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ORIGINAL ARTICLE

Particle sizes effect of the elements in the South China Sea sediment off Pahang coastal during the Northeast monsoon (pre-) and the Southwest monsoon (post-) periods

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Abstract The Pahang water determined an effect of the sizes of sediment particles on 11 elements distribution during the monsoon season. The elements were of very high concentration in a sediment particle size of 40, 63, and 90 µm. The lower concentration of the elements was associated with a sediment size of 125, 250, and 500 µm. It has been observed in this research study that a concentration of elements increases with a decrease in a size of the sediment particles. The sediment from the Northeast (pre-) monsoon consisted of a finer particle size than the Southwest (post-) monsoon sediments. Overall, the concentration of the elements in the Northeast (pre-) monsoon sediment was higher than the Southwest (post-) monsoon sediment. The Northeast monsoon is highly influenced due to an input of fresh sediment from the rivers into the South China Sea as well as, due to a redistribution in the surface sediment. There were many differences in sediment element content between the two monsoon seasons, but an anthropogenic impact was only found in lead (Pb).

Keywords Particle size · Surface sediment · Elements · South China Sea · Northeast monsoon · Southwest monsoon

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Introduction

Heavy and trace elements are among those environmental pollutants that are most common and significant. The daily residential activities contribute in a production of these elements, which flow from a river toward a sea. The housing wastes and municipal remnants are the main source of this pollution. The industrial activities also contribute to this element pollution up to a great extent. Along with these industrial revolutions, an expansion and the spread of the elements in a whole world are also growing rapidly with time (Fyfe 1998).

Almost 97 % of the elements in a sea are related to a stream sediment through the river mass transport process into an ocean (Gibbs 1977). The sediments and soils could be the important evidences in the forensic investigations (Murray 2004; Murray and Tedrow 1992), as they display apparent variations in physical, chemical, and biological quality. As a fact, these parameters reflect the differences in a main material geology, soil formation processes, and human activities (Collins et al. 1997; Ingram and Lin 2002; Rawlins et al. 2003). The concentration of an element in a sediment does not only provide bioavailability, mobility, and element's toxicity, but also useful as an indicator of a pollution in an aquatic environment (Hooda 2010). A comparison between the physical and chemical parameters of a sediment sample is very important to consider an effect of variations in a size of particle indecision.

A high concentration of an element in sediment is not necessarily due to the anthropogenic influence; instead, it may originate from physical and chemical changes during a process of precipitation and formation of solid (Zwolsman et al. 1993) or affected by the particle size (Loring and Rantala 1992). A source of elements, both natural and anthropogenic in sediment, is difficult to be determined,

except for the studies, which involve a size of a fraction. In the studies that are related to a sediment, a coarse (1–2 cm or 250–500 mm) and fine (63–125 and <63 mm) sediment composition are frequently studied (Winspear and Pye 1995; Saye and Pye 2006; Saye et al. 2006). However, in a study of pollution, a focus is given at a fraction size of <60 or <20 mm, which shows less changes between the coarse and bulk sediment samples (Ackermann 1980).

Cr and Pb accumulation in sediment of the Kaštela Bay in the Middle Adriatic showed to have a strong correlation with the finest sediment fractions that is <20–54 μm (Ujević et al. 2000). In general, the concentration accumulated was four times higher than >54 μm particle size. Based on the principal component analysis, it is concluded that the polluted elements indicated the anthropogenic origins by urban and industrial wastewaters. Recent research on elemental analysis in Kerala, India, determined the distribution and toxicity levels of selected elements in various beach sediments (Suresh et al. 2015). Kerala is one of the world's areas with high level of radiation background. Their findings proved that Cu, Ni, and Zn have high influenced by silt and clay particle sizes as well as the total organic content in the sediments.

In 1986 (Shazili et al. 1988), the Matahari Expedition demonstrated that the elements collected during the sampling activities from the Pahang coastal waters were derived from the anthropogenic sources of Pb, whose concentration ranges from 2 to 41 ppm in a fractional size of <63 μm. The Pb concentration in an earth's crust is 13 ppm (Taylor 1964). A main source of these elements comes from the industrial activities, municipal waste, and human activities along the Pahang coast (Shazili et al. 1988). Recently, it corresponds to an industrial revolution, expansion, and elemental spread (Fyfe 1998). For this research study, the fractional sizes of 500, 250, 125, 90, 63, and 40 μm have been selected to represent a coarse particle size to a finer particle size.

The three main points that describe the importance of this study are discussed below;

1. In the previous studies, a focus was given to below 63 μm fraction size, whereas this study has focused on a size fraction of 500–40 μm to obtain a difference in the concentrations of the coarse and fine particle sizes. It aimed to determine whether a concentration of elements is higher in fine particles or coarse particles.
2. It determined a seasonal impact in a process of elemental distribution by a current and water turbulence.
3. It identified a level of contamination that is present within an area of study that could affect an environment.

