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Integrated Assessment of Heavy Metal Contamination in Sediments from Gebeng Industrial Estate, Pahang, Malaysia

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Abstract

Gebeng is one of the most important industrial regions in Pahang, Malaysia. The study was conducted in the Gebeng industrial estate to investigate the effect of industrialization on heavy metal pollution in the surface sediments of the industrial area. In this study, it has been found that the sediments were highly contaminated especially by Co , Hg and As which is supported by the values of enrichment factors, contamination factors, geo-accumulation index, pollution load indexes and contamination assessment by sediment quality guidelines. According to the hierarchical cluster analysis (HCA) the studied heavy metal pollution were ranked as Co > Hg > As > Pb > Zn > Cu > Cr > Cd > Ni > Ba and the sampling stations were ranked as WS1 > DSRS3 > DSRS1 > USRS4 > DSRS2 > USRS3 > WS3 > WS2 > USRS2 > USRS1.Moreover, it was found that all the three zones (the wetland sediments, upstream and downstream river sediments) were polluted by heavy metals. Three principal components were extracted from principal component analysis, they accounted for more than 84% of the total variability and detected the industrial activities was the source of pollution. The results indicated that the industrial dumping is going on indiscriminately. The study will help in the strategic management of the industries through providing heavy metals pollution of sediments.

Keywords: Gebeng, sediment, heavy metals, geo-accumulation-index, pollution load index.

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 consumed by lives[2]. Anthropogenic impact, parent material and weathering processes may influence a lot on heavy metal concentrations. Heavy metals are concerned because of their persistence and toxic effects [3]. As they are chemically and biologically not degradable, so they have been posed major pollution factors[4]. Now a day, heavy metal contaminations are severe in eastern and western part of Johor Strait, Malaysia[5]. It is reported that a large number of industries are active in Gebeng industrial area. The Tungguk is the main river in the studied area that affected by industrial dumping and flows through the Gebeng industrial regions. In addition, the lowlands especially, the wetlands surrounding of the industries are also affected by industrial dumping. In spite of socio-economic importance of the study area, no studies have been conducted to find out heavy metal pollution of the surface sediments. The objectives of this research were to find out the heavy metal pollution of the surface sediments in the study area.

Material and Methods

Study area and the selection of stations: Gebeng industrial estate (figure-1) is the main industrial area at Kuantan, the capital city of Pahang, Malaysia. The industrial region is located near Kuantan Port. The sampling stations are situated between 03° 58'34" N 103°23' 17" E and 03°58'13"N 103°23'23E. Sujaul et al[6], stated that the prominent industries of the study area are chemicals, petro-chemicals, energy, gas, metal, metal work factories, coal mining, rare earth plant, food processing, polypropylene and various manufacturing industries. On the basis of types of industries, topography and discharge points, upstream and downstream of the river, sampling stations were selected from the Tunggakriver and from the industrial area.

Sampling, data collection and analysis: Sediment samples were collected from August 2012 to July 2013 from three zones. Total of 10 sampling points were selected from 3 zones, where five replications of each sample were taken. There were three stations at wetland sediments (WS), four stations from upstream river sediments (URSS) and another three stations from downstream river sediments (DRSS). Sediment sampling was made according to the standard procedure. Sediment samples were collected using Van Veen grab sampler from the study area. The collected samples were put into the polythene bags. All samples were cleaned, air dried, grinded and sieved in the laboratory before analysis.

Laboratory Analysis: Air dried and sieved samples were used for analysis. The amount of heavy metals was analyzed by microwave acid digestion procedure with a mixture of HNO_3 – HF-HCl. After digestion, metals were determined by using ICPMS. Mercury was determined by taking 0.2gm sediment samples then it analyzed by Direct Mercury Analyzer (DMA 80).

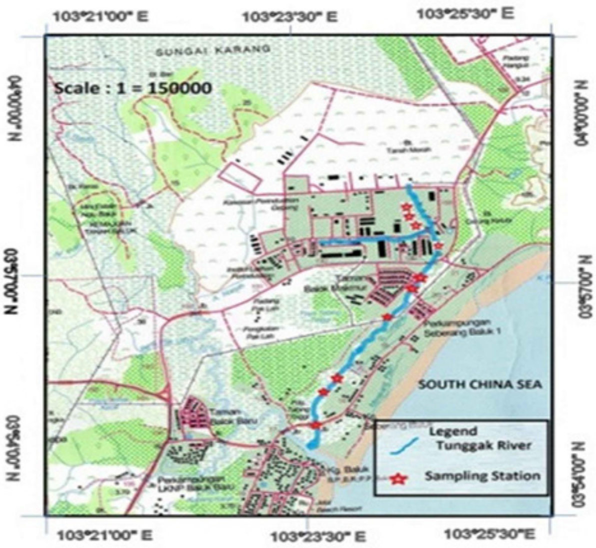

Figure-1
Map of the study area with sampling stations

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,principal component analysis (PCA) and cluster analysis were done to find out the relationship among parameters, and sources of contamination as well as classify the variables in various categories.

