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Ecological Risk Posed by Heavy Metals Contamination of Ship Breaking Yards in Bangladesh

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ABSTRACT: Pollution of water and soils by heavy metals is an emerging problem in industrialized countries. The present study was conducted to investigate the heavy metals concentration in water and sediment samples from ship breaking sites of Sitakunda to assess the potential ecological risk posed by heavy metal using different methods. Heavy metals concentration was analyzed by Atomic Absorption Spectroscopy. Concentrations of all the tested heavy metals except Cr in water samples of ship breaking site, Sitakunda were lower than recommended values. The mean concentration of Cr was found 0.511± 0.284 mg/l. Concentrations of all the tested heavy metals except Mn in sediment samples were higher than standard limit. The concentrations of Pb, Mn, Cr, Cu and Zn in the sediment were 55.93±18.70, 20.08±4.03, 106.8±47.65, 50.09±18.31, and 70.71±19.45 mg/kg, respectively. Based on Geoaccumulation Index, Contamination factor, Sediment Quality Guidelines, the sediment of ship breaking site can be treated as unpolluted to moderately polluted with Pb, Zn, Cr and Cu but unpolluted with Mn. The Enrichment factors of Pb, Mn, Cr, Cu and Zn in the sediment were: 2.97±0.98, 0.035±0.008, 1.97±0.88, 1.99±0.73, and 1.17±0.32, respectively. The Enrichment factor (>1) in all sampling sites, suggesting source of those metals (Pb, Cr, Cu and Zn) were more likely to be anthropogenic. Based on the Potential Ecological Risk Index the ship breaking site posed to low risk to the environment. The results of present study clearly indicated that the ship breaking site was moderately polluted with heavy metals and pose low risk to the ecosystem.

Key words: Heavy metals, Ship breaking yard, Geo-accumulation Index, Pollution load Index, Transfer factor

INTRODUCTION

Environmental pollution has become a major concern of developing countries in the last few decades. There is a growing sense of global urgency regarding the pollution of our environment by an array of chemicals used in various activities (Tariq *et al*., 2008). Large quantities of chemical elements infiltrate the water running off of the cultivated soils thereby entering the animal and human food chain (Akoto *et al*., 2008). The major industrial areas in Bangladesh are situated in the midst of populated regions, major cities, and along the banks of the rivers or coastal site that facilities disposal of waste to the environment directly or without treatment (Kawser *et al.,* 2011). Metal polluting industries such as textiles, tannery, ship breaking and electronics etc. are flourishing gradually (Islam *et al*., 1997). Ship breaking is the process of dismantling an obsolete vessel's structure for scrapping or disposal. Ship breaking is a challenging process, due to not only the structural complexity of ships but also due to the involvement many environmental, safety, and health issues (OSHA, 2001). The Department of Environment (DOE) has categorized the Ship Breaking Industry (SBI) as 'Red' in 1995 (DoE, 1997). The Environmental Impact assessment (EIA) was not conducted before the establishment of SBI. Wastes of the scrapped ships are discharged directly into its adjacent areas which are ultimately draining into the Bay of Bengal. These wastes especially oil and oily

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substances, polychlorinated byphenyls, tri-substituted organostannic compounds, polycyclic aromatic hydrocarbons etc. and different types of trace and heavy metals (Cd, Pb, and Hg) are being accumulated into the marine biota.

Heavy metal accumulation in plants varies with plant species as well as soil properties. The metal's absorption efficiency of different plants was evaluated by either plant uptake potential or soil-to plant transfer factors of the metals by Rattan *et al*. (2005). These heavy metals are not abundant in soil, but there may be an accumulation of these heavy metals through urban wastes and industrial effluents. The uptake of heavy metals in cereals and vegetables is likely to be higher and accumulation of these toxic metals in human body created growing concern in the recent days. The aims of this study were to determine the concentrations of heavy metals in water and sediments sample of ship breaking site, Sitakunda, Chittagong and also to assess the potential ecological risk posed by heavy metals using different methods.

MATERIALS & METHODS

Reference standard heavy metals cadmium, copper, lead, chromium, manganese, iron and zinc were obtained from Kanto Chemical Co. Inc., Japan. Samples of water and sediment were collected from in and around ship breaking yard of Sitakunda, Chittagong of Bangladesh. Most ship breaking yards of Bangladesh are situated along the coast of Chittagong Fauzdarhat to Kumira under the Sitakunda upazila of Chittagong. The present study site is situated at Bhatiary, Fauzdarhat under the Sitakunda upazila. The area of Fauzdarhat is about 7 km beach situated approximately 20 km southwest of Chittagong city. The geographical location of the ship scrapping zone is between latitude 22^{o}252 and 22^{o}282 N, and longitude 91^{o}422 and 91^{o}452 E. The study area is shown in Fig. 1.