Methodology

Sample collection

The State of Pahang is famous in palm oil, tourism, oil industry, port, and fisheries. Processing and utilization of oil are likely to contribute to the increasing Pb element concentrations in these waters. Al, Li, Fe, Pb, Zn, Cr, Ba, Co, Cu, Mg, and Mn elements were selected, because they are abundant heavy and trace elements that can be compared with an earth's crust value. Due to a high concentration of these elements compared with the earth's crust value, there is also anthropogenic contamination possibility.

To gain a better understanding of the level of elements in surface sediment of the Pahang waters, the samples were taken twice representing the Northeast and Southwest monsoons. It is due to fact that the South China Sea region is strongly influenced by both monsoons throughout a year. Figure 1 shows the 26 research stations that were selected on the Pahang coast, which extended from 3°55.0′N 103°25.4′E to 2°55.0′N 103°57.0′E. The research stations were plotted into the six transects. The first station of each transect was located approximately at the three nautical miles from the Pahang shoreline and extended off to an offshore, at approximately 23 nautical miles. Sampling was carried out in October 2003 and April 2004.

Surface sediment was collected using the Smith McIntyre grab. A few scoops of the sediment (approximately within a surface and 5 cm deep) were sampled using an acid-washed plastic scoop. The samples were then kept in a double polyethylene zip lock bag, and kept under −20 °C and then transported to a laboratory.

Sample analysis

A total of 20 samples of pure water were analyzed using the inductively coupled plasma mass spectrophotometer Perkin Elmer Elan 9000 (ICP–MS). The detection limit values are recorded in Table 1.

The grain size analysis was carried out by sieving 100 grams of sediment in the six serial sieves using an automatic serial sieve shaker for the 15 min. Sieve series were arranged according to a model decline size, namely, 500, 250, 125, 95, 63, and 40 μm. As for the elemental analysis, a material preparation and sediment digestion was carried out according to the US-EPA 3051A. The digestion process was carried out using the microwave lab station (Milestone Ethos 1600) simultaneously for the 10 samples without an element loss. The 0.5 g of the sediment samples were put in a Teflon vessel and mixed with a mixture of nitric acid, hydrochloric, and hydroflouric, digested under a

