Peertechz

International Journal of Aquaculture and Fishery Sciences
aquaculture@peertechz.us
LIFE SCIENCES GROUP

INTERNATIONAL JOURNAL OF Aquaculture and Fishery Sciences OPEN ACCESS JOURNAL

ISSN: 2455-8400 DOI: https://doi.org/10.17352/ijafs

Research Article

Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment

Mohammad Ashraful Alam[1]*, Flura[1], Md. Anisur Rahman[1], Azhar Ali[2], Ahmed Ishtiaque Amin Chowdhury[3], Md. Hashibur Rahman[5], Md. Moniruzzaman[1], Md. Rahamat Ullah[4] and Yahia Mahmud[5]

[1]Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, Bangladesh

[2]Bangladesh Fisheries Research Institute, Riverine Sub-Station, Rangamati, Bangladesh

[3]Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

[4]Bangladesh Fisheries Research Institute, Riverine Sub-Station, Patuakhali, Bangladesh

[5]Bangladesh Fisheries Research Institute, Headquarters, Mymensingh, Bangladesh

Received: 06 August, 2022
Accepted: 22 August, 2022
Published: 23 August, 2022

***Corresponding author:** Mohammad Ashraful Alam, Senior Scientific Officer, Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, Bangladesh, Tel: +88-01717367436; E-mail: mohammad.bfri@gmail.com

Keywords: Ecological risk; Halda; Heavy metal assessment; Mitigation measures

Abstract

To evaluate the present status of heavy metals in the sediments of river Halda, seven heavy metals, *viz.* Cd, Cr, Cu, Fe, Mn, Pb, and Zn were assessed by Bangladesh Fisheries Research Institute by collecting data from 4 sampling locations (Khondokia Khal, Katakhali, Madari Khal, and Madarsha) and ecological risk impending from these metals were depicted from the study. The concentration of heavy metals in the sediments of the river Halda ranged from 0.89-1.04 for Cd, 24.72–67.30 for Cr, 1.16-7.58 for Cu, 27899.31-60076.37 for Fe, 476.12–1137.20 for Mn, 0.77-8.33 for Pb and 40.33–121.77 mg kg^{-1} for Zn, respectively. The sediment geo-accumulation index (I_{geo}) values showed contamination only from two heavy metals Cd (1.10 ± 0.16) and Mn (1.48 ± 0.37). The average pollution load index (PLI) (0.37 ± 0.10) showed no marks of pollution in the studied sites, however; the mean degree of contamination factor (CF) showed moderate pollution. In the present study, the highest degree of contamination was observed at Katakhali (3.79 ± 2.07) followed by three other sites. The overall degree of contamination of four sampling sites was 2.68 ± 1.84 which indicated a low degree of contamination. The concentration of Cr ranged between 24.72–67.30 mg/kg with the highest (56.7 ± 9.4, mg/kg) at Madarshah and the lowest (30.2 ± 5.1, mg/kg) at Khondokia Khal. The highest concentration of Fe, Mn, and Zn (53926.3 ± 5338.2, 980.9 ± 145.1, and 108.0 ± 13.5 mg/kg) exhibited similar results to Cu and Pb; the maximum levels were found at Madarshah and the minimum levels (33571.1 ± 5456.0, 566.7 ± 92.8 and 56.0 ± 17.9 mg/kg) at Khondokia Khal, respectively. The enrichment factor (EF) (0.08 ± 0.02 to 4.16 ± 0) demonstrated none to moderate enrichment of the river. Nevertheless, the ecological risk factor (E^i_r) (17.83 ± 14.29 to 759.14 ± 192.26) and risk index (RI) (711.26 ± 122.55 to 1272.04 ± 175.19) exposed low to serious ecological risk for the river Halda.

Introduction

Widespread urbanization coupled with industrial development [1] is imposing a severe threat on the harmony of the aquatic environment through different types of pollutants. Of them, heavy metals are considered the most common environmental pollutants [2] and in recent years it has appeared as a great concern for the aquatic environment [3-9], especially in the developing countries where environmental quality maintenance and hygiene structure do not pace up with population growth and rapid urbanization [10]. Albeit, heavy metals (Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn) are essential components of the environment [11,12], biological food chain, and important for human health [13-18]; they can cause detrimental effects even at low concentrations. Furthermore, heavy metals are non-degradable and can bio-accumulate and bio-magnify in mussels, oysters, shrimps, and fish and can be transferred to humans via the food chain [19-32]. Recently, bioaccumulation and toxicity of heavy metals [33,34] have appeared as a global concern [35] due to having a negative impact on human health, fish, and invertebrates [23-39].

Fluvial natural water bodies are largely liable for the translocation of [40-42] heavy metals that enter the systems through terrestrial runoff, atmospheric deposition, sewage discharge, and others [43,44]. Heavy metals are poorly soluble

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

in water and are mostly scavenged by fine particles leading to their accumulation in sediments [45,46]. Thus, sediments become the main repository of heavy metals and other chemicals [46,47] and act as the indicator for water pollution in lakes [48] and rivers [49,50]. The sediment matrix provides the best natural hallmarks of recent environmental perturbations. With the change of environmental conditions viz. pH, oxidation-reduction potential (E_h), salinity and organic matter, and heavy metals retained in sediments can be remobilized and dissolved into the water again, causing secondary contamination [51-53]. Therefore, the identification and quantification of heavy metals in water and sediments are important environmental issues [54]. Several studies about contamination of heavy mental in soils have been carried out all over the world [55- 62].

Heavy metal and metalloid exposure has been increasing in recent years in Bangladesh [38,63,64] from different industries, domestic wastes, and agrochemicals that deteriorate water quality [37,65,66]. To address this issue, several authors have studied the heavy metals in different rivers of Bangladesh [2,10,67-72]. However, very few studies have been conducted to date to assess the heavy metal contamination of the Halda River. In Bangladesh, Halda is one of the most important rivers where Indian major carps shed their eggs naturally during the breeding season making this river a unique heritage of this country [73-76]. But the river is being polluted day by day by different natural and anthropogenic pollutants. Aquatic plants (microalgae and seaweeds) have the highest photosynthetic efficiency, are the highest biomass producers, are resistant to several pollutants, and have the ability to grow on land that is often inappropriate for other uses [77]. The cells of aquatic plants, such as seaweeds, have bioactive compounds and contain functional groups, including carboxyl, hydroxyl, amino, and sulphate, that can act as metal-binding sites between the adsorbent and adsorbate [78]. The present study was conducted to evaluate the status of heavy metals, their probable ecological risk, and mitigation measures to confirm the unimpeded biodiversity of river Halda.