A total of 15 (500 ml each) of water samples were collected randomly from the sites. Plastic container of 500 ml was used for sampling purpose. For measurement of metal concentration, immediately after collection of water sample 1 ml of 65% concentrated HNO_3 was added to each of the samples, mixed one minute and transferred to the laboratory for analysis. Samples were properly labeled and preserved at -20 ^{0}C to preclude the risk of hydrolysis and oxidation.

Total 15 (1 Kg each) sediment samples were collected from the ship breaking site. Polyethylene bags were used for collecting the sediment samples. The samples were transferred to the laboratory as early as possible. The samples were properly labeled and preserved at -20 ^{0}C. Samples were digested with nitric acid for heavy metal determination as described by Baker and Amacher (1982). Water samples (500 ml) were filtered using Whatman No. 41 (0.45 µm pore size) filter paper for estimation of dissolved metal content. Filtrate (500 ml) was preserved at room temperature with 2 ml nitric acid to prevent the precipitation of metals. 50 ml of the sample was transformed into clean glass and concentrated nitric acid was added to for it's digestion. The solution was heated at 95 ^{o}C without boiling until dry. After cooling the samples were diluted to 50 ml with de-ionized water. Finally, the sample solution was aspirated into air acetylene flame in an atomic absorption spectrophotometer.

Sediment samples were oven dried at 95^{O}C (48 h) dried and ground into fine powder using pestle and mortar. Further 15 g of fine powder sediment sample was taken in a conical flask to which 15 ml of 1M HNO_3 (9 ml of distilled water + 1 ml of nitric acid) was added. Then 30 ml of distilled water was added to the mixture and the solution was kept for 24 h with cover. After 24 hours, distilled water was added to the solution up to 150 g by weight. The sample was then centrifuged and filtered by Whatman No. 41 filter paper. Filtrates were finally analyzed by AAS. Atomic Absorption Spectroscopy (AAS) (Model: AA-6401F, Atomic Absorption Flame Spectrophotometer, SHIMADZU) was used for the determination of heavy metals. To provide element specific wavelengths, a light beam from a lamp whose cathode is made of the element being determined is passed through the flame. A device such as photon multiplier can detect the amount of reduction of the light intensity due to absorption by the analyte and this can be directly related to the amount of the element in the sample.

The heavy metal contamination in the coastal sediments was evaluated by comparison with the sediment quality guideline proposed by USEPA. Geo-accumulation index (Igeo) was used to determine metals contamination in sediments, by comparing current concentrations with pre-industrial levels and calculated by the following equation of Muller (1969).

$$Igeo = \log_2 (Cn/1.5\ Bn)$$

Where, Cn is the concentration of element 'n' and Bn is the geochemical background value in this study. The geo-accumulation index (Igeo) scale consists of seven grades (0-6) ranging from unpolluted to highly pollute are shown as follow:

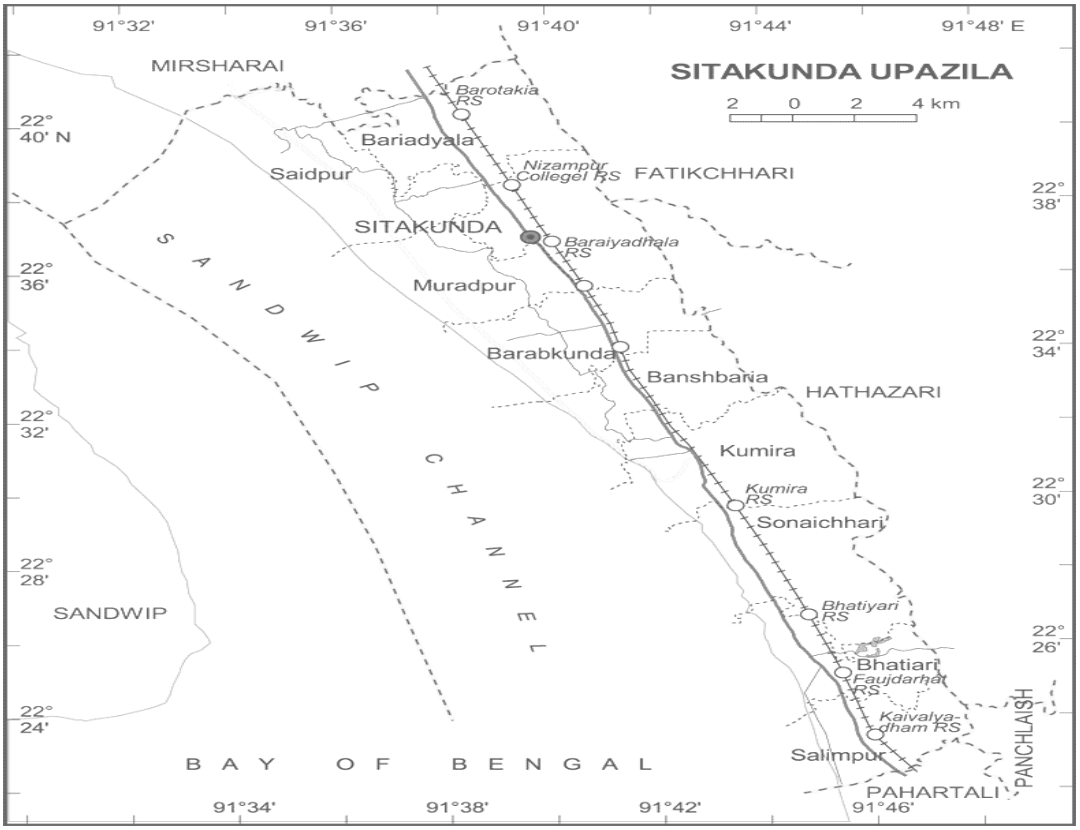

Fig. 1. Map of the study location Sitakunda Upazila, Chittagong, Bangladesh

I_{geo} Value	Class	Sediment Quality
≤ 0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly to extremely polluted
>6	6	Extremely polluted

The contamination factor (Cf) and the degree of contamination (Cd) are used to determine the contamination status of sediment in the present study. Cf values for describing the contaminations level (Hakanson, 1980) are as follow:

Contamination Factor	Level of Contamination
Cf < 1	low contamination
1≤ Cf < 3	moderate contamination
3≤ Cf < 6	considerable contamination
Cf > 6	very high contamination

The contamination factor is calculated according to the eq. and the degree of contamination (Cd) was defined as the sum of all contamination factors.

$$\mathrm{CF} = \frac{\text{Measured Concentration}}{\text{Bacground Concentration}}$$

Where, Background value of the metal = world surface rock average given by Martin and Meybeck (1979).

To evaluate the magnitude of contamination in the environment, the enrichment factors (EF) were computed related to the abundance of species in source material to that found in the earth’s crust and also it is a convenient measure of geochemical trends and is used for making comparison between areas (Sinex *et al.*, 1981) Enrichment Factor (EF) can be expressed as:

$$\mathrm{EF} = \frac{Cn}{CR}$$

Where, EF is ratio between the measured metal concentration (Cn) and the reconstructed background metal concentration (CR) instead of the average metal concentration in shale.

Each sampling site was evaluated for the extent of metal pollution by employing the method based on the

pollution load index (PLI) developed by Thomilson *et al.*, (1980) as follows:
PLI = n" (CF1 × CF2 × CF3 × .... CFn)

Where, *n* is the number of metals studied (seven in this study) and *CF* is the contamination factor defined by CF = C_{metal} / $C_{background}$. C_{metal} is the concentration of pollutant in sediment and $C_{background}$ is the background value for the metal. The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI >1 indicates deterioration of site quality.

The Potential Ecological Risk Index (RI) was originally introduced by Hakanson (1980) to assess the degree of heavy metal pollution in soil, according to the toxicity of metals and the response of the environment. RI could evaluate ecological risk caused by toxic metals comprehensively. The calculating methods of RI are listed below:

$F_i = C^i_n / C^i_o$
$E^i_r = T^i_r \times F_i$
$RI = \sum_{i=1}^{n} = Ei$

Where, Fi is the single metal pollution index; C^i_n is the concentration of metal in the samples; C^i_o is the reference value for the metal; E^i_r is the monomial potential ecological risk factor; T^i_r is the metal toxic response factor. The values for each element are in the order Zn = 1 < Cr = 2 < Cu = Ni = Pb = 5 < As = 10 < Cd = 30. RI is the potential ecological risk caused by the overall contamination. There are four categories of RI and five categories of E^i_r as follow:

Statistical software SPSS 16.0 was applied to determine the mean concentrations and standard deviation of heavy metals from the sampling sites. Relationships of heavy metal concentrations in sediments were tested by Pearson correlation analysis. Statistical significance was tested at 95% confidence level. The mean is the arithmetic average of a set of values, or distribution. The *arithmetic mean* is the "standard" average, often simply called the "mean". Following formula was used to calculate the mean concentration of metals:

$$\bar{X} = \frac{1}{n}\sum_{i=0}^{n} Xi$$

Where, $\bar{X}$ = Mean of concentration of metal, X_i = Observed metal concentration in different samples
Following formula was used to calculate the standard deviation of metal concentration.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=0}^{n}(Xi - \bar{X})}$$

Where, σ = Standard deviation of the data, N = Sample size
95% certainty is expressed in 95% confidence level. Normal distribution was performed to assess 95% confidence level due to sample size was below 30. To determine the confidence level by normal distribution, following formula was used. $z = \frac{\bar{X} - \mu o}{\frac{\sigma}{\sqrt{n}}}$

Where, = Sample mean, μ_0= Mean of particular metal, σ = Standard deviation of corresponded metal, n = Sample Size.
Results of the analysis were statistically analyzed by using of SPSS v.16 and Microsoft Excel 2007 software. Variations were considered significant at $p < 0.05$.

RESULTS & DISCUSSION

Heavy metal concentrations in the water samples collected from ship breaking site in Sitakunda are presented in Table 1. Concentrations of heavy metal ranges were: Pb: 0.134-0.904 mg/l; Mn: 0.103-0.589 mg/l; Cr: 0.150-0.976 mg/l; Cu: 0.107-0.750 mg/l; Zn: 0.017-0.850 mg/l. Cd was not detected in any of the tested sample and order of heavy metals concentration in the water samples were Cr > Pb> Zn > Cu > Mn > Cd. The mean concentration of heavy metals in water samples of ship breaking site, Sitakunda similar to the previously reported result in Karnaphuli River (Bashar *et al.* 2007). Finding of this study was higher compared to metals concentration Coastal water of Sitakunda, Chittagong as reported by Tamanna *et al*. (2010). The mean concentration of Cu was 0.267 ± 0.192 mg/l in water samples of ship breaking site, which was substantially higher than the Cu concentration (0.070 mg/l) in water from Palk Strait, Bay of Bengal (Govindasamy *et al.,* 2011) and also water of Ganga River in West Bengal (Kar *et al.,* 2008). Ship breaking activities that carry huge amount of Zn containing materials, therefore the study area was contaminated with Zinc.

E^i_r Value	Grades of ecological risk	RI value	Grades of the environment
E^i_r< 40	Low risk	RI<110	Low risk
40≤E^i_r<80	Moderate risk	110≤RI<200	Moderate
80 ≤E^i_r<160	Considerable risk	200≤ RI<400	Considerable risk
160 ≤E^i_r<320	High risk	400≤RI	Very high risk
320≤ E^i_r	Very high risk		

Pearson's correlation coefficient matrix among the selected heavy metals is presented in Table 2. No Significant correlations were found among the metals in water that could be indicating the source input or sources of pollution are different such as anthropogenic as a result of various human activities in ship breaking yard and neighboring coastal communities.

Sediment contamination poses one of the worst environmental problems in ecosystems, acting as sinks and sources of contaminants in aquatic sys-tems and sediment analysis plays an important role in assessing the pollution status of the environment (Mucha *et al*., 2003).The heavy metal concentrations in different sediment samples collected from ship breaking site in Sitakunda are presented in Table 3. Concentrations of heavy metal ranges were: Pb: 16.398-85.825.mg/kg; Mn: 12.596-28.345 mg/kg; Cr: 39.748-232.175 mg/kg; Cu: 25.245-83.356 mg/kg; Zn: 37.045-103.876 mg/kg dry weights. Cd was not detected in any of the tested sample and order of heavy metals concentration in sediment samples were: Cr > Zn > Pb > Cu > Mn > Cd. Comparing the metals concentrations in sediment sample of the ship breaking site with the previously studied results of that region, it is found that present findings is similar to the concentrations in sediment of ship breaking site Sitakunda, Chittagong (Hossain *et al*., 2006). The present study was higher than compared to the concentration ranges of heavy metals in salt marsh sediments of the Karnafuli River coast as reported by Siddique (2012). The higher concentration of Cr in water of ships breaking site was probably due to the activities of dismantling of large ship along the coast that carry huge amount of Cr bearing materials such as painting material, anti corrosive materials and chromium alloy and metal producing industry along the coast.

