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## **FINAL REPORT**

# **TRACE METAL CONTAMINATION IN COASTAL SEDIMENT OF SAPANGAR AND KOTA KINABALU PORTS**

**NOVEMBER 2017**

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## **Executive Summary**

The distribution, accumulation and enrichment of trace metals in sediments of Sapangar Bay, Sabah were investigated. Sediment samples from 12 locations of Sapangar Bay were collected and characterized for trace metals (arsenic (As), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), lead (Pb), titanium (Ti), vanadium (V) and zinc (Zn)), organic matter and grain size. Result showed that the concentration of one potentially toxic metal (Cd) and four essential metals (Ca, Mg, Mn and Zn) in some locations of Sapangar Bay were higher than the recommended value of metals in sediment by FAO/WHO and USEPA guidelines, and Pollution Load Index (PLI). The baseline concentrations of V, Ti, Pb, Mn, Li, Fe and Zn were 30.48 mg/kg, 0.0321%, 6.98 mg/kg, 157.22 mg/kg, 35.49 mg/kg, 1.021% and 46.57 mg/kg, respectively. The concentration of most metals was comparable to the baseline, except for Mn and Zn which showed higher enrichment in most parts of Sapangar Bay. In conclusion, most of the trace metal concentrations, except Cd in Sapangar Bay is still within the permissible levels and should not cause threats to public health.

**Key words:** Trace metals, Sapangar Bay, Baseline concentration, Enrichment

## **1.0 Introduction**

Estuarine and coastal areas are particularly vulnerable to pollution from extensive anthropogenic and lithogenic activities such as shipping industry which discharged various kinds of pollutants including heavy metals (Tan and Ransangan, 2015; Zaaboub et al., 2014). When the pollutants level is exceeding the standard range, it can negatively affect the survival, growth and diversity of marine inhabitants (Bradl, 2005; Wright and Welbourn, 2002).

The level of heavy metals contamination in marine sediments is a critical factor for evaluating potential environmental effects due to their associated bio-toxicity, high environmental stability and high bioaccumulation in the food chain (Chon et al. 2010; Kishe and Machiwa 2003; Pan and Wang 2011; Süren et al. 2007; Rezayi et al. 2011). Studies have shown that heavy metal toxicity and accumulation are not only dependant on metal

concentrations but other factors such as the form in which the metal component is present, the type and concentration of other materials and the integration of sediment grain size and organic carbon are also known to contribute significant role (Hardman 2006; Rai et al. 1981; Wang et al. 2002)

In an aquatic environment, minute quantities of some metals, such as copper, zinc, iron, manganese and nickel are essential for biological systems to function, but their excessive concentration can be toxic to living organisms. Other metals such as cadmium, mercury, arsenic and lead are non-essential and therefore have toxic effects on living organisms (Amiard et al. 1987; Barka et al. 2001; Hanna et al. 1997).

Studies showed acute heavy metal intoxications through direct contact to human and aquatic life, and indirect toxicity through accumulations of metals in food chain, may damage the central nervous system, the cardiovascular and gastrointestinal systems, lungs, kidneys, liver, endocrine glands, and bones (Wang et al., 2002).

Despite the importance, studies on heavy metals pollution in Malaysian marine environments are limited and if there were, they are only concentrated in Peninsular Malaysia (Yap and Al-Barwani, 2012; Sany et al. 2012; Shazili et al., 2006; Yap et al., 2007, 2006, 2004; Ismail et al., 1993). Hence, the need for a detail and comprehensive study on heavy metals contaminations in Sabah coastlines, particularly areas within and adjacent to sea ports, is essential in order to establish the baseline information for heavy metal monitoring. Therefore, the present study is aimed to evaluate the status of metal pollution in Sapangar and Kota Kinabalu ports, and in their vicinity areas.