Materials and methods

Sampling sites

The present study was conducted in the Halda river which lies between 22° 25′ 13″–22° 48′ 51.37″ N and 91° 45′ 00″–91° 52′ 33″ E [79]. Four sampling points viz. Khondokia Khal, Katakhali, Madari Khal, and Madarsha of the river were selected for sediment sample collection. These "Khals" (local name for canals) are the main discharge routes carrying the pollution loadings towards the Halda river. Sampling and data collection were done on monthly basis for one year (from July 2020 to June, 201). The global positioning system (GPS) coordinates of the sampling sites are furnished in Figure 1 and Table 1.

Sample collection, preparations and analysis

A total of 48 surface soil samples were collected for one year from the selected sampling locations of the Halda river in clean polythene covers circumventing all possible contamination. Samples were collected from the river bed with the help of an Ekman dredge (10–50 cm layer of the soil) and the location of each sample was recorded using a handheld GPS (Table 1). At each sampling site, three replicate samples were collected and

Figure 1: Map of the study area and the location of different sampling sites.

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

mixed to form a representative sample. Samples from the same locations were further mixed to form only four representative samples for four locations. Seven common heavy metals, *viz.* Cd, Cr, Cu, Fe, Mn, Pb, and Zn were selected for assessment. In the pretreatment phase, the soil samples were air-dried at room temperature. Plant roots, large stones, debris, organic residues, and visible intrusions present in the samples were removed carefully. Finally, the samples were crushed, ground, and passed through a 0.85 mm plastic sieve and stored at 4°C until the spectrophotometric reading was completed Table 2.

After completion of all pretreatment works, sediment samples were transferred to the soil and water analysis laboratory of the Institute of Water and Flood Management of Bangladesh University of Engineering and Technology (BUET) immediately for analysis. Here, 2 g is equivalent to 1L of the ICP run sample. Concentrations thus can be said as µg/2 g of sample or mg/2kg sample. Concentration is thus multiplied by 0.5 to get the mg/kg value.

Samples were handled carefully. Recommended clean powder-free latex gloves and lab coats were used during the analysis for eluding contamination. Glassware was properly cleaned with chromic acid solution and distilled water. Analytical grade chemicals and reagents were used to get better results. Blank determinations were used to get the correct instrumental readings. The intensity of heavy metal pollution in surface sediments of the river Halda was assessed using several different indices derived utilizing the metal concentration data.

Sediment quality assessment

Index of geo-accumulation: The geo-accumulation index (I_{geo}) reduces the interference of human factors in the assessment of soil contamination and is hosted to replace the traditional single factor Nemerrow index [81]. I_{geo} was first introduced by Müller [82] and it has been widely applied to sediment geochemistry to assess the degree of heavy metal contaminations in sediments. The I_{geo} is defined by the following equation:

$$I_{geo} = \log_2 (Cn/1{:}5\times Bn) \qquad (1)$$

where Cn is the content of elements in the sediment samples and Bn is the geochemical background concentration for the same elements (n). The background values of the studied elements used for the calculation of this index are the same as those used in the calculation of the contamination factors (CFs). Factor 1.5 is the background matrix correction factor due to lithological variations. The I_{geo} index contains seven classes [83,84] (Table 3).

As I_{geo} could reduce the effects of parent rocks and protruding artificial effects on soil heavy metal contamination, it is suitable for the evaluation of soil heavy metal contaminations in industrial and mining gathering areas. However, evaluation of I_{geo} for a single heavy metal contaminant, the index cannot provide a comprehensive description of the contamination status of the study area. Accordingly, an evaluation based on the comprehensive index method is necessary. Therefore, the traditional Nemerow index (IN) was improved by replacing the single factor index with I_{geo} (Table 4). The following Equation (3) was utilized:

$$IN = \sqrt{(I_{geomax}{}^2 + I_{geoave}{}^2)/2} \qquad (2)$$

I_N = 1.86 (In the present study).

Table 1: GPS location of selected sampling points of the river Halda.

Places	GPS Point (Longitude and Latitude)
Madarsha	N 22⁰27´59´´ E 091⁰51´47´´
Madari Khal	N 22⁰26´97´´ E 090⁰51´56´´
Khondokia Khal	N 22⁰26´13´´ E 091⁰52´44´´
Katakhali Khal	N 22⁰26´13´´ E 091⁰52´18´´

Table 2: Wave length used in emission measurements and the instrumental detection limit for measurement by using ICP.

Elements	Wavelength (nm)	The instrumental detection limit (µg/l)
Cd	228.8	0.1
Cr	205.5	0.4
Cu	324.7	0.4
Fe	238.2	0.3
Mn	259.3	0.1
Pb	220.3	1.7
Zn	213.8	0.2

Source: Praveen Sarojam [80]. PerkinElmer, Inc. Shelton, CT 06484 USA.

Table 3: Index classification of sediment quality [85].

I_{geo} Values	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
4-5	5	Strongly to extremely polluted
≥6	6	Extremely polluted

Contamination factor, degree of contamination and modified degree of contamination

The Contamination Factor (CF) and Degree of Contamination (C_d) are used to assess the pollution load of the sediments with respect to heavy metals [54]. The CF is the ratio obtained by dividing the concentration of each metal in the sediment by the baseline or background value [84]. CF for each metal was determined by the following formula [86]:

$$CF = \frac{\text{Concentration of measured metal}}{\text{Background Concentration of the same metal}} \qquad (3)$$

To facilitate pollution control, Hakanson [86] proposed a diagnostic tool named 'degree of contamination' (C_d) and it is determined as the sum of the CF for each sample:

$$cd = \sum_{i=1}^{n} CF \qquad (4)$$

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

The C_d is aimed at providing a measure of the degree of overall contamination in surface layers in a particular core or sampling site. Hakanson [86] has provided four grade ratings of sediments based on CF and C_d values (Table 5).