Results and Discussion

Heavy metals concentrations and contamination assessment by sediment quality guidelines (SQGs): The sediment quality guideline values were compared with the analyzed heavy metals concentrations. Table-2 displayed effect range low (ERL)[7], effect range medium (ERM)[7], threshold effect level (TEL)[7], toxic effect threshold (TET) [7] and severe effect level (SEL)[7] low alert level (LAL)[8], high alert level (HAL)[9]. Arsenic content in the samples ranged between 2.55-24.67 µg/gm with a mean value of 10.22 µg/g (Table1). The highest concentration of As was determined at station WS1 (24.67 µg/gm.) and the least at station WS3 (2.55 µg/gm.). It showed that all sampling stations were above LAL. Average values of As of stations WS 3, USRS 1 and USRS 2 were found between LAL and TEL, whereas station USRS 3, USRS 4, DSRS1 DSRS2 and DSRS 3 were above TEL (table-2) nevertheless, only station WS1 was found above TET limit. The high arsenic pollution was recorded in the sediment of the Daliao River owing to intensive industrial activities[10]. The analyzed Barium varied from 5.93 to 125.6 9 µg/gm. (table-1), where the average value was 46.63 µg/gm. The highest Ba (125.69 µg/gm) was found at station DSRS 3 while the lowest value was observed in station USRS 1 (5.93 µg/gm). The mean values of Ba at station USRS 3, DSRS 1, DSRS 2 and DSRS 3 were observed above the LAL. 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.[11] determined Ba contamination because of industrial processes in petrochemical industrial area at Pancevo in Serbia Cadmium content was relatively low ranged from 0.01 to 0.27 µg/gm (table-1) and the average value was 0.08 µg/gm. According to sediment quality guidelines, average values of station WS 3, USRS 1 and USRS 4 were below LAL, while remainder stations were above LAL. The higher Cd concentrations in surface sediments of Yenshui, Ell-ren and Potzu rivers were found due to industrial activities Tsai et al.[12]. Cobalt concentrations of studied sediments were varied widely between 0.13 to 1383.85 µg/gm (table-1). The mean value was calculated as 492.74 µg/gm. The heaviest Co content in the studied samples were recorded at station WS1 and the lowest value was determined at site USRS 1 .It was found that the average values of all stations were above LAL. Moreover, the mean values of station WS 1, USRS 3, USRS 4, DSRS 1, DSRS 2 and DSRS 3 were above HAL. It is mentionable that Co content of station WS1 and DSRS 3 were 11.5 and 11.28 times higher than HAL respectively. Zhou et al. [13] worked with sediments in the Pearl River estuary, China and detected Co pollution by industrial activities. Chromium content of studied sediments found to be varied from 8.47 to 25.18 µg/gm (table-1). The high value was determined at station WS1 while the least value was observed at station USRS 3. The average was computed 17.73 µg/gm. In accordance with sediment quality guidelines average values of all stations were above LAL but below TEL and ERL Shtiza et al. worked on the sediment of Zalli I Germanit and Mat river of Albania[14] and detected Cr contamination owing to industrial processes. Copper concentrations were ranged between 0.36 to17.24 µg/gm. (Table 1) with a mean value 6.87 µg/gm. The highest result (17.24 µg/gm) was observed at station DSRS 3 and the low value (0.36 µg/gm) was recorded at station USRS1. The mean value of all stations except WS 3, USRS 1 and USRS 2 were above LAL. Ramos et al.[15] observed Cu pollution due to industrial interference in the sediments of the Ebro River, Spain. Mercury content of the studied sediments was found to be ranging between 0.218 to 4.793 µg/gm (table-1). The mean value was 0.919 µg/gm .The value of all stations were above TEL Station DSRS 3 was considered two and half times higher than SEL [severe effect level]; station DSRS 2 was just above the TEL [toxic effect level]. Ram et al.[16] detected high Hg content in the sediment of the Ulhas estuary, India and they detected Hg pollution due to dumping of effluents from different industries namely chlor-alkali plants. The highest Ni concentration (14.17µg/gm) was observed at station WS 1, while the least value (0.50 µg/gm) was recorded at station USRS 1. The average value of stations WS 1, WS 3, DSRS 1, DSRS 2 and DSRS 3 were above LAL, while other stations were below LAL. Lead value ranged between 1.68 to 115.27 µg/gm (Table 1). The average values of all stations were above LAL. Moreover, the values of station WS 1 and DSRS 3 were above ERL and TEL limit. Lam et al worked on surface sediment of Victoria, Harbour, Hong Kong, China and found Nickel pollution because of industrial activities[17]. Lead value ranged between 1.68 to 115.27 µg/gm (table-1). The average values of all stations were above LAL. Moreover, the values of station WS1 and DSRS 3 were above ERL and TEL limit. Zinc concentrations were measured relatively low and found to be varied between 2.71 to 63.63 µg/gm (table-1). The average value was recorded as 30.79 µg/gm. The highest value (63.63 µg/gm) was estimated at station DSRS 3 and the lowest value 2.71 µg/gm was determined at station USRS 2. The average values of all stations were above LAL, but below TEL and ERL Zhang et al.[18] recorded that the Pb and Zn pollution in the sediments of Yangzong lake in China caused by ore mining and refinery.

