

Assessment of Water and Sediment Quality of Noakhali Canal, Noakhali, Bangladesh



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Abstract

The present investigation has been conducted to examine the surface water and sediment quality especially some selected heavy metals of Noakhali canal adjacent to Bangladesh Small Cottage and Industries Corporation (BSCIC), Begumganj, Noakhali, Bangladesh. The concentrations of heavy metals in water and sediment have been analyzed by means of Flame Atomic Absorption Spectrophotometer (FAAS). The mean values of pH, EC, TDS, P, K, SO₄²⁻, Cl⁻, NaCl and Temperature in surface water were 6.744, 1302μS/cm, 634.9mg/L, 0.0835mg/L, 0.466cmol+, 2.978mg/L, 328.289mg/L, 2.46mg/L and 26.84 °C, respectively. The average concentration of Fe and Mn in surface water was 0.55mg/L and 0.4081mg/L and the rest of heavy metals were found below detection limit. The mean values of pH, EC, OC, OM, TN, P, K, S in sediment sampling sites were 6.83, 565.5, 2.427%, 4.185%, 0.21%, 43.1μg/g, 0.5 meq/100gm, 157μg/g, respectively. The order of heavy metals in sediment was Fe > Mn > Zn > Pb > Cu. Almost all water and sediment quality parameters and heavy metals were within acceptable limit prescribed by national and international standards except Fe, EC, OC, OM, S, P and K. According to Sediment Quality Guideline, sediment samples were not polluted for Pb, Cu, Mn, and Zn. The geo-accumulation index (I_{geo}) showed no pollution for most of the sampling sites for all studied heavy metals except Fe. The I_{geo} value of Fe showed that the sediment was unpolluted to moderately polluted. Pollution Load Index (PLI) and Contamination Factor (CF) also showed no pollution for all the examined heavy metals. This study can be used as a baseline to monitor the quality of water and sediment of this canal which will help to preserve a healthy aquatic ecosystem.

Keywords: Heavy metals; Water and sediment quality; Geo-accumulation index; Contamination factor; Pollution load index; Noakhali canal

Abbreviations: BSCIC: Bangladesh Small Cottage and Industries Corporation; FAAS: Flame Atomic Absorption Spectrophotometer; I_{geo}: Geo-Accumulation Index; PLI: Pollution Load Index; CF: Contamination Factor

Introduction

Heavy metal pollution is considered to be a serious threat to any aquatic ecosystems owing to its toxicity, long-term persistence, ubiquity, non-biodegradability, and subsequent accumulation into the food chain [1]. Heavy metals enter these aquatic systems mainly through natural inputs such as weathering and erosion of rocks and anthropogenic sources including industrial, urban and agricultural activities, sewage disposal and terrestrial runoff [2]. Numerous industries have been set up in many cities including the quantity of new industries is consistently expanding [3]. Bangladesh is one of the most polluted countries, which currently holds 1176 industries that discharge about 0.4 million m³ of untreated waste to the rivers in a day [4]. As a result of rapid urbanization and industrialization in Bangladesh, economic growth is increasing but the environment is changing extremely

[5]. So, study on heavy metals as well as physical and chemical qualities of water and sediment like pH, EC, TDS, P, K, SO₄²⁻, Cl⁻, OM, OC, TN in rivers, lakes, fish and sediment have been a noteworthy environmental core interest which are required for the growth of phytoplankton, zooplankton and fish [6-9]. The identification and quantification of heavy metal in aquatic environment is an imperative environmental issue and the distribution processes of heavy metals are controlled by a dynamic set of physical-chemical equilibria, i.e. metal solubility is chiefly controlled by pH, concentration and type of ligands and chelating agents, oxidation-state of mineral components and the redox condition of the system [10-11]. Noakhali canal receives industrial wastewater directly from industries and also domestic and agro-chemical wastes which contribute heavy metal pollution and deterioration of other

water and sediment quality parameters. However, to the best of our knowledge, no significant studies have been undertaken to investigate the pollution level of the Noakhali canal situated in Noakhali District of Bangladesh. The present investigation has

been conducted to observe the status of selected heavy metals in water and sediment of Noakhali canal. Moreover, determination of the general water and sediment quality of Noakhali canal has also been conducted.