To calculate the degree of contamination, at least five sediment samples are required to provide a mean concentration and to compare with the background value. To avoid this constraint, a generalized index was developed [87]; named the modified degree of contamination (mCd) to assess the overall heavy metal contamination of soil (Table 6). The modified degree of contamination (mCd) was estimated using the following equation:

$$mCd = \frac{\sum_{i=1}^{n} CF}{n} \quad (5)$$

Enrichment factor

Enrichment factor (EF) is a convenient method to evaluate the magnitude of anthropogenic heavy metal contaminants [88] in the environment [89]. The EF was calculated using the following equation:

$$EF = \frac{\left(\frac{cM}{cFe}\right)sample}{\left(\frac{cM}{cFe}\right)Earth'scrust} \quad (6)$$

Where, the (CM/CFe) sample is the proportion of concentration of heavy metal (CM) and iron (CFe) in the sediment sample, and (CM/CFe) Earth's crust is the proportion of heavy metal and iron in the Earth's crust [90]. Iron (Fe) is used for the geochemical normalization to calculate the enrichment factor. Different values of EF, indicates different degrees of enrichment; where EF<1= indicates no enrichment; EF<3 = minor enrichment; EF 3–5 = moderate enrichment; EF 5–10 = moderately severe enrichment; EF 10–25 = severe enrichment; EF 25–50 = very severe enrichment; and EF>50 = extremely severe enrichment [88,91].

Pollution load index

Pollution Load Index (PLI) determines the communal effects of various pollutants in sampling sites deposited in soils and sediments [92]. The PLI for each site has been estimated by the multiplications of the n^{th} root of the studied heavy metals [93].

$$PLI = (CF1 \times CF2 \times CF3 \times ...... \times CFn)^n \quad (7)$$

where CF is the contamination factor and n is the number of metals. The PLI of >1 indicates pollution, whereas <1 indicates no pollution [94]. This index provides a quick assessment for unskilled people to compare the pollution status of different places.

Ecological risk factor and risk index

The E_r^i is widely used to assess the ecological risk of heavy metals in sediments [95]. The index was calculated by the following equations [86]:

$$ER^i = Tr^i \times C^i \quad (8)$$

$$RI^i = \sum Er^i \quad (9)$$

Where E_r^i is the potential ecological risk factor for a given contaminant and T_r^i is the toxic response factor of each element, including Cd = 30, Cr = 2, Cu = 5, Fe = 2.82, Mn = 1, Pb = 1 and Zn = 1 [95-101]. The risk index (RI) is the sum of E_r^i and represents the potential toxicity response of various heavy metals in sediments. The E_r^i and RI values [98,101,102] are furnished in Table 7.

Probable effects level

Probable effects levels (PEL) are guidelines widely accepted to evaluate bio-toxic risks of sediments. Since heavy metals always occur in sediments as complex mixtures, the mean PEL quotient (m-PEL-Q) method has been proposed and used to determine the possible biological effect of combined toxicant

Table 4: Improved Nemerow Index [81].

IN Values	Class	Sediment quality
0 < IN ≤ 0.5	0	Uncontaminated
0.5 < IN ≤ 1.0	1	Uncontaminated to moderately contaminated
1.0 < IN ≤ 2.0	2	Moderately contaminated
2.0 < IN ≤ 3.0	3	Moderately to heavily contaminated
3.0 < IN ≤ 4.0	4	Heavily contaminated
4.0 < IN ≤ 5.0	5	Heavy to extremely contaminated
IN > 5.0	3	Extremely contaminated

Table 5: Sediment classes according to CF and C_d values [86].

CF/C_d Values	Class	Sediment quality
CF>1	0	Low CF
1≤CF<3	1	Moderate CF
3≤CF<6	2	Considerable CF
CF≥6	3	Very high CF
C_d<6		Low degree of contamination
6<C_d<12		Moderate degree of contamination
12<C_d<24		Considerable degree of contamination
C_d> 24		High degree of contamination

Table 6: Sediment classifications according to mCd [87].

mCd Values	Contamination situation
mCd<1.5	Nil to very low degree of contamination
1.5<mCd<2	Low degree of contamination
2≤mCd<4	Moderate degree of contamination
4≤mCd<8	High degree of contamination
8≤mCd<16	Very high degree of contamination
16≤mCd<32	Extremely high degree of contamination
mCd≥32	Ultra-high degree of contamination

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

groups by calculating the mean quotients for a range of heavy metals using the following formula:

$$\text{PEL-Q}=\frac{\sum_{i=1}^{n}\left(\frac{Ci}{PELi}\right)}{n} \quad (10)$$

Where C_i is the content of measured element i, PEL_i is the PEL value of element i, and n is the number of elements. Several classes of toxicity probability [103] for biota are presented in (Table 8).

Equipment used

Ekman dredge (10–50 cm layer of the soil), handheld GPS, 0.85 mm plastic sieve, spectrophotometer, and clean polythene covers.

Statistical analysis

The data were compiled and processed initially using Microsoft Excel and further investigations were carried out using different statistical software packages. For example, the one-way analysis of variance (ANOVA) was performed by JMP (version 14) software to delineate whether any significant (*P* < 0.05) spatial variation exists in the concentration of heavy metals. Pearson's product-moment correlation matrix (Table 9) was obtained by using GraphPad Prism (version 6). Cluster analysis (CA) was performed to find out the similarity and variation with the influencing factors of studied heavy metals [104]. The dendrogram was prepared to show the similarity among heavy metals and to identify their sources of origin using Past software (version 4). The analytical output of the present study performed through different software is presented as charts and Tables.

Table 7: Ecological risk factor (E_r^i) and risk index (RI) for studied metals in the river Halda.

E_r^i Values	Ecological Class
<40	Low ecological risk
40< E_r^i≤80	Moderate ecological risk
80< E_r^i≤160	Appreciable ecological risk
160< E_r^i≤320	High ecological risk
E_r^i>320	Serious ecological risk
RI Values	Ecological Class
<150	Low ecological risk
150≤RI <300	Moderate ecological risk
300≤RI <600	Considerable ecological risk
RI>600	High ecological risk

Table 8: Probable effects level quotient and ecological classification of the river Halda.

