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Trace Elements in Water and Surface Sediments of the Bhairab, Rupsha and Pausur River in Bangladesh

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Abstract: This study investigated the arsenic, iron and manganese pollution level of the Bhairab, Rupsha and Pausur river water and sediments at five sampling stations of Jessore, Khulna and Bagerhat districts in Bangladesh. Average concentration of arsenic, iron and manganese in river water was acceptable range of surface water standard in Bangladesh. Average concentration of arsenic, iron and manganese in river sediments was lower than world surface rock average value but it was showed higher than background soil and USEPA SQG standard value for sediment. Maximum concentration of arsenic, iron and manganese was found on the Bhairab river sediments. Arsenic, iron and manganese was detected in the river sediment which order was Bhairab>Rupsha> Passur. Average leaching (TCLP) of arsenic from sediment was lower than USEPA TCLP standard (<5mg/Kg) for hazardous waste which was not hazardous for aquatic environment. Contamination factor, geo accumulation index and pollution load index analysis data was indicated that the pollution level was low in the Bhairab, Rupsha and Pausur river sediment which order was Bhairab>Rupsha> Pausur. This study can contribute some reference data on water and sediment quality monitoring of three rivers in the Bengal delta plain.

Keywords: *Arsenic; Water; Sediment; TCLP; USEPA; Pollution Index*

Introduction: Bangladesh is a land of river; the Padma, the Meghna and the Jamuna are the main rivers of Bangladesh. More than 405 rivers are passing through this country including 53 international rivers [1]. The Padma Basin, covering the south western parts of Bangladesh which is called the Bengal delta plain. Sediments is the complex mixture of various mineral species as well as organic waste which is represent as ultimate sink for heavy metals discharged in to the environment [2]. Chemical leaching of bedrocks, water drainage basins and run off from banks are the primary sources of heavy metals [3]. Others anthropogenic pollution sources are mining operations, discharges of industrial wastes and agricultural runoff [4]. Heavy metals are serious pollutants due to their toxicity ,persistence and no degradability in the environment[5]. Heavy metals contamination in aquatic eco systems through river sediments is the most challenging issues for protecting aquatic environmental pollution [6]. Heavy metals can be absorbed by suspended solids and strongly accumulated in sediments when it is discharged into aquatic environment [7]. Polluted sediments can acts as a sources of heavy metals when it can be dissolve and contributed for debasing of water quality [8]. Many researcher have been conducted

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research studies on heavy metals contamination in river sediments [9]. In Bangladesh many studies has been investigated the contamination of heavy metals in the Meghna, Shitolokha, Turag and Buriganga river sediments [10, 11, 12, 13]. Limited studies have been monitored the heavy metals contamination and leaching characteristics of river sediment in southern delta rivers Bhairab-Rupsha and Pausur [14, 15]. The Bhairab, Rupsha and Pausur river is passing through Noapara, Fultala, Shiromoni, Rupsha and Mongla industrial and municipal area of Jessore, Khulna and Bagerhat districts in Bangladesh [14, 15]. There are many jute processing, cement manufacturing, fertilizer manufacturing, construction materials and automobile oil processing industries are available on the bank of these rivers which waste water drainage lines were directly connected with river without any treatment[14]. Industrial and municipal wastes can cause heavy metal pollution in river water and sediments. All of industries and business related activities have a relationship with the Bhairab-Rupsha-Pausur River for transportation from the inland water port to Mongla sea port and Noapara river port which can contribute heavy metal pollution in river water and sediments .The huge population communities are using the Bhairab-Rupsha-Passur River for such diverse purposes as domestic and industrial supply, crops irrigation, transportation, recreation and fisheries. River water and sediment quality monitoring is very important for surface water safety and aquatic life. This research objective is to assess the concentration of heavy metals and degree of contamination in the Bhairab-Rupsha and Pausur river water and sediments.