Materials and Methods

Study area

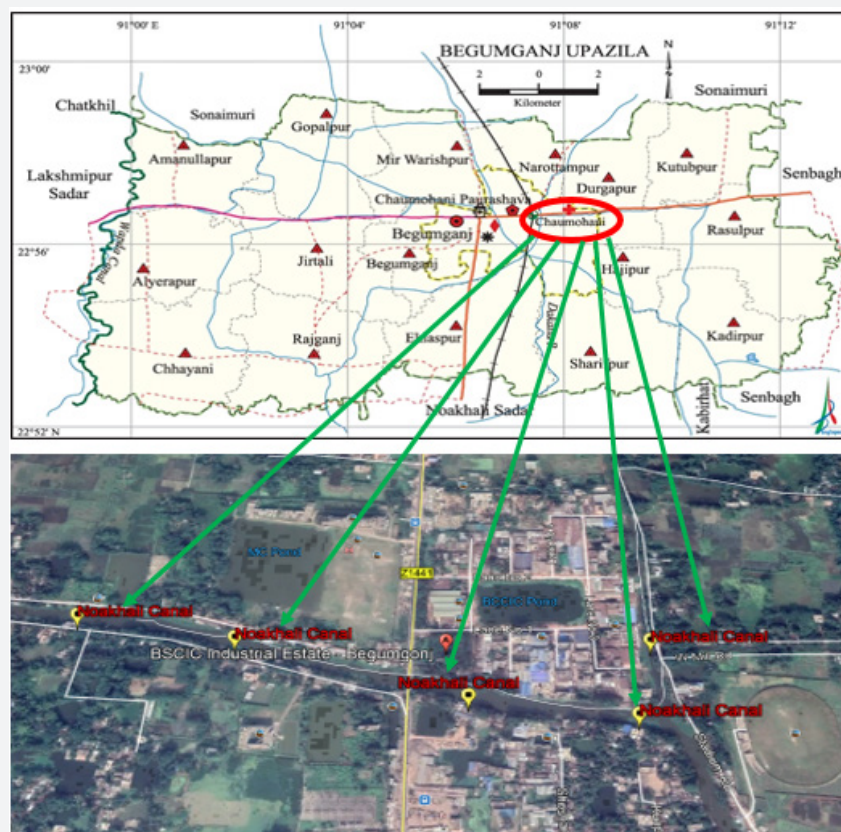


Figure 1: Map of study area (Noakhali canal surrounding BSCIC industrial estate).

The study area has been shown in Figure 1 which is located at the Mir Warishpur union under Begumganj upazila of Noakhali District at 22°56'57.0"N and longitude 91°06'18.6"E. It is situated beside the Dhaka-Noakhali highway road locally named as BSCIC Industrial Estate [12]. The samples were collected from ten different predetermined sampling sites from Noakhali canal which receives effluent from BSCIC Industrial State, Municipal areas, Roads and Highways and agricultural runoff water.

Samples collection and preparation

Ten water and ten sediment samples were collected from the predetermined sampling sites. Surface water samples were collected from the canal water about 10-20 cm below. In order to collect water and sediment samples plastic bottles (500ml) as well as polyethylene bags were used. For measurement of heavy metal concentration, 65% concentrated HNO₃ acid was added to each sample instantly to bring the pH below 2 [13]. Sediment samples were taken at a depth of 0-10cm and immediately transferred into polyethylene bags. Sediment samples were dried in a dry and dust-free place at room temperature in order to grind into fine

powder before sieved under 2mm mesh for storing in plastic container [14].

Physico-chemical analysis of canal water

The pH was measured with a pH meter (WTW pH 522, Germany). EC, TDS, NaCl, and Temperature were measured by following the procedure of Richard (1954) with an Electrical Conductivity meter (Martin Bench, EC meter). P was measured with visible spectrophotometer Model (DR 3800- HACH) (APHA, 1998). K was measured by using the Flame Photometer. SO₄²⁻ was measured with a spectrophotometer at 535nm wavelength.

