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Original Article

Assessment of Heavy Metal Contents in Surface Sediment of the Tungguk River Surrounding the Industrial Complex of Gebeng City

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ABSTRACT: Gebeng is one of the most important industrial regions in Kuantan, Pahang. The study was conducted in the Gebeng industrial estate to investigate the effect of industrialization on heavy metal concentration in the river tributaries. Sediments were collected from 10 different strategic stations along the river bed. Selected heavy metals were measured by using Inductively Coupled Plasma Mass Spectrometry. Several approaches were used to assess the pollution level of studied sediments. The results revealed that sediments were highly polluted, especially by Co (Contamination factor up to 276.00, Enrichment factor up to 61.00 and Geo-accumulation index up to 55.00) and Hg (CF up to 120.00, EF up to 49.00 and Igeo up to 80.00). The studied heavy metal pollution were ranked as Co> Hg> As> Pb> Zn> Cu> Cr> Cd> Ni>Ba. Based on pollution level sampling stations were classified as 1>10>8>7>9>6>3>2>5>4. This study will help in the river management strategy of the nation through providing updated heavy metals status of the studied sediment.

KEYWORDS: Gebeng, Sediment, Heavy metals, Pollutant

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INTRODUCTION

Generally, sediments are being contaminated through industrial activities[1]. The main problem behind sediment pollution is the entry of metals in food chain and consumption by living beings[2]. Anthropogenic impact, parent material and weathering processes may influence a lot on heavy metal concentrations. Heavy metals are is a matter of concern because of their persistence and toxic effects[3]. The contaminants are not easily degradable by chemical and biological processes and thus have been posed as major pollution factors[4]. Now a day, heavy metal contaminations are severe in Malaysia[5]. It is reported that a large number of industries are active in Gebeng industrial area. The Tunggak is the main river in the studied area that is affected by industrial dumping and flows through the Gebeng industrial regions[6]. Despite socio-economic importance of the river, no studies have been conducted to find out heavy metal pollution in sediments. The objective of the research was to find out the heavy metal pollution of sediments from industrial stream in the study area.

MATERIALS AND METHODS

Study area and selection of sampling stations

Gebeng industrial estate is the main industrial area at Kuantan, the capital city of Pahang, Malaysia (Figure 1). The industrial region is located near Kuantan Port. On the basis of types of industries, topography and discharge points, a total of 10 stations were selected on the Tunggak river bed for sampling.

Sampling, data collection and analysis

Sediment samples were collected from the river bed on October 2012. Sediment sampling was made according to the standard procedure. Five replications of each sample were taken from each sampling station. Sediment samples were collected using Van Veen grab sampler from study area. The collected samples were put into the polythene bags. All samples were cleaned, air dried, ground and sieved in the laboratory before analysis.

Sediment quality guidelines (SQGs*)*

Different pollution measuring criteria for heavy metals evaluation such as Effect Range Low (ERL)[7], Low Alert Level (LAL)[8], High Alert Level (HAL)[9], Threshold Effect Level (TEL), Toxic Effect Threshold (TET) and Severe Effect Level (SEL)[7] from various sediment guidelines were used to comment on pollution level.

The sediment contamination assessment

Different pollution indicators were used such as enrichment factor (EF), contamination factor (CF), geo-accumulation index (Igeo), Pearson's correlation coefficient, principal component analysis and cluster analysis to get a relative ranking of sampling stations.

Enrichment Factor (EF)

Enrichment factor describes the anthropogenic impact on sediments by using the following equation.

EF= $$EF = \frac{(Me/X)sample}{(Me/X)background}$$

Where, M= Metal: X = (As, Ba, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn) in this study[10].

Contamination factor (CF)

Contamination factor is estimated by dividing the concentration of each metal in the sediment by the background value. It is used effectively for assessing contamination and evaluating the environmental pollution.

$$CF = \frac{C, heavymetal}{C, background}$$

Where C is concentration.CF values were suggested by Hakanson[11].

The geo accumulation index (Igeo)

The geo accumulation index is based on the geochemical data that makes possible to map the areas according to their pollution degree. Igeo values are calculated using the following equation[12].

$$\lg eo = \log 2\left(\frac{Cn}{1.5Bn}\right)$$

Where, Cn is the measured concentration of the element, Bn is the geochemical background concentration for the average continental shale and 1.5 is the factor. Certified values (µg/g) of heavy metals in standard reference material® 1646a estuarine sediment was used[13].