PEL-Q Values	Ecological Class
PEL-Q < 0.1	8% probability of toxicity
PEL-Q = 0.11-1.5	21% probability of toxicity
PEL-Q = 1.51-2.3	49% probability of toxicity
PEL-Q > 2.3	73% probability of toxicity

Results and discussion

The concentrations of heavy metals in the sediments of river Halda collected from four sampling locations are presented in Table 9. A one-way ANOVA followed by the Tukey-Kramer test was used to identify the significant differences among the mean concentration of different heavy metals and the results demonstrated significant (*P* < 0.05) spatial differences. The concentration of heavy metals in the sediments of the river Halda found in the present study ranged from 0.89-1.04 for Cd, 24.72–67.30 for Cr, 1.16-7.58 for Cu, 27899.31-60076.37 for Fe, 476.12–1137.20 for Mn, 0.77-8.33 for Pb and 40.33–121.77 mg kg^{-1} for Zn. The chronological order of the heavy metals found in the present study was: Fe>Mn>Zn>Cr>Pb>Cu>Cd.

The findings in the present study revealed that the concentrations of all studied heavy metals in the sediment were above the permissible limit as set by WHO [105,106] USEPA [107], and DoE [108] (Table 10). In addition to comparing the data of the present study with some other global standards, the results were also compared with some previous works on the same river and another important river system in Bangladesh (Table 11). The results demonstrated that most all heavy metal concentrations were lower than Buriganga, Dhaleshwari, and Shitalakhya as these rivers are severely polluted by municipal and industrial effluents, sewerage, and other non-treated chemicals. However, the present status of the river Halda is not peasant as the condition of the river is gradually exacerbating compared to some recent investigations.

The highest mean concentration of Cd (1.0 ± 0.1) was found at Katakhali Khal, whereas; in the other three sampling locations, it was found beyond the detection limit. The amount of Cd found in the present study was above the acceptable global and country limit presented in Tables 10 and 11. The result was compared with some previous investigations carried out with the sediment samples of different important rivers of Bangladesh and varying results were found. The concentration of Cd in the river Halda was lower than that of the Buriganga

Table 9: Heavy metal concentration in the sediments of the river Halda.

Sites	Metal Concentrations (mg/kg) (Mean±SD)						
	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Khondokia Khal	*BDL	30.2±5.1[c]	2.7±0.6[b]	33571.1±5456.0[b]	566.7±92.8[c]	4.3±0.6[b]	56.0±17.9[b]
Katakhali Khal	1.0±0.1	38.7±7.0[bc]	2.0±1.1[b]	37804.2±2470.9[b]	635.1±43.6[bc]	1.4±0.9[c]	67.5±15.8[b]
Madari Khal	*BDL	47.3±1.3[ab]	4.0±0.7[ab]	48814.1±1760.4[a]	853.8±76.7[ab]	2.9±0.8[bc]	84.9±8.9[ab]
Madarshah	*BDL	56.7±9.4[a]	6.4±1.3[a]	53926.3±5338.2[a]	980.9±145.1[a]	7.6±0.9[a]	108.0±13.[5]a
*CRV	0.28 ±0.03	107.0 ± 4.0	29.1 ± 1.1	-	-	29.0 ±1.6	114.0 ± 6.0

*BDL= Below Detection Limit; CRV = Certified Reference Values; Levels not connected by the same letters are significantly different.

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

[2,10,40], Dhaleshwari [110], Turag [112] and Shitalakhya river [114], but higher than Karnafuly [63,111], Meghna [113] and Brahmaputra river [70]. It was also higher than the result of previous studies [115] on heavy metal concentrations of the river Halda (Table 11). This might be associated with the collecting of samples from different sites than the present study. The results indicate that the heavy metal commination of the river Halda is gradually exasperating.

The concentration of Cr ranged between 24.72–67.30 mg/kg with the highest (56.7 ± 9.4, mg/kg) at Madarshah and the lowest (30.2 ± 5.1, mg/kg) at Khondokia Khal. The mean concentration exceeded the limit set by WHO [105,106], USEPA [107], and DoE [108] (Table 10). Mohiuddin, et al. [2] and Islam, et al. [114] found a higher concentration of Cr than the present study in the Buriganga and Shitalakhya rivers, respectively. On the contrary, Ahmed, et al. [110] in Dhaleshwari; Islam, et al. [101] and Ali, et al. [63] in Karnafuly; Banu, et al. [112] in Turag; Hassan, et al. [113] in Meghna; Bhuyan, et al. [70] in Brahmaputra and Bhuyan, et al. [79] in Halda found the lower concentration of Cr than the present study.

The concentrations of Cu and Pb ranged between (1.16-7.58 and 0.77-8.33 mg/kg) and the highest (6.4 ± 1.3 and 7.6 ± 0.9 mg/kg) concentrations of both of these metals were found at Madarshah and the lowest (2.0 ± 1.1 and 1.4 ± 0.9 mg/kg) at Katakhali Khal, respectively. The concentration of these two heavy metals was above the acceptable limit set by WHO [105]. Furthermore, these were also higher than the results obtained by Ali, et al. [63], Banu, et al. [112], and Bhuyan, et al. [70] in the Karnafuly, Turag, and Brahmaputra rivers, respectively. But these were lower than Mohiuddin, et al. [2], Ahmed, et al. [110], Islam, et al. [114], and Bhuyan, et al. [115]; who studied the heavy metals of sediment samples of Buriganga, Dhaleshwari, Shitalakhya and Halda rivers, respectively. Nevertheless, the concentration of Pb in the present study was also lower than the amount found by Islam, et al. [111] and Hassan, et al. [113] in the Karnafuly and Meghna rivers, respectively Table 12.

The highest concentration of Fe, Mn, and Zn (53926.3 ± 5338.2, 980.9 ± 145.1, and 108.0 ± 13.5 mg/kg) exhibited similar results to Cu and Pb; the maximum levels were found at Madarshah and the minimum levels (33571.1 ± 5456.0, 566.7 ± 92.8 and 56.0 ± 17.9 mg/kg) at Khondokia Khal, respectively. The concentration of Mn found in the present study (759.0 mg/kg) was substantially lower than the Buriganga (4036 mg/kg) river but it was higher than the level found in some other important rivers in Bangladesh by Islam, et al. [108], Hassan, et al. [113], Bhuyan, et al. [45,115]. On the contrary, the concentration of Zn found in the present study (max 108.0 ± 13.5 mg/kg) was lower than Buriganga [2,10,40] and Shitalakhya [114] but higher than Karnafuly [111], Meghna [113] and Brahmaputra [45] rivers, respectively.