Materials & Method: This study was conducted on water and sediments quality monitoring at 5 sampling points in rainy season. River water and sediments sample was collected in June, 2016 from the estuaries of 5 different sampling stations which stations were Daitala Bridge, Afra Bridge, Noapara ferry ghat, Rupsha bridge and Mongla port [Figure-01, Table-01]. Water sample was collected in 100ml plastic bottles for metal analysis which was preserved by 2ml of 6N nitric acid [16]. Surface sediments (0-10cm) were collected in poly bag by using grab samples from five sampling stations [17]. Sediments sample were dried in electric oven at 105˚C for 48 hours which was digested with 15ml of concentrated nitric acid and 3ml of 30% hydrogen peroxide on hot plate at 95˚C under fume hood [16].

Concentration of iron and manganese was measured by flame-AAS method and arsenic was measured by HG-AAS (AA-7000, Shimadzu, Japan) method. On the other hand sediments sample moisture contents, pH and organic matter was analysis by gravimetric, membrane electrode and dichromate method respectively. The river sediments TCLP test was conducted by using USEPA method which sample was mixed with TCLP extraction fluid (pH 2.88 & 4.89) at 1:20 ratio and it was mixing at 30±2 rpm for 18 hours by using suspension mixer [18]. For evaluating the degree of contamination in the sediments four parameters; Contamination Factor (CF), Pollution Load Index (PLI) and Geo-accumulation Index (I_{geo}).was used which was calculated by the following equation.

Contamination Factor (CF): Contamination factor is expressed the level of contamination of sediment by metal is expressed by this equation.

$$CF = C_{msample} / C_{mbackground} \quad \text{eq. 1}$$

Where $C_{msample}$ is the concentration of a given metal in river sediment and $C_{m\ background}$ is value of metal equals to the world surface rock average [19].

Pollution Load Index (PLI): Pollution load index was calculated by the following equation [19].

$$PLI = (CF_1 \times CF_2 \text{-------} CF_n)^{1/n} \quad \text{eq. 2}$$

Where CF is the contamination factor and n is the number of metals.

Geo Accumulation Index (Igeo): Enrichment of metal concentration above baseline concentration was calculated by the following equation.

$$I_{geo} = \text{Log}_2 [C_{m\ sample} / (1.5 \times C_{m\ background})] \quad \text{eq. 3}$$

Where C_m sample is the measured concentration of element n in the sediment sample and C_m background is the geochemical background value (world surface rock average by [19]. The factor 1.5 is introduced to include possible variation of background values due to lithogenic effect.

Table 1. Geographical information of study area

Sample ID	River Name	Sampling Station	Union	Upazila	District	GPS Position	
						Latitude (N)	Longitude (E)
RS-1	Bhairab	Daitala Bridge	Kachua	Jessore Sadar	Jessore	$23^0 09' 55''$	$89°16' 53.4''$
RS-2	Bhairab	Afra Bridge	Basundia	Jessore Sadar	Jessore	$23^0 06' 52.6''$	$89^0 23' 58''$
RS-3	Bhairab	Noapara Ferry Ghat	Noapara	Abhainagar	Jessore	$23^0 01' 64''$	$89^0 23' 58''$
RS-5	Rupsha	Rupsha Bridge	Labanchara	Rupsha	Khulna	$22^0 28' 17.5''$	$89^0 35' 32.5''$
RS-6	Passur	Mongla Port Dock Yard	Mongla	Mongla	Bagerhat	$22^0 28' 16.0''$	$89°35' 32.5''$

Fig. 1: Location of study area and GPS position

Results and Discussion: River sediments analysis results were showed in the Table-02 and Table-03 which was collected from three rivers at five sampling stations. Arsenic, iron and manganese contents were analyzed in river water samples which were presented in Table-02. Moisture contents, pH, organic matter, arsenic, iron and manganese contents were measured in river sediments sample which was showed in Table-03.