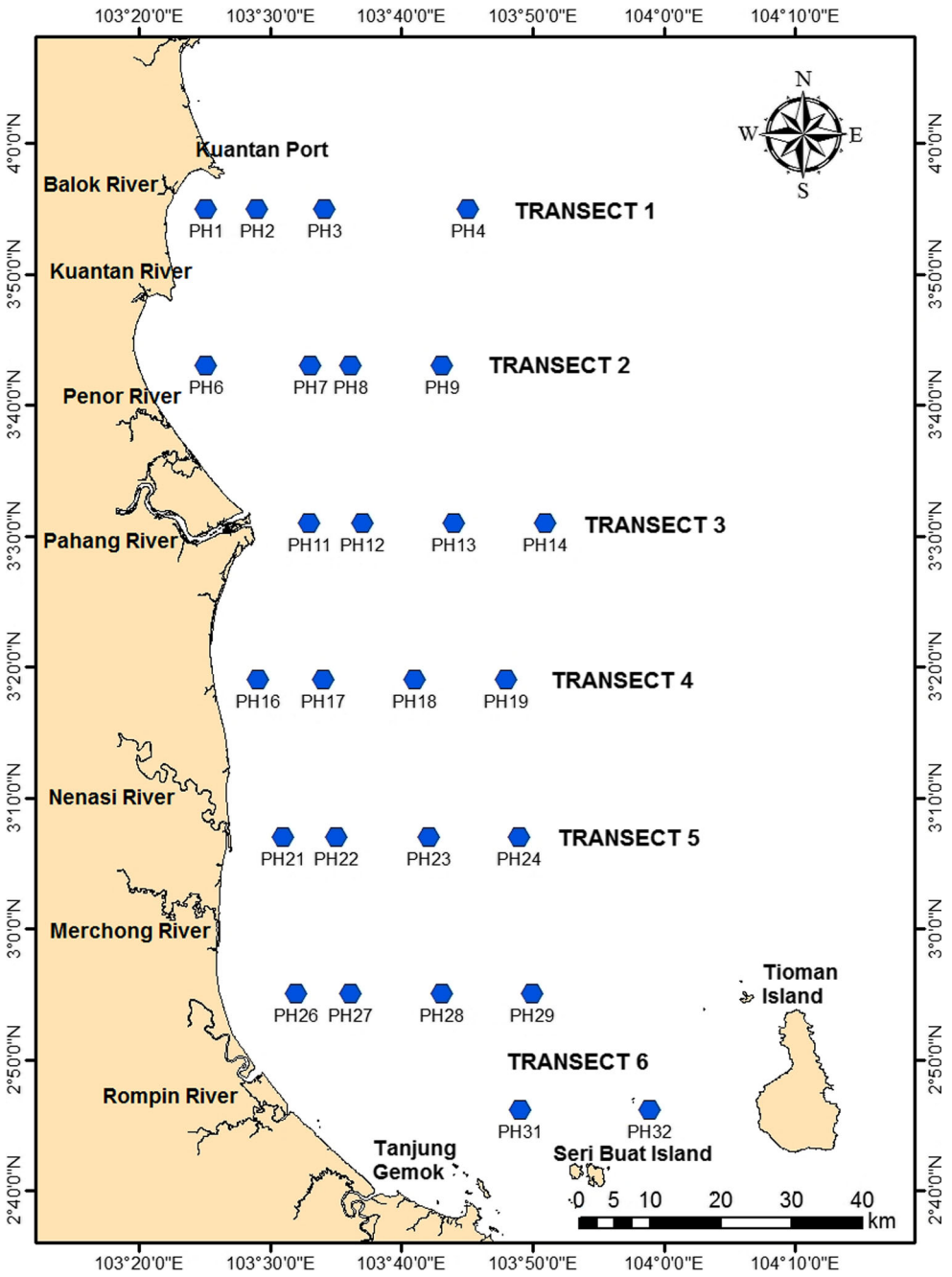

Fig. 1 Sampling stations on the Pahang coast, South China Sea

Table 1 Certified and obtained value from NBS 1646a sediment standard reference analysis ($n = 30$)

Element	Mg (%)	Al (%)	Cr	Mn	Fe (%)	Co	Cu	Zn	Ba	Pb	Li
Certified value (μg g^{-1})	0.39	2.3	41	235	2	5	10	49	210	12	18
ICP-MS Result (μg g^{-1})	0.4	2.2	42	234	2.1	5	11	49	212	11	18
Recovery (%)	103	97	101	100	105	96	105	100	101	97	98
Total element detection limit (μg kg^{-1})	0.010	0.003	0.006	0.017	0.022	0.012	0.006	0.009	0.005	0.004	0.012
ICP-MS detection limit (μg kg^{-1})	0.010	0.003	0.002	0.006	0.010	0.003	0.002	0.008	0.005	0.003	0.010

microwave heating at 210 °C for 30 min, and cooled down for 1 h and 30 min. Elements concentration was analyzed using the inductively coupled plasma mass spectrophotometer Perkin Elmer Elan 9000 (ICP–MS). A standard reference material NBS 1646a (Estuarine Sediment) was used for a recovery test. A quality control parameter was determined using a blank sample. All the samples were analyzed in the three replicates, whereas blank and standard reference materials were analyzed in the ten replicates.

A concentration of elements was calculated according to the following formula:

$$\text{Elements concentration} = \frac{\text{Mean concentration of element (ng/ml)} \times \text{volume (ml)} \times \text{dilution factor}}{\text{Dry sample (g)}}$$

Data analysis

The two-way ANOVA without replication was applied to define the significance of data set obtained between sampling stations, elements, sediment particle sizes, and sampling periods. In the meantime, the correlation analysis was applied to define the association of parameters. Both statistical analyses were carried out using SPSS ver. 11.5 software.

The level of pollution for this study was assessed using a normalization test, followed by the enrichment factor (EF) (Mason and Moore 1982 and Wedepohl 1995) and the geoaccumulation index (*Igeo*) (Muller 1979). The listed tests are common tools that are used to define if a production of an element is influenced via either natural process or anthropogenic input (Adamo et al. 2005; Vald'es et al. 2005; Reddy et al. 2004; Selvaraj et al. 2004; Woitke et al. 2003; Aloupi and Angelidis 2001 and Horig et al. 1991). The normalization test consists of a graph of an element versus a normalized element (Adamo et al. 2005). In this study, Al was used as the normalizer element as it has the best correlation with all elements. Moreover, it can also mitigate the variations produced by a sediment's heterogeneous deposit. Furthermore, the purpose of element reference is to minimize the variables from the external sources or high concentrations in a study (Abrahim et al. 2008). The normalization test in this study was carried out by plotting a graph using the SPSS ver. 11.5 software, as shown in Table 5 and Anova two ways. If a plotted element falls within a radius of a 95 % confidence level, an element exits naturally. In the meantime, if a plotted element falls outside a radius of 95 % confidence level, it is considered as an anthropogenic input. The EF test, if the calculated EF exceeds a value of 1, it is considered as a contribution from an anthropogenic source. Table 2 represents a classification of a level of pollution in a sediment (Christophoridis et al. 2009). This classification method is based on a geochemical data that enables to map a study area and distinguish the various subareas, according to a level of pollution.

Table 2 *Igeo* pollution classification

Igeo	Igeo class	Description of sediment quality
<0	0	Uncontaminated
0–1	1	Uncontaminated to moderately contaminated
1–2	2	Moderately contaminated
2–3	3	Moderately contaminated to strongly contaminated
3–4	4	Strongly contaminated
4–5	5	Strongly contaminated to extremely contaminated
>5	6	Extremely contaminated

Results and discussions

Concentration of elements

The digestion method was validated by the sediment standard reference, NBS 1646a (Estuarine Sediment) by the US Department of Commerce, National Institute of Standards and Technology (NIST), Washington, DC. Table 1 shows that the averages of elements recovered are 96–105 %. Table 3 shows a summary of mean concentration and standard deviation between stations of the selected elements in the surface sediment of Pahang coastal during the pre-monsoon and post-monsoon seasons.