A higher concentration of these metals might be the outcome of discharges from textile and paint industries and domestic sewage waste [10,40,109,113,116,117,118]. Bhuyan and Baker [115] also reported the seasonal fluctuations in the level of the heavy metals in the river Halda.

The I_{geo} values have been presented in Table 12. In all sampling sites, the I_{geo} values of all studied heavy metals except Mn configured negative values after calculation, indicating that these sites were not polluted by the heavy metals but Mn (Table 12). The overall I_{geo} values of all studied heavy metals ranged from -6.01 to 1.86. Muller [85] classification of sediment quality disclosed that all sites were moderately polluted due to contamination with Mn and the orderly arrangements of the sites on the basis of the concentration of metals stand Madar shah>Madarikhal>Katakhali>Khondokia. Mohiuddin, et al. [2] studied the I_{geo} values for Mn for 11 locations in the Buriganga river and found the values >1.0, indicating moderately polluted sediment quality. Islam, et al. [72] found higher I_{geo} values for Cd and extremely contaminated sediment quality in Turag, Buriganga, and Shitalakhya. Hasan, et al. [113] studied the sediment quality of the Meghna river and found positive values for Cd, Pb, Ni and Zn indicating unpolluted to moderately polluted sediment. In the Karnafuly river in Bangladesh, I_{geo} values for As, and Cr exposed unpolluted to extremely polluted status [63]. In the Bortala river in China, the I_{geo} values of Ni,

Table 10: Global standards of different heavy metals compared to the present study.

Global Standards	Heavy Metals					
	Cd	Cr	Cu	Mn	Pb	Zn
WHO (1993)	0.003	0.05	2.00	0.50	0.01	3.00
WHO (2004)	-	0.05	2.00	0.40	-	-
USEPA (2008)	0.005	0.10	-	0.05	-	5.00
DoE (1997) standard	0.005	0.05	-	0.10	0.05	5.00
Present Study	1.0	43.22	3.77	759.0	4.05	79.10

Table 11: The concentration of heavy metals in some others rivers in Bangladesh (mg/kg).

Rivers	Heavy Metals						References
	Cd	Cr	Cu	Mn	Pb	Zn	
Buriganga	3.33	177.50	344.20	4036	79.80	502.30	[2,40,109]
Dhaleshwari	2.08	27.39	37.45	-	15.79	-	[110]
Karnofuly	0.24	0.76	1.22	15.30	4.96	16.30	[111]
Turag	1.40	0.44	1.57		1.64	1.08	[112]
Meghna	0.23	31.74		442.60	9.47	79.02	[113]
Shitalakhya	5.01	74.82	143.70		28.36	200.60	[114]
Halda	0.04	8.84	5.90	139.50	8.80	79.58	[115]
Brahmaputra	0.001	0.01	0.12	1.44	0.11	0.01	[70]
Present Study	1.00	43.22	3.77	759.0	4.05	79.10	

Table 12: Geo-accumulation indices (I_{geo}) of heavy metals for sediments of all studied sites in the river Halda.

Stations	Geo-accumulation indices (I_{geo})							Improved Nemerow Index (I_N)
	Cd	Cr	Cu	Fe	Mn	Pb	Zn	
Khondokia	*BDL	-2.33±0.25	-4.80±0.30	-1.09±0.24	1.10±0.24	-2.86±1.62	-2.00±0.45	1.60
Katakhali	0.73±0.64	-1.97±0.27	-5.35±0.76	-0.91±0.10	1.26±0.10	-3.10±2.74	-1.70±0.32	1.50
Madarikhal	*BDL	-1.67±0.04	-4.23±0.25	-0.54±0.10	1.69±0.13	-3.41±0.37	-1.35±0.16	1.60
Madarshah	*BDL	-1.42±0.23	-3.58±0.31	-0.40±0.14	1.89±0.21	-1.99±0.18	-1.01±0.18	1.53
Mean±SD	1.10±0.16	-1.84±0.40	-4.49±0.40	-0.73±0.32	1.48±0.37	-2.58±1.54	-1.52±0.47	1.56±0.05

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

Zn, Cr, As, and Cu indicated no pollution [119]. On the contrary, Malvandi [120] found higher I_{geo} values for As and Se and sediment class ranged from unpolluted to extremely polluted in the Zarrin-Gol River, Iran. Rahman, et al. [121] and Hassan, et al. [113] have opined that a higher concentration of Al and Mn originates lithogenically and is associated with spinning mills and paint industries wastes. The higher I_{geo} values as a result of the increased concentration of Mn found in the river Halda might be the result of similar lithogenic and anthropogenic effects.

To quantify the soil heavy metal contamination in the study area, the improved Nemerow index (IN), which depicts the combined effects of all heavy metals were assessed. The I_N ranged from 1.50 to 1.60 in all four sampling sites which indicates the study area is moderately contaminated and these results also comply with the results of $I_{geo.}$ Akbor, et al. [122] found severe contamination in some sampling sites of the river Buriganga in Bangladesh in terms of $I_{N.}$ Guan, et al. [79] also found extreme commination in all sampling sites in the mining gathering area in Tianjin, China. The reasons for getting higher values in their studies are quite obvious, they conducted their studies in heavily industrialized areas and the anthropogenic load was much higher in those areas compared to the present study.

Table 13 shows the results of contamination factors (CF) and pollution load index (PLI), degree of contamination, and modified degree of contamination (mC_d) of heavy metals in sediment samples collected from the river Halda. The overall CF value for Cadmium (Cd) was >3.0 indicating considerable contamination of this metal, however; the CF values for all other heavy metals exhibited "low contamination". The CF values found in the present study in the river Halda was lowered compared to the values found in the river Meghna [113] and Buriganga [10,40,69]. The river Buriganga is polluted by the thousands of industrial and sewerage lines that dispose of huge volumes of toxic wastes into the river [123] every day. The Meghna river is also polluting different sites from industries that are situated on the banks of this river or very close to the river system. The dominant industries in this area are shipyard, cement, paper, jute, super board, oil, sugar, food processing, salt, and chemical industries. The river receives wastewater directly from these industries and also domestic and agro-chemical wastes contribute to heavy metal pollution in water and sediment [110]. In many other investigations around the world where the CF has been calculated, higher values of CF values were found. For example, CF value from 1.3 to 5.5 was found in the Balok river [96]; 0.14 to 6.08 was found in the Dikrong river [124]; 0.44 to 2.47 was found in the Yauri river [125] and 1.1 to 14.6 was found in the Tamaki estuary [87].

