EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 8(1) (2015) 133-143

Distribution of Selected Heavy Metals in Sediment of the River Basin of Coastal Area of Chanthaburi Province, Gulf of Thailand

Jakkapan Potipat [a, b], Nongnutch Tangkrock-olan [c] and Herbert F. Helander [d]

[a] *Graduate School, Faculty of Science, Burapha University, Chonburi, 20131 Thailand*
[b] *Department of Environmental Science, Faculty of Science and Technology, Rambhai Barni Rajabhat University, Chantaburi, 22000 Thailand*
[c] *Department of Aquatic Science, Faculty of Science, Burapha University, Chonburi, 20131 Thailand*
[d] *Department of Gastroresearch, Sahlgren Academy, Göteborg University, Sweden*

Abstract

The sediment samples from 24 stations in coastal area of Chanthaburi Province were collected during March 2012 to March 2013 and analyzed for heavy metal contents (Pb, Cd, Cr, Fe, Cu and Zn), pH, organic matters and grain sizes. The correlation analyses showed that heavy metal concentrations were affected by the content of organic matter and the size of clay particles. The evaluation of the quality of sediment was carried out using the geoaccumulation index (I_{geo}) and the enrichment factor (EF) as well as the comparison with those in the Thailand's sediment quality guideline (SQG) values. The results of the geoaccumulation index and the enrichment factor values of the heavy metals content in the sediments revealed that the study area was unpolluted and not enriched, respectively. The relationship between the heavy metals concentration and the organic matter, and the clay particle was proposed by using the multiple regression equations.

Keywords: heavy metals; geoaccumulation index (I_{geo}); enrichment factor (EF); Chanthaburi Province

1. Introduction

Heavy metal pollution is a serious and widely environmental problem due to the persistent and non-biodegradable properties of the contaminants. Sediments are ultimate sink and storage of heavy metals accumulated in coastal areas carried by particles that have been transported as a result of erosion and advection from original sites in the terrestrial environment (Förstner, 1978).

The distribution of heavy metals level in the sediments are often analyzed based on the total metal content (Yap and Wong, 2011) as well as some geochemical indices to help and support the investigation of heavy metal pollution in the study area. The degree of heavy metals loading in the sediment can be harmful to the environment depending on the geochemical condition existing in the sediments. Peng *et al*. (2009) reported that the data of pH, organic matter and grain size which temporally and spatially varied amongst collected sediment samples are main influence on heavy metals mobilization in sediments.

The studies using the geoaccumulation index (I_{geo}) and the enrichment factor (EF) to study on the distribution of heavy metals in the sediments as well as to evaluate and to assess the degree of heavy metals contamination of polltuion in the land-sea environment in many parts of the world (Naji and Ismail, 2011; Yap and Wong, 2011; Banerjee *et al*., 2012; Ong *et al*., 2013).

The coastal area of Chanthburi Province on the Gulf of Thailand has a total coastline of approximately 120 kilometers. It covers around 1,722 square kilometer of the three river basin namely: the Wang-Ta-Nord, the Chanthaburi and the Welu. The largest mangrove area in the eastern part of Thailand with high abundance and biodiversity of flora and fauna was located in the Welu river basin (Aksornkoae, 1975). This region is notable for various kinds of anthropogenic activities including: agriculture, fisheries, gemstone mining, tourism, recreation activities and urban communities (Raine, 1994).

The aim of this study is to investigate the concentration and the distribution of heavy metals in the surface sediments from 24 stations of the river basin of coastal area of Chanthaburi Province and to classify the quality assessment of surface sediments by using the geoaccumulation index (I_{geo}) and the enrichment factor (EF). The determination on the relationship between the heavy metal concentrations and sediment characteristics (pH, organic matter and grain size) and the evaluation on the distribution of heavy metals using PCA (Principal Component Analysis) and the multiple regression anlysis have been included.

2. Materials and Methods

2.1. Sediment sampling station

The surface sediments were collected from 24 stations along the study sites which were divided into 3 zones symbolically: A, B and C representing industrial (near Map Ta Phut industrial estate), urban community and agriculture or conservative land use areas, respectively (Fig. 1). At each station, the composite sediments of 3 subsamples were collected by using the Ekman grab during March 2012 to March 2013. The surface sediment samples from each station were placed in the polyethylene plastic bags and kept in an ice box during the transportation to the laboratory at Rambhai Barni Rajabhat University to be stored at -20^{o}C in a freezer for further analysis

2.2. Heavy metals analysis

The heavy metals determined included Pb, Cd, Cr, Fe, Cu and Zn. The sediment samples were microwave digested using a mixture of aqua regia (HNO_3: HCl, 1:3 v/v) and hydrofluoric acid (HF) (Thongra-ar *et al*., 2008). The instrumental analysis was carried out by using the graphite furnace atomic absorption spectrophotometer Model SpectrAA-640 Varian (Pb, Cd, Cr) and the flame atomic absorption spectrophotometer Model Spectrometer 3110, Perkin-Elmer (Fe, Cu, Zn).