Distribution of elements during the post-monsoon period

Within the post-monsoon period, the concentrations of Al, Cr, Li, and Mn were high at the station PH1 and decreased toward the southeast of the sampling area. Based on the normalization graph, Al, Cr, Li, and Mn for each station were within 95 % confidence level. Both tests defined the native behavior of these elements in the surface sediments

Table 3 Mean concentration in size fraction during pre-monsoon and post-monsoon

Size (μm)	Al (%)		Fe (%)		Li (mg kg^{-1})		Pb (mg kg^{-1})		Zn (mg kg^{-1})		Cr (mg kg^{-1})		Ba (mg kg^{-1})		Co (mg kg^{-1})		Cu (mg kg^{-1})		Mg (mg kg^{-1})		Mn (mg kg^{-1})	
	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	POSt-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M
40																						
Mean	1.6	0.901	1.7	1.5	9.3	11	43	23	59	20	22	23	154	101	5.7	3.2	19	4.3	6695	9100	263	159
STDV	±1.2	±0.4	±0.9	±0.4	±2.8	±3.2	±17	±5.9	±26	±4.9	±8.7	±6.4	±99	±24	±3.6	±0.4	±6.3	±1.5	±2339	±1729	±117	±123
63																						
Mean	1.8	0.821	2.1	1.9	9.3	9.8	47	22	57	20	20	22	147	120	5.9	2.9	18	4.7	6538	8645	253	174
STDV	±1.2	±0.379	±1.3	±0.710	±3.9	±3.2	±21	±3.9	±23	±5.5	±10	±5.2	±104	±43	±3.4	±0.730	±5.4	±2.1	±2436	±2035	±90	±105
90																						
Mean	1.8	0.745	2.1	1.8	8.7	8	44	19	57	18	17	15	125	137	4.9	2.4	17	4	6536	7943	251	179
STDV	±1.1	±0.36	±1.3	±0.880	±3.9	±2.8	±20	±5.7	±27	±5.0	±8.7	±5.7	±100	±66	±2.9	±0.780	±4.4	±1.8	±2315	±2343	±161	±94
125																						
Mean	1.2	0.591	1.6	1.3	7.4	6.3	37	16	35	16	9.9	10	99	141	4.1	2	10.9	2.8	6065	7174	131	138
STDV	±0.850	±0.290	±1.1	±0.690	±3.3	±3.1	±17	±4.6	±18	±4.6	±4.2	±4.2	±81	±82	±2.4	±1.0	±4.6	±1.1	±3318	±2754	±122	±81
250																						
Mean	0.971	0.476	1.4	1.1	7.2	5.4	31	14	30	8.5	8.3	8.1	79	110	4.1	1.9	9.8	2.2	6120	6776	100	106
STDV	±0.74	±0.44	±1.1	±0.820	±3.7	±4.0	±18	±5.7	±16	±4.8	±4.5	±5.7	±68	±83	±2.5	±1.1	±4.7	±1.0	±4047	±2705	±100	±96
500																						
Mean	0.78	0.326	0.99	1	6	4.6	27	12	28	6.3	7.5	6.9	60	79	3.5	1.1	9.8	1.8	5578	6108	75	86
STDV	±0.700	±0.420	±0.710	±0.750	±3.2	±3.9	±17	±5.5	±18	±3.3	±4.5	±5.4	±41	±75	±1.9	±1.1	±4.9	±1.0	±3543	±2813	±92	±90

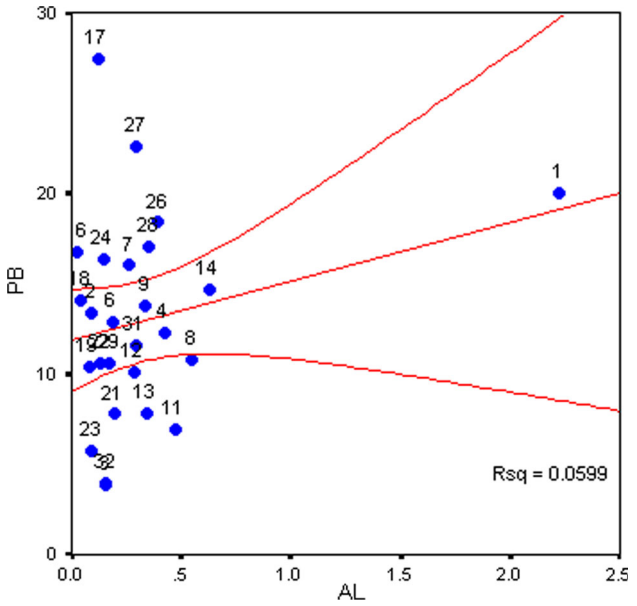

Fig. 2 Pb normalization for a 500-μm particle size during post-monsoon

of South China Sea off Pahang coast. The station PH1 was located at the Transect 1, with high density of human population, Kuantan Port and several small rivers nearby. The PH1 was also located near to a small gulf with a current vortex circular flow. The listed activities are the probable causes of high levels of Al, Cr, Li, and Mn at the station PH1. A concentration of Ba was found to be extremely high at the station PH12, i.e., which is the furthest station from the coastline in the Transect 3 during the post-monsoon period as affected by the South China Sea strong currents. The current drought during the post-monsoon period was strongly observed compared with pre-monsoon period (Adiana et al. 2014). However, the normalization graph for Ba was similar to Al, Cr, Li, and Mn that define the non-anthropogenic sources.