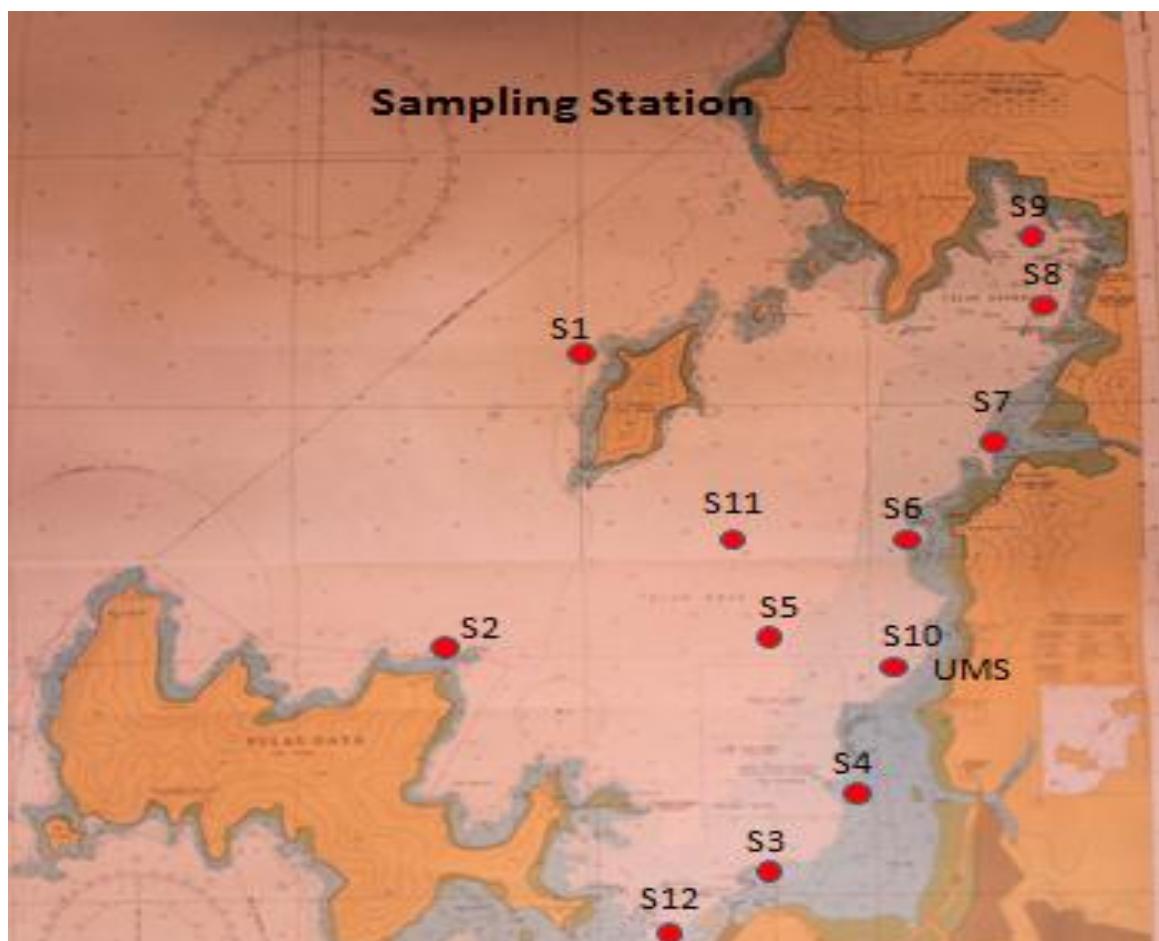
The environmental aspects that has to be considered in relation to the port developments and activities are categorized into nine groups; water quality, coastal hydrology, bottom contamination, marine and coastal ecology, air quality, noise and vibration, waste management, visual quality, and socio-cultural impacts ([www.unescap.org](http://www.unescap.org))

Sediment pollutions are caused by toxic or harmful substances, oils, oily mixtures and other hazardous materials. Contaminations of bottom sediments are often measured by the size of sediment particles, pH, color, smell, oil and grease, organic materials and concentration of organic content of nitrogen, phosphorus, sulphide and toxic substances such as heavy metals and pesticides ([www.unescap.org](http://www.unescap.org)).

## 2.0 Materials and Methods

### 2.1 Sampling Stations

Sampling was conducted in Spangar Bay from April 2016 to March 2017, where 12 sampling stations were chosen for this purpose as shown in **Figure 1** and **Table 1**. The bay has an equatorial climate with uniform temperature, high humidity and heavy rainfall due to its proximity to the equator (Malaysian Meteorological Department, 2016). The potential anthropogenic activities possibly contributing to the accumulation of trace metals in the bay has been summarized in **Table 1**. In general, the bay is surrounded by Sapangar Bay Container Terminal, a major naval base for the Royal Malaysian Navy, Sapangar Bay Oil Terminal, main campus for Universiti Malaysia Sabah, Universiti Teknologi MARA Sabah Branch, Politeknik Kota Kinabalu, Kota Kinabalu Industrial Park and a few major towns such as Likas, Kota Kinabalu and Inanam.



**Figure 1:** Map showing the locations of the sampling stations within the Sapangar Bay.

**Table 1:** GPS positions of the sampling stations and its respective features

Station	GPS position	Features
1	6°04.226'N, 116°04.091'E	Behind (west side ) of Sapangar Island, assumed to have less anthropogenic disturbances
2	6°02.224'N, 116°02.989'E	Near Gaya Island, active human activities (housing area)
3	6°00.246'N, 116°05.119'E	In front of Likas beach, active human activities, receiving discharges from few drainage systems
4	6°00.768'N, 116°05.805'E	In front of Yayasan Sabah, active human activities, receiving discharges from two river systems (Inanam and Likas)
5	6°02.129'N, 116°05.717'E	In front of UMS jetty
6	6°03.028'N, 116°06.152'E	In front of UMS Beach, near Kg. Kibagu
7	6°03.864'N, 116°05.956'E	Active human settlement, floating houses (Kg. Kibagu), shallow area, receiving discharges from Menggatal river
8	6°04.512'N, 116°07.085'E	In front of Sepanggar Port, active shipping and human activities
9	6°05.250'N, 116°07.592'E	In front of Malaysian Navy Base, active shipping and human activities
10	6°02.440'N, 116°06.410'E	In front of UMS Jetty, receiving discharges from monsoon drains from UMS campus, aquaculture discharges
11	6°02.118'N, 116°04.558'E	Located in the deepest area of Sapangar bay, ship passage
12	5°59.808'N, 116°04.666'E	Active shipping and human activities, in front of Kota Kinabalu Port

\* GPS: Global Positioning System



Bow View (Station 1)



Starboard view Station 1 (Pulau Sapangar)



Port side view Station 1 (overlooking Gaya Island)



Station 2 (Pulau Gaya)