Physico-chemical analysis of canal sediment

pH was measured with pH meter WTW pH 522, Germany from the suspension of sediment water. EC was measured by using EC meter (Martin Bench EC meter). OC, OM and TN were measured by using the Walkley and Black oxidation method. P was measured by following the method of Bray and Kurtz when the sample pH < 7.0 and the Olsen method when the sample pH > 7.0. K was measured from the suspension of sediment water reading

by flame photometer. SO_4^{2-} was measured by a spectrophotometer at 535nm wavelength.

Estimation of heavy metals in water and sediment

Concentrated HNO_3 acid was used to digest the water samples, described by APHA [13]. Concentrated HNO_3 acid and concentrated $HClO_4$ acid were used to digest the sediment samples [15] and samples were analyzed by Flame Atomic Absorption Spectrophotometer (Model: AA-7000; Shimadzu, Japan) in order to detect heavy metals like Pd, Cu, Cd, Fe, Zn and Mn by following the manufacturer’s instructions.

Sediment quality assessment

Geo-accumulation index (Igeo)

Muller [16] developed the Geo-accumulation index (Igeo) which is widely used in the assessment of metal contamination in sediment and soil by comparing current concentration with pre-industrial levels [17,18].

Igeo is calculated using the following formula [15]:

Table 1: Index classification of sediment quality (Muller, 1981) [19].

Igeo value, Muller (1981)	Class	Sediment Quality
≤ 0	0	Unpolluted
0-1	1	Unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	Moderately to strongly polluted
3-4	4	Strongly polluted
4-6	5	Strongly to extremely polluted
≥6	6	Extremely polluted
CF values, Hakanson (1980) [20]	Class	Sediment quality
CF <1	1	Low CF
1 ≤ CF <3	2	Moderate CF
3 ≤ CF <6	3	Considerable CF
CF ≥ 6	4	Very high CF

Pollution load index (PLI)

Pollution Load Index (PLI) is used to find out the mutual pollution effect at different stations by the different elements in sediment and gives an assessment of the overall toxicity status of each sampling station. PLI for each site was determined by the following equation proposed by Tomlinson et al. [22].

$$PLI = \sqrt[n]{CF_1 * CF_2 * CF_3 * \dots * CF_n}$$

where, CF is the contamination factor. n is the number of metals. The PLI value of >1 is polluted, whereas <1 indicates no pollution [23] which is quickly understood to compare the pollution status of different places.

Results and Discussion

Physico-chemical characteristics of water of Noakhali Canal

The values of water quality parameters in Noakhali canal at different sites have been given in Table 2. The mean values of pH, EC, TDS, P, K, SO_4^{2-} , Cl⁻, NaCl and Temperature were 6.744,

$$Igeo = \log(Cn / 1.5 * Bn) \quad (1)$$

where, Cn is the measured concentration of the metal (n) in the sediment. Bn is the geochemical background of the metal (n). The factor 1.5 is used for the possible variations of the background data due to lithological variations. Muller [19] classified Igeo values into seven classes in Table 1.

Contamination factor (CF)

The Contamination Factor (CF) and Contamination Degree (CD) are used to assess the pollution load of the sediment according to heavy metals [10]. CF for each metal was determined by the following formula [20]:

$$CF = \frac{\text{Measured metal concentration}}{\text{Background concentration of the same metal}} \dots\dots\dots (2)$$

Where, CD for each site was calculated as sum of all contamination factors [21]. Hakanson [20] has provided four grade ratings of sediment based on CF values (Table 1).

1302µS/cm, 634.9mg/L, 0.0835mg/L, 0.466cmol+, 2.978mg/L, 328.289mg/L, 2.46mg/L and 26.84°C, respectively. The mean values of pH, TDS, SO_4^{2-} , Cl⁻ and NaCl in the Noakhali canal were within the acceptable limit whereas the mean values of EC were higher than the acceptable limit compared to standard of Bangladesh for inland surface water [3]. Water containing TDS concentrations below 1000mg/L is usually acceptable as per WHO standards. According to Nadia [24], water use for irrigation with high TDS value may reduce the production of crops. The mean value of P was 0.835mg/L. According to Stone and Thomforde [25], the phosphate level of 0.06 mg/L is favorable for fish which does not support the present study for the survival of fish in the study area. The mean value of potassium (K) was 0.466mg/L. Rahman & Ahsan, observed 0.23 meq/100g K at Atkapalia, Noakhali. The mean value of Sulphur was 2.978mg/L which is used in the pharmaceuticals industry as well as agricultural practices. Chlorides get mixed into canal water from different point sources of industries of BSCIC and non-point sources of agricultural and municipal runoff. Temperature was in the acceptable limit according to ECR [3].