Laboratory Analysis

Air dried and sieved samples (2.00 mm sieves) were used for analysis. The amount of heavy metals was analyzed by microwave acid digestion procedure with a mixture of HNO_3 –HF-HCl[14]. After digestion, metals were determined by using Inductively Coupled Plasma Mass Spectrometry (ICPMS). Mercury was determined by taking 0.2 g sediment samples and then it was analyzed by Direct Mercury Analyzer (DMA 80).

Statistical Analyses

Statistical analysis was done by SPSS software using version 16.0. Standard deviation and average were calculated by SPSS. Pearson's correlation analysis (2 tailed), principal component analysis (PCA) and cluster analysis were done to find out the relationship among heavy metals and other parameters as well as the pollution level of various parameters.

RESULTS AND DISCUSSIONS

Arsenic (As)

Arsenic content in the samples ranged between 2.55-24.67 µg/g with a mean value of 10.22 µg/g (Table 1). The highest concentration of As was found at station 1 (24.67 µg/g.) and the least at station 3 (2.55 µg/g.). It showed that all sampling stations were above low alert level (LAL). Average values of As of stations 3, 4 and 5 were found between low alert level (LAL) and threshold effect level (TEL),whereas station 6, 7, 8 , 9 and 10 were above threshold effect level (TEL) but below toxic effect threshold (TET), nevertheless, only station 1 was found above TET range. Enrichment factors for As at station 1, 6, 7, 8 and 9 were deficiency to low enrichments, while remainder stations (2 and 4) were found significant enrichment. In addition, the sampling station 3, 5 and 10 were considered moderate enrichment[11]. Contamination factors of station 3, 4 and 5 were found as low contaminated, station

2, 6, 7, 8, 9 and 10 were observed moderately contaminated while station 1 was classified into considerable contamination[11]. The geo-accumulation indexes of all stations were found between 0.00 and 1.00 (Table 4), which categorized as unpolluted to moderately polluted[12]. As was positively correlated and statistically significant at 5% level with Co (r = 0.707, p = 0.022), Pb (r = 0.740, p = 0.014) and Zn (r = 0.757, p = 0.011). Moreover, Arsenic had a strong positive correlation with Cu (r = 0.864, p = 0.001) and Ni (r = 0.784, p = 0.007). Due to industrial processes the As content in the studied sediment was observed higher. The high arsenic pollution was recorded in the sediment of the Daliao River owing to intensive industrial activities[15].

Barium (Ba)
The analyzed Barium varied from 5.93 to 125.6 9 µg/g. (Table 1), where the average value was 46.63 µg/g. The highest Ba (125.69 µg/g) was found at station 10 while the lowest value was observed in station 4 (5.93 µg/g). The mean values of Ba at station 6, 8, 9 and 10 were observed above the LAL. Furthermore, Ba concentrations at station 10 were 2.5 times higher than LAL. EF values of all stations were <2, denoted as deficiency to low enrichment[10]. The CF of all sampling stations were exhibited <1, indicated that all the stations were included into low contamination[10]. The I-geo values of As for all stations were found unpolluted to moderately polluted[12]. It has been observed from correlation analysis that Ba had a moderate positive correlation with Hg (r = 0.668, p = 0.035). The Ba pollution was identified due to the activities of chemical industries, petrochemical industries, metal industries, steel industries, coal mining and coal using industries. Relic *et al*. determined Ba contamination because of industrial processes in petrochemical industrial area at Pancevo in Serbia[16].

Cadmium (Cd)
Cadmium content was relatively low ranged from 0.01 to 0.27 µg/g (Table 1) and the average value was 0.08 µg/g. The least value 0.01 µg/g. was observed at station 3, 4, 6 and 7 whereas the high value was measured at station 9. According to sediment quality guidelines, average values of station 3, 4 and 7 were below LAL, while remainder stations were above LAL. But the Cd concentrations of all stations exhibited below TEL and ERL. The results (Table 2) of EF were measured below 2 which evaluated as deficiency to low enrichment[10]. Calculated data of CF stated that stations 9 and 10 were above 1.00 and presented at Table 3 that included into moderate pollution class[11]. However, other stations were below 1.00 classified into low contamination category. The geo-accumulation data of all stations recorded between 0.00 and 1.00, showed unpolluted to moderately polluted[12]. Cd had a positive correlation with Cu (r = 0.725, p = 0.018) and which is statistically significant at 5% level The higher Cd concentrations in surface sediments of Yenshui, Ell-ren and Potzu rivers were found due to industrial activities[17].