Table 2. Arsenic, iron and manganese concentration in river water

Sample ID	Sampling Station Name	River Name	Conc. of arsenic in river water (mg/L)	Conc. of iron in river water (mg/L)	Conc. of manganese in river water (mg/L)
RW-1	Daitala	Bhairab	0.025	0.43	0.23
RW-2	Afra	Bhairab	0.017	0.82	0.09
RW-3	Noapara	Bhairab	0.013	2.32	0.11
RW-5	Rupsha	Rupsha	0.011	1.07	0.08
RW-6	Mongla	Pausur	0.010	2.15	0.04
Maximum			0.025	2.32	0.23
Minimum			0.010	0.43	0.04
Average			0.015	1.36	0.11
STD. Deviation			0.006	0.83	0.07
Bangladesh DoE standard for surface water(1997)			0.05	0.30	0.10
WHO standard for surface water(1993)			0.01	0.30	0.10
USEPA standard for surface water(2002)			0.01	0.30	0.10

Moisture content pH and Organic matter in sediment: Average concentration of moisture content, pH and organic matter in river sediments were 38.07 ± 5.18%, 8.38 ± 0.35 and 1.29 ± 1.21 % respectively (Table-03). Maximum moisture contents and organic matter was monitored

44.22% and 3.41% at Daitala station in the Bhairab river sediments (Table-03).On the other hand minimum moisture contents and organic matter was measured 30.42% & 0.43% at Rupsha Bridge station in the Rupsha river sediments. Maximum pH was monitored 8.79 at Mongla Port Dock yard station in the Passur River sediments. Minimum pH was measured 8.00 at Daitala station in the Bhairab river sediments. This study was showed that pH of the three rivers sediments was slightly alkaline and level of organic matter was low.

Arsenic in water and sediments: Average concentration of arsenic in the river water and sediment was showed 0.015±0.006mg/L & 8.72±2.10mg/Kg respectively (Table-02 & Table-03). Average concentration of arsenic in river water was lower than DoE standard (<0.05mg/L) but it was higher than WHO and USEPA standard (<0.01mg/L) [20]. Average concentration of arsenic in the river sediments was lower than world surface rock average (13.00mg/Kg) and mean shale concentration (16.4mg/Kg)(Table-03). On the other hand average concentration of arsenic in river sediments was higher than USEPA SQG standard (6.00mg/Kg) which was exceed than Toxicity Reference Value (TRV). Maximum concentration of arsenic was monitored 0.025mg/L and 11.85mg/Kg in the Bhairab river water and sediment at Daitala bridge station (Table-02, Table-03 & Fig-2). Arsenic contents of the Bhairab river sediments at Dailata station washigher than others sampling stations due to higher contents of organic matter, tidal flow and agriculture runoff which was washed from upper stream and deposited on river surface sediments. Minimum concentration of arsenic was found 0.010mg/L and 6.88mg/Kg in the Passur river water and sediment at Mongla Port Dock Yard station due to lower contents of organic matter and strong current flow (Table-02, Table-03 & Fig-2). Concentration of arsenic in river sediments was higher than USEPA SQG standard at all sampling station which was indicated the ecological risk for aquatic environment. Fig-7 was showed that the relation between the concentration of arsenic and organic matter in sediments which relation coefficient was 0.788.

Iron in water and sediments: Average concentration of iron was showed 1.36±0.83mg/L & 22039.00 ± 2453.07mg/Kg respectively (Table-02& Table-03). Average concentration of iron in river water was higher than DoE and USEPA standard (>0.30mg/L)[20]. Average concentration of iron in the river sediments was lower than world surface rock average concentration (35900mg/Kg). Maximum concentration of iron was showed 2.32mg/L and 26319.50mg/Kg in the Bhairab river water and sediments at Noapara and Daitala station (Table-02, Table-03 & Fig-3). Minimum concentration of iron was measured 0.43mg/L & 20442.67mg/Kg in the Bhairab river water and sediments at Daitala and Noapara station (Table-02, Table-03 & Fig-3).

It was showed that iron concentration in river sediments were higher than USEPA SQG standard (>30mg/Kg) at all sampling stations along three rivers which was the presented the ecological risk for aquatic environment. Fig-8 was showed that iron concentration and organic matter in sediments has a strong relation which relation coefficient was showed 0.952.

Table 3. Moisture contents, pH, organic matter, arsenic, iron and manganese concentration in river sediments.