The selected sediment characteristics were determined as follows: the pH in surface sediments were measured in a 1: 2.5 (sediment: water) suspension (Madejón *et al*., 2002), organic matter (OM) by using the weight loss on ignition technique (Combs and Nathan, 1998) and particle size the distribution by using the sieve analysis technique (American Society for Testing Materials, 2007).

The precision and accuracy of the analytical techniques were assessed by comparing with those of the Marine Sediment Reference Material (MESS-3) from the National Research Council of Canada and this was found to be close to the certified values (Table 1).

2.3. Statistical analysis

All statistical analyses were performed by using Statistical Package for Social Science (SPSS) Version 18 (Serial No.5083337). The correlation coefficient between the heavy metal concentrations, the organic matter, the grain size and the pH in the surface sediment showed differences of these relationships. The Principal Component Analysis (PCA) and the multiple regression technique were used to summarize of the distribution of heavy metals in the study area.

3. Results and Discussion

3.1. The concentration of heavy metals and sediment characteristics

The average variation of heavy metal concentrations in the sediments of the river basin of coastal area of Chanthaburi Province from 24 stations were 1.818 ± 0.525 µg/g for Pb, 0.018 ± 0.005 µg/g for Cd, 8.644 ± 1.648 µg/g for Cr, 17,860 ± 3,385 µg/g for Fe, 7.414 ± 1.952 µg/g for Cu and 18.122 ± 3.367 µg/g for Zn (means ± SD) as shown in Table 2. The highest average concentrations of Pb, Cd, Cr, Fe and Zn in the sediment were observed in the Chanthaburi river basin (B), while the highest average concentration of Cu was found in the Welu river basin (C). All the heavy metals concentrations observed were lower than those from the sediment quality guideline (SQG) for Thailand (PCD, 2006) as well as the world average sediment (Sparks, 2003).

The correlation coefficient analysis between the heavy metal concentrations and the sediment characteristics with correlation coefficient values were shown in Table 3 displaying positive correlation with the sediment organic matter (OM) in silt and clay particles, whereas Pb, Fe and Zn showed negative correlation with pH and sand particle. The result of this study indicated that the OM and clay particle were relatively more statistically significant than pH, silt and sand particles in controlling the distribution of Pb, Cd, Cr, Fe, Cu and Zn in the sediments of high *r*

Table 1. The content analysis and recovery percentage of the certified reference material (Marine Sediment Reference Materials: MESS-3) from the National Research Council, Canada

Element	Certified value	Present study (n=5)	% Recovery	Coefficient of variation
Pb	21.1 ± 0.7	18.8 ± 0.7	89.0	3.7
Cd	0.24 ± 0.01	0.20 ± 0.02	84.2	10
Cr	105 ± 4	93 ± 5	88.8	5.3
Fe	43,400 ± 1,100	38,870 ± 850	89.6	2.2
Cu	33.9 ± 1.6	37.5 ± 1.6	110.6	4.3
Zn	159 ± 8	168 ± 7	105.7	4.2