The PLI represents the number of times by which the metal content in the sediment exceeds the background concentration and gives a summative indication of the overall level of heavy metal toxicity in a particular sample [43]. The PLI of all sampling sites presented in Table 13 was calculated according to Tomlinson, et al. [93] and the values ranged from 0.29 to 0.51 with the overall value for all four sampling sites (0.37 ± 0.10) considered to be unpolluted. Individual PLI of all sites was also <1 that must be classified as unpolluted. The order of PLI of four sampling sites from higher to lower was Khondoki a>Katakhali>Madarikhal>Madarshah. The PLI values found in the present study in the river Halda were lower than in some previous studies, for instance; Ali, et al. [63] found higher PLI values in the Karnafuly river. Mohiuddin, et al. [126] reported PLI values of 4.9-24.2 and 5.2-27.4 in summer and winter samples of the Buriganga river which was manifold higher than the present study. Ahmed, et al. [110] stated that 100% of sampling points of the Buriganga river had PLI>1, which indicated a polluted condition. In another study, Islam, et al. [127] also reported similar results. Furthermore, Abdullah, et al. [96] and Varol [84] found higher PLI values than the present study in the Balok and Tigris rivers, respectively. The reasons for these higher PLI values might be associated with the direct disposal of untreated effluents in the river from different industrial and agro-chemical sources.

In the present study, the highest degree of contamination was observed at Katakhali (3.79 ± 2.07) followed by three other sites. The overall degree of contamination of four sampling sites was 2.68 ± 1.84 which indicated a low degree of contamination. Similarly, mC_d for the seven analyzed elements was found <1.5 in the present study, indicating nil to a lower degree of contaminations. Both of these parameters (C_d and mC_d) exhibited a lower range of values in the present study compared to some previous investigations at home and abroad. Sikder, et al. [69] and Akbor, et al. [122] found a higher degree of contamination than the present study in the Buriganga river. Sivakumar, et al. [128] in Tamil Nadu, India, and Abrahim and Parker [87] in New Zealand found higher mCd values than the preset study. However, they conducted their study in the coastal areas where all suspended and dissolved solids are washed out by the river and depositions are higher. Considering the average mCd, it should be noted that compared to geo-chemical background values, cadmium is highly enriched than other elements in the sampling sites. This localized enrichment is considered to be linked with the application of phosphate fertilizers to arable soils. Acidification of soils and lakes may also result in enhanced mobilization of cadmium from soil and sediments [129].

Table 13: Metal contamination factors (CF) and pollution load index (PLI), degree of contamination, and modified degree of contamination (mC_d) in the sediment of the river Halda.

	Contamination Factor							PLI	Degree of Contamination	mC_d
Stations	Cd	Cr	Cu	Fe	Mn	Pb	Zn			
Khondokia	*BDL	0.30±0.05	0.05±0.01	0.71±0.12	0.63±0.10	0.14±0.13	0.39±0.12	0.29	1.52±0.30	0.22±0.04
Katakhali	2.14±1.87	0.39±0.07	0.04±0.02	0.80±0.05	0.71±0.05	0.05±0.05	0.47±0.11	0.34	3.79±2.07	0.54±0.30
Madarikhal	*BDL	0.47±0.01	0.08±0.01	1.03±0.04	0.95±0.09	0.14±0.04	0.59±0.06	0.35	2.24±0.15	0.32±0.02
Madarshah	*BDL	0.57±0.09	0.13±0.03	1.14±0.11	1.09±0.16	0.38±0.05	0.75±0.09	0.51	2.92±0.31	0.42±0.04
Overall (Mean±SD)	3.33±0	0.43±0.11	0.06±0.05	0.92±0.20	0.74±0.38	0.15±0.17	0.46±0.31	0.37±0.10	2.68±1.84	0.37±0.18

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

The values of enrichment factor (EF) of studied heavy metals found in the sediments of the river Halda have been furnished in Table 14. The results showed that the mean EF values for cadmium (Cd) were>4, suggesting a moderate enrichment of the river. However, the EF values for other metals studied at all sites showed "minor enrichment" (Table 14). In some previous investigations where the EF has been calculated, for instance; the mean EF values of Cr, Ni, and Zn in the Luanhe river and the mean EF values of As, Ni, and Cu in the Bortala river [130] were >1.5. Abdullah, et al. [96] and Varol [84] opined that the heavy metals resulting in higher EF entirely originate from the natural processes or crustal material. This might affect the EF values of the present study as well.

To assess the ecological risk of the studied elements to the river Halda, the potential ecological risk indices (E_r^i and RI), were measured and are summarized in Table 15. The order of potential ecological risk factor (E_r^i) of heavy metals in sediments of the river Halda was Mn> Cr>>Zn>Cu>Pb>Cd. Except for Fe, the mean Mn concentration of four sites poses serious ecological risk whereas Cr and Zn pose appreciable to moderate ecological risk, respectively. The mean potential ecological risk coefficient of Cd, Cu, and Pb was lower than 40, which belongs to low ecological risk. Also, the values of RI at all sites were >600 which indicated high ecological risk. In brief, the E_r^i and RI indices for the studied elements in the surface sediment of the river Halda pose a potential ecological risk. Rahman, et al. [131] found lower E_r^i and RI indices in an adjacent area of Dhaka Export Processing Zones than in the present study. The reasons might be that they conducted their study in a floodplain area and in a river located at Savar Upazila which receives lower content of municipal effluent surges than the capital Dhaka. But in another study, Islam, et al. [132] found significantly higher E_r^i and RI indices in the Burignaga river than in the river Halda. Malvandi, et al. [120] found lower indices values in the Zarrin-Gol River in Iran. Solaiman, et al. [98] found higher E_r^i for Cd in Egypt whereas other studied heavy metals exhibited lower values than the present study. Sivakumar, et al. [128] found lower RI than the present study. The reasons behind this discrepancy of E_r^i and RI indices with local and international studies might be associated with the receiving of different types of contaminants from different anthropogenic sources where variation among metallic elements normally exists.