Cobalt (Co)
Cobalt concentrations of studied sediments were varied widely between 0.13 to 1383.85 µg/g (Table 1). The mean value was calculated as 492.74 µg/g. The heaviest Co content in the studied samples were recorded at station 1 and the lowest value was determined at site 4 .It was found that the average values of all stations were above LAL. Moreover, the mean value of station 1, 6, 7, 8, 9 and 10 were above HAL. It is mentionable that Co content of station 1 and 10 were 11.5 and 11.28 times higher than HAL respectively. The cobalt EF profile (Table 2) at station 1, 7, 8, 9 and 10 were 60.41, 57.07, 60.99, 57.33 and 59.44 respectively; those were belonged to extremely high enrichment, where station 6 showed very high enrichment. Moreover, station 4 was moderate enrichment and remaining 2, 3 and 5 stations belonged to deficiency to low enrichment[10]. The obtained CF of station 2, 3, 4 and 5 (Table.3) were denoted low pollution category. In addition, the CF values of station 1, 6, 7, 8, 9 and 10 found above 32.00 which regarded as very highly polluted[11]. The Igeo value estimated at station 1,6, 7, 8, 9 and 10 were 55.43, 6.95, 18.96, 36.90, 24.98 and 54.36 respectively (Table 4) that was interpreted as very strongly polluted, while the rest stations were found unpolluted to moderately polluted[12]. Co has been exhibited a positive correlation with Hg (r = 0.663, p = 0.037), Ni (r = 0.796, p = 0.006) and Zn (r = 0.674, p = 0.033). In addition, Co was strongly correlated and statistically significant at 1% level with As (r = 0.707, p = 0.022), Cu(r = 0.855, p = 0.002) and Pb (r = 0.808, p = 0.005). The EF value of Co suggested anthropogenic impact on the river sediment. The highest EF

values of Co were found at station 1 due to metallic effluent, industrial waste water discharges. Zhou *et al*. (2004) worked with sediments in the Pearl River estuary, China and detected Co pollution by industrial activities[18].

Chromium (Cr)
Chromium content of studied sediments found to be varied from 8.47 to 25.18 µg/g (Table 1). The high value was determined at station 1 while the least value was observed at station 6.The average was computed 17.73 µg/g. In accordance with sediment quality guidelines average values of all stations were above LAL but below TEL and ERL. Calculated EF data of station 4 were 3.16 that regarded as moderate enrichment, but all remainder sampling stations were grouped into deficiency to low enrichment. CF data of all stations were below 1.00 which recommended low contamination. According to Muller's classification for geo-accumulation index all stations were categorized into unpolluted to moderately polluted. Shtiza *et al*. worked on the sediment of Zalli I Germanit and Mat river of Albania[19] and detected Cr contamination owing to industrial processes.

Copper (Cu)
Copper concentrations were ranged between 0.36 to17.24 µg/g. (Table 1) with a mean value 6.87 µg/g. The highest result (17.24 µg/g) was observed at station 10 and the low value (0.36 µg/g) was recorded at station 4. The mean value of all stations except 3, 4 and 5 were above LAL, but all stations below TEL. EF results (Table 2) of only station 2 showed above 2.00 indicated moderate enrichment but all remainder stations were deficiency to low enrichment[9]. From the CF data (Table 3) of stations 1, 8, 9 and 10 were between 1.00 and 3.00, which classified into moderately polluted, while remaining stations were included into low pollution level[10]. Correlation analysis explained that Cu was positively correlated with Cd ($r = 0.725$, $p = 0.018$), Ni ($r = 0.670$, $p = 0.034$) and Pb ($r = 0.642$, $p = 0.046$). Furthermore, Cu was strongly correlated with Co ($r = 0.855$, $p = 0.002$), As ($r = 0.864$, $p = 0.001$), and Zn ($r = 0.836$, $p = 0.003$). It has been found from the calculation that the geo-accumulation index of Cu values for all stations were 0.00 to 1.00, denoted unpolluted to moderately polluted[12]. Ramos *et al*. (1999) observed Cu pollution due to industrial interference in the sediments of the Ebro River, Spain[20].