Apart from that, the concentrations of Co, Cu, Fe, Pb, and Zn were highly distributed in the coastal region, whereas Mg was randomly distributed among the sampling stations. According to the normalization graphs and the calculated EF values, Co, Cu, Fe, and Mg were considered as naturally contributed to the collected surface sediment. Pb concentration laid outside of 95 % confidence level (Fig. 2), and the EF value of Pb was higher in a fractional size of 250 μm (EF = 51) and 500 μm (EF = 57). Further analysis was carried out using the geoaccumulation index to determine a level of Pb pollution. The *Igeo* test (Table 4) shows a Pb level is 'non-polluted' to moderately polluted. An average value is between −0.74 and 0.72. A sample size of 40 and 63 μm fell in a 'non-polluted' to 'moderately polluted,' whereas a sample size of 90–500 μm showed the *Igeo* level of 'non- polluted'. Based on the Pearson

Table 4 EF and *Igeo* average in the post-monsoon samples

Particle size (μm)	Enrichment factor	Geoaccumulation index
40		
Mean	18	0.21
STDEV	7.7	0.42
63		
Mean	21	0.18
SDTEV	10	0.27
90		
Mean	22	−0.08
SDTEV	22	0.44
125		
Mean	21	−0.27
SDTEV	10	0.4
250		
Mean	51	−0.56
SDTEV	99	0.72
500		
Mean	57	−0.74
SDTEV	79	0.7

correlation, a significant correlation was found between Pb in relation to Al, EF value and sediment particle size. A concentration of Al, in particular grain sizes, played an important role in the EF determination, especially for a sample highly contains of sand. In general, a low concentration of Al increased the EF value, although no anthropogenic source was involved.

Recently, Pb is commonly used in an antifouling paint, alternatively, for the tributylin (Bryan and Langston 1992; Yebra et al. 2004). This type of paint is frequently used in a region near a coastline. Consequently, it will contribute to an input of Pb into a marine water column, namely, the South China Sea. During the post-monsoon season, a high concentration of Co, Cu, and Mg was found in the coarse particle size at the station, PH31. It is due to the presence of a seawater current between the Tioman Island and Seri Buat Island. The increasing in seawater current velocity through a narrow path between both the islands washed away the small particle size from station PH31 and leaved the coarse sediment settled down at station PH31.

Distribution of elements during the pre-monsoon period

During the period of the pre-monsoon, most of the selected elements were randomly distributed particularly, the Mg. Li and Al showed high concentrations in the transect 3, 4, 5 and coastal region. A similar situation occurred with Cr, Co, and Ba, as they were highly distributed at the transects

Table 5 EF and *Igeo* average in the pre-monsoon samples

Particle size (μm)	Enrichment factor	Geoaccumulation index
40		
Mean	28	1
STDEV	20	0.55
63		
Mean	25	1.1
STDEV	26	0.66
90		
Mean	19	1
STDEV	10	0.66
125		
Mean	26	0.8
STDEV	19	0.64
250		
Mean	34	0.52
STDEV	31	0.72
500		
Mean	46	0.26
STDEV	53	0.82

3 and 4. The concentration of Mn was high at transects 1 and 2. The concentrations of Fe, Pb, Cu, and Zn were high at the nearer coastal stations and the middle transects nearby the Pahang River estuary. A probable high input of Fe, Pb, Cu, and Zn was due to a river-flow discharge from the land-based activities via the Pahang River estuary. The Pahang River is the biggest river in the Peninsular Malaysia. The estuary has a shallow depth with a mild slope within 10 km toward the offshore. A high concentration of the elements in this area is due to the strong river currents outflow the sea compared with the sea current. The flushed out suspended materials through the Pahang River precipitate on the seabed surface of the South China Sea off the Pahang River. During the pre-monsoon season, the suspended material is easier precipitate than during the post-monsoon season due to the lack of water turbulence and low water level.

Despite of high distribution of selected elements found in the surface sediment, the normalization graphs showed most of the elements were naturally exist except for Pb. Similar to the post-monsoon season (Table 5; Fig. 3), Pb was laid outside of 95 % confidence level. The EF values were higher than the earth's crust value. An input of Pb in the pre-monsoon period was less than the post-monsoon, which received a lot of influx of the rivers with large quantities due to a heavy rain. However, the *Igeo* is between 0.26 and 1.1 in all particle sizes, classified as non-polluted to moderately polluted.