The mean Probable effects level (PEL) was calculated for the four sampling sites based on the metals Cd, Cr, Cu, Fe, Mn, Pb, and Zn to evaluate the potential risk to aquatic lives [103]. The PEL ranged from 0.04 to 1.09, and the mean probable effects level quotient (PEL-Q) ranged from 0.26 to 0.45 with an overall value of 0.35 ± 0.08 (Table 16). The results indicated that the combination of heavy metals may have a 21 % probability of being toxic (Table 8). Probable effects level (PEL) and effects level quotient (PEL-Q) of heavy metals of any native river were not reported in the literature, therefore; it was not possible to compare the results of the present study with the previous ones. However, Li, et al. [133] found a similar probability of toxicity on the Weihai coast, China. Soliman, et al. [98] also found 30% probability of being toxic on the Mediterranean coast, Egypt.

Heavy metals in sediments normally originate from

Table 14: The values of enrichment factor (EF) of studied heavy metals for sediments in the river Halda.

Stations	Enrichment Factors (EF)						
	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Khondokia	*BDL	0.42±0.01	0.08±0.00	1.00±0.00	0.89±0.02	0.21±0.20	0.54±0.09
Katakhali	4.17±0.28	0.48±0.06	0.05±0.03	1.00±0.00	0.88±0.01	0.06±0.06	0.58±0.10
Madarikhal	*BDL	0.46±0.01	0.08±0.02	1.00±0.00	0.92±0.05	0.14±0.04	0.57±0.04
Madarshah	*BDL	0.49±0.03	0.11±0.02	1.00±0.00	0.95±0.06	0.34±0.07	0.66±0.05
Mean±SD	4.16±0	0.47±0.03	0.08±0.02	1.0±0.0	0.91±0.03	0.22±0.12	0.59±0.05

Table 15: Potential ecological risk factors (E_r^i) and risk index (RI) for studied heavy metals in the river Halda.

Stations	E_r^i							RI	Risk grade
	Cd	Cr	Cu	Fe	Mn	Pb	Zn		
Khondokia	*BDL	60.47±10.23	13.68±2.87	94670.37±15385.84	566.68±92.83	14.47±12.71	55.97±17.90	711.26±122.55	Low
Katakhali	19.30±16.87	77.46±14.08	10.12±5.57	106607.96±6968.00	635.13±43.61	4.57±4.96	67.46±15.84	814.03±85.90	Low
Madarikhal	*BDL	94.53±2.54	20.23±3.40	137655.67±4964.23	853.85±76.66	14.45±3.89	84.93±8.91	1068.00±84.18	Low
Madarshah	*BDL	113.48±18.73	31.83±6.54	152072.06±15053.86	980.91±145.10	37.85±4.70	107.96±13.52	1272.04±175.19	Low
Mean±SD	5.79±12.25	80.43±18.68	16.48±7.83	116121.54±22269.59	712.20±161.01	14.21±12.63	71.98±18.72	901.10±206.10	Low
E_r^i grade									

Table 16: Probable effects level and effects level quotient of heavy metals in the river Halda.

	PEL							PEL-Q
Stations	Cd	Cr	Cu	Fe	Mn	Pb	Zn	
Khondokia	0.00±0.00	0.19±0.03	0.03±0.01	0.84±0.14	0.52±0.08	0.03±0.02	0.21±0.07	0.26±0.05
Katakhali	0.15±0.13	0.24±0.04	0.02±0.01	0.95±0.06	0.58±0.04	0.01±0.01	0.25±0.06	0.31±0.05
Madarikhal	0.00±0.00	0.30±0.01	0.04±0.01	1.22±0.04	0.89±0.13	0.03±0.01	0.31±0.03	0.40±0.02
Madarshah	0.00±0.00	0.35±0.06	0.06±0.01	1.35±0.13	0.89±0.13	0.07±0.01	0.40±0.05	0.45±0.05
Mean±SD	0.23±0.03	0.27±0.07	0.04±0.02	1.09±0.23	0.72±0.20	0.04±0.02	0.29±0.09	0.35±0.08

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

different natural and anthropogenic sources [134]. It is well established that organic matter and grain size are two main factors influencing the heavy metal regimes in the sediments [135]. The connotation among metals in sediment affords crucial information on sources and pathways of heavy metals in the aquatic milieu. The result of correlations between heavy metals conceded with the results of PCA and CA endorsed some new relations between parameters, viz. strong, moderately strong, and very strong, indicating that their sources of origin are similar, especially from industrial effluents, municipal wastes, and agricultural inputs. With this view, a correlation matrix was applied to discover relationships among studied elements and to determine a possible common metal source in the river Halda. According to the Pearson correlation matrix, (95% confidence level, $P=0.05$), a significant correlation was found among some metals studied (Table 17). Cr displayed close relationships with Cu, Fe, Mn, and Zn. Similarly, Cu showed a close relation with Fe and Mn. Iron showed a close relationship between Mn, Pb, and Zn. Mn showed a close relationship with Zn and Pb showed a close relationship with Zn proposing a common source of these metals. These highly significant positive correlations between heavy metals suggest the possibility of common sources of origin which may be anthropogenic [136]. On the other hand, the rest of the elemental pairs showed no significant correlation with each other which could be an indication of separate source input or sources of

Table 17: Pearson's Correlation Matrix of heavy metals of Halda river.

	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Cd							
Cr	-0.019						
Cu	-0.578*	0.757*					
Fe	-0.218	0.966*	0.814*				
Mn	-0.239	0.961*	0.847*	0.984*			
Pb	-0.408	0.544	0.733*	0.575*	0.594*		
Zn	-0.092	0.939*	0.738*	0.944*	0.918*	0.649*	

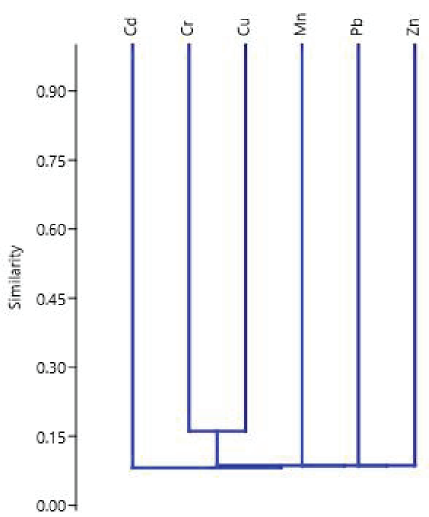

Figure 2: Bray-Curtis similarity index of heavy metals found in the sediments of the river Halda.