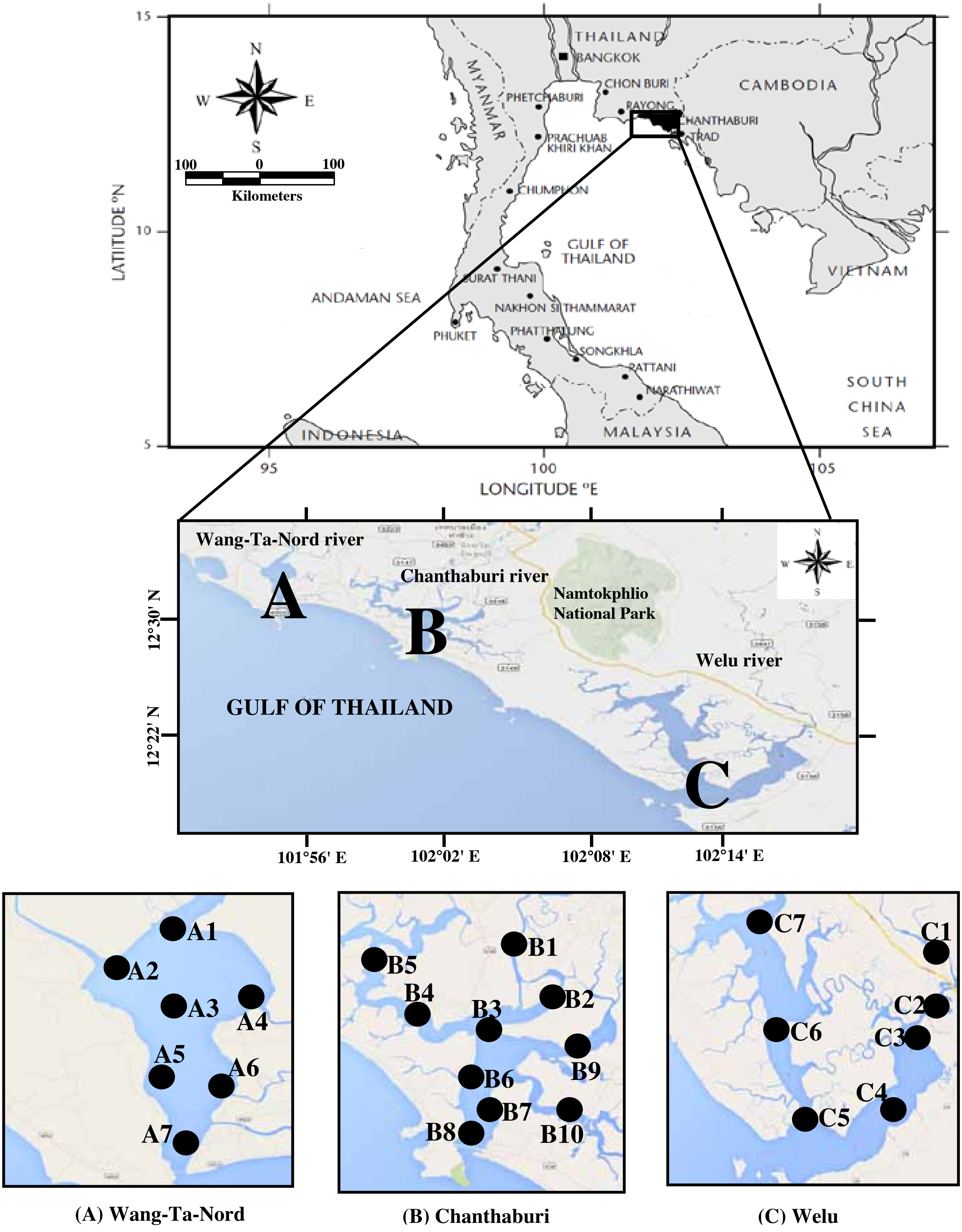

Figure 1. The three river basins of Chanthaburi coastal area and sampling stations

Table 2. The concentration of heavy metals (μg/g) and characteristics in sediments of the three river basin of coastal area of Chanthaburi Province

Location		Concentration of heavy metals (μg/g)						pH	OM %	Particle Size Distribution		
		Pb	Cd	Cr	Fe	Cu	Zn			Sand %	Silt %	Clay %
A Wang-Ta-Nord (7 stations)	Mean	1.536	0.016	8.192	16,689	7.542	17.930	7.66	2.4	41.5	41.7	16.8
	Max	2.511	0.024	10.731	20,492	9.800	21.392	8.11	3.3	45.3	45.2	20.6
	Min	1.045	0.010	6.327	10,733	5.831	13.322	7.26	1.9	37.5	39.3	13.9
B Chathaburi (10 stations)	Mean	2.209	0.020	9.322	19,615	6.653	19.199	7.77	2.7	38.9	41.6	19.5
	Max	3.039	0.028	11.308	22,671	8.998	21.941	8.23	3.6	42.3	45.6	24.3
	Min	1.577	0.017	7.740	16,981	3.692	14.272	7.23	1.9	33.8	37.0	16.3
C Welu (7 stations)	Mean	1.542	0.016	8.127	16,526	8.372	16.774	7.49	3.1	39.1	40.8	20.1
	Max	2.075	0.027	10.763	20,767	10.832	22.675	8.06	4.2	42.8	43.7	25.2
	Min	1.084	0.09	4.948	10,059	5.938	11.644	7.04	2.5	35.6	39.2	16.9
Sediments of the coastal area of Chanthaburi (24 stations)	Mean	1.818	0.018	8.644	17,860	7.414	18.122	7.66	2.7	39.7	41.4	18.9
	SD	0.525	0.005	1.648	3,385	1.952	3.367	0.37	0.6	2.8	2.3	2.9
World average sediment Sparks (2003)		19	0.17	72	41,000	33	95					
Proposed sediment quality guidelines (SQG) for Thailand by PCD (2006)*		35.8	0.99	81	-	31.6	121					