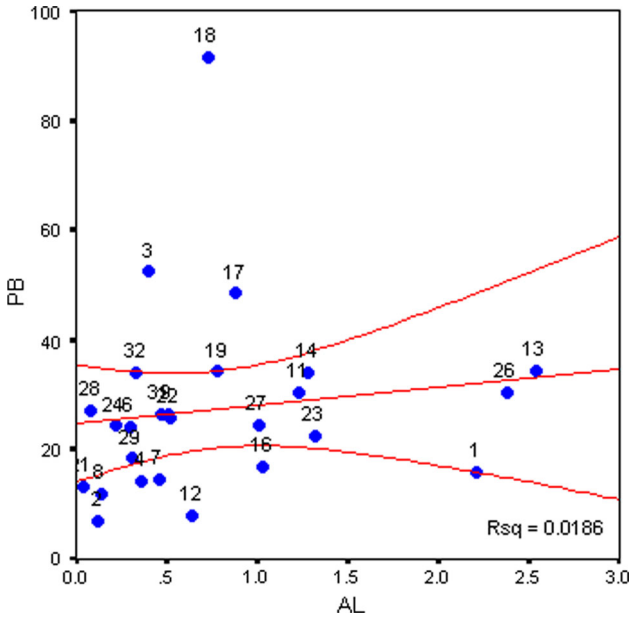

Fig. 3 Pb normalization for a 500-μm particle size during pre-monsoon

Distribution of elements in correlation with sediment particle sizes

The element distribution showed that all the elements are high in the fine grain size, namely, 40, 63, and 90 μm. The elements' concentration increases with the decreasing in sediment size, which is in agreement with several studies conducted measuring the elements' concentration in the size fractions. A study by Stone and Droppo (1996) reported that the concentrations of Pb, Cu, and Zn in river sediment samples increased due to a decline in a size of particle. A high element concentration was derived from the fine particles of 40, 63, and 90 μm in size. The lowest concentrations were mostly derived from the coarse particles sized between 250 and 500 μm. An effect of a size of a sediment particle is crucial to determine a high and low element concentration, as indicated in the reference materials. A fine particle size has a large surface area that facilitates the elements to stick compared with the coarse particle size.

It has been observed by many research studies that the highest element concentrations were strongly correlated with the sediment particle size that is less than 63 μm depending on the width of a surface particle (Thorne and Nickless 1981; Förstner et al. 1982; Arujo et al. 1988; Cauwet 1987). A characteristic of a fine particle sediment (having a large surface width, high organic content, and high bond capacity) explains most of a particle sediment's fine bond; however, the physical chemistry qualities the rest, especially salinity is very important (Hamilton et al.

Table 6 *p* value of the Anova test without replicating for an element

	Mg	Al	Cr	Mn	Fe	Co	Cu	Zn	Ba	Pb	Li
40											
Station	≥0.05	≥0.05	≤0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05
Season	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05	≤0.05	≥0.05	≥0.05	≥0.05
63											
Station	≤0.05	≥0.05	≤0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05
Season	≥0.05	≤0.05	≥0.05	≤0.05	≥0.05	≤0.05	≤0.05	≤0.05	≥0.05	≤0.05	≥0.05
90											
Station	≤0.05	≤0.05	≤0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05	≥0.05	≤0.05
Season	≥0.05	≤0.05	≤0.05	≤0.05	≥0.05	≤0.05	≤0.05	≤0.05	≥0.05	≤0.05	≥0.05
125											
Station	≤0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05	≥0.05	≥0.05	≤0.05	≥0.05	≥0.05
Season	≥0.05	≤0.05	≥0.05	≥0.05	≥0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≥0.05
250											
Station	≥0.05	≥0.05	≤0.05	≥0.05	≥0.05	≤0.05	≥0.05	≥0.05	≤0.05	≥0.05	≤0.05
Season	≥0.05	≤0.05	≥0.05	≥0.05	≥0.05	≤0.05	≤0.05	≤0.05	≥0.05	≤0.05	≤0.05
500											
Station	≥0.05	≤0.05	≤0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≥0.05	≤0.05
Season	≥0.05	≤0.05	≥0.05	≥0.05	≥0.05	≤0.05	≤0.05	≤0.05	≥0.05	≤0.05	≥0.05

1979; Apte et al. 1989; Little and Smith 1994). Hallberg (1974) found that the concentrations of heavy elements in a coastal area are related to a total organic material and fine size of a particle. However, in an anomalous state, a concentration of an element does not increase with a decrease in a size of a particle size (Moore et al. 1989; Ramesh et al. 1990; Krumgalz 1989; Combest 1991). A chemical composition and mineralogy, a degree of surface oxidation, and total organic material influence a content level of an element in a sediment fraction and affect a concentration of elements in the sediment samples (Martinic et al. 1990; Krumgalz 1989).

The two-way Anova showed all elements have a significant value ($p \leq 0.05$) between different seasons except for Fe as it was not affected by different seasons or stations (Table 6).