Mercury (Hg)
Mercury content of the studied sediments was found to be ranging between 0.218 to 4.793 µg/g (Table 1). The mean value was 0.919 µg/g .The value of all stations were above TEL Station 10 was considered two and half times higher than SEL; station 9 was just above the TEL. The EF values (Table 2) showed that sampling points 4 showed extremely high enrichment; in contrast, station 2, 3, 5 and 10 were of very high enrichment levels. Moreover station 7, 8 and 9 were significant enrichment. However the station 1 was moderate enrichment[10]. The CF values (Table 3) revealed that stations 4 and 5 suggested considerable pollution but remaining stations were of very high pollution.

The calculated Igeo values (Table 4) of station 5 and 10 denoted very high and strongly polluted, station 1 and 8 strongly polluted, sampling point 7 included in moderate to strongly polluted, while remaining 2, 3, 4, 5 and 6 were classified into moderate pollution[12]. Correlation analysis suggested that Hg had a moderate positive correlation with Ba ($r = 0.668$, $p = 0.035$) and Co ($r = 0.663$, $p = 0.037$). Ram *et al*. (2003) detected high Hg levels in sediment of the Ulhas estuary, India, they claimed due to dumping of effluents from different industries namely chlor-alkali plants, the Hg pollution was identified[21].

Nickel (Ni)
Nickel concentrations were found relatively low and varied from 0.50 to 14.17 µg/g. with an average value 3.53 µg/g (Table.1). The highest concentration (14.17µg/g) was observed at station 1, while the least amount (0.50 µg/g) was recorded at station 4. The average value of stations 1, 3, 8, 9 and 10 were above LAL, while other stations were below LAL. However, all stations were below TEL and ERL. EF data exhibited that the values of all stations were below 1.00. So, all stations were grouped into deficiency to low enrichment. It was revealed that CF results of all stations were below 1.00 showed low pollution category. In accordance with Muller's classification for geo-accumulation index, all stations were unpolluted to moderately polluted. Ni was positively correlated and statistically significant at 1% level with As (r =

0.784, p = 0.007), Co (r = 0.796, p = 0.006), Cu (r = 0.670, p = 0.046) and Pb (r = 0.951, p = 0.000). Lam *et al*. (1997) worked on surface sediment of Victoria, Harbour, Hong Kong, China and found Nickel pollution because of industrial activities[22].

Lead (Pb)
Lead values ranged between 1.68 and 115.27 µg/g (Table 1). The average values of all stations were above LAL. Moreover, the values of station 1 and 10 were above ERL and TEL limit. The calculated EF values of station 1, 3 and 5 were between 2.00 to 5.00 denoted moderate enrichment[9]. None the less, other sampling points were included into deficiency to low enrichment. CF data revealed (Table 3) that station 1 was very highly polluted; station 10 considerably polluted and station 9 belonged to moderate pollution. Nevertheless, the remaining stations were classified as low. The computed Igeo data of station 1 and 10 were moderately polluted, whereas, the rest stations demonstrated unpolluted to moderately pollute. The Pb had a moderate positive correlation with As (r = 0.740, p = 0.014) and Cu (r = 0.642, p = 0.046). It has been found that Pb was strongly correlated with Co (r = 0.808, p = 0.005), and Ni (r = 0.951, p = 0.000). The lead pollution was recorded in sediments of lakes Geneva and Lucerne in central Europe owing to industrial interference[23].

Zinc (Zn)
Zinc concentrations were measured relatively low and found to be varied between 2.71 and 63.63 µg/g (Table 1). The average value was recorded as 30.79 µg/g. The highest value (63.63 µg/g) was estimated at station 10 and the lowest value 2.71 µg/g was determined at station 5. The average values of all stations were above LAL, but below TEL and ERL. The obtained values from EF calculation of station 2 and 3 were 2.00 to 5.00 denoted moderate enrichment (Table 2)[10]. But the remaining stations were <2 considered deficiency to low enrichment. From the calculation, it was found that CF values of all stations were below 1.00 which regarded as low pollution class[11]. The geo-accumulation data of all stations of the studied sediments were 0.00 to 1.00 that exhibited unpolluted to moderately polluted[12]. From the correlation analysis it was observed that Zn was positively correlated with As (r = 0.757, p = 0.011) and Co (r = 0.674, p = 0.033). Moreover, Zn had a strong positive correlation with Cu (r = 0.836, p = 0.003). Zhang *et al*. (2011) recorded that the Pb and Zn pollution in the sediments of Yangzong lake in China caused by ore mining and refinery[24].