* Equilibrium Partitioning Approach (EqP) Method

Table 3. The correlation coefficient between heavy metals, pH, organic matter and grain size (n=24)

	Pb	Cd	Cr	Fe	Cu	Zn	pH	OM	Sand	Silt	Clay
Pb	1.000										
Cd	0.687**	1.000									
Cr	0.484*	0.636**	1.000								
Fe	0.409*	0.553**	0.638**	1.000							
Cu	-0.009	0.339	0.249	0.122	1.000						
Zn	0.331	0.682**	0.608**	0.645**	0.312	1.000					
pH	0.033	0.234	0.327	-0.697**	0.308	-0.619**	1.000				
OM	0.556**	0.613**	0.422*	0.443*	0.408*	0.558**	-0.462*	1.000			
Sand	-0.103	0.105	0.072	-0.160	0.254	0.144	0.131	-0.486*	1.000		
Silt	0.099	0.063	0.253	0.066	0.268	0.164	0.157	-0.327	-0.384	1.000	
Clay	0.602**	0.553**	0.412*	0.473*	0.562**	0.575**	-0.246	0.740**	-0.688**	0.405*	1.000

*, **: Correlation is significant at the 0.05 and 0.01 level, respectively

values. Chen *et al*. (2007) demonstrated that the OM and clay were more important factor in affecting the heavy metals distribution than other characteristics in the studied sediment of high correlation coefficient values. An organic compound in the sediment plays an important role in heavy metals distribution because heavy metals are generally bounded in largest fraction to the OM (Peng *et al*., 2009). The grain size is the one of the most investigated supported indicative of heavy metals distribution when the grain size decreases and the metal contents increases.

3.2. Geoaccumulation index (I_{geo})

The geoaccumulation index (I_{geo}) was used to define the degree of anthropogenic pollution in the sediment (Förstner *et al*., 1993). The geoaccumulation index can be calculated using the following equation:

$$I_{geo} = \log_2\left(\frac{C_n}{1.5 \times B_n}\right)$$

where C_n is the measured concentration of the sediment for heavy metal (n), B_n is the geochemical background concentration of the heavy metal (n) and 1.5 is the correction factor for variation in the background values due to lithogenic effects. In the present study, the average crust concentrations were used as the background values of: 12.5 µg/g for Pb, 0.2 µg/g for Cd, 100 µg/g for Cr, 56,300 µg/g for Fe, 55 µg/g for Cu, and 70 µg/g for Zn (Taylor, 1964).

The classification and results of I_{geo} values of the study area are shown in Table 4 and in Table 5, respectively. Whereas, Table 5 show the negative values (I_{geo}<0) indicated that there was no pollution from the heavy metals in all the river basin of Chanthaburi coastline. Fe and Zn are highest I_{geo} values and concentration in sediment as shown in Fig. 2. Glasby *et al*. (2004) indicating that the crustal weathering may be the main source of Fe and Zn in the sediment which major element in the earth's crust have highest I_{geo} values. It is known that floods enhance the transportation of natural and anthropogenic sediment into the river and subsequently deposit in the environment of the river mouth. Chanthaburi Province was classified as a high risk area of landslide, water flow and flood due to the landslide disaster of Kitchakood Mountain in 2000 and flooding crisis in 2006 (Anecksamphant, 2004). Furthermore, Fe and Zn are micronutrients in a fertilizer and an addition to the ingredient of supplementary food in shrimp farms whereas in 2003 the shrimp farm land, urban land and agriculture developing area are continuously increasing in Chanthaburi Province up to these days (Runping and Kheoruenromne, 2003).