Table-1
Distribution of heavy metals in the studied sediment

Station		As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
		µg/gm									
WS1	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
	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
WS2	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
	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
WS3	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
	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
USRS1	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
	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
USRS 2	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
	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
USRS3	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
	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
USRS 4	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
	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
DSRS1	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
	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
DSRS2	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
	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
DSRS3	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
	Mean	13.38±2.98	122.24±1.94	0.18±0.07	1354.46±11.31	11.95±2.88	13.5±1.53	4793.07±11.67	5.08±0.74	59.60±1.06	42.43±4.19

Table-2

Sediment quality guidelines (SQGs) and the sediment Contamination assessment

Metal	Effect range low (ERL) Mac Donald etal. [7] µg/g	Effect range medium (ERM) Mac Donald etal. [7] µg/g	Low alert level (LAL) F.T. Manheim [8] µg/g	High alert level (HAL) USEPA. [9]µg/g	Threshold Effect Level TELMacDonald etal. [7]µg/g	Toxic Effect Threshold TET, MacDonald etal. [7]µg/g	Severe Effect Level SEL MacDonald etal. [7] µg/g
As	33	85	0.5	70	5.9	17	33
Ba	NA	NA	50	1000			
Cd	5	9	0.04	9.6	0.60	3.00	10.00
Co	NA	NA	0.5	120			
Cr	80	145	4	370	37.3	110	110
Cu	70	390	2	270	35.7	86	110
Hg	0.15	1.3			0.17	1	2
Ni	30	50	3	50	18	61	75
Pb	35	110	2	218	35	170	250
Zn	120	270	5	410	123	540	820

Assessing the pollution status by metal enrichment factors (EF) and geo-accumulation index (Igeo): The enrichment factors are shown in table-3. The mean enrichment factors of Co were found 20.72, 24.55 and 59.25 for wetlands sediments, upstream and downstream river sediments respectively. The mean EF values of three downstream river stations were greater than 40.00 expressed by extremely high enrichments whereas remaining two zones were detected very high enrichment[19]. The mean values of Hg were found 20.67, 22.94 and 14.81 for wetlands, upstream and downstream river sediments respectively. According to Sutherland[19] the wetlands and upstream river sediments showed very high enrichments while the downstream river sediments denoted significant enrichment for Hg. The mean value of EF for As at all three zones between 2.0 to 5.0 indicated moderate enrichments. In addition, in case of Pb, only the mean of enrichment factor for wetlands sediments was calculated as moderate enrichments while other two zones were exhibited deficiency to low enrichment. However, the mean enrichment factors value of studied Ba, Cd, Cr, Cu, Ni and Zn for all stations of three zones were found (<2.0) indicated deficiency to low enrichment. According to Zhang and Liu[20], EF values greater than 1.5 meant that the sources were more likely to be anthropogenic. In this research, the extremely high enrichment factors values of Co and Hg; higher EF values for As and Pb suggested that the pollution were due to anthropogenic, such as industrial activities. Tessier, et al[21] worked on Toulon bay (France) and found high EF for Hg, Cu, Pb and Zn and commented sources of contamination were human activities. Table-4 illustrated the computed geo-accumulation index values of studied sediments. The maximum lgeo index (55.43) of Co was showed at wetlands sediments when the minimum lgeo index of Co was (0.02) at downstream river sediments. The mean lgeo values of Co were estimated higher than the highest limits for all three zones. It was found that all three zones were very strongly polluted with Co[22]. For Hg, the mean lgeo index at downward river sediments was found 29.65 which indicated it was very strongly polluted whereas, the upstream river sediments belonged to moderately polluted and wetland sediments classified as moderately to strongly pollution. The geo-accumulation indexes of studied sediments for As, Ba, Cd, Cu, Cr, Ni and Zn were observed between 0.00 to 1.00 which denoted unpolluted to moderately polluted.