Table 2: Values of water quality parameters in Noakhali canal Noakhali, Bangladesh.

Sample ID	pH	EC (µS/cm)	TDS (mg/L)	P (mg/L)	K (cmol+)	SO ₄ ²⁻ (mg/L)	Cl ⁻ (mg/L)	NaCl (mg/L)	T (Celsius)
W-1	6.5	650	328	0.37	0.32	6.77	163.07	1.3	26.4
W-2	6.7	660	332	0.68	0.3	2.01	167.32	1.6	26.8
W-3	6.55	770	377	1.18	0.39	1.47	191.43	1.5	26.9
W-4	6.7	1310	597	0.55	0.39	1.48	262.33	2.3	26.3
W-5	6.77	1320	635	0.63	0.39	3.69	347.41	2.5	26.8
W-6	6.8	1390	675	0.67	0.38	3	340.32	2.6	26.9
W-7	6.85	1420	691	0.65	0.41	2.56	368.68	2.1	26.9
W-8	6.72	1420	712	0.57	0.45	3.34	382.86	2.8	27
W-9	7.04	2690	1320	2.32	1.23	2.77	679.22	5.2	27.1
W-10	6.81	1390	682	0.73	0.4	2.69	380.25	2.7	27.3
Min	6.5	650	328	0.37	0.3	1.47	163.07	1.3	26.3
Max	7.04	2690	1320	2.32	1.23	6.77	679.22	5.2	27.3
Mean	6.744	1302	634.9	0.835	0.466	2.978	328.289	2.46	26.84
SD	0.152	572.081	286	0.56	0.271	1.519	151.753	1.098	0.298887
ECR (1997)	6.5-8.5	1200	2100	-	-	-	-	-	-

SD=Standard Deviation, ECR= Environment Conservation Rules.

Determination of some trace metallic constituents in surface water of Noakhali Canal, Noakhali, Bangladesh

Table 3: Concentration of some selected heavy metallic constituents in surface water of Noakhali canal Noakhali, Bangladesh.

Sample ID	Pd (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Zn (mg/L)
W-1	BDL	BDL	BDL	0.071	0.004	BDL
W-2	BDL	BDL	BDL	0.073	0.002	BDL
W-3	BDL	BDL	BDL	0.083	0.46	BDL
W-4	BDL	BDL	0.014	3.77	1.033	BDL
W-5	BDL	BDL	BDL	0.074	0.001	BDL
W-6	BDL	BDL	0.011	0.073	0.507	BDL
W-7	BDL	BDL	BDL	0.18	1.501	BDL
W-8	BDL	BDL	0.01	0.058	0.012	BDL
W-9	BDL	BDL	0.011	0.096	0.028	BDL
W-10	BDL	BDL	BDL	1.022	0.533	BDL
Maximum	-	-	-	3.77	1.501	-
Minimum	-	-	-	0.058	0.001	-
Mean	-	-	-	0.55	0.4081	-
SD	-	-	-	1.169303	-	-
DoE [3]	0.05	0.005	-	0.3-1.0	0.1	5
WHO (1993) guideline	0.01	0.003	-	NA	0.5	3
USEPA [26]	NA	0.005	0.5	0.3	0.05	5
DoE (27)	0.05	0.5	0.5	2	5	5

SD=Standard Deviation, BDL=Below Detection Limit, WHO=World Health Organization, USEPA= Unites States Environmental Protection Agency.