The primary purposes of sediment quality guidelines (SQGs) are to protect aquatic biota from the harmful and toxic effects related with sediment bound contaminants and is a useful tool for evaluating potential for contaminants within sediment to induce

Table 1. Heavy metal concentration of water sample in ship breaking site in Sitakunda

Sample ID	Concentration (mg/L)					
	Pb	Cr	Mn	Cd	Cu	Zn
S_AW_1	0.235	0.314	0.195	BDL	0.136	0.154
S_AW_2	0.272	0.150	0.164	BDL	0.127	0.098
S_AW_3	0.292	0.560	0.164	BDL	0.118	0.765
S_AW_4	0.290	0.807	0.129	BDL	0.117	0.365
S_AW_5	0.344	0.807	0.171	BDL	0.107	0.056
S_AW_6	0.563	0.235	0.137	BDL	0.140	0.437
S_AW_7	0.334	0.247	0.108	BDL	0.267	0.197
S_AW_8	0.134	0.970	0.239	BDL	0.455	0.840
S_AW_9	0.243	0.578	0.187	BDL	0.750	0.648
S_AW_{10}	0.675	0.374	0.206	BDL	0.131	0.375
S_AW_{11}	0.483	0.478	0.119	BDL	0.354	0.017
S_AW_{12}	0.870	0.735	0.103	BDL	0.275	0.850
S_AW_{13}	0.591	0.336	0.314	BDL	0.294	0.234
S_AW_{14}	0.904	0.134	0.589	BDL	0.174	0.567
S_AW_{15}	0.854	0.936	0.123	BDL	0.567	0.032
Maximum	0.904	0.976	0.589		0.750	0.850
Minimum	0.134	0.150	0.103		0.107	0.017
Mean	0.477	0.511	0.196		0.267	0.320
Std	0.265	0.284	0.122		0.192	0.282

Std-Standared deveation, BDL-Below Detection Limit

Table 2. Correlation coefficients (r) among heavy metal in water of the ship breaking site

Water/water	Pb	Mn	Cr	Cu	Zn
Pb	1.00				
Mn	.1208	1.00			
Cr	.3746	-0.3659	1.00		
Cu	.0724	0.40017	0.089	1.00	
Zn	.2103	0.02490	0.1766	0.04135	1.00

Table 3. Heavy metal concentrations of sediment sample in ship breaking site, Sitakunda

Sample ID	Concentrations (mg/kg)					
	Pb	Mn	Cd	Cr	Cu	Zn
S_ASd_1	67.791	18.979	BDL	132.426	83.356	93.347
S_ASd_2	34.994	23.299	BDL	114.458	53.570	55.698
S_ASd3	61.960	21.366	BDL	147.007	78.076	57.341
S_ASd_4	54.045	22.859	BDL	142.081	64.976	61.306
S_ASd_5	46.062	22.588	BDL	76.743	61.768	37.045
S_ASd_6	75.078	17.829	BDL	223.175	73.376	87.073
S_ASd_7	73.231	20.079	BDL	164.376	36.786	65.918
S_ASd_8	51.197	21.335	BDL	98.754	25.2453	76.567
S_ASd_9	63.317	23.107	BDL	85.341	31.564	63.936
S_ASd_{10}	85.825	12.596	BDL	82.375	40.453	56.568
S_ASd_{11}	37.486	13.313	BDL	59.674	49.155	59.498
S_ASd_{12}	16.39	16.449	BDL	39.784	39.809	97.964
S_ASd_{13}	79.875	18.979	BDL	89.877	35.905	103.876
S_ASd_{14}	47.373	19.609	BDL	68.147	45.597	54.745
S_ASd_{15}	53.994	28.345	BDL	77.867	31.765	89.845
Maximum	85.825	28.345		223.175	83.355	103.876
Minimum	16.398	12.596		39.784	25.2453	37.045
Mean	55.936	20.089		106.806	50.0932	70.715
Std	18.708	4.033		47.651	18.315	19.454

Std –Standard deviation BDL-Below Detection Limit

biological effects (Spencer and Macleod, 2002).The heavy metal contamination in the coastal sediments was evaluated by comparison with the sediment quality guideline proposed by USEPA (1987, 1989). These criteria are shown in Table 4. Present study shows that all the sampling sites are moderately to heavily polluted for Pb, Cr and Cu. On the other hand, Mn and Zn in all study sediments belong to unpolluted sediments.