Table-3
The enrichment factor values of sediments in the study area

Parameters	Wetland Sediments, Mean, Range	Upstream River Sediments, Mean, Range	Downstream River Sediments, Mean, Range
As	3.60 (0.76-7.83)	2.57 (0.89-5.41)	2.06 (0.59-4.70)
Ba	0.28 (0.04-0.43)	0.52 (0.12-1.06)	0.11 (0.09-0.12)
Cd	0.89 (0.21-1.60)	0.77 (0.04-1.57)	0.37 (0.09-0.68)
Co	20.72 (0.77-60.41)	24.55 (0.57-57.07)	59.25 (57.33-60.99)
Cr	0.82 (0.09-1.60)	1.22 (0.23-3.16)	0.12 (0.06-0.16)
Cu	1.28 (0.26-2.71)	0.62 (0.29-1.29)	0.33 (0.29-0.46)
Hg	20.67 (4.07-35.24)	22.94 (6.40-48.71)	14.81 (6.53-26.20)
Ni	0.35 (0.11-0.62)	0.16 (0.06-0.27)	0.05 (0.05-0.07)
Pb	2.26 (1.50-3.25)	1.34 (0.34-2.53)	0.71 (0.21-1.11)
Zn	1.82 (0.20-2.59)	0.64 (0.38-1.32)	0.27 (0.19-0.32)

Table-4
The geo-accumulation index (lgeo) of sediments at three zones in study area

Parameters	Wetland Sediments, Mean, Range	Upstream River Sediments, Mean, Range	Downstream River Sediments, Mean, Range
As	0.44 (0.10-0.70)	0.19 (0.12-0.30)	0.42 (0.40-0.43)
Ba	0.03 (0.02-0.03)	0.05 (0.01-0.11)	0.07 (0.05-0.12)
Cd	0.11 (0.04-0.19)	0.04 (0.01-0.07)	0.19 (0.05-0.29)
Co	18.51 (0.05-5543)	6.50 (0.02-18.95)	38.74 (24.97-54.36)
Cr	0.07 (0.05-0.10)	0.06 (0.05-0.07)	0.07 (0.06-0.09)
Cu	0.28 (0.21-0.34)	0.12 (0.02-0.30)	0.23 (0.20-0.27)
Hg	2.28 (1.51-3.75)	1.53 (1.12-2.13)	29.65 (3.96-79.88)
Ni	0.05 (0.02-0.10)	0.02 (0.01-0.02)	0.03 (0.03-0.05)
Pb	0.72 (0.10-1.89)	0.10 (0.04-0.14)	0.50 (0.13-1.02)
Zn	0.15 (0.12-0.18)	0.07 (0.02-0.16)	0.16 (0.14-0.19)

Calculation of contamination factors (CF), pollution load index (PLI) and the level of pollution: The results of pollution load index and contamination factors are presented in table-5. According to Hakanson[23], the CF values of three zones were found very highly contaminated by Hg. It is also mentionable that the mean CF value of Hg for downstream river sediments was 9 times higher than highest limits. Moreover, the mean CF values for Co ranged from 32.39 to 193.00. It was calculated that the CF values of Coat wetlands sediments, upstream river sediments and downstream river sediments were 15, 5 and 32 times higher than top limits proposed by Hakanson[23]. Arsenic was found moderately polluted for three zones (wetlands sediments, upstream and downstream river sediments). The mean CF values of Cu indicated that only river downstream sediments were included into moderate pollution whereas other two zones were grouped into low pollution category. In case of Pb, the wetlands sediments were classified in considerable pollution and downstream river sediments categorized into moderate pollution but upstream river sediments was grouped at low contamination. However, it revealed that mean CF values of Ba, Cd, Cr, Ni and Zn were found <1 at all three zones indicated low pollution. It was exhibited that the PLI index values of downstream river and wetlands sediments were greater than 1, which indicated anthropogenic inputs were supported by Tomlinson, et al[24].