Elements distribution between pre-monsoon and post-monsoon in relation to the sediment grain size

A high concentration of Al, Fe, Pb, Zn, Co, and Cu appeared during the pre-monsoon compared with the post-monsoon season in all the sizes of fractions. However, Mg showed high concentration during the post-monsoon in all the sizes of fractions. During the pre-monsoon, the highest concentrations of Li and Cr showed in the coarse fractions, whereas Ba was highly distributed in the fine fractions. In the meantime, during the post-monsoon season, the high concentrations of Li and Cr were found in the fine fractions, while Ba was high in the coarse fractions.

Figure 4 shows a high concentration of Al, Fe, Pb, Zn, Ba, Co, Cu, Mg, and Mn during the pre-monsoon season. A concentration of Li is high during the post-monsoon season. A Cr shows similar level of concentration during the pre- and post-monsoon seasons (Fig. 4). A concentration of Mg is the same between the grain sizes mainly in the post-monsoon due to an influence of salt content in the marine water column. The concentrations of Al and Pb are two times; Zn and Co are three times as well as Cu is four times higher during the pre-monsoon than the post-monsoon period.

Table 7 shows a comparison of elements concentration (min and max) elsewhere. The concentrations of element in this study were comparable with those found in Terengganu sediment (Shazili et al. 2007) except for Cu, Zn, and Pb were slightly higher than the concentration level discovered by Shazili et al. (2007). Besides that, the element's concentration was lower than the guided value by Australian and New Zealand for fresh and marine system (Anzec 2000). The concentration of selected elements found in this study was lower than those reported in the earth crust (Mason and Moore 1982) except for Pb, the concentration was higher than the earth crust value due to enrichment of Pb via human activities.

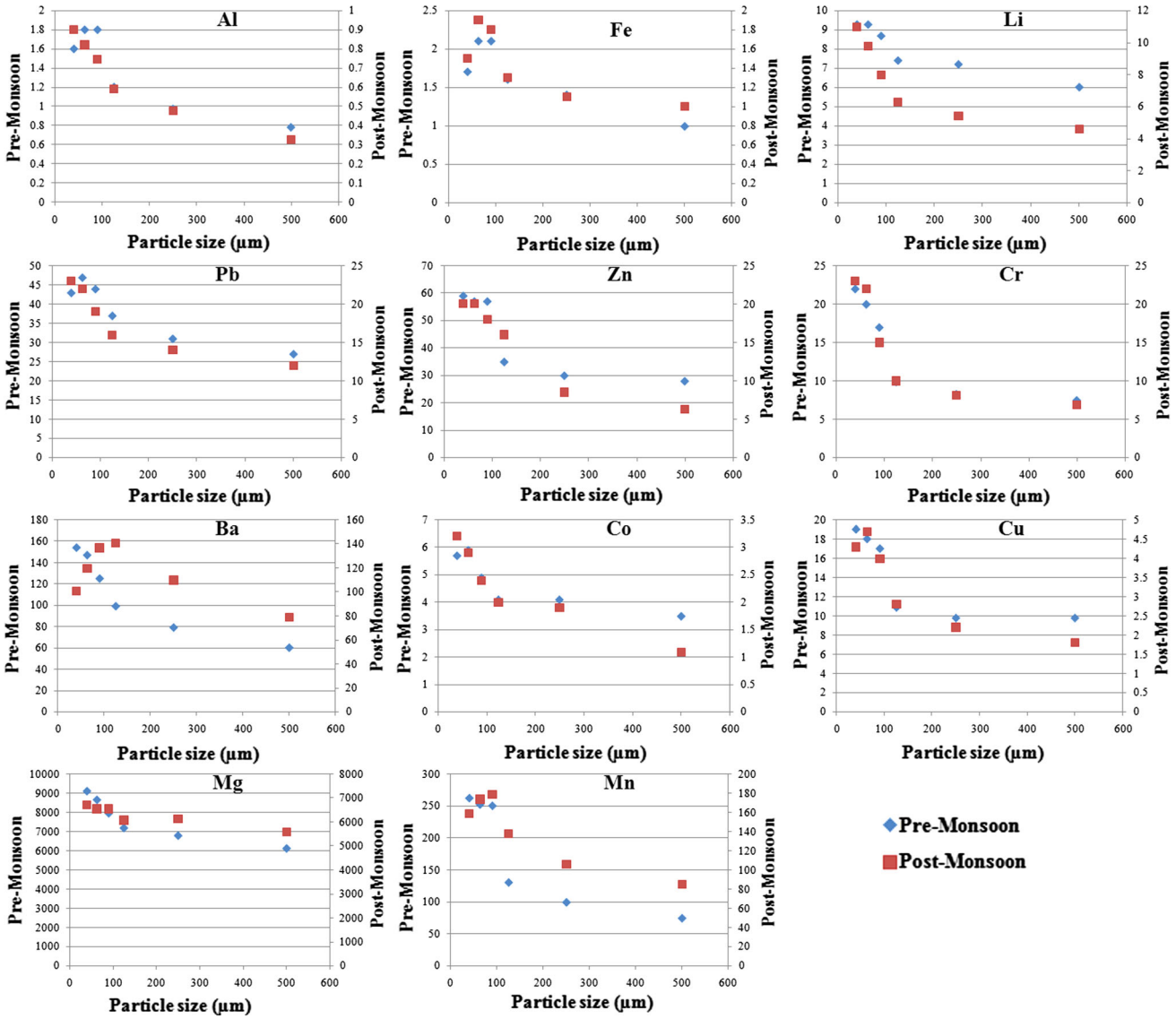

Fig. 4 Elements concentration average during the pre and post-monsoon seasons in a size fraction