Station 3 (Likas coastal area)



Station 4  
(River mouth of Sungai Inanam)



Station 5  
(Behind Dewan Undangan Negeri Sabah)



Station 6 (Kampung Kebagu)



Station 7 (Sapanggar Container Port)



Station 8 (Oil Terminal)



Station 9 (At the end of Sapanggar Bay)



UMS Jetty (Station 10)



Station 11 (The middle of the bay,  
anchorage area of the ships)



Station 12 (Old Kota Kinabalu Port)

**Figure 1:** Photos of the sampling sites

## 2.2 Collection of Sediment Samples

The upper layers of sediment samples were collected using a Peterson stainless steel grab with an area of 0.04 m<sup>2</sup> and a penetration of about 5 cm (Figure 2). The samples were then kept in airtight metal-free polyethylene bags and stored at 4°C in dark condition.



**Figure 2:** Sediment collection using the grab sampler

### 2.3 Organic Content and Sediment Composition

In laboratory, a small subsample of 5 g sediment was oven dried at 105 °C until constant weight obtained and then heating in a muffle furnace at 550 °C for 6 h. The organic carbon was estimated according to the equation below.

$$\text{Organic carbon} = ((\text{DW} - \text{DW}_{550})/\text{DW}) * 100$$

Where:

DW = Dry weight after oven dried at 105 °C

DW<sub>550</sub> = Dry weight after combustion at 550 °C for 6 h

On the other hand, 100 g of sediment subsample was air dried at room temperature on plastic trays, grinded and mixed thoroughly. The sediment clay-silt percentage was measured by using a laser diffraction particle size analyzer (Sequola, Canada) according to Agrawal and Pottsmith, (2000).

## **2.4 Heavy Metals**

All the equipment and glassware were first acid washed in 10% nitric acid solution to avoid metal contamination. The sediment was acid digested (6:1:2; nitric acid: perchloric acid: hydrochloric acid) at 180 °C for 10 h according to Matthai et al. (1998). The extract was then collected in 0.5M HNO<sub>3</sub>, filtered through GF/C filter paper (47 mm, 0.45 µm, Whatman) and stored in Scintillation Vials Low Potassium Glass bottles at 4 °C until analysis.

Concentration of 14 trace metals including, arsenic (As), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), lead (Pb), titanium (Ti), vanadium (V) and zinc (Zn) were measured by a Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (A Perkin-Elmer Sciex ELAN 5000 ICP mass spectrometer). A standard torch for this instrument was used an outer argon gas flow rate of 15 L/min and an intermediate gas flow of 0.9 L/min (Date and Gray, 1988). The procedural blanks and quality control samples were made from the standard solution for each metal and analyzed once in every ten samples to check for sample accuracy (Yap et al., 2006).

## **2.5 Statistical Analyses**

The total organic content, silt-clay percentage and trace metals concentration were analyzed using the SPSS Windows Statistical Package (version 21). Tests were judged to be significant at p<0.05 level. Prior to analyses, all variables were tested for normality and homogeneity of variances. One-way ANOVA were performed followed by Turkey multiple comparison tests (Turkey HSD) to make specific contrast in spatial variation of silt-clay percentage, organic contents and trace metal concentrations.

Normalization was performed by geochemical normalization method as described by Newman and Watling (2007). Fe and Li were selected as reference elements. Linear regressions were first performed for each trace metal on the reference elements. The appropriate reference element for each metal was selected based on the highest coefficient value of the regression (Newman and Watling, 2007). Subsequently, data sets in scatter plot were tested for linearity of distribution under the condition of p<0.05 and r<sup>2</sup>>0.9. Metals with concentration that much higher than the upper limit of the 95% confidence band were

eliminated as the outliers, this procedure was repeated until the above two criteria were met (Loring, 1991).

Baseline concentration of trace metals was calculated using the linear regression relationship equation between a trace metal element and reference element (Newman and Watling, 2007; Colizza et al., 1996).

$$C_M = aC_N + b$$

Where:

$C_M$  = Baseline concentration

$C_N$  = Concentration of reference element

a and b = Regression constants of the equation

The enrichment factor was calculated according to Middleton and Grant (1990).

$$EF = \frac{X(s)/R(s)}{X(b)/R(b)}$$

Where:

$X$  = Element concentration

$s$  = Sample

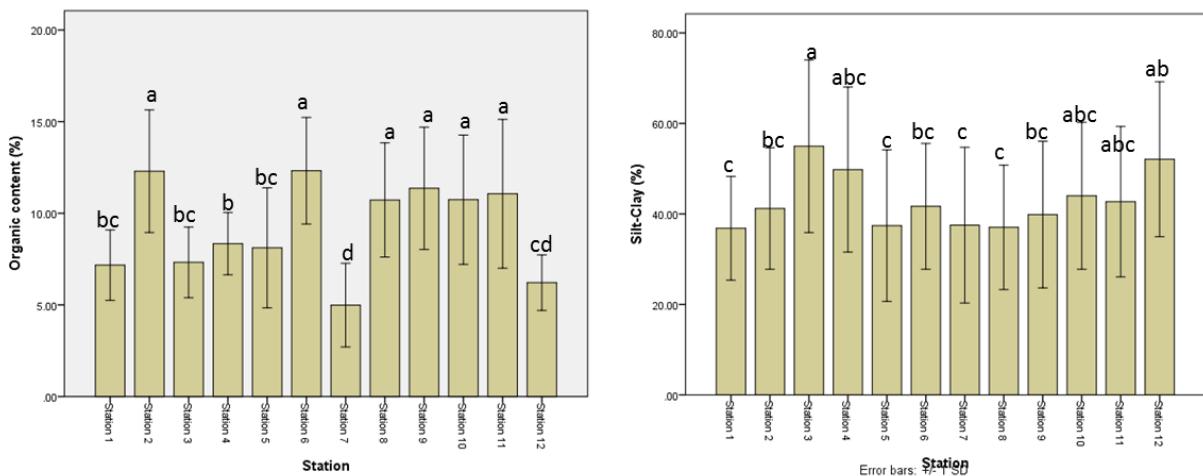
$b$  = Background value

$R$  = Reference metal

### 3.0 Results

#### 3.1 Organic Content and Sediment Composition

Spatial variations of organic content and silt-clay percentage in the sediment of Sapangar Bay are summarized in **Figure 3**. The organic content in the sediment was significantly higher ( $p<0.05$ ) in stations 2, 6, 8, 9 10 and 11 (range from 10.73 to 12.32%) than that in other stations (4.99 to 8.34%). Sediment silt-clay percentage in station 3 (54.95%) was significantly higher ( $p<0.05$ ) than in stations 1, 2, 5, 6, 7, 8 and 9 (36.83 to 41.67%).



**Figure 3:** Spatial variations of sediment organic content and silt-clay percentage (mean $\pm$  SD) from April 2016 to March 2017

### 3.2 Trace Metals

The concentrations of Cr, Fe, Li, Ni, Pb, Ti and V in the sediment of all sampling stations were lower than the recommended permissible value as suggested by FAO/WHO and USEPA guidelines and the Pollution Load Index (PLI). However, the concentrations of Mn and Zn in the sediment of several stations (Mn= S2 and S11; Zn= S3, S4, S6, S8 and S9) were slightly higher, whereas the concentrations of Ca (all stations), Cd (all stations) and Mg (all except S7) were much higher than the recommended value (Table 2).

Pearson's correlation coefficients between sediment properties (organic content and silt-clay percentage) and the trace metals concentration are presented in **Table 3**. In general, a positive correlation was observed between most metals (Li ( $r^2= 0.615$ ;  $p<0.01$ ), V ( $r^2=0.582$ ;  $p<0.01$ ), Fe ( $r^2=0.514$ ;  $p<0.01$ ), Mn ( $r^2=0.513$ ;  $p<0.01$ ), Pb ( $r^2=0.385$ ;  $p<0.05$ ), Cd ( $r^2=0.219$ ;  $p<0.01$ ), Zn ( $r^2=0.164$ ;  $p<0.01$ ) and As ( $r^2=0.146$ ;  $p<0.01$ )) and organic content in the sediment. On the other hand, only As, Cr, Ni and Zn were positively correlated, whereas Ti was negatively correlated with silt-clay percentage in sediment.

**Table 1** Concentration of trace metal (mean $\pm$ SD ) in the sediment of Sapangar Bay

	As (mg/kg)	Ca (%)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Fe (%)	Li (mg/kg)	Mg (%)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Ti (%)	V (mg/kg)	Zn (mg/kg)
S1	1.76 $\pm$ 1.17	1.04 $\pm$ 2.09	0.34 $\pm$ 0.19	29.0 $\pm$ 31.6	44.31 $\pm$ 62.02	0.63 $\pm$ 0.27	29.69 $\pm$ 11.96	0.84 $\pm$ 0.16	243.66 $\pm$ 92.87	14.81 $\pm$ 13.08	4.54 $\pm$ 2.20	0.018 $\pm$ 0.009	20.63 $\pm$ 8.36	38.07 $\pm$ 24.14
	3.20 $\pm$ 1.10	5.66 $\pm$ 0.96	0.31 $\pm$ 0.19	18.2 $\pm$ 12.4	35.67 $\pm$ 56.47	1.35 $\pm$ 0.22	61.62 $\pm$ 10.05	1.11 $\pm$ 0.16	421.92 $\pm$ 86.33	20.54 $\pm$ 12.69	9.96 $\pm$ 3.93	0.039 $\pm$ 0.008	42.73 $\pm$ 7.61	55.72 $\pm$ 22.01
S3	5.84 $\pm$ 1.40	5.39 $\pm$ 1.20	0.38 $\pm$ 0.19	18.7 $\pm$ 9.4	38.54 $\pm$ 61.09	1.02 $\pm$ 0.21	28.31 $\pm$ 4.78	0.62 $\pm$ 0.10	115.80 $\pm$ 19.18	10.92 $\pm$ 7.63	8.32 $\pm$ 1.59	0.032 $\pm$ 0.007	27.40 $\pm$ 6.24	56.68 $\pm$ 21.75
	7.08 $\pm$ 1.92	2.52 $\pm$ 0.85	0.37 $\pm$ 0.21	23.2 $\pm$ 16.6	59.57 $\pm$ 93.56	1.32 $\pm$ 0.26	31.84 $\pm$ 6.80	0.55 $\pm$ 0.11	107.21 $\pm$ 36.65	15.67 $\pm$ 12.51	11.03 $\pm$ 2.45	0.041 $\pm$ 0.010	37.10 $\pm$ 8.29	66.70 $\pm$ 25.81
S5	4.38 $\pm$ 1.54	3.85 $\pm$ 0.70	0.31 $\pm$ 0.20	19.8 $\pm$ 23.0	46.92 $\pm$ 81.53	1.10 $\pm$ 0.25	35.10 $\pm$ 8.15	0.69 $\pm$ 0.11	188.52 $\pm$ 31.35	14.60 $\pm$ 13.89	8.22 $\pm$ 2.21	0.031 $\pm$ 0.009	29.40 $\pm$ 8.61	49.06 $\pm$ 17.55
	5.63 $\pm$ 1.37	5.58 $\pm$ 1.16	0.36 $\pm$ 0.21	23.1 $\pm$ 23.9	49.73 $\pm$ 65.11	1.37 $\pm$ 0.28	50.81 $\pm$ 10.07	0.91 $\pm$ 0.22	274.94 $\pm$ 58.75	18.64 $\pm$ 14.25	10.02 $\pm$ 2.06	0.041 $\pm$ 0.014	41.46 $\pm$ 9.57	63.04 $\pm$ 32.45
S7	3.61 $\pm$ 1.34	0.48 $\pm$ 0.24	0.34 $\pm$ 0.19	32.9 $\pm$ 28.7	13.91 $\pm$ 15.56	0.82 $\pm$ 0.22	20.06 $\pm$ 5.30	0.31 $\pm$ 0.08	52.34 $\pm$ 26.96	19.95 $\pm$ 19.51	5.01 $\pm$ 1.64	0.030 $\pm$ 0.009	23.73 $\pm$ 6.15	44.16 $\pm$ 21.50
S8	5.25 $\pm$	5.75 $\pm$	0.32 $\pm$	19.8 $\pm$	15.74 $\pm$	1.26 $\pm$	44.46 $\pm$	0.82 $\pm$	213.99 $\pm$	17.21 $\pm$	8.02 $\pm$	0.040 $\pm$	38.73 $\pm$	59.36 $\pm$