Principal Component Analysis
In this analysis two components were extracted, they accounted for more than 76% of the total variability (Table 7). The first principal component account for 57.24% which is high for Co, Cu, As, Ni, Pb, Cd, Zn and Hg (Table 6) that reflects the higher deposition of those parameters. The percentage of the second component is (19.71% of total variation) is high for Ba and Hg. Large negative loadings of the component are for Cr and Zn (Table 6).

Cluster analysis
Hierarchical cluster analysis was done using CF values of the heavy metals. Figure 2 illustrated four clusters A (Ba, Ni, Cd, Cr, Cu, Zn Pb), B (As), C (Hg) and D (Co) which represent the intensity of pollution in group basis. Here we have found that Co and Hg were highly polluted .On the basis of HCA tree the studied heavy metal pollution were ranked as Co> Hg> As> Pb> Zn> Cu> Cr> Cd> Ni>Ba. Figure 3 stated three clusters. Based on contamination level sampling stations were ranked as 1>10>8>7>9>6>3>2>5>4 (Figure 3).

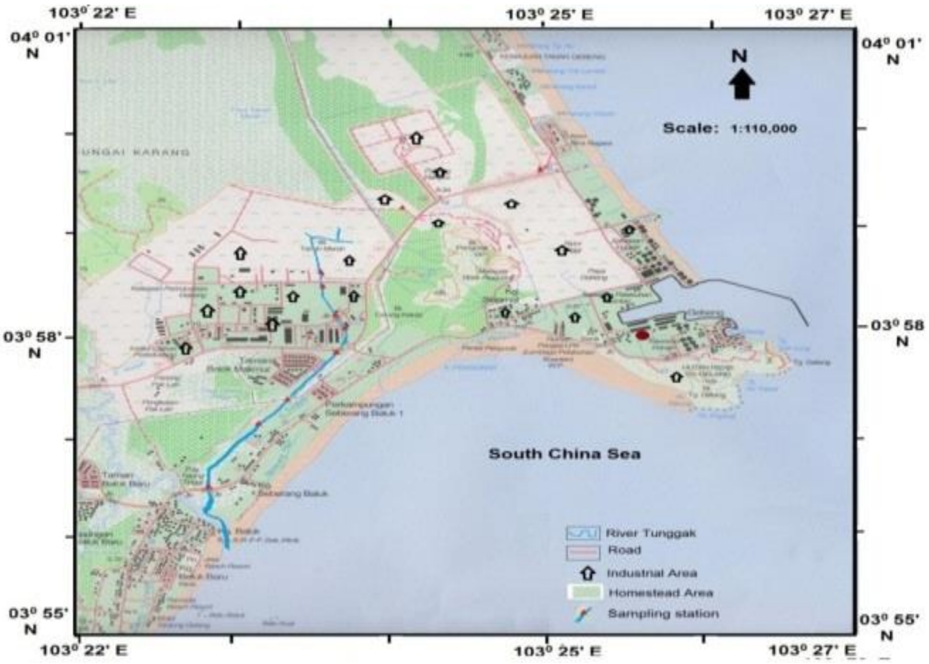

Fig.1 Location of the study area

Table 1. Distribution of heavy metals in the studied sediment.

