Sites 5, Cd at all the sites (except Site 4) and Ni at Sites 2, 3 and 5 were above their respective ERL values but less than ERM values, this indicates a range within which biological effects could occur occasionally by the present of these metals at the sampling sites. None of the studied metals concentration was found above the ERM values except Zn at Site 2 indicating the effects of Zn would be expected to occur frequently on biota at this sampling site.
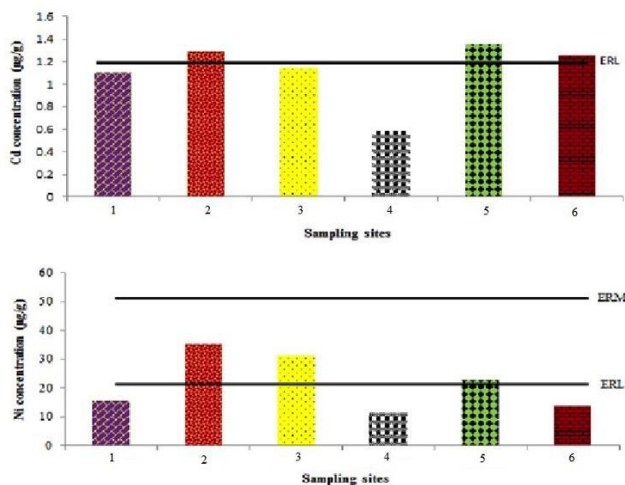

Fig. 3 b). Comparison of Cd and Ni concentrations (µg/g d/w) in surface sediments of west coast of Peninsular Malaysia with their respective ERL and ERM values.

IV. CONCLUSION

In conclusion, the study revealed Zn and Cd as metals of great concern. Based on surface sediment assessment for heavy metals contamination the sampling sites were classified within moderate to low levels of contamination which indicates certain level of pollution in some of the study areas. However, there is no special guideline for Malaysian sediment to be followed; therefore continuous assessment is needed to establish the background data for heavy metals in the area, which could be used internationally.

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