Multivariate statistical analysis of heavy metals: Pearson correlation analyses among studied parameters are shown in table-6. The interpretation was done by significance at ($p<0.01$) and ($p<0.05$) level and also in accordance with the findings of Karuthan[25]. Arsenic (As) had a strong positive correlation (>0.85) and significance ($p<0.01$) with Cu, Ni and Zn while it showed a positive significance ($p<0.05$) with Co and Pb. Moreover, Ba and Cd were moderately correlated with each other, while Ba and Cd had positive moderate correlation with Hg and Cu respectively. Never the less, no correlation was found with Cr. In addition, Co was strongly correlated and statistically significant ($p<0.01$) with As, Cu and Pb and it has been exhibited a positive significance ($p<0.05$) with Hg, Ni and Zn. In this study, Cu was strongly correlated and highly significant ($p<0.01$) with Co, As and Zn while Cu was positively significant ($p<0.05$) with Cd, Ni and Pb. The Hg was exhibited to be positively significant ($p<0.05$) with Ba and Co. Ni was positively correlated and statistically significant ($p<0.01$) with As, Co, Cu and Pb. The Pb had a moderate positive correlation with As and Cu, whereas it was highly significant ($p<0.01$) with Co and Ni. Moreover, Zn was positively correlated with Cu and As and statistically significant ($p<0.01$) and also positive moderate correlation with Co. From the above discussion, it can be said that there is a strong positive relationship among most of the studied heavy metals. It suggested that those metals were originated from the same sources and it could be anthropogenic activities such as industrial processes which are supported by the opinion of Chabukdhara and Nema[26]. In this analysis principal component analysis (PCA) was done to explain the sources of heavy metal pollution in the studied sediments. Here PCA was calculated with Varimax rotation. Three principal components were extracted, they accounted for more than 84% of the total variability (table-7). The first principal component account for 37.901% of total variance which showed strong loadings for Pb and Ni (value more than 0.900), while moderate loadings with As, Cd, Co and Cu (table-7) that suggests the deposition anthropogenic contamination like industrial activities for those parameters (the value of each parameter is above 0.600). The PC2 was explained 25.795% total variability and moderate loadings with Ba and Hg (value more than 0.845) indicated anthropogenic sources such as industrial processes. PC3 illustrated 21.258% of total variance and moderate loadings with Cr and Zn (value above 0.783) (table-6). According to the factor loading classification of Liu et al.[27], the above interpretations were given. Based on loadings strength three factors were extracted that are presented at table-8, it also supported by figure-2, where the parameters from same and similar sources were plotted closely. The members of same factor are originated from the same sources and a strong loading indicates human interference like industrial activities. Factor 1 comprised of Ni, Pb, As, Cd, Co and Cu. Varol[28] worked on the sediments of Tigris river and found those metals derived from the anthropogenic sources. In addition, Ba and Hg included into Factor 2. Dou, et al.[29], conducted a research on heavy metals in surface sediments of the eastern Beibu Bay, South China Sea and commented Hg pollution was due to anthropogenic activities. Moreover, Factor 3 members were Cr and Zn indicated that the industries using Cr and Zn metals had contributed to pollution. Hierarchical cluster analysis was done for grouping the metals, ranking the metal pollution and sampling stations figure-3 illustrated four clusters. Cluster A composed of Co that was the higher group, the cluster B and C consisted of Hg and As respectively. Cluster D, the largest group comprised of seven members (Ba, Ni, Cd, Cr, Cu, Zn and Pb). On the basis of HCA tree the studied heavy metal pollution were ranked as Co > Hg > As > Pb > Zn > Cu > Cr > Cd > Ni >Ba. Moreover, figure-4 stated four clusters. Based on contamination level sampling stations were ranked as WS1 > DSRS3 > DSRS1 > USRS4 > DSRS2 > USRS3 > WS3 > WS2 > USRS2 > USRS1 (figure-4). Station WS1 was categorized into highest ranked cluster. It indicates that the station 1 has the heaviest pollution level among all stations. The station DSRS3 and DSRS1 were classified as second and third highest ranking respectively. All the remaining stations were grouped into fourth cluster (figure-4).

Conclusion

The obtained data of enrichment factors, contamination factors, the geo-accumulation indices and pollution load indexes as well as multivariate statistical analysis made clear that the surface sediments of the study area are contaminated by heavy metals like Co, Hg, As, Pb and Zn. In addition, the downstream river sediment zone is more affected than wetlands and upstream river zones. Furthermore, the station wetland sediment 1 was highly affected due to vicinity of metal industries while the station downstream river sediment 3 is also badly contaminated because it is the outlet of passing the industrial wastes, effluents to the South China Sea. From the discussion, it is clear that the industrial activities are contributing in the heavy metals contamination. The measures have to be taken urgently; otherwise whole eco system will be affected.