Station		As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
		µg/gm									
	Range	15.38-24.67	31.94-37.66	0.08-0.22	1377.09-1383.85	11.37-25.18	10.84-15.46	739.72-753.44	8.08-14.17	105.99-115.27	40.01-46.77
1	Mean	21.69±3.15	34.97±2.67	0.14±0.07	1380.92±3.47	16.74±3.39	12.12±4.88	747.23±6.89	11.33±5.23	109.86±2.57	44.32±2.52
	Range	11.19-17.54	27.29-31.95	0.07-0.08	0.93-1.43	9.89-11.41	7.85-11.60	290.85-311.43	2.31-2.52	5.75-5.92	40.98-45.05
2	Mean	16.24±2.06	30.36±2.66	0.08±0.01	1.28±0.52	10.67±0.76	9.03±1.59	302.33±9.74	2.42±0.11	5.84±0.09	42.25±2.63
	Range	2.55-3.67	13.06-19.77	0.01-0.05	0.42-2.54	13.61-16.91	0.87-2.96	314.77-325.02	2.44-4.29	7.51-12.64	24.22-33.11
3	Mean	3.12±0.98	17.77±2.49	0.03±0.02	1.13±0.75	14.87±1.78	1.98±0.65	319.98±4.67	3.25±0.63	8.62±3.59	29.62±4.47
	Range	3.61-4.19	5.93-9.42	0.01-0.04	0.13-2.64	13.61-16.91	0.36-2.89	221.85-236.27	0.50-0.91	1.68-2.99	4.13-9.44
4	Mean	3.93±0.27	7.93±2.02	0.02±0.02	2.12±0.42	15.08±1.78	1.51±0.68	227.34±3.88	0.72±0.21	2.47±0.7	7.53±2.25
	Range	2.95-4.13	46.57-48.70	0.04-0.07	0.53-0.66	10.48-11.23	1.10-1.15	217.55-229.10	1.21-1.27	5.23-6.10	2.71-5.17
5	Mean	3.63±0.61	47.34±0.67	0.05±0.02	0.61±0.07	10.87±0.37	1.13±0.03	224.33±3.31	1.24±0.03	6.29±1.17	4.33±1.4
	Range	6.36-7.62	109.37-115.94	0.01-0.07	169.37-175.19	8.47-12.68	2.85-4.65	337.39-358.55	1.59-2.34	7.13-8.82	13.04-21.29
6	Mean	7.44±0.89	112.64±3.28	0.05±0.03	173.06±5.33	10.17±1.93	3.63±0.79	349.34±6.56	1.86±0.42	7.88±0.72	17.71±3.06
	Range	8.52-10.17	38.83-43.80	0.01-0.01	462.74-479.70	14.33-16.29	3.59-6.10	417.99-434.57	2.03-2.70	5.94-7.39	34.44-43.87
7	Mean	9.26±1.18	41.53±1.66	0.01±0.0	472.23±5.37	15.23±3.59	4.79±1.89	425.14±6.81	2.33±0.34	6.73±2.18	38.21±5.89
	Range	8.67-13.10	50.41-60.93	0.02-0.08	916.36-924.63	17.12-18.35	7.10-16.57	780.87-798.01	2.34-4.70	7.02-7.58	39.80-60.25
8	Mean	11.13±3.72	58.43±1.96	0.04±0.03	919.36±2.37	17.65±3.09	10.87±1.93	789.62±8.57	3.68±1.21	7.32±0.16	47.43±5.85
	Range	9.79-14.68	51.11-64.87	0.16-0.27	616.31-629.22	12.94-16.07	8.32-12.39	1015.99-1027.69	2.99-3.77	18.13-25.44	30.48-37.23
9	Mean	12.39±3.1	56.85±4.68	0.22±0.06	622.23±6.52	14.06±2.89	10.11±1.57	1021.27±30.08	3.4±0.39	20.92±2.98	34.03±5.7
	Range	7.02-16.95	119.54-125.69	0.12-0.26	1341.89-1363.81	11.35-12.65	9.72-17.24	4617.03-4802.55	4.38-5.86	56.61-60.42	25.39-63.63

Table 2. EF values of studied sediments in the River of Gebeng industrial area.

Station	Location	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
1	03º 58'34" N 103º23' 17" E	0.76	0.04	0.21	60.41	0.09	0.26	4.07	0.11	2.05	0.20
2	03°48' 55" N 103° 19' 20"E	7.83	0.43	1.60	0.77	0.78	2.71	22.70	0.32	1.50	2.59.
3	03º59 '16"N103º 23' 18"E	2.23	0.37	0.88	1.00	1.60	0.87	35.24	0.62	3.25	2.67
4	03º59'457"N 103º24'203"E	5.41	0.32	1.14	3.64	3.16	1.29	48.71	0.27	1.81	1.32
5	03º 59' 37" N 103º24' 46"E	2.74	1.06	1.57	0.57	1.25	0.53	26.37	0.25	2.53	0.42
6	03°48'55" N 103º19'19"E	1.26	0.57	0.35	36.92	0.26	0.38	9.28	0.09	0.71	0.38
7	03º57'19 "N 103°22'59"E	0.89	0.12	0.04	57.07	0.23	0.29	6.40	0.06	0.34	0.47
8	03º57'40" N 103°23'15"E	0.59	0.09	0.09	60.99	0.14	0.36	6.53	0.05	0.21	0.32
9	03º57'54"N 103º23'23"E	0.91	0.12	0.68	57.33	0.16	0.46	11.72	0.07	0.82	0.32
10	03º58'13"N 103º23'23E	4.70	0.13	0.26	59.44	0.06	0.29	26.20	0.05	1.11	0.19

Table 3. CF values of studied sediments in the River of Gebeng industrial area.