Table 4. The geoaccumulation index classification (Förstner *et al*., 1993)

Sediment Accumulation Index (I_{geo})	I_{geo} Class	Pollution Intensity
>5	6	Very Strong Pollution
>4-5	5	Strong to Very Strong
>3-4	4	Strongly Polluted
>2-3	3	Moderately to Strongly
>1-2	2	Moderately to Polluted
>0-1	1	Unpolluted to Moderate
<0	0	Practically Unpolluted

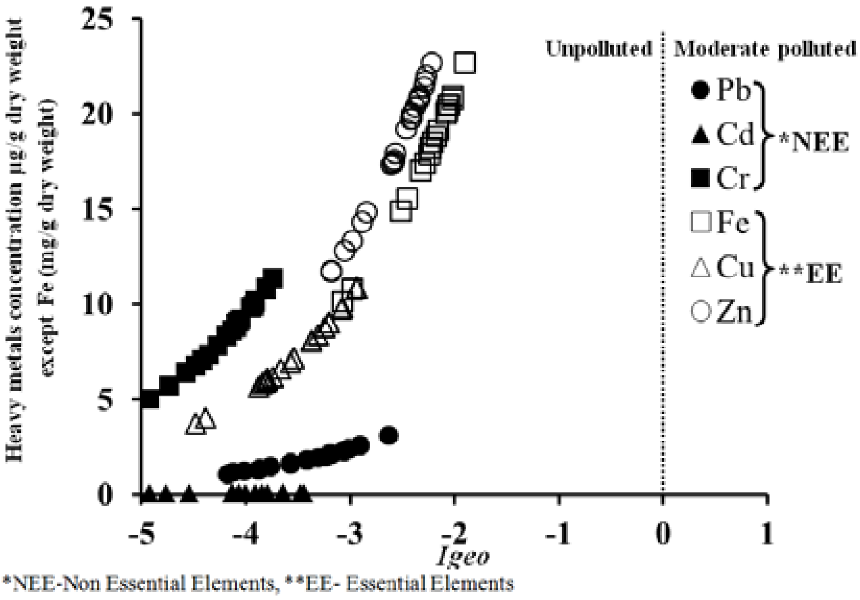

Figure 2. The plot of heavy metal concentrations and I_{geo} index

3.3. Enrichment Factor (EF)

The Enrichment Factor is a tool to differentiate the sources of heavy metals between lithogenic and naturally occurring Iron (Fe) whereas it has been used successfully by several researches to normalize the heavy metals distribution in river and estuarine sediments (Rule, 1986; Herut and Sandler, 2006; Naji and Ismail, 2011; Banerjee *et al*., 2012). The EF for Fe-normalization is defined by:

$$EF_{\text{Heavy metals}} = \frac{(M_X/Fe_X)_{\text{sample}}}{(M_C/Fe_C)_{\text{shale}}}$$

where M_x is the concentration of heavy metals in the examined sample, Fe_x is the concentration of Fe in the examined sample, M_c is the concentration of heavy metals in average shale or undisturbed sediment and Fe_c is the concentration of Fe in average shale or undisturbed sediments. As there were no reported data available, the average shale values used in this study were those by Turekian and Wedepohl (1961) of background levels heavy metals. The undisturbed sediment values utilized were: 20 µg/g for Pb, 0.3 µg/g for Cd, 90 µg/g for Cr, 45 µg/g for Cu, and 95 µg/g for Zn.

The EF results from the present investigation were shown in Table 5 and the classification of EF values was shown in Table 6. The EF values of all heavy metals at all stations were found to be less than 1 (EF<1) which indicated that there was no heavy metals enrichment detected in the study area (Fig. 3).

The results of an analysis of the I_{geo} and EF values (Figs. 2 and 3) showed that the distribution of the Essential Elements (Fe, Cu and Zn) were higher than that of the Non Essential Elements (Pb and Cd except Cr). Hem (1985) reported that Cr was the 17th most abundant metal in the earth's crust and it was found that the amount in sedimentary rock was higher than those of Pb and Cd. In addition, Cr is a major component of steel alloys furnitures (10-26%) and it is used in many products in daily life more than Pb and Cd (Bielicka *et al*., 2005).

Zn is a natural element of highest enrichment factor and high concentration found in the sediment in the river basin is a result of derivation and accelerated erosion on land (Baptista Neto *et al*., 2000). Furthermore, the widespread of urbanization, the use of fertilizers and pesticides in agricultural activities are minor sources of Zn (Ghrefat and Yusuf, 2006).

3.4. PCA (Principal Component Analysis)

The results of the PCA study on the sediment of the three sampling sites point out that the tendency of the heavy metals distribution was distinctly located which revealed an obvious separation in the first principal score axis as shown in Fig. 4. The first group containing the sample from the Welu river basin (C) could be distinguished in the lower right of the plot. The second group are mostly the sample from the Wang-Ta-Nord river basin (A) is located in the upper right of the plot. The third group of samples from the Chanthaburi river basin (B) was found in the left of the first principal score axis.