	1.84	3.28	0.19	17.3	12.91	0.42	14.41	0.17	61.12	12.23	2.77	0.014	12.98	28.21
S9	4.41±	<b>4.47±</b>	<b>0.35±</b>	19.2±	19.51±	1.32±	47.11±	<b>0.90±</b>	233.42±	16.85±	8.81±	0.045±	41.86±	<b>67.47±</b>
	1.63	<b>2.47</b>	<b>0.21</b>	16.9	13.78	0.33	11.17	<b>0.17</b>	53.11	10.98	2.31	0.012	10.35	<b>23.92</b>
S10	4.46±	<b>7.42±</b>	<b>0.32±</b>	14.9±	14.63±	0.94±	29.73±	<b>0.71±</b>	174.01±	12.04±	6.87±	0.031±	29.98±	45.25±
	1.42	<b>2.12</b>	<b>0.20</b>	11.2	18.51	0.32	9.70	<b>0.14</b>	44.28	9.43	2.05	0.012	9.73	22.01
S11	3.26±	<b>4.36±</b>	<b>0.26±</b>	27.8±	21.94±	1.28±	49.65±	<b>0.92±</b>	<b>337.36±</b>	18.57±	8.55±	0.037±	38.08±	52.09±
	1.51	<b>1.43</b>	<b>0.18</b>	45.8	28.26	0.33	15.79	<b>0.23</b>	<b>170.61</b>	17.52	2.28	0.010	10.92	19.76
S12	4.41±	<b>7.92±</b>	<b>0.32±</b>	12.7±	12.94±	0.73±	25.28±	<b>0.66±</b>	124.55±	6.97±	6.03±	0.020±	20.43±	46.62±
	2.04	<b>1.71</b>	<b>0.20</b>	4.0	17.17	0.25	9.61	<b>0.18</b>	56.58	2.95	2.17	0.008	8.05	25.96
<b>SRM</b>	<b>0.519</b>	<b>0.148</b>						<b>0.388</b>						
<b>1646</b>	<b>6.23±</b>	±	±	<b>40.9±</b>	<b>10.01±</b>	<b>2.008±</b>	-	±	<b>234.5±</b>		<b>11.7±</b>	<b>0.456±</b>	<b>44.84±</b>	<b>48.9±</b>
<b>a</b>	<b>0.21</b>	<b>0.02</b>	<b>0.07</b>	<b>1.9</b>	<b>0.34</b>	<b>0.039</b>		<b>0.009</b>	<b>2.8</b>	<b>22.5</b>	<b>1.2</b>	<b>0.021</b>	<b>0.76</b>	<b>1.6</b>

**Table 3:** Pearson's correlation coefficients between sediment properties (organic content and silt-clay percentage) and the concentration of trace metals