The concentrations of heavy metals in water of Noakhali Canal has been given in Table 3. The mean concentrations of Fe and Mn were 0.55mg/L and 0.4081mg/L, respectively. Cu was found in the very low concentration. Pd, Cd and Zn were found below detection limit. Fe was higher than the acceptable limit of USEPA [25] guideline. Max Infrastructure Limited where Fe is used as a

raw material which effluents may be the main reason of the high concentration of Fe including the natural sources.

Location of industries and their waste disposal system may be the responsible for variation of concentration of heavy metals [28].

Pearson's correlation co-efficient among water quality parameters and some selected trace metallic constituents in Noakhali canal.

Table 4: Correlation coefficients(r) among concentrations of water quality parameters and heavy metals of surface water in Noakhali Canal.

	Temperature	pH	EC	TDS	P	K	SO ₄ ²⁻	Cl	NaCl	Fe	Mn
Temperature	1										
Ph	0.57	1									
EC	0.449	.899**	1								
TDS	0.481	.899**	.998**	1							
P	0.443	0.613	.743*	.753*	1						
K	0.366	.726*	.892**	.900**	.929**	1					
SO ₄ ²⁻	-0.267	-0.306	-0.171	-0.147	-0.281	-0.092	1				
Cl	0.57	.905**	.984**	.991**	.733*	.876**	-0.114	1			
NaCl	0.486	.866**	.976**	.980**	.789**	.921**	-0.147	.968**	1		
Fe	-0.492	-0.052	0.025	-0.026	-0.192	-0.116	-0.368	-0.115	-0.03	1	
Mn	-0.113	0.134	0.025	-0.007	-0.198	-0.202	-0.424	-0.038	-0.171	0.467	1

** . Correlation is significant at the 0.01 level (2-tailed). * . Correlation is significant at the 0.05 level (2-tailed).

Pearson's correlation coefficient of heavy metals was studied using statistical software SPSS (version 22.0) which has been summarized in the Table 4. Correlation Co-efficient shows the significant positive correlation between EC-pH (r=.899), TDS-pH (r=.899), TDS-EC (r=.998) at p<0.01 level; P-EC (=.743), P-TDS (= .753) at p<0.05 level; K-EC (= .892), K-TDS (= .900), K-P (= .929) at p<0.01 level, K-pH (= .726) at p<0.05 level; Cl-pH (= .905), Cl-EC (= .984), Cl-TDS (= .991), Cl-K (= .8766) at p<0.01 level whereas Cl-P (.733) at p<0.05 level; NaCl-pH (= .866), NaCl-EC (.976), NaCl-TDS (= .980), NaCl-P (= .789), NaCl-K (= .921), NaCl-Cl (= .968) at

p<0.01 level.

The significant correlations may reflect the fact that these chemicals had similar pollution levels and the similar pollution sources. From the correlation co-efficient, it is evident that increasing pH increased the concentration of EC, TDS, K, Cl⁻ and NaCl. The rest of elemental pairs (Mn and Fe) showed no significant correlation with each other, suggesting that these metals are not associated with each other and lack of their identical behavior in aquatic environment.

Sediment quality of Noakhali Canal

Table 5: Values of sediment quality parameters in Noakhali canal, Noakhali, Bangladesh.

Sample ID	pH	EC (µS/cm)	OC (%)	OM (%)	TN (%)	P (µg/g)	K (meq/100gm)	S (µg/g)
S-1	6.2	477	2.81	4.85	0.242	0.89	0.47	139.03
S-2	6.7	338	2.65	4.56	0.228	0.51	0.41	72.1
S-3	6.35	373	2.43	4.2	0.21	2.33	0.37	120.15
S-4	6.65	477	3.1	5.34	0.267	7.9	0.51	211.88
S-5	7.05	475	1.66	2.85	0.143	177.1	0.43	176.92
S-6	6.83	558	2.1	3.63	0.181	3.2	0.5	150.95
S-7	7.07	896	3.1	5.34	0.267	112.28	0.63	199.21
S-8	7.12	732	2.7	4.66	0.233	49.49	0.47	217.08
S-9	6.77	663	2.11	3.64	0.182	5.59	0.48	198.84
S-10	7.56	665	1.61	2.78	0.139	71.44	0.74	83.83
Min	6.2	338	1.61	2.78	0.139	0.51	0.37	72.1
Max	7.56	896	3.1	5.34	0.267	177.1	0.74	217.08
Mean	6.83	565.5	2.427	4.185	0.21	43.1	0.5	157
SD	0.394	172.91	0.541	0.933	0.046	60.627	0.108	52.524
Standard for Soil (SRDI, 2012)	6.6-7.4	-	-	1.7-3.5	0.181-0.28	10.51-15.76	0.181-0.28	15.1-22.6