Sample ID	Sampling points	Name of River	Moisture contents in sediments (%)	Conc. Of pH in sediments	Conc. Of organic matter in sediments (%)	Conc. Of Arsenic in sediments (mg/Kg)	Conc. Of Manganese in sediments (mg/Kg)	Conc. Of Iron in sediments (mg/Kg)
RS-1	Daitala	Bhairab	44.22	8.00	3.41	11.85	1338.83	26319.50
RS-2	Afra	Bhairab	40.01	8.25	1.10	8.03	417.83	21842.17
RS-3	Noapara	Bhairab	39.71	8.71	0.90	9.78	410.83	20442.67
RS-5	Rupsha	Rupsha	30.42	8.15	0.43	7.05	377.50	20978.50
RS-6	Mongla	Pausur	35.97	8.79	0.62	6.88	375.83	20612.17
Maximum			44.22	8.79	3.41	11.85	1338.83	26319.50
Minimum			30.42	8.00	0.43	6.88	375.83	20442.67
Average			38.07	8.38	1.29	8.72	584.17	22039.00
STD. Deviation			5.18	0.35	1.21	2.10	422.30	2453.07
World surface rock average(mg/Kg)						13	750	35900
Mean shale Concentration(mg/Kg)						16.40	850	46700
USEPA SQG. Conc(mg/Kg)						6.00	30	30
Background soil average (mg/Kg)						5.12	157.67	10549.67

Manganese in water and sediments: Average concentration of manganese in river water and sediments was0.11 ± 0.07mg/L &584.17 ± 422.30mg/Kg respectively (Table-02 & Table-03).Average concentration of manganese in the river water was higher than DoE and USEPA standard (>0.10mg/L) [20]. Average concentration of manganese in the river sediments was lower than world surface rock average (750mg/Kg).Maximum concentration of manganese was showed 0.23mg/L and 1338.83mg/Kg in the Bhairab river water and sediments at Daitala station which concentration was higher than others sampling stations due to high concentration of organic matter tidal flow and agriculture runoff (Table-02, Table-03 & Fig-4). Minimum concentration of manganese was measured 0.04mg/L & 375.83mg/Kg in the Passur river water and sediments at Mongla port station which concentration was lower than others sampling stations due to lower organic contents and strong current flow (Table-02, Table-03 & Fig-4). It was showed that manganese concentration in river sediments were higher than USEPA SQG standard at all sampling stations which was indicated the ecological risk for aquatic environment. Fig-9 was showed that the relation between manganese concentration and organic contents in the river sediments which relation coefficient was 0.970.