This PCA indicated the differences in the heavy metals concentration observed in the sediment samples from the three river basin of coastal area of Chanthaburi Province. The distribution of heavy metals depends on their concentration in the sediment as well as the

Table 5. Heavy metals enrichment factor (EF) and geoaccumulation index (I_{geo}) values in the three river basin of coastal area of Chanthaburi Province

Station	Pb		Cd		Cr		Fe		Cu		Zn	
	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}
A1	0.28	-3.88	0.15	-4.92	0.36	-4.35	-	-2.98	0.68	-3.57	0.69	-2.83
A2	0.35	-2.90	0.22	-3.64	0.22	-4.41	-	-2.31	0.61	-3.07	0.51	-2.59
A3	0.21	-3.56	0.15	-4.13	0.26	-4.08	-	-2.24	0.34	-3.81	0.60	-2.29
A4	0.17	-4.16	0.18	-4.13	0.29	-4.18	-	-2.51	0.44	-3.74	0.64	-2.46
A5	0.20	-3.41	0.15	-3.99	0.27	-3.80	-	-2.04	0.46	-3.20	0.48	-2.42
A6	0.20	-3.86	0.13	-4.54	0.30	-4.08	-	-2.44	0.48	-3.54	0.43	-2.98
A7	0.15	3.88	0.12	-4.32	0.16	-4.57	-	-2.05	0.41	-3.37	0.48	-2.41
B1	0.38	-2.63	0.18	-3.84	0.32	-3.74	-	-2.17	0.34	-3.78	0.46	-2.60
B2	0.31	-3.06	0.26	-3.43	0.28	-4.04	-	-2.31	0.44	-3.54	0.61	-2.34
B3	0.19	-3.57	0.13	-4.13	0.27	-3.90	-	-2.08	0.47	-3.20	0.43	-2.59
B4	0.26	-3.01	0.13	-4.13	0.22	-4.08	-	-2.02	0.29	-3.88	0.48	-2.40
B5	0.30	-2.90	0.17	-3.78	0.26	-3.94	-	-2.08	0.42	-3.37	0.51	-2.37
B6	0.27	-3.02	0.14	-4.06	0.23	-4.08	-	-2.06	0.19	-4.47	0.35	-2.88
B7	0.18	-3.41	0.14	-3.90	0.21	-4.06	-	-1.90	0.18	-4.38	0.48	-2.27
B8	0.26	-3.04	0.18	-3.64	0.25	-3.92	-	-2.02	0.29	-3.84	0.50	-2.33
B9	0.25	-3.22	0.17	-3.84	0.21	-4.27	-	-2.15	0.50	-3.20	0.46	-2.58
B10	0.28	-3.20	0.17	-4.06	0.27	-4.13	-	-2.31	0.51	-3.31	0.64	-2.26
C1	0.38	-3.56	0.17	-4.76	0.26	-4.92	-	-3.07	0.62	-3.80	0.58	-3.17
C2	0.24	-4.11	0.13	-5.06	0.28	-4.72	-	-2.98	0.59	-3.78	0.54	-3.17
C3	0.15	-4.01	0.08	-5.06	0.19	-4.47	-	-2.20	0.37	-3.66	0.34	-3.04
C4	0.18	-3.76	0.16	-4.06	0.25	-4.08	-	-2.22	0.51	-3.24	0.49	-2.56
C5	0.19	-3.56	0.14	-4.06	0.26	-3.90	-	-2.06	0.56	-2.93	0.56	-2.21
C6	0.28	-3.17	0.22	-3.64	0.30	-3.92	-	-2.28	0.59	-3.08	0.57	-2.40
C7	0.22	-3.31	0.20	-3.47	0.27	-3.80	-	-2.02	0.54	-2.93	0.50	-2.33
Max	0.38	-2.63	0.26	-3.43	0.36	-3.74	-	-1.90	0.68	-2.93	0.69	-2.21
Min	0.15	-4.16	0.08	-8.67	0.16	-4.92	-	-3.07	0.18	-4.47	0.34	-3.17
Mean	0.24	-3.42	0.16	-4.29	0.26	-4.14	-	-2.27	0.45	-3.53	0.51	-2.56
SD	0.07	0.42	0.04	1.04	0.04	0.30	-	0.32	0.13	0.41	0.09	0.29
Average crust (μg/g) [a]	12.5		0.2		100		56,300		55		70	
Average shale (μg/g) [b]	20		0.3		90		47,200		45		95	

(A-Wang-Ta-Nord, B-Chanthaburi and C-Welu)

[a] Taylor (1964)