SD=Standard Deviation, SRDI=Soil Resource Development Institute

The values of physico-chemical parameters measured in Noakhali canal sediment at different sites have been given in Table 5. The mean values of pH, EC, OC, OM, TN, P, K, S were 6.83, 565.5, 2.427%, 4.185%, 0.21%, 43.1µg/g, 0.5meq/100gm, 157µg/g, respectively. Values of pH was within the acceptable limit according to the SRDI (2012) standard soil quality. According to Chennakrisnan [29] the low pH values indicate the effluent from food industries. The mean value of EC was 565.5µS/cm. APHA [12] stated that a failing sewage system would raise the conductivity due to the presence of chloride, phosphate, and nitrate which may be the main reason of high concentration of EC. The mean value of OC was 2.427%. Boyd [30] reported that OC value 0.60%- 1.5% is highly suitable for aquaculture in Bangladesh. Where most of the value exceeded the normal values, which is highly detrimental to the aquatic organisms.

Ahmed [31] suggested that OC is increasing in the pond only for using supplementary feeds and it remains unused. Effluents from the several food industry and fish feed processing unit mix into the canal water which is responsible for getting high value of OC in the study area sediment. The mean value of OM was 4.185% and the coastal region contain the higher OM [32]. The presence of organic matter can influence the accumulation of heavy met-

als in the sediment [9,33]. The mean concentration of TN was 0.21%. Haque [33] estimated the range of nitrogen is 0.1%- 0.3% in the coastal region of Bangladesh which support the good TN condition of canal water. The mean value of P was higher than the SRDI (2012) medium acceptable limit. Haque [33] suggested that the P range between 8-24µg/g in soil is good for fish cultivation which does not support the present study. The main causes of high value of P in the canal water is industrial and municipal wastes [34] which support the present study. The mean value of K was 0.5meq/100gm. All values were higher in the acceptable limit according to the standard of SRDI (2012). Rahman & Ahsan [33] estimated K at Atkapalia, Noakhali which mean value was 0.23meq/100gm. This value is lower than the present study. Fignoni [35] stated that the base of K is also used to control the pH. So, food industry is highly responsible for the high concentration of K in the canal sediment. The mean value of sulphur was very higher than the acceptable limit according to SRDI (2012) medium standard for soil. Rahman et al. [35] conducted an experiment in the farmer's field at Atkapalia, Noakhali during the winter season of 1999-2000 and 2000-2001 under Farming Systems Research and Development (FSRD). The sulphur of soil was 65.2µg/g in their estimation. Which does not support the present study.

Measurement of heavy metals in sediment of Noakhali canal

Table 6: Concentration of some selected heavy metallic constituents in sediment of Noakhali canal, Noakhali, Bangladesh

Sample ID	Pd (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
S-1	0.611	0.578	398.7	7.775	8.925
S-2	0.688	0.579	428.9	8.225	3.3
S-3	0.572	0.527	400.7	8.675	3.35
S-4	0.701	0.709	403.2	7.4	5.15
S-5	0.671	0.587	383.3	8.425	2.65
S-6	0.516	0.599	383.8	6.15	3.775
S-7	0.677	0.62	381.3	6.655	3.95
S-8	0.605	0.594	413.2	7.175	3.5
S-9	1.255	0.609	431	7.275	5.75
S-10	3.334	0.692	553	9.4	2.925
Maximum	3.334	0.709	553	9.4	8.925
Minimum	0.516	0.527	381.3	6.15	2.65
Mean	0.936	0.6094	417.71	7.7155	4.3275
SD	0.857	0.054	50.713	0.982	1.878
WHO (2004) SQG [37]	NA	-	NA	NA	123
USEPA (1999) SQG [36]	40	-	30	30	110
CCME (1999) SQG [38]	35	26	NA	NA	123
Typical content (Soil) [40]	32	-	-	437	64

SD=Standard Deviation, WHO=World Health Organization, USEPA= Unites States Environmental Protection Agency, SQG=Sediment Quality Guideline, Typical content (soil), Madejon et al., (2002).