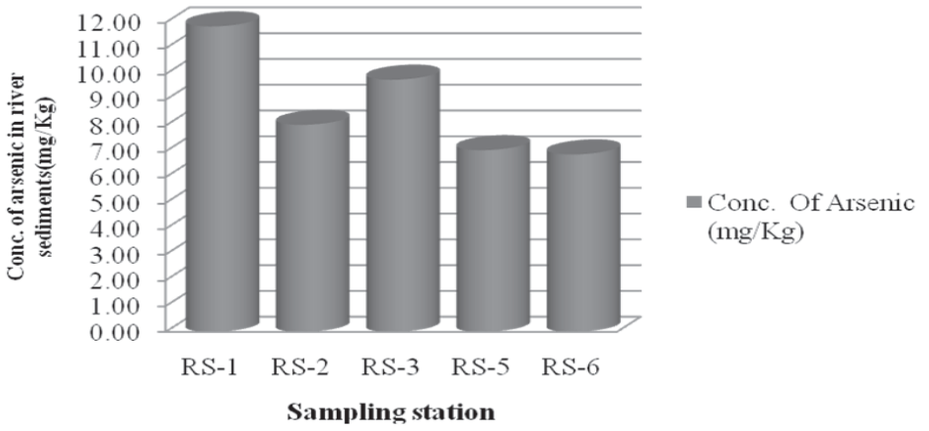

Fig 2: Arsenic concentration graph in river sediments

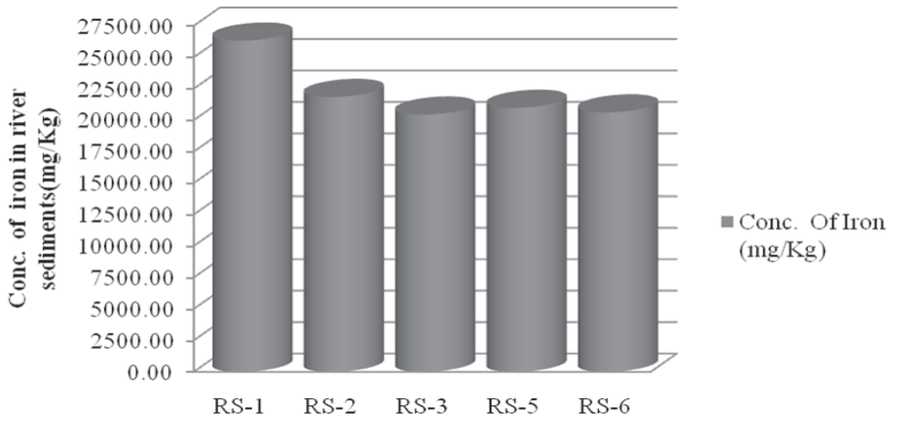

Fig. 3: Iron concentration graph in river sediments

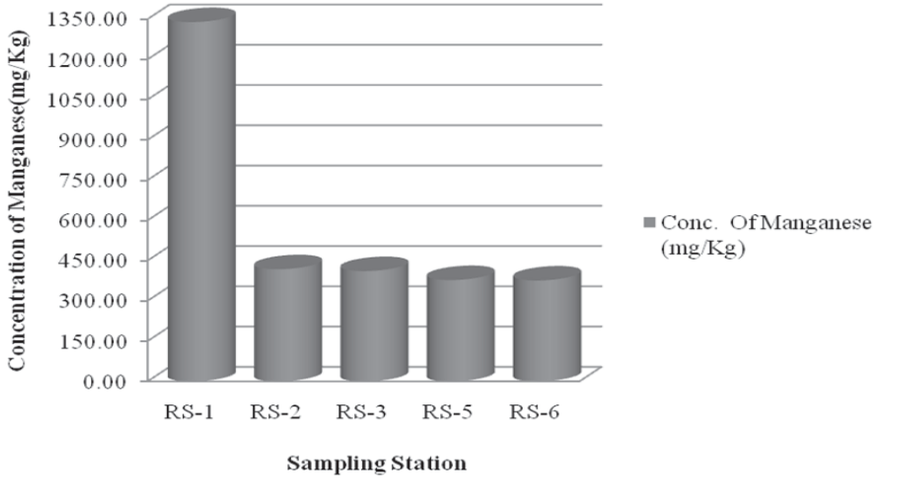

Fig 4: Manganese concentration graph in river sediments

Leaching properties of sediment: Leaching characteristics is the indicator of toxicity level of contaminated waste, sludge, soil or sediment for environment which is determined by TCLP test. Average TCLP value for leaching of arsenic and manganese from sediment was showed 0.19±0.12mg/Kg and 58.23±31.57mg/Kg which was lower than USEPA TCLP standard 5mg/Kg (Table-04). Maximum leaching concentration of arsenic and manganese was monitored0. 39mg/Kg and 114.10mg/Kg in the Bhairab River sediment at Daitala station due to high concentration of arsenic and manganese in sediment (Table-4). Minimum leaching concentration of arsenic and manganese was detected 0.11mg/Kg and 37.98mg/Kg in the Passur river sediment at Mongla port station which sediments sample arsenic and manganese concentration was lower than others sediments(Table-4). Fig-5 & Fig-6 were showed the leaching concentration has a relation with total arsenic and manganese concentration in river sediment which relation coefficients were 0.964 and 0.989.

Pollution status: According to USEPA standard (USEPA, 1998) for chemical contaminations in the river sediments were evaluated by comparison with the sediment toxicity reference value (TRV).It is a toxicological index for aquatic life which is used for ecological risk assessment in aquatic environment. The study was showed that arsenic, iron and manganese concentration in river sediment was higher than USEPA recommended TRV value which can effect on ecological system in aquatic environment.