According to the Muller scale, the calculated results of Igeo values are shown in Table 5. For Pb sediment quality be considered as moderately polluted (0≤ Igeo<2) for all stations while for Mn sediment quality was recorded unpolluted for all stations (Igeo<0). For Cr, Cu, and Zn sediment quality be considered as from unpolluted to moderately polluted (0≤ Igeo<1) for all stations.

Contamination factors of the sediment samples of ship breaking yard is presented in Table 6. In the present study, maximum contamination factor was found at the sampling site at the point where the degree of contamination factor was 11.7964 that indicate ($6 \leq C_d < 12$) moderate degree of contamination. The lowest degree of contamination factor was found 4.47 at the sampling site indicated low degree of contamination ($C_d < 6$). The mean contamination factors of all the metals were found: Pb: 2.459 (moderate contamination); Mn: 0.444 (low contamination); Cr: 2.272 (moderate contamination); Cu: 1.565 (moderate contamination); Zn: 1.178 (moderate contamination).

Enrichment Factor for the investigated sampling site is presented in Table 7. In the present study, EF value for all the metal (Pb, Cr, Cu and Zn) except Mn were found above 1 in all sampling site suggesting source of those metal (Pb, Cr, Cu and Zn) are more likely to be anthropogenic. A value of $0.5 \leq EF \leq 1.5$ suggests that traces of metal may be due to crystal materials or natural weathering processes (Zhang *et al.*, 2002). Samples having EFc value greater than 5 are considered to be contaminated with that particular element. According to Khan *et al.* (1992) EFc values <5 are considered significant. Areas with EFc values <1 should be viewed with caution as they imply preferential release of these metals, making them bioavailable.

Pollution Load Index (PLI) for the investigated stations was illustrated in Fig. 2. In this study, except two sites the PLI value of all sampling site are smaller than 1 (PLI < 1), indicating that entire site are perfect except two. Pollution load indices were found >1 at two sampling sites, both of the sites are very near to the ship breaking yard. This attributed that a high amount of metallic discharge from ship breaking activities.

The present the ecological risk assessment results of heavy metals in sediment of ship breaking site were summarized in Table 8. It was found that the average monomial risk factors E^i_r of metals in sediment of ship breaking site were ranked in the following order Mn < Zn < Cr < Cu < Pb. The average monomial

Table 4. Comparisons of heavy metal concentrations with EPA guidelines for sediments

Metal	Not polluted mg/kg	Moderately polluted mg/kg	Heavily polluted mg/kg	Present study mg/kg
Pb	<40	40-60	>60	55.93±18.70
Mn	<300	300-500	>500	20.08±4.03
Cr	<25	25-75	>75	106.8±47.65
Cd	na	na	> 6	BDL
Cu	<25	25-50	>50	50.09±18.31
Zn	<90	90-200	> 200	70.71±19.45

Na- not available, BDL-Below Detection Limit

Table 5. Geo-accumulation index (Igeo) values of heavy metals in sediments of ship breaking site, Sitakunda

Sample ID	Geo accumulation Index Igeo				
	Pb	Mn	Cr	Cu	Zn
S_ASd_1	1.17	-5.15	0.90	0.79	0.05
S_ASd_2	0.22	-4.85	0.90	0.15	-0.69
S_ASd3	1.04	-4.98	0.90	0.70	-0.65
S_ASd_4	0.84	-4.88	0.90	0.43	-0.55
S_ASd_5	0.61	-4.90	0.90	0.36	-1.28
S_ASd_6	1.32	-5.24	0.90	0.61	-0.04
S_ASd_7	1.28	-5.07	0.90	-0.38	-0.44
S_ASd_8	0.77	-4.98	0.90	-0.92	0.61
S_ASd_9	1.07	-4.87	0.90	-0.60	0.67
S_ASd_{10}	1.51	-5.74	0.90	-0.24	0.49
S_ASd_{11}	0.32	-5.66	0.90	0.034	0.57
S_ASd_{12}	-0.87	-5.36	0.90	-0.26	0.70
S_ASd_{13}	1.41	-5.15	0.90	-0.41	0.79
S_ASd_{14}	0.65	-5.10	0.90	-0.07	-0.13
S_ASd_{15}	0.84	-4.57	0.90	-0.59	0.58

Table 6. Contamination factor for the sediment Sample of the ship breaking site in Sitakunda