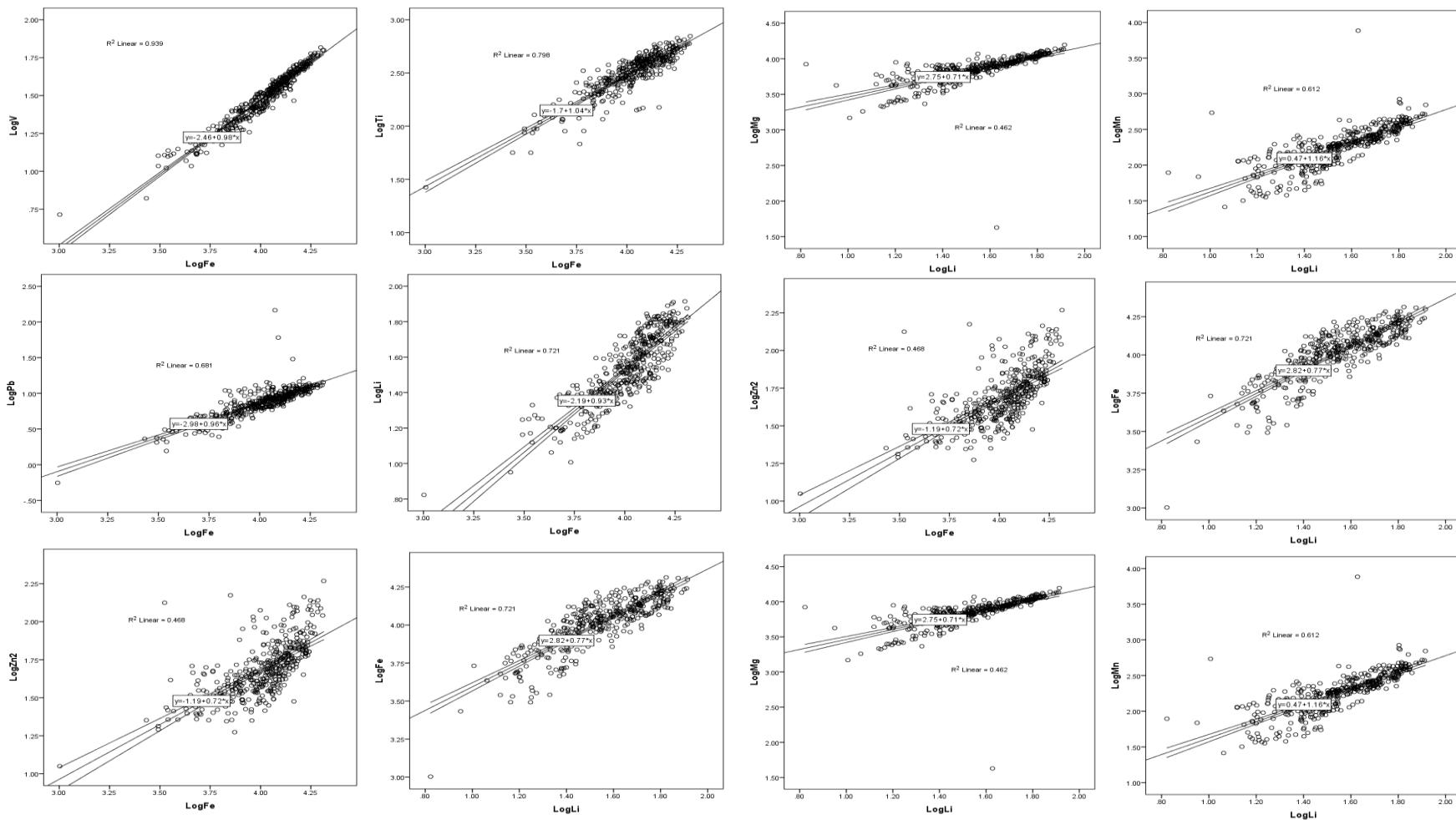
	As	Cd	Cr	Fe	Li	Mn	Ni	Pb	Ti	V	Zn
Organic content	+.146**	+.219**	-	+.514**	+.615**	+.513**	-	+.385**	+.501**	+.582**	+.164**
Silt-Clay percentage	+.176**	-	+.111*	-	-	-	+.129*	-	-.112*	-	+.136*

The significant coefficients: \*\*, p<0.01; \*, p<0.05

### **3.3 Metal Enrichment**

The resultant regression line with 95% confidence limits between metals and reference elements are illustrated in **Figure 4**. Metals V, Ti, Li, Pb and Zn showed strong positive correlation with Fe, with  $r^2$  values of 0.94, 0.80, 0.72, 0.68 and 0.47, respectively. Whereas, Fe, Mn and Mg were strongly correlated with Li with  $r^2$  value of 0.72, 0.61 and 0.46, respectively. On the other hand, element As, Ca, Cr, Cu and Ni did not correlate with any reference elements.

All data points were retained for the element V. However, for other elements, many data points which the concentrations were much higher than the upper limit of the 95%, were eliminated prior to the regression analysis (Table 4). The improved data indicated that the baseline concentrations of V, Ti, Pb, Mn, Li, Fe and Zn were 30.48 mg/kg, 0.0321%, 6.98 mg/kg, 157.22 mg/kg, 35.49 mg/kg, 1.021% and 46.57 mg/kg, respectively.