Table 4. Leaching concentration (TCLP) of arsenic, iron and manganese in river sediments

Sample ID	Sampling points	Name of River	Conc. of initial pH (TCLP) in sediments	Conc. of final (0.1N HCl treated) pH (TCLP) in sediments	Conc. Of leached (TCLP) arsenic in sediment (mg/Kg)	Conc. Of leached (TCLP) iron in sediment (mg/Kg)	Conc. Of leached (TCLP) manganese in sediment (mg/Kg)	TCLP extractor
RS-1	Daitala	Bhairab	8.00	6.00	0.39	0.25	114.10	Fluid-2(pH 2.88)
RS-2	Afra	Bhairab	8.25	0.32	0.12	0.67	48.48	Fluid-1(pH 4.89)
RS-3	Noapara	Bhairab	8.71	0.80	0.23	5.13	48.83	Fluid-1(pH 4.89)
RS-5	Taltala	Bhairab	8.15	6.33	0.11	5.06	41.75	Fluid-2(pH 2.88)
RS-6	Mongla	Pausur	8.79	2.20	0.11	2.38	37.98	Fluid-1(pH 4.89)
Maximum			8.79	6.33	0.39	5.13	114.10	
Minimum			8.00	0.32	0.11	0.25	37.98	
Average			8.38	3.13	0.19	2.70	58.23	
STD. Deviation			0.35	2.86	0.12	2.33	31.57	

Geo Accumulation Index: Geo accumulation index is to evaluate the heavy metal contamination in sediments which is proposed by Muller, 1979 [19]. The geo accumulation index scale developed by Pekey. It was monitored that the value of contamination factor and geo accumulation index was lower than 1 which was indicated the pollution level in river sediment was low (Table-05).

Table 5. Contamination factor, Geo accumulation Index and pollution Load index of arsenic, iron and manganese in river sediments

Parameter			Arsenic		Manganese		Iron		Pollution status	
Sample ID	Sampling points	Name of River	Cont. factor (Cf)	Geo accumulation Index (Igeo)	Cont. factor (Cf)	Geo accumulation Index (Igeo)	Cont. factor (Cf)	Geo accumulation Index (Igeo)	Degree of Contamination (C_d)	Pollution Load Index (PI)
RS-1	Daitala	Bhairab	0.91	-0.21	1.79	0.08	0.73	-0.31	3.43	1.06
RS-2	Afra	Bhairab	0.62	-0.39	0.56	-0.43	0.61	-0.39	1.78	0.60
RS-3	Noapara	Bhairab	0.75	-0.30	0.55	-0.43	0.57	-0.42	1.87	0.62
RS-5	Rupsha	Rupsha	0.54	-0.44	0.50	-0.47	0.58	-0.41	1.63	0.55
RS-6	Mongla	Pausur	0.53	-0.46	0.50	-0.48	0.57	-0.42	1.60	0.54
Maximum			0.91	-0.21	1.79	0.08	0.73	-0.31	3.43	1.06
Minimum			0.53	-0.46	0.50	-0.48	0.57	-0.42	1.60	0.54
Average			0.67	-0.36	0.78	-0.35	0.61	-0.39	2.06	0.67
STD. Deviation			0.16	0.10	0.56	0.24	0.07	0.05	0.77	0.22