Station	Location	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
1	03º 58'34" N 103º23' 17" E	3.48	0.17	0.93	276.18	0.41	1.21	18.62	0.49	9.39	0.91
2	03°48' 55" N 103° 19' 20"E	2.61	0.14	0.53	0.27	0.26	0.90	7.56	0.11	0.50	0.86
3	03º59 '16"N103º 23' 18"E	0.50	0.08	0.20	0.23	0.36	0.19	7.99	0.14	0.74	0.61
4	03º59'457"N 103º24'203"E	0.63	0.04	0.13	0.42	0.37	0.15	5.68	0.03	0.21	0.15
5	03º 59' 37" N 103º24' 46"E	0.58	0.23	0.33	0.12	0.27	0.11	5.61	0.05	0.54	0.09
6	03°48'55" N 103º19'19"E	1.19	0.54	0.33	34.6	0.25	0.36	8.70	0.08	0.67	0.36
7	03º57'19 "N 103°22'59"E	1.49	0.19	0.07	94.45	0.37	0.49	10.63	0.10	0.57	0.78
8	03º57'40" N 103°23'15"E	1.79	0.28	0.27	183.87	0.43	1.08	19.74	0.16	0.63	0.97
9	03º57'54"N 103º23'23"E	1.99	0.27	1.47	124.45	0.34	1.01	25.53	0.15	1.79	0.69
10	03º58'13"N 103º23'23E	2.15	0.58	1.20	270.89	0.29	1.35	119.83	0.22	5.09	0.87

Table 4. Metal geo-accumulation index (I-geo) values and the variations at each sampling station.

Station	Location	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
1	03º 58'34" N 103º23' 17" E	0.70	0.03	0.19	55.43	0.10	0.34	3.75	0.10	1.89	0.18
2	03°48' 55" N 103° 19' 20"E	0.52	0.03	0.11	0.05	0.05	0.21	1.51	0.02	0.10	0.17
3	03º59 '16"N103º 23' 18"E	0.10	0.02	0.04	0.04	0.07	0.29	1.60	0.03	0.17	0.12
4	03º59'457"N 103º24'203"E	0.13	0.01	0.03	0.09	0.07	0.30	1.14	0.01	0.04	0.03
5	03º 59' 37" N 103º24' 46"E	0.12	0.05	0.07	0.02	0.05	0.02	1.12	0.01	0.11	0.02
6	03°48'55" N 103º19'19"E	0.24	0.11	0.05	6.94	0.05	0.07	1.75	0.02	0.14	0.08
7	03º57'19 "N 103°22'59"E	0.30	0.04	0.01	18.95	0.07	0.10	2.13	0.02	0.12	0.16
8	03º57'40" N 103°23'15"E	0.43	0.06	0.05	36.90	0.09	0.22	3.96	0.03	0.13	0.19
9	03º57'54"N 103º23'23"E	0.401	0.05	0.29	24.97	0.07	0.20	5.12	0.03	0.36	0.14
10	03º58'13"N 103º23'23E	0.43	0.12	0.24	54.36	0.06	0.27	79.88	0.05	1.02	0.17

Table 5. Correlation Analysis among different parameters.

	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
As	1									
Ba	0.15	1								
Cd	0.598	0.4	1							
Co	0.707*	0.43	0.604	1						
Cr	0.171	-0.42	-0.106	0.424	1					
Cu	0.864**	0.391	0.725*	0.855**	0.221	1				
Hg	0.292	0.668*	0.596	0.663*	-0.15	0.62	1			
Ni	0.784**	0.054	0.498	0.796*	0.434	0.670*	0.281	1		
Pb	0.740*	0.177	0.584	0.808**	0.262	0.642*	0.44	0.951**	1	
Zn	0.757*	0.147	0.32	0.674*	0.398	0.836**	0.332	0.593	0.44	1

Table 6. Component matrix.