The heavy metal concentrations in the study area sediment at all sampling sites have been given in Table 6. The order of heavy

metals concentration in sediment was Fe >Mn> Zn >Pb>Cu. Pd and Zn were not found in the water sampling sites but was found

in the sediment sampling sites. Pd and Zn may be absorbed onto the clay particles or it may uptake by biota. The mean concentration of Pd was 0.936mg/kg which is released from industries and vehicles may travel long distances. The mean concentration of Cu was 0.6094mg/kg. The concentrations of Fe in every sampling site were very higher than the acceptable limit according to USE-PA [36] SQLs. The mean concentration of Mn was 7.7155mg/kg. Mn is essential for many organisms as well as human which may

be used in pharmaceuticals industry. The mean concentration of Zn was 4.3275mg/kg. Concentration of Pd, Cu, Mn, Zn were in the acceptable limit comparing to the WHO [37], USEPA [36], CCME [38], SQLs & Madejon et al. [39] typical content of soil. Though the mean and high concentration of heavy metals were below the WHO [37], USEPA [36], CCME [38] and the soil typical content, they might be concentrated in the course of time [40] where Fe was higher than the acceptable limit.

Pearson’s correlation co-efficient among sediment quality parameters and some selected heavy metallic constituents in Noakhali Canal

Table 7: Correlation coefficients among concentrations of sediment quality parameters and heavy metals of surface water in Noakhali canal.

	pH	EC	OC	OM	TN	P	K	S	Pb	Cu	Fe	Mn	Zn
pH	1												
EC	0.599	1											
OC	-0.467	0.098	1										
OM	-0.469	0.099	1.000**	1									
TN	-0.467	0.099	1.000**	1.000**	1								
P	0.598	0.378	-0.346	-0.351	-0.347	1							
K	.710*	.670*	-0.154	-0.154	-0.155	0.287	1						
S	0.033	0.516	0.348	0.347	0.349	0.227	-0.05	1					
Pb	.646*	0.249	-0.556	-0.555	-0.555	0.138	.762*	-0.415	1				
Cu	0.513	0.332	0.016	0.014	0.014	0.097	.728*	0.185	0.562	1			
Fe	0.564	0.115	-0.476	-0.475	-0.475	-0.034	.637*	-0.518	.960**	0.493	1		
Mn	0.141	-0.423	-0.46	-0.461	-0.459	0.173	0.069	-0.629	0.58	0.019	.635*	1	
Zn	-.637*	-0.057	0.411	0.413	0.41	-0.455	-0.099	0.171	-0.203	-0.016	-0.2	-0.236	1

** . Correlation is significant at the 0.01 level (2-tailed). * . Correlation is significant at the 0.05 level (2-tailed).

Pearson’s correlation coefficient among different sediment quality parameters and heavy metals are presented in Table 7. Correlation co-efficient shows the positive significant between several elements’ pairs OM-OC (=1.00), TN-OC (=1.00), TN-OM (=1.00), Fe-Pd (=0.960) at p<0.01 level. And Pd-pH (=0.646), Pd-K

(=0.762), Cu-K (=0.728), Fe-K (=0.637), Mn-Fe (=0.635) at p<0.05 level. It also shows a negative correlation coefficient with Zn-pH (= -0.635) at p<0.05 level. The Pearson correlation suggests that increasing pH results Pd accumulation in sediment.

Assessment of sediment heavy metals contamination

Geo-accumulation index

Table 8: Geo-accumulation Index (Igeo) values of heavy metals of the canal sediment.