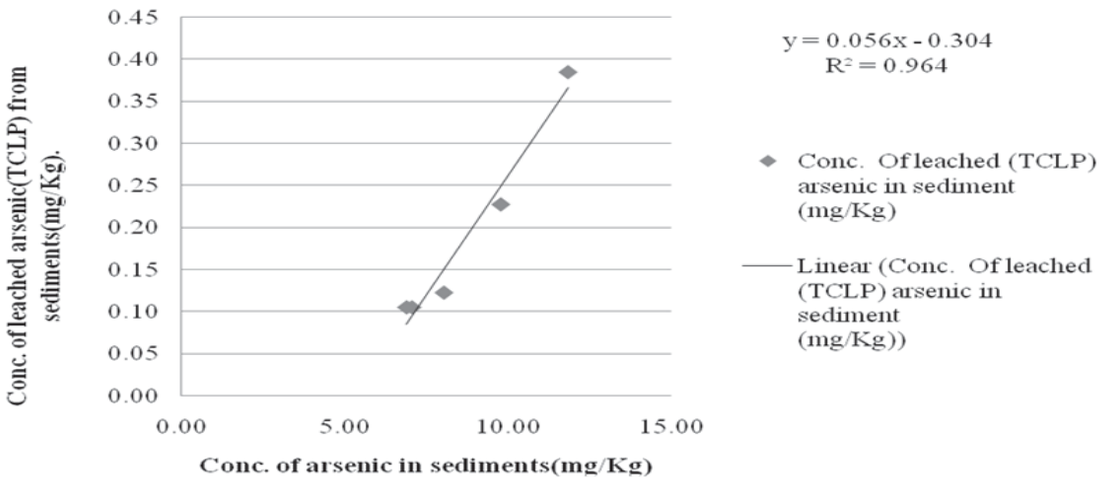

Fig. 5: Co-relation graph between arsenic contents and leaching concentration (TCLP) in river sediments

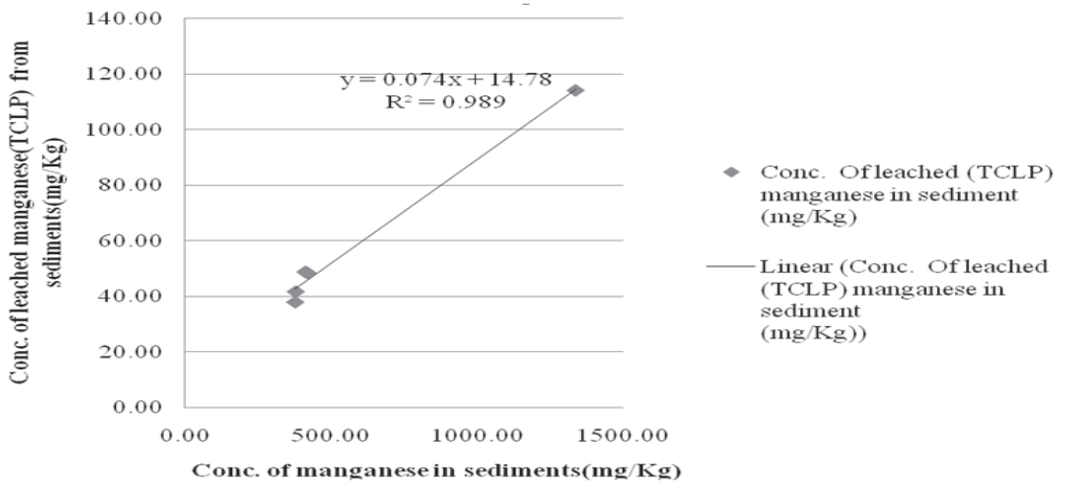

Fig. 6: Co-relation graph between Manganese contents and leaching concentration (TCLP) in river sediments

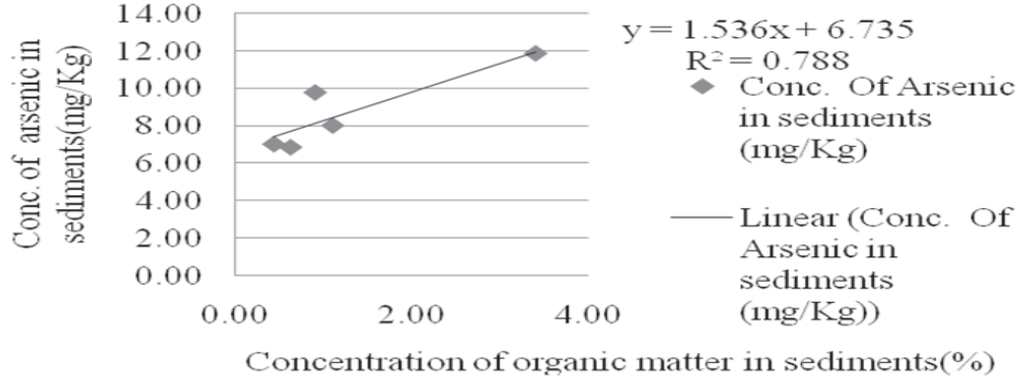

Fig. 7: Co-relation graph between Arsenic and Organic matter contents in river sediments