**Figure 4:** Scatter plots of trace metals with a suitable reference element in the coastal sediment of Sapangar Bay. The solid line represents the regression line with  $p < 0.05$  with the 95% confidential intervals

**Table 4:** Linear regression equations for various metals, reference elements and the corresponding calculated baseline concentrations in the sediment of Sapangar Bay

Element	Sample				Background
	N	n	removed	Formula	
V	407	407	0	$\text{Log}_{10}\text{V}=-2.46+0.98*\text{Log}_{10}\text{Fe}$	30.48 mg/kg
Ti	389	349	40	$\text{Log}_{10}\text{Ti}=-1.8+1.07*\text{Log}_{10}\text{Fe}$	0.0321%
Pb	405	347	59	$\text{Log}_{10}\text{Pb}=-3.06+0.97*\text{Log}_{10}\text{Fe}$	6.98 mg/kg
Mn	405	299	106	$\text{Log}_{10}\text{Mn}=0.02+1.42*\text{Log}_{10}\text{Li}$	157.22 mg/kg
Li	407	286	121	$\text{Log}_{10}\text{Li}=-3.4+1.23*\text{Log}_{10}\text{Fe}$	35.49 mg/kg
Fe	407	286	121	$\text{Log}_{10}\text{Fe}=2.89+0.73*\text{Log}_{10}\text{Li}$	1.021%
Zn	407	225	182	$\text{Log}_{10}\text{Zn}=-1.31+0.74*\text{Log}_{10}\text{Fe}$	46.57 mg/kg
Mg					
As					
Ca					
Cd					
Cr					
Cu					
Ni					

The degree of metal enrichment estimated based on the geochemical normalization is summarized in **Table 5**. In general, the V and Ti in all stations were similar to the baseline value with very low variation of about 10%. Slight increment with Pb, Mn, Li, Fe and Zn relative to the base line concentrations were observed throughout the bay, whereas high enrichment with Mn was observed in stations 1, 2 and 11. Moreover, high enrichment with Fe was observed in stations 4 and 7, whereas Zn in station 12.

**Table 5:** Metals enrichment factor in sediment of Sepanggar Bay

	V	Ti	Pb	Mn	Li	Fe	Zn
S1	1.10	0.91	1.05	<b>1.85</b>	1.36	0.74	1.32
S2	1.06	0.92	1.08	<b>1.55</b>	1.31	0.76	0.90
S3	0.90	1.00	<b>1.19</b>	0.92	0.80	<b>1.25</b>	1.22
S4	0.94	0.99	<b>1.22</b>	0.76	0.69	<b>1.44</b>	1.11
S5	0.90	0.90	1.09	<b>1.21</b>	0.92	1.09	0.98
S6	1.01	0.95	1.07	<b>1.22</b>	1.07	0.94	1.01
S7	0.97	1.16	0.89	0.59	0.70	<b>1.42</b>	1.18
S8	1.03	1.01	0.93	1.09	1.02	0.99	1.03
S9	1.06	1.08	0.98	<b>1.12</b>	1.03	0.97	<b>1.12</b>
S10	1.07	1.05	1.07	<b>1.32</b>	0.91	1.10	1.06
S11	1.00	0.92	0.98	<b>1.53</b>	<b>1.12</b>	0.90	0.89
S12	0.94	0.87	<b>1.21</b>	1.11	1.00	1.00	<b>1.40</b>

## **4.0 Discussion**

### **4.1 Organic Content and Sediment Composition**

The result of current study showed that the organic content in the sediment was significantly higher at UMS, Sapangar Port, ship passage, and near Gaya Island. Mangrove swamp sediment is known to rich in organic content, where it has been estimated that mangrove sediment contains at least three to four times higher organic content than the continental margin sediments (Jennerjahn and Ittekkot, 1997). This is due to mangroves enhance sedimentation of suspended matter during flooding and thus act as sink for allochthonous materials (Furukawa et al., 1997). Therefore, the huge coverage of mangrove swamp at UMS and Sapangar Port could explain the high organic content in their sediment. On the other hand, Gaya Island has five major villages, where most the villages live in squatter settlements at the shoreline with no proper drainage system (Shah and Selamat, 2016). Therefore, accumulation of daily domestic wastes in this area could contribute to high organic content in its sediment.

Granulometric characteristic of sediment shows the silt-clay percentage in sediment was significantly lower at the windward of Sapangar Island, Sapangar Port and in front of UMS. This is expected as finer sediment particles particularly the silt and clay are transported from high to low energy areas (Tan et al., 2016). Therefore, this could explain the relatively lower silt and clay composition at the areas which exposed directly to water current.

### **4.2 Trace Metals**

Sediments have a good record of time integrated contaminant status and are therefore can be used as an economic monitoring tool to detect anthropogenic impact over time (Sany et al., 2014; Daskalakis and O'Connor, 1995). In addition, sediment also plays a major role in the transport and storage of metals, they are also frequently used to identify the source of contaminants and determine dispersion pathways in marine system (Birch et al., 2001). Therefore, current study used marine sediment as a monitoring tool to evaluate the organic and trace metal contamination status in Sapangar Bay.

In current study, the concentrations of most elements were lower than the recommended values for metals in sediment as suggested by FAO/WHO and USEPA guidelines, Pollution Load Index (PLI). However, the concentration of Mn, Zn, Ca, Cd and Mg recorded in several stations were slightly higher than the recommended value. Among these metals, only Cd is classified as potentially toxic metal, whereas other elements (Mn, Zn, Ca and Mg) are essential metals, which generally harmless to human unless when intake is excessive or ingested in low concentration over a long time period (Uluozlu et al., 2007).