Sample ID	Contamination Factor(C_f)					Degree of contamination
	Pb	Mn	Cr	Cu	Zn	
S_ASd_1	2.94	0.04	2.81	2.60	1.55	9.96
S_ASd_2	1.52	0.05	2.43	1.67	0.92	6.61
S_ASd3	2.69	0.047	3.12	2.43	0.95	9.26
S_ASd_4	2.35	0.05	3.02	2.03	1.02	8.47
S_ASd_5	2.00	0.05	1.63	1.93	0.61	6.23
S_ASd_6	3.26	0.034	4.74	2.29	1.45	11.79
S_ASd_7	3.18	0.04	3.49	1.14	1.09	8.97
S_ASd_8	2.22	0.05	2.10	0.78	1.27	6.43
S_ASd_9	2.75	0.05	1.81	0.98	1.06	6.67
S_ASd_{10}	3.73	0.028	1.75	1.26	0.94	7.71
S_ASd_{11}	1.62	0.029	1.26	1.53	0.99	5.45
S_ASd_{12}	0.71	0.03	0.84	1.24	1.63	4.47
S_ASd_{13}	3.47	0.04	1.91	1.12	1.73	8.28
S_ASd_{14}	2.05	0.04	1.44	1.42	0.91	5.89
S_ASd_{15}	2.34	0.06	1.65	0.99	1.49	6.55
Mean	2.45	0.04	2.27	1.56	1.17	7.52

Table 7. Enrichment Factor (EF) of heavy metals in sediments of ship breaking site, Sitakunda

Sample ID	Enrichment factor				
	Pb	Mn	Cr	Cu	Zn
S_ASd_1	3.56	0.03	2.45	3.33	1.55
S_ASd_2	1.84	0.04	2.11	2.14	0.92
S_ASd3	3.26	0.04	2.72	3.12	0.95
S_ASd_4	2.84	0.04	2.63	2.59	1.021
S_ASd_5	2.42	0.04	1.42	2.47	0.61
S_ASd_6	3.95	0.03	4.13	2.93	1.45
S_ASd_7	3.85	0.04	3.04	1.47	1.09
S_ASd_8	2.69	0.04	1.82	1.00	1.27
S_ASd_9	3.33	0.04	1.58	1.26	1.06
S_ASd_{10}	4.51	0.025	1.52	1.61	0.94
S_ASd_{11}	1.972	0.02	1.10	1.96	0.99
S_ASd_{12}	0.86	0.03	0.73	1.59	1.63
S_ASd_{13}	4.20	0.03	1.66	1.43	1.73
S_ASd_{14}	2.49	0.03	1.26	1.82	0.91
S_ASd_{15}	2.84	0.056	1.44	1.27	1.49
Mean	2.97	0.035	1.97	1.99	1.17
Std	0.98	0.008	0.88	0.73	0.32

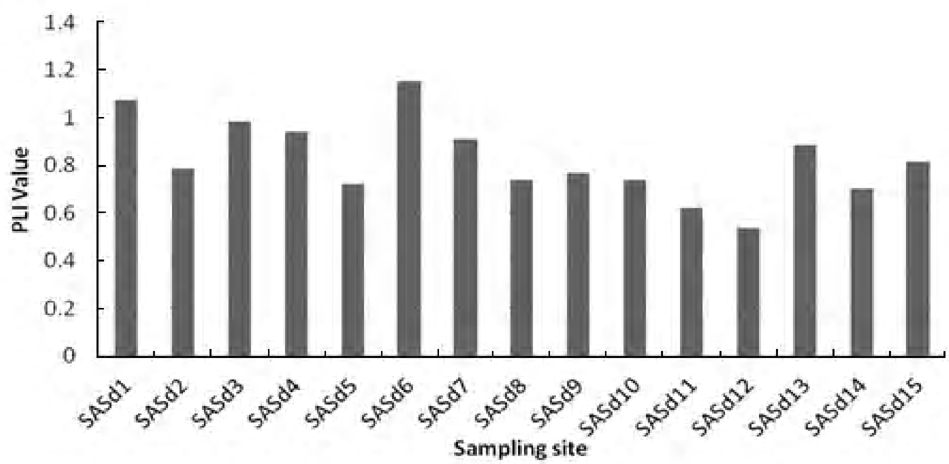

Fig. 2. Pollution Load Index (PLI) of the study area

Table 8. Heavy metal potential ecological risk indexes in sediment of ship breaking site in Sitakunda