[b] Turekian and Wedenphol (1961)

Table 6. The classification of enrichment factor (Naji and Ismail, 2011)

EF range	Assessment Category	Comment
< 1	I	no enrichment
1 - 2.9	II	minor enrichment
3 - 4.9	III	moderate enrichment
5 - 9.9	IV	moderately severe enrichment
10 - 24.9	V	severe enrichment
25 - 49.9	VI	very severe enrichment
> 50	VII	extremely severe enrichment

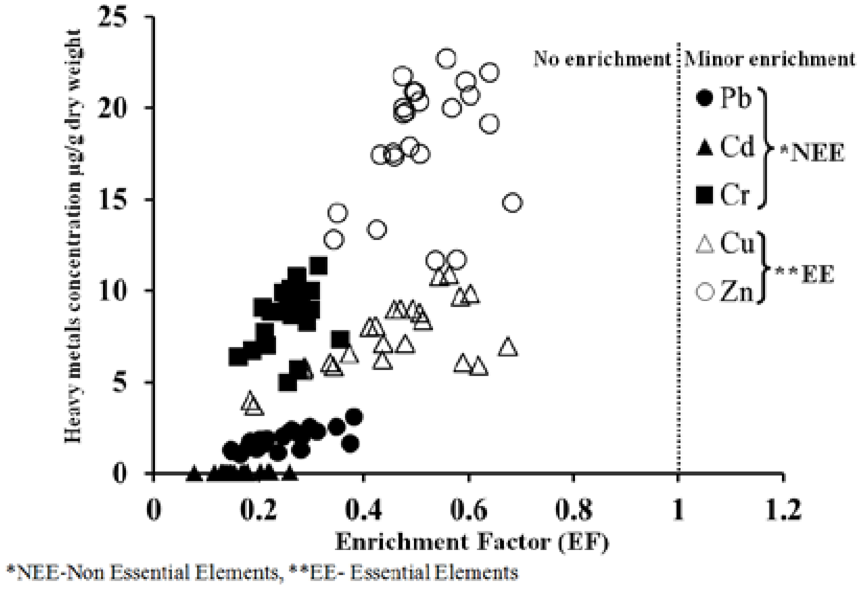

Figure 3. The plot of heavy metal concentrations and enrichment factor (EF)

physicochemical characteristics of both sediment and seawater (de Vallejuelo *et al.*, 2014). However, there are several sources of heavy metals in the sediment from the Chanthanburi coastline and from the different of land use in the boundary of each river basin. In the past (1991), land use in the coastal zone of Chanthaburi Province was dominated by prawn aquaculture developments (45.3% of the land portion of the study area). The major terrestrial land uses within the coastline are rice paddies (24.5%), fruit orchards (14.2%), mangrove forests (6.1%), rubber plantations (4.9%) and upland forests (3.5%) (Raine, 1994). Moreover, the widespread encroaching urbanization, tourism and recreation activities are continuously increasing in both upland and coastline area of Chanthaburi Province, especially along the Chanthaburi river.

3.5. Multiple regression analysis

The relationship between the heavy metals concentration and the sediment characteristics could

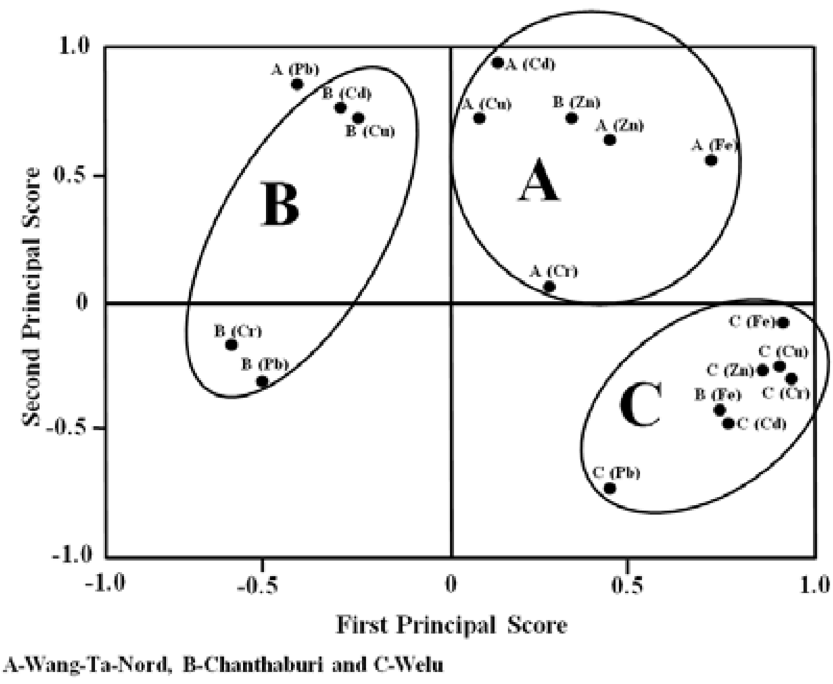

Figure 4. Principal component analysis of heavy metal concentrations in sediments of the three river basin of coastal area of Chanthaburi Province