Metal processing is known to be the main anthropogenic source of Zn pollution (Nriagu and Pacyna, 1988). During the manufacturing of steel, a significant amount of Zn waste in the form of dust is generated from the steel smelting process. This dust is typically disposed at a hazardous waste landfill site. These pollutants can enter the estuary during heavy rainfall via river runoff. Therefore, high number of steel processing factories in Kota Kinabalu and Turan areas could explain the high Zn concentration at river mouth of Menggatal River, Inanam River and Likas River.

Sewage sludge and paint are the major anthropogenic sources of environmental Mn (Kamaruzzaman et al., 2011). High concentration of Mn at Gaya Island is expected as the domestic wastes are directly discharged to the sea without a proper treatment (Shah and Selamat, 2016). On the other hand, station 11 in current study is the deepest area of the bay and also the anchorage place before vessels entering the port. Shipping has been reported as an important source of Mn pollution in marine environment (Tornero and Hanke, 2016). Release of Mn from ship's hull at this high traffic zone can significantly increase the Mn concentration in the environment.

The main anthropogenic sources of cadmium in aquatic environment are from various industrial processes such as production of television tube phosphors, preparation of special alloys and solders, metal plating, nuclear reactor shields and rods, pigments in yellow or brown paints (for coloring plastics, glass, and enamels), stabilizers for processing PVC polymers, nickel-cadmium rechargeable batteries, and electronic waste (Nriagu and Pacyna, 1988). Cadmium coating are mainly applied via electroplating or dipping to another metal as a thin film for protection against corrosion. Seldom is it possible to recover the metal economically. Furthermore some researchers have shown that most cadmium additions to water or land are from

atmospheric deposition (Nriagu and Pacyna, 1988). Since Kota Kinabalu Industrial Park (KKIP), a major industrial real-estate in Sabah is located nearby the Sapangar Bay, therefore the intensive use of Cd in different industrial processes could explain the relatively high Cd in the bay.

Compare to peninsular Malaysia, the metals concentration in the sediment of Sapangar Bay were much lower than what have recorded in the coastal areas of Peninsular Malaysia, which measured about 2.5 to 5% of Fe, 3000 to 5000 mg/kg of Mn, 600 to 900 mg/kg of Zn and 10 to 30 mg/kg of Pb (Shazili et al., 2006; Ismail et al., 1993). Compare to Marudu Bay, north coast of Sabah, the concentration of most trace metals were comparable or lower, except for the As in station 4, Mn in stations 4 and 11, and Cd in all stations were higher in Sapangar Bay than that recorded in Marudu Bay (As=0 to 2.9 mg/kg; Mn=93 to 318 mg/kg; Cd=0 to 0.3 mg/kg) (Tan et al., 2016).

The result of Pearson's correlation coefficients demonstrated that the variation of trace metal concentration in the sediment of Sapangar Bay is more closely related to the organic content rather than the clay-silt percentage (grain size). This is due to the fact that the grain size distribution in Sapangar Bay is almost even in most of the stations (S1, S2, S4, S5, S6, S7, S8, S9, S10 and S11). The result of current study demonstrated that most of the trace metals in the sediment responded positively to organic content. Similar result has been reported in other studies where organic matter has higher chemical affinity for trace elements (Tan et al., 2016; Weiguo et al., 2001).

### **4.3 Metal Enrichment**

Enrichment Factor (EF) is a useful tool for differentiating the man-made and natural sources of metal contamination (Tan et al., 2016). Fe and Li have been used as reference elements in this study due to its natural origin with minimal human impact (Weisberg et al., 2000). In the V/Fe regression plot, the high coefficient of  $r^2=0.939$  was obtained. In addition, the enrichment study also suggests no enrichment with V occurred in Sapangar Bay. For other elements, numbers of data points were suspected of being enriched, and therefore were removed until  $r^2>0.9$  was achieved for the purpose of accurate metal baseline concentration determination.

High Mn enrichment was observed in S1, S2 and S11, the stations near the Sapangar and Gaya Island, where the main anthropogenic sources of Mn are contributed by paint, metal components and sewage effluents (Ideriah et al., 2012; Alluri et al., 2007). High Fe enrichment was recorded in S4 and S7, in front of river mouth which suggests that the enrichment could be contributed by river runoff of industrial effluents. On the other hand, high Zn enrichment was observed in S12, in front of KK port in which used of paint and metal components by boats and ships could be the potential source of Zn enrichment.

By comparing the metal baseline concentration in Sapangar Bay to Marudu Bay at north coast of Sabah, the baseline concentration of V, Ti and Zn were slightly higher in Sapangar Bay, whereas Pb, Mn and Fe were lower than that in Marudu Bay. Metal baseline concentrations in sediment are depending on sediment mineralogy, granulometry and organic content (Newman and Watling, 2007). Therefore, this suggests that the natural mineralogical composition of the parent material and granulometry and the organic matter content of the host sediment in Sapangar Bay and Marudu Bay are different.

## **5.0 Conclusion**

Concentration of trace metals in the coastal sediment of Sepangar Bay is currently within the safe level and, presumably poses no threat to public health. To date, the concentration of most trace metals in the coastal sediment of the bay is comparable or lower compared to that in peninsular Malaysia and North coast of Sabah. However, localized anthropogenic enrichment with trace metals, particularly cadmium might require more attention since it is classified as potentially toxic metal and is actively produced by various industrial processes from industrial areas. In order to improve or at least maintain the current environmental status of the bay, spatial and temporal monitoring of trace metals and other environmental parameters need to be done on regular basis.

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