Table-5
The contamination factor and pollution load index (PLI) of heavy metals of the studied sediment

Parameters	**Wetland Sediments, Mean, Range**	**Upstream River Sediments Mean, Range**	**Downstream River Sediments, Mean, Range**
As	2.19 (0.50-3.48)	0.97 (0.58-1.49)	1.97 (1.79-2.15)
Ba	0.13 (0.08-0.17)	0.25 (0.04-0.54)	0.37 (0.27-0.58)
Cd	0.55 (0.20-0.93)	0.21 (0.07-033)	0.98 (0.27-1.47)
Co	92.22 (0.23-276.18)	32.39 (0.12-94.45)	193.00 (124.45-270.89)
Cr	0.37 (0.26-0.41)	0.31 (0.25-0.37)	0.35 (0.29-0.43)
Cu	0.76 (0.19-1.21)	0.27 (0.11-0.49)	1.14 (1.01-1.35)
Hg	11.39 (7.56-18.62)	7.65 (5.61-10.63)	55.03 (19.74-119.83)
Ni	0.24 (0.11-0.49)	0.06 (0.03-0.10)	0.17 (0.15-0.22)
Pb	3.54 (0.50-9.39)	0.49 (0.21-0.67)	2.50 (0.63-5.09)
Zn	0.79 (0.61-0.91)	0.34 (0.09-0.78)	0.84 (0.69-0.97)
Pollution load index (PLI)	1.47	0.67	1.35

Table-6
Pearson correlation coefficient matrix of studied parameters

	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
As	1									
Ba	0.15	1								
Cd	0.598	0.400	1							
Co	0.707*	0.430	0.604	1						
Cr	0.171	-0.420	-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*	0.146	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	0.379	0.674*	0.398	0.836**	0.372	0.593	0.44	1

** Correlation is significant at the 0.01 level and for * at the 0.05 level

Table-7
Rotated Component Matrix (Extraction method: principal component analysis, Rotation method: varimax with Kaiser normalization)

Parameters	**Principal Component**		
	1	**2**	**3**
As	0.796	0.186	0.365
Ba	0. 043	0.898	-0.088
Cd	0.668	0.533	-0.027
Co	0.650	0.432	0.543
Cr	0.144	-0.444	0.785
Cu	0. 607	0.517	0. 536
Hg	0..254	0. 845	0.159
Ni	0.902	-.0250	0.350
Pb	0.936	0.115	0.158
Zn	0.376	0.272	0.783
Eigen value	3.790	2.579	2.126
Total Variance (%)	37.901	25.795	21.258
Cumulative Variance (%)	37.901	63.695	84.954

Table-8
The dimension reductions of contaminants based on loadings strength in the studied samples