Samples Site	Pd	Cu	Fe	Mn	Zn
S-1	-1.823	-2.0043	1.885	-2	-1.07
S-2	-1.769	-2.0043	1.916	-2	-1.522
S-3	-1.853	2.0043	1.887	-2	-1.522
S-4	-1.769	-1.9208	1.889	-2.055	-1.309
S-5	-1.795	-2.0043	1.868	-2	-1.598
S-6	-1.92	-2.0043	1.8686	-1.13	-1.455
S-7	-1.777	-2	1.866	-2.102	-1.424
S-8	-1.826	-2	1.9	-2.296	-1.481
S-9	-1.522	-2	1.919	-2.296	-1.267
S-10	-1.086	-0.9586	2.027	-1.95	-1.568

Karbassi et al. [41] stated that Igeo values have been used to explain sediment quality. According to the Muller [15] formu-

la, the calculated results of Igeo values of the sediment are given in Table 8. According to Muller [18] scale (Table 1), a qualitative

scale of pollution intensity [42]. Igeo values of Pd, Cu, Zn and Mn were below 0 (zero) that indicates class 0 (zero) and sediment from canal is unpolluted for these measured heavy metals. Igeo

value of Fe was 1-2 that indicates that the sediment of canal is unpolluted to moderately polluted for Fe.

Contamination factor (CF)

Table 9: Contamination Factor (CF), Contamination Degree (CD) and ePollution Load Index (PLI) values.

Sample ID	Contamination Factor (CF)						Degree of Contamination (CD)	Pollution Load Index (PLI)
	Pd (mg/Kg)	Cu (mg/Kg)	Fe (mg/Kg)	Mn (mg/Kg)	Zn (mg/Kg)			
S-1	0.03055	0.012844	0.008447	0.009147	0.093947	0.154936	0.019539	
S-2	0.0344	0.012867	0.009087	0.009676	0.034737	0.100767	0.016834	
S-3	0.0286	0.011711	0.008489	0.010206	0.035263	0.09427	0.015922	
S-4	0.03505	0.015756	0.008542	0.008706	0.054211	0.122264	0.0186	
S-5	0.03355	0.013044	0.008121	0.009912	0.027895	0.092522	0.015793	
S-6	0.0258	0.013311	0.008131	0.007235	0.039737	0.094215	0.015168	
S-7	0.03385	0.013778	0.008078	0.007829	0.041579	0.105115	0.016509	
S-8	0.03025	0.0132	0.008754	0.008441	0.036842	0.097488	0.016116	
S-9	0.06275	0.013533	0.009131	0.008559	0.060526	0.1545	0.020931	
S-10	0.1667	0.015378	0.011716	0.011059	0.030789	0.235642		
Mean	0.0786	0.0135	0.0088	0.009	0.0455	1.1434	0.025232	

Contamination factor of sediment sampling sites is shown in the Table 9. Maximum degree of contamination is 0.236 in S-10 sampling site. All the sampling sites have contamination factor (CF) >1 indicating low concentration for all tested heavy metals. The mean values of contamination factor for all sampling sites were (CF)>1 indicating low concentration. On the basis of the mean values of CF, sediment is enriched for metals in the following order: Pd> Zn > Cu >Mn> Fe.

Pollution load index

The PLI represents the number of times by which the metal content in the sediment exceeds the background concentration. It gives a summative indication of the overall level of heavy metal toxicity in a particular sampling site [2]. According to the Tomlinson et al. [21] formula, the calculated PLI values of all sampling sites are presented in Table 9. The PLI ranged from 0.015 to 0.025. The present study showed that the PLI values of all sampling sites were lower than 1. It indicates no pollution. The PLI can provide some understanding to the public of the area about the quality of a component of their environment [42].

Conclusion

According to the scientific literature and to the best of our knowledge this is the first study which provide information on heavy metals pollution of Noakhali canal Noakhali, Bangladesh. The following conclusions can be drawn from the present study: Compare to the investigated data with different national and international guidelines, it is evident that the canal is in good condition with lower level of heavy metal contamination except higher level of Fe contamination in sediment and water which could mainly be attributed to geological and industrial sources.

This study clearly demonstrated the quality of canal water and sediment surrounding the industrial and municipal areas which will provide useful information to the policy maker and policy planner of the People’s Republic of Bangladesh for the pollution control as well as implement sustainable strategies to keep the canal free from domestic and industrial effluents.

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