Table 7. Multiple regression equation of heavy metals concentration in sediments of coastal area of Chanthaburi Province

Heavy metals (μg/g)	Multiple regression equation	R^2	Significance of regression
Pb	Y_{Pb} = 1.630 + 0.634(OM; %) + 0.101(Clay; %)	0.657	0.000
Cd	Y_{Cd} = 0.022 + 0.005(OM; %) + 0.001(Clay; %)	0.699	0.000
Cr	Y_{Cr} = 11.584 + 0.047(OM; %) + 0.149(Clay; %)	0.618	0.002
Fe	LogY_{Fe} = 3.397 + 0.038(OM; %) + 0.012(Clay; %) – 0.095(pH)	0.412	0.030
Cu	Y_{Cu} = 13.038 + 1.415(OM; %) + 0.094(Clay; %)	0.541	0.023
Zn	Y_{Zn} = 9.817 + 1.729(OM; %) + 0.002(Clay; %) – 1.696(pH)	0.433	0.032

be explained by the multiple regression equations as displayed in Table 7. The results of statistical analysis revealed that all heavy metals had significantly positive relationship with the organic matter (OM) and the clay particle size whereas Fe and Zn had also significantly negative relationship with the pH. This finding was in accordance with that of Buajan and Pumijumnong (2010) which demonstrated major affect and high relationship of OM to heavy metals in the sediment. The organic matter in the sediment is very important in controlling the heavy metals mobility and leaching in the sediment. The heavy metals forming complexes with OM can be carry to be deposited whereas the forms are enhanced or retained depending on the physicochemical characteristics of the sediments (Toribio and Romanyà, 2006). Haque and Subramanian (1982) reported that metal adsorption capacity increased with decreased grain size (sand<silt<clay) due to increased surface area.

For the changing pH in the sediment, it was found that the greater sediment acidity change, the sediment-porewater partitioning which was in favor of the dissolved phase would increase the dissolved metal concentration in the sediments (Hutchins *et al.*, 2007). The pH range of marine sediment is typically between 6.5 to 7.8 when pH drop to 5-6 the sediment would increase in the concentration of the heavy metals (Simspson *et al.*, 2004).

4. Conclusion

This study integrated two approaches for evaluation and monitoring of the heavy metals pollution, approach 1: comparing with Thailand's sediment quality guideline (SQG), approach 2: use sediment quality index (SQI) such as geoaccumulation index (I_{geo}) and enrichment factor (EF). The PCA and multiple regressions techniques used were combined to support and confirm the data analysis of the heavy metals distribution. The abundance of heavy metals measured in surface sediment was decreasing as follows: Fe>Zn>Cr>Cu>Pb>Cd and the major mechanism of the distribution of all heavy metals was controlled by the organic matter (OM) and the clay particle size. The geoaccumulation index (I_{geo}) and the enrichment factor (EF) showed that the low contamination of heavy metals was found at all stations which indicated that the heavy metals pollution in sediment of the river basin of coastal area of Chanthaburi was not a serious threat to the local ecosystem in study area. However, the investigation and monitoring should be continuously performance to assess the long term effect of heavy metals in Chanthaburi coastline.

Acknowledgements

This research work is a sub-theme of the Ph.D. dissertation entitled "Distribution, Bioconcentration and Depuration of Selected Heavy Metals in the River Basin of Chanthaburi Coastal Areas", which is financially supported by the Higher Education Research Promotion (HERP) under Office of the Higher Education Commission of Thailand. The author gratefully acknowledges Assistant Professor Dr. Pichan Sawangwong for their kindly help and invaluable assistance.

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Received 17 September 2014
Accepted 7 November 2014

Correspondence to
Mr.Jakkapan Potipat
Department of Environmental Science,
Faculty of Science and Technology,
Rambhai Barni Rajabhat University,
Chanthaburi, 22000
Thailand
Tel: +668 3068 0800
Fax: +66 3947 1060
Email: bomb1112@yahoo.com