Conclusion

Generally, the sediment particle size was affecting the element's concentration. The concentration of Al, Cr, Li, Mn, Ba, Co, Fe, Pb, and Zn decreased in a larger sediment particle. A sample of size 63 µm showed the highest concentration of an overall size studied. In a meanwhile, a sample size of 250 and 500 µm showed the lowest concentration of studied elements. The stronger correlation between studied elements with Al compared with Fe and Li lead to the selection of Al as a normalization element. The normalization graphs showed a distribution of Cr, Li, Mn, Ba, Co, Cu, Fe, Pb, and Zn that fulfills a natural concentration pattern. Some samples having a size of 125 and 500 µm showed the anthropogenic effect in the enrichment factor analysis, such as Fe, Zn, Cr, and Pb. However, the geoaccumulation index showed Fe, Zn, and Cr was classified as non-polluted, whereas Pb was found to be non-polluted to moderately polluted. It showed that the low concentration of Al in the sediment due to sandy sediment bed causing a high EF value for Pb. Therefore, a normalization of the elements verses Al for sandy area was not precise, because it provided an anthropogenic effect due to a very low concentration of Al. Besides that, an average

Table 7 Comparison between element concentration (min and max) with elsewhere

	40 μm	63 μm	90 μm	125 μm	250 μm	500 μm	*a*	*b*	*c*	*d*	*e*
Mg (%)											
Pre M	0.23–12	0.08–1.1	0.28–12	0.610	0.610	0.560	na	*td*	*td*	*td*	2.1
Post M	0.65–1.9	0.61–1.4	0.47–1.4	0.720	0.680	0.610					
Al (%)											
Pre M	0.25–3.4	0.33–42	0.53–4.0	1.3	1.0	0.780	4.5	*td*	*td*	*td*	8.1
Post M	0.56–1.8	0.38–1.9	0.20–1.6	0.590	0.480	0.330					
Cr (mg kg^{-1})											
Pre M	10–38	8.0–47	4.2–40	10	8.3	7.5	18	32	26	52	100
Post M	12–36	12–30	7.8–34	11	8.1	6.9					
Mn (mg kg^{-1})											
Pre M	91–528	132–460	74–663	132	101	75	306	100	460	*td*	950
Post M	50–395	60–409	53–417	138	107	87					
Fe (%)											
Pre M	0.81–3.4	0.59–5.3	0.56–6.0	1.6	1.4	1.0	3.8	200	*td*	*td*	5.0
Post M	0.92–2.3	1.2–3.5	1.1–4.8	1.4	1.2	1.1					
Co (mg kg^{-1})											
Pre M	2.3–13	1.8–13	1.3–11	4.1	4.1	3.6	*td*	20	*td*	*td*	25
Post M	2.5–3.6	1.4–4.4	1.1–3.9	2.0	1.9	1.8					
Cu (mg kg^{-1})											
Pre M	8.8–32	8.7–25	8.0–25	11	10	10	4.3	34	16	19	55
Post M	2.7–8.4	2.5–9.4	0.91–7.5	2.8	2.3	1.9					
Zn (mg kg^{-1})											
Pre M	17–28	72–106	19–120	35	31	29	21	50	120	124	70
Post M	10–28	10–33	7.9–31	17	8.5	6.4					
Ba (mg kg^{-1})											
Pre M	45–311	18–353	25–363	100	79	60	*Id*	165	*td*	*td*	*500*
Post M	80–157	73–231	42–296	142	111	79					
Pb (mg kg^{-1})											
Pre M	23–85	20–89	20–97	37	32	27	15	47	31	30	13
Post M	11–33	14–29	10–35	17	15	13					
Li (mg kg^{-1})											
Pre M	5.6–14	2.5–16	3.5–20	7.5	7.2	6.1	*Id*	2.0	*td*	*td*	*20*
Post M	7.2–18	3.6–17	3.4–15	*6.3*	5.5	4.7					

na not available, *Pre M* per monsoon, *Post M* post monsoon

(a) Terenggu, Shazili et al. (2007); (b) Aquatic toxicity reference value (1999); (c) Anzec (2000); (d) Sediment quality guideline, USEPA (2000); (e) Earth crust, Mason and Moore (1982)

concentration of the elements in the pre-monsoon's sample is higher than the post-monsoon's sample. The South China Sea current influence, freshwater entry, and rain have resulted in a decrease in the elements' concentration in the post-monsoon's sample.

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