Factor 1	Factor 2	Factor 3
Ni	Ba	Cr
Pb	Hg	Zn
As		
Cd		
Co		
Cu		

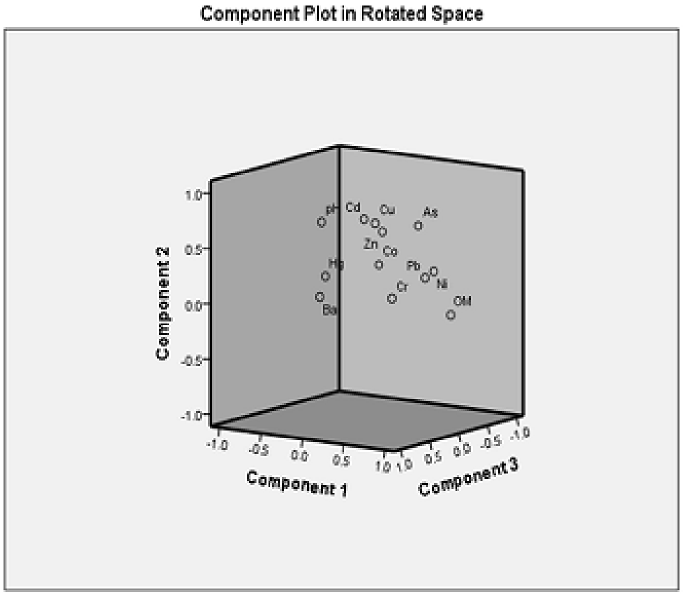

Figure-2
Component plot of heavy metals in rotated space

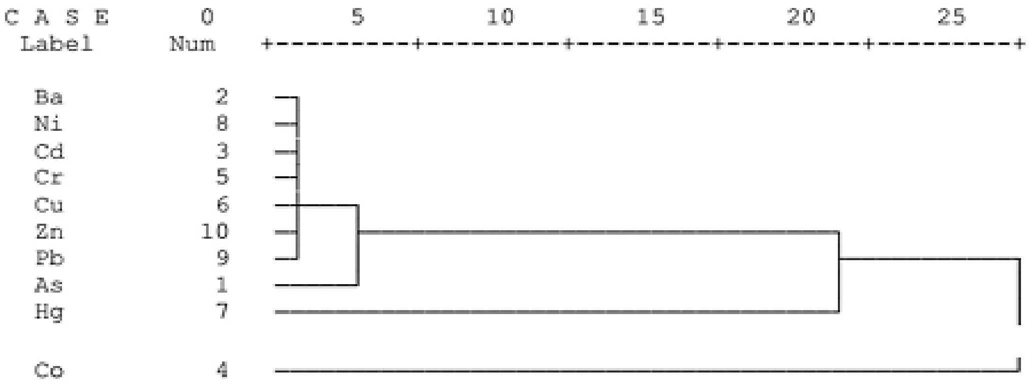

Figure-3
Dendrogram representing clustering of heavy metals

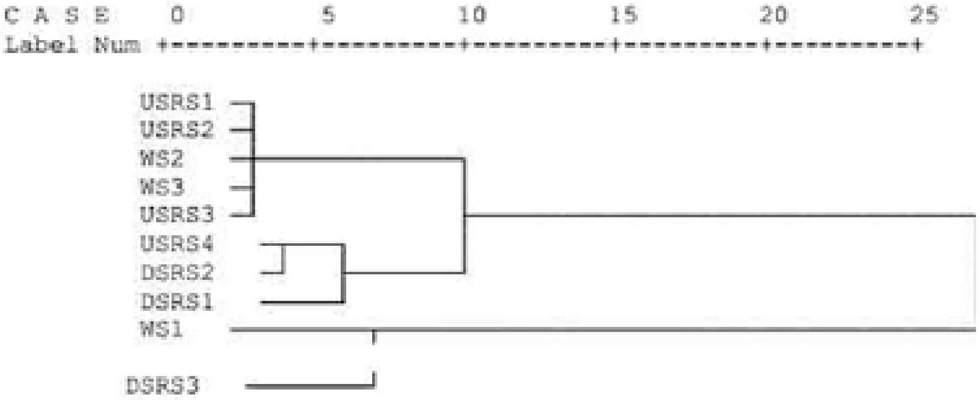

Figure-4
Dendrogram of hierarchical cluster analysis showing sampling stations

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References

1. Wang C., Liu S., Zhao Q., Deng L and Dong S., Spatial variation and contamination assessment of heavy metals in sediments in the Manwan Reservoir, Lancang river, *Ecotoxicology and Environmental Safety.,* **82**, 32–39 (**2012)**

2. Ankley G.T. Toro D.D.M. Hansen D.J. and Berry W.J., Technical basis and proposal for deriving sediment quality criteria for metals, *Environmental Toxicology and Chemistry.*, **15**, 2056–2066 (**1996)**

3. MacFarlane G.R. and Burchett M.D., Cellular distribution of Cu, Pb and Zn in the Grey Mangrove, Avicennia marina (Forsk.)Vierh, *Aquatic Botany.,* **68**, 45-59 **(2000)**

4. Tam N.F.Y. and Wong Y.S., Spatial variation of heavy metals in surface sediments of Hong Kong mangrove swamps, *Journal of Environmental Pollution.,* **110 (2),** 195-205 **(2000)**

5. Zulkifli S.Z. Ismail A., Yusuff F.M., Arai T. and Miyazaki N., Johor Strait as a Hotspot for Trace Elements Contamination in Peninsular Malaysia, Springer*, Bull Environ Contam. Toxicol.,* **84,** 568–573 **(2009)**

6. Sujaul I., Hossain M., Nasly M.A. and Sobahan M.A., Effect of industrial pollution on the spatial variation of surface water quality, *Am. J. Environ. Sci.,* **9(2),** 120–129 **(2013)**

7. MacDonald D.D, Ingersoll C.G. and Berger T.A., Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems, Arch. *Environ. Contam.Toxicol*., **39**, 20–31 **(2000)**

8. Manheim F.T. and Commeau J.A., Chemical analyses (trace elements), in: L.J. Poppe (Ed.), Data File Atlantic Margin Coring Project (AMCOR), *U.S. Geological Survey.,* Open-File Report 81-239, 44–51

9. USEPA, The National Sediment Quality Survey: A report to Congress on the extent and severity of sediment contamination in surface waters of the United States: U.S., *Environmental Protection Agency, Office of Science and Technology*, Washington D.C., Report No. EPA-823-D-96-002 **(1996)**