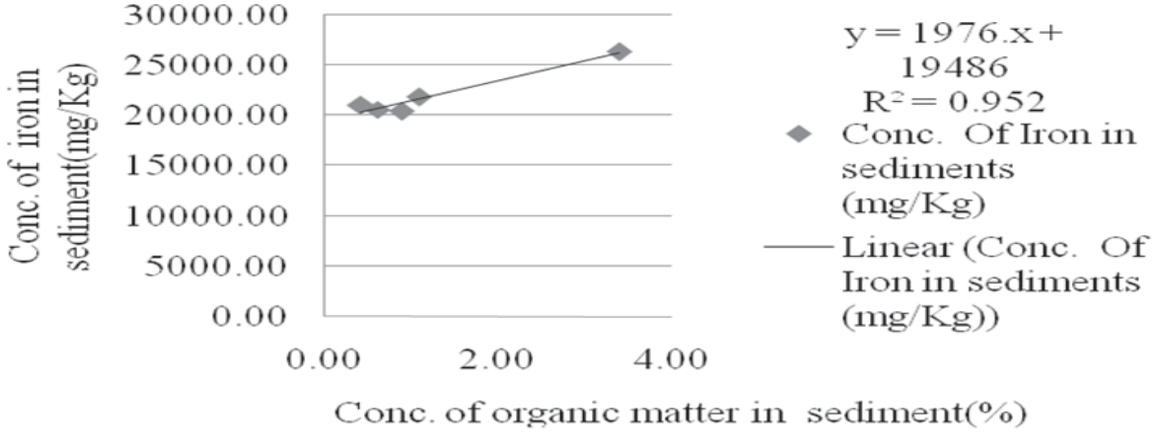

Fig. 8: Co-relation graph between Iron and Organic matter contents in river sediments

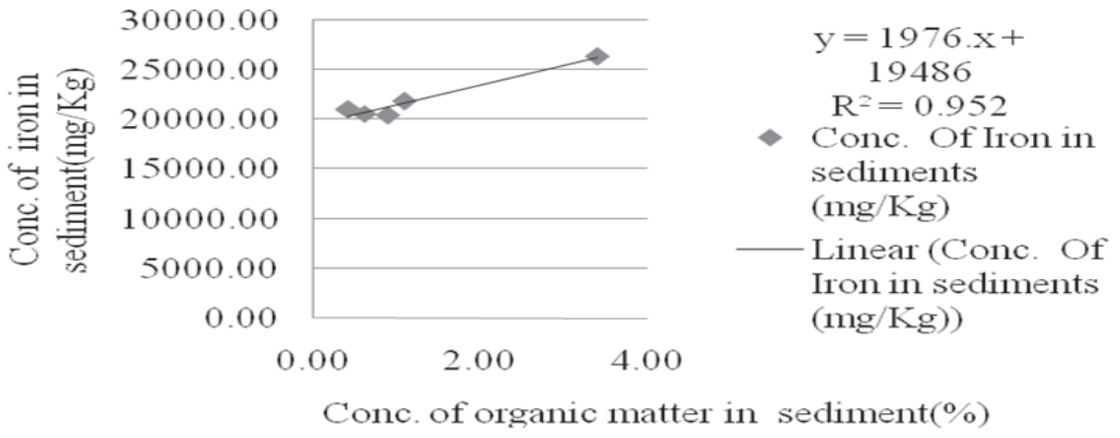

Fig. 9: Co-relation graph between Manganese and Organic matter contents in river sediments

Degree of Contamination and Pollution Load Index: Degree of contamination was lower than 8 which were indicated the pollution level was low. On the other hand pollution load index values were lower than 1 (except RS-1) at RS-2, RS-3, RS-5 and RS-6 sampling stations which location s were not polluted (Table-05). In case of RS-1 at Dailata station in the Bhairab river sediment sample pollution load index was higher than 1.00 which location river sediment was polluted.

Conclusions: Arsenic, iron and manganese concentration in river sediments was analyzed to measure the load of heavy metals, its leaching properties and pollution status monitoring. According to study analysis data was expressed the concentration of arsenic, iron and manganese in river sediment was exceeded than TRV value which was recommended by USEPA. Except Daitala station all of sampling stations sediment sample pollution level was low. Daitala station was indicated the heavy metal pollutants were deposited on upper river sediment through human activities and tidal flow system.

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