Element	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
Component 1	0.865	0.384	0.737	0.941	0.279	0.941	0.638	0.848	0.847	0.770
Component 2	-0.170	0.799	0.343	-0.021	-0.792	0.063	0.593	-0.360	-0.154	-0.225

Table 7. Total variance explained.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.724	57.244	57.244	5.724	57.244	57.244	5.609
2	1.971	19.709	76.953	1.971	19.709	76.953	2.333
3	0.800	8.001	84.954				
4	0.707	7.069	92.022				
5	0.423	4.234	96.257				
6	0.245	2.451	98.707				
7	0.100	1.003	99.710				
8	0.017	.171	99.881				
9	0.012	.119	100.000				
10	-3.390E-16	-3.390E-15	100.000				

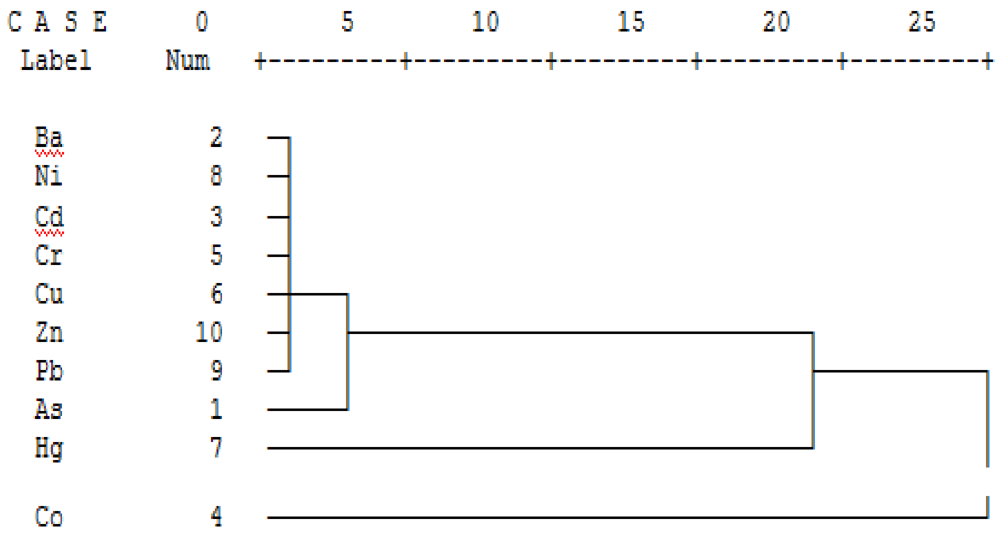

Figure 2. Hierarchical cluster analysis of different heavy metals pollution.

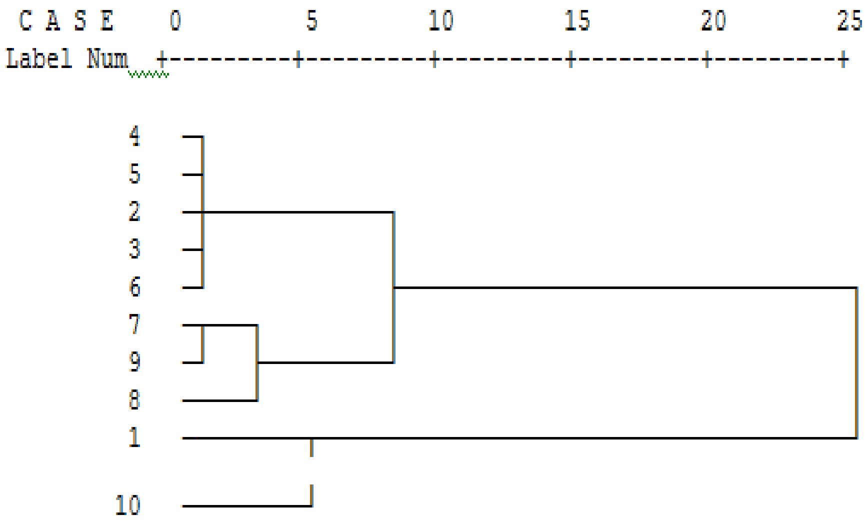

Figure 3. Hierarchical cluster analysis of various sampling stations.

CONCLUSION

The studied results pointed out that the industrial interference has been caused the heavy metal contamination in the sediment. Moreover, the station 1 is badly affected due to vicinity of metal industries and the dumping of industrial wastes and effluents. The station 10 is also highly polluted because it is the outlet of passing the industrial wastes, effluents as well as industrial pollutants into the South China Sea. The differences of results among stations are varied due to types of wastes and effluents thrown from industries. The emphasis could be given on recycling of industrial wastes and effluents as well as more supervision is needed. So it is high time to create awareness among general public, industrialist and planners as well as measures have to be taken, otherwise the environment would be in vulnerable.

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