10. Wang S., Wang P., Men B., Lin C. and He M., Chemical forms and ecological risk of arsenic in the sediment of the Daliao River System in China, *Environ. Monit. Assess*., **184(4)** 2237-45 **(2012)**

11. Relic D., Dordevic D., Sakan S., Andelkovic I., Miletic S. and Duricic J., Aqua regia extracted metals in sediments from the industrial area and surroundings of Pancevo, Serbia, *Journal of Hazardous Materials.,***186**, 1893-1901 **(2011)**

12. Tsai L., Yu K. and Ho S.T., Cadmium distribution in sediment profiles of the six main rivers in southern Taiwan, *Journal of Hazardous Materials.*, **148 (3)** 630-639 **(2007)**

13. Zhou H.Y., Peng X.T. and Pan J. M., Distribution, source and enrichment of some chemical elements in sediments of the Pearl River Estuary, China, *Continental Shelf Research.,* **24**, 1857–1875 **(2004)**

14. Shtiza A., Swennen R. And Tashko A., Chromium and nickel distribution in soils, active river, overbank sediments and dust around the Burrel chromium smelter (Albania), *Journal of Geochemical Exploration,* **87**, 92-108 **(2005)**

15. Gonzalez R.M. J. and Hemardez L.M., Sequential Extraction of Copper, Lead, Cadmium and Zinc in Sediments from Ebro River (Spain): Relationship with Levels detected in Earthworms, *Bull. Environ. Contam.Toxicol*., **62**, 301-308 **(1999)**

16. Ram A., Rokade M.A., Borole D.V. and Zingde M.D., Mercury in sediments of Ulhas estuary, *Marine pollution Bulletin.,***46**, 846-857 **(2003)**

17. Lam M.H.W., Tjia A.Y.W., Chan C.C.C., Chan W.P. and Lee W.S., Speciation study of Chromium, Copper and Nickel in coastal estuarine sediments polluted by domestic and industrial effluents, *Marine pollution Bulletin*., **34**, 949-959 **(1997)**

18. Zhang E., Liu E., Shen J., Cao Y. and Li Y., One century sedimentary record of lead and zinc pollution in Yangzong Lake, a highland lake in southwestern China, *Journal of Environmental Sciences.,* **24(7)**, 1189-1196 **(2011)**

19. Sutherland R.A., Bed sediment-associated trace metals in an urban stream, Oahu, Hawaii, *Environ. Geol.,* **39**, 611–627 **(2000)**

20. Zhang J. and Liu C.L., Riverine composition and estuarine geochemistry of particulate metals in China-weathering features, anthropogenic impact and chemical fluxes, Estuar, *Coast. Shelf Sci*., **54**, 1051–1070 **(2000)**

21. Tessier E., Garnier C., Mullot J., Lenoble V., Arnaud M., Raynaud M. and Mounier S., Study of the spatial and historical distribution of sediment inorganic contamination in the Toulon bay (France)., **62 (10)**, 2075–2086 **(2011)**

22. Muller G., The heavy metals pollution of the sediments of Neckars and its tributary: stocktaking, Hem. *Zeitung.,* **105,** 157-164 **(1981)**

23. Hakanson L., Ecological risk index for aquatic pollution control, Asedimentological approach, *Water Res.,* **14**, 975–1001 **(1980)**

24. Tomlinson D.C., Wilson J.G. , Harris C.R. and Jeffery D.W., Problems in the assessment of heavy metals levels in estuaries and the formation of a pollution index, *Helgol. Wiss.Meeresunters,* **33**, 566–575 **(1980)**

25. Karuthan C., Structural Equation Modeling Using AMOS, *Unpublished Module,* Kualampur **(2009)**

26. Chabukdhara M. and Nema A.K., Heavy metals assessment in urban soil around industrial clusters in Ghaziabad, India, probabilistic health risk approach, *Ecotoxicol. Environ. Saf.,* **87**, 57–64 **(2013)**

27. Liu C.W., Lin K.H. and Kuo Y.M., Application of factor analysis in the assessment of ground water quality in a black foot disease area in Taiwan, *Science of the Total Environment.,* **313**, 77-89 **(2003)**

28. Varol M., Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques, *J. Hazard. Mater.,* **195**, 355–64 **(2011)**

29. Dou Y., Li J., Zhao J., Hu B. and Yang S., Distribution, enrichment and source of heavy metals in surface sediments of the eastern Beibu Bay, South China Sea, *Marine Pollution Bulletin,* **67(1–2)**, 137–145 **(2013)**