Sample ID	Ecological Risk For Single Metal E_r^i					RI
	Pb	Mn	Cr	Cu	Zn	
S_ASd_1	14.73	0.08	5.63	13.02	1.55	35.03
S_ASd_2	7.60	0.10	4.87	8.370	0.92	22.50
S_ASd3	13.46	0.09	6.25	12.19	0.95	33.57
S_ASd_4	11.74	0.10	6.04	10.15	1.02	29.60
S_ASd_5	10.01	0.10	3.26	9.65	0.61	24.58
S_ASd_6	16.32	0.078	9.49	11.46	1.45	38.91
S_ASd_7	15.91	0.08	6.99	5.74	1.09	30.307
S_ASd_8	11.12	0.09	4.20	3.94	1.27	20.92
S_ASd_9	13.76	0.102	3.63	4.93	1.06	23.98
S_ASd_{10}	18.65	0.05	3.50	6.32	0.94	30.09
S_ASd_{11}	8.14	0.05	2.53	7.68	0.99	19.98
S_ASd_{12}	3.56	0.07	1.69	6.22	1.63	13.10
S_ASd_{13}	17.36	0.08	3.82	5.61	1.73	28.43
S_ASd_{14}	10.29	0.08	2.89	7.12	0.91	21.96
S_ASd_{15}	11.73	0.12	3.31	4.96	1.49	21.69
Mean	12.29	0.08	4.54	7.82	1.17	

Table 9. Correlation coefficients (r) among heavy metal in sediment sample

Sediment/sediment	Pb	Mn	Cr	Cu	Zn
Pb	1.00				
Mn	-0.116	1.00			
Cr	0.520*	0.103	1.00		
Cu	0.860*	-0.074	0.543*	1.00	
Zn	0.120	-0.036	0.068	-.133	1.00

Note: * is significant at p<0.05 (2-tail)

Table 10. Correlation co-efficient (r) between the heavy metal in sediment and water

Sediment/water	Pb	Mn	Cr	Cu	Zn
Pb	0.158	-0.124	-0.406	0.268	0.261
Mn	0.317	0.592*	-0.325	0.257	0.043
Cr	0.092	-0.542*	-0.255	0.148	-0.104
Cu	0.613*	0.523*	-0.345	0.789*	0.248
Zn	0.073	-.0179	0.006	0.134	0.689*

Note: * Correlation is significant at p<0.05 (2- tail)

ecological risk for all selected metals were found below 40 that indicated all metals posed low risk to the surrounding ecosystem and Risk Index also found below 110 at all sampling site that indicate surrounding environment were exposed low risk.

Pearson's correlation coefficient matrix among the selected heavy metals is presented in Table 9. Significant correlations between the contaminants of Pb and Cr (r=0.520), Pb and Cu (r=0.860), Cr and Cu (r=0.543) are significantly correlated with each other, whereas the rest of elemental pairs show no significant correlation with each other, suggesting that these metals are not associated with each other and their identical behavior transport in coastal environment. Elemental association may signify that each paired elements has identical source or common sink in the sediments (Singh *et al.,* 2002).

Pearson's correlation coefficient matrix between the selected heavy metals in sediment and water is presented in Table10. Significant correlations between the contaminants of Pb and Cu (r =0.613), Mn and Mn (r =0.592), Mn and Cr (r =0.542), Mn and Cu (r =0.523), Cu and Cu (r =0.789), Zn and Zn (r =0.689), These correlations between sediment and water heavy metals may reflected that these heavy metals had similar pollution level and similar pollution sources as described by Li *et al,* (2009). However, most of the metal in water and sediment are not significantly correlated even some metal show negative correlation, these metals might have different anthropogenic and natural sources in sediments of the area of study.

CONCLUSION

- Concentrations of all the tested heavy metals except Cr in water samples of ship breaking site, Sitakunda were lower than recommended values. The mean concentration of Cr was 0.511mg/l. Concentrations of all the heavy metals except Mn in sediment samples of ship breaking site, Sitakunda were higher than guidelines. Mean Concentration of heavy metals concentration in sediment samples were in order: Cr > Zn > Pb > Cu > Mn.
- Considering USEPA, Geoaccumulation Index (Igeo) and Contamination Factor (C_f) the sediment samples are moderately to heavily pollute with Pb, Cu, Zn and Cr. Enrichment factor (EF) value for all the metals (Pb, Cr, Cu and Zn) except Mn were found > 1 in all sampling sites suggesting source of those metal (Pb, Cr, Cu and Zn) are more likely to be anthropogenic. The average monomial ecological risks for all selected metals were found below 40, which indicated all metals posed to low risk to the surrounding ecosystem.

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