Table 18: Factor loadings on elements in sediments from the river Halda (n = 12).

Element	PC1	PC2
Cd	0.979	-0.464
Cr	0.966	-0.074
Cu	0.920	0.133
Mn	0.981	-0.046
Pb	0.532	0.881
Zn	0.960	-0.021
Eigen value	4.911	1.018
% variance explained	82	17
Cumulative % variance	81.86	98.84

pollution. In contrast, no positive correlations were observed between Cd and other metals, suggesting that Cd pollution might be from a different source than other metals. Bhuyan and Bakar [79] and Hossain, et al. [137] also found a similar type of association between different heavy metals in the river Halda. Hassan, et al. [113] and Akbor, et al. [122] studied the metal-to-metal correlation of the Buriganga river and found a positive correlation among most of the metals except for very few metals with no significant correlation Figure 2.

The principal component analysis (PCA) disclosed that all heavy metals could be grouped into two components (Eigen values>1) which explains 98.84% of the total variance (Table 18). The first component (PC1) accounted for about 82% of the total variance and exhibited high loading values for Cd, Cr, Cu, Mn, and Zn, whereas the second component (PC2) accounted for 17% of the total variance and exhibited high loading value only for Pb. Together with Pearson's Correlation Matrix (significant positive correlations between pairs of variables), we speculated that elements with loading values in the PC1 (Cd, Cr, Cu, Mn, and Zn) were from the lithogenic (natural) origin [138]. Probable sources are industrial discharges, municipal waste, household garbage, and urban runoff [122]. On the contrary, in the PC2, Pb presented a high loading value also implying its natural or anthropogenic origin. Pb mainly transfers as a reducible element in surface sediments and is strongly allied with Fe and Mn oxides acting as the natural accumulators of the metal in sediments [139]. Bhuyan and Bakar [115] found almost similar results in the river Halda with the existence of two principal components. On the other hand, Bhuyan, et al. [79] found three principal components in the river Halda, and Akbor, et al. [122] found four principal components in the river Buriganga while analyzing the heavy metals of sediment samples from the respective rivers. Soliman, et al. [98] also found two principal components while analyzing the heavy metals in sediments from the Mediterranean coast, Egypt, and Li, et al. [133] found three components in the Weihai coast, China. The difference that was visible in terms of the nos. of components and loading values of different elements might be due to spatial variations and procedures applied for heavy metal detection and analysis.

Conclusion and recommendations

The results of this investigation disclose vital information about metal contamination in sediments of the river Halda. The

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

distribution order of heavy metal concentration in sediments was Fe>Mn>Zn >Cr>Pb>Cu and >Cd (mg/kg), respectively and the heavy metals were above the certified reference values set by WHO [106] and USEPA [140]. Albeit, the seven elements showed different distribution characters, lithogenic or anthropogenic contributions were the main sources of these metals. The adverse impact of heavy metals on aquatic biota was assessed using different indices. The average I_{geo} values displayed pollution only from two heavy metals Cd (1.10 ± 0.16) and Mn (1.48 ± 0.37). The average PLI (0.37 ± 0.10) exhibited no marks of pollution among the studied sites, however; the average CF values showed a moderate degree of pollution. The average EF (0.08 ± 0.02 to 4.16 ± 0) demonstrated none to moderate enrichment of the river. Nevertheless, average E_r^i (17.83 ± 14.29 to 759.14 ± 192.26) and RI (711.26 ± 122.55 to 1272.04 ± 175.19) exposed low to serious ecological risk for the river Halda.

Multivariate statistical analysis demonstrated significant correlations between the studied heavy metals indicating similar sources and/or similar lithogenic/anthropogenic processes regulating the occurrence of these metals. In light of the findings of the present study, the following recommendations can be made:

- No industrial effluents should be allowed to dispose of in the river Halda without prior treatment
- No mining and dumping sites should be allowed on the bank of the river Halda
- Canals carrying municipal sewerage discharge to the river Halda should be stopped permanently
- The construction of a dam on the upper stretch of river Halda for water management and irrigation should not be allowed
- No project should be allowed to collect water from the river Halda for municipal use
- No mechanized boats should be allowed to run through the river Halda
- The natural navigation route of the river Halda should be maintained
- The river should be allowed only for research purposes and further research should be conducted on this aspect to know the future status and trends of heavy metals

Halda is an important river in Bangladesh. This study will support understanding of the present status of metal pollution in the river Halda and could be used as a useful tool for the academicians, researchers, and authorities of the Govt. of Bangladesh to formulate future management strategies to conserve and restore the river as it is considered as the only natural breeding ground of Indian major carps and declared as the Bangabandhu Fisheries Heritage.

References

1. Silambarasan K, Senthilkumaar P, Velmurugan K. Studies on the distribution of heavy metal concentrations in River Adyar, Chennai, Tamil Nadu. European J Exp Biol. 2012; 2(6):2192-2198.
2. Mohiuddin KM, Alam MM, Ahmed I, Chowdhury AK. Heavy metal pollution load in sediment samples of the Buriganga river in Bangladesh. J Bangladesh Agril Univ. 2015; 13(2): 229-238.
3. Dabaradaran S, Naddafi K, Nazmara S, Ghaedi H. Heavy metals (Cd, Cu, Ni and Pb) content in two fish species of Persian Gulf in Bushehr Port Iran. Afr J Biotechnol. 2010; 37:6191-6193.
4. Wilson B, Pyatt FB. Heavy metal dispersion, persistance, and bioccumulation around an ancient copper mine situated in Anglesey, UK. Ecotoxicol Environ Saf. 2007 Feb;66(2):224-31. doi: 10.1016/j.ecoenv.2006.02.015. Epub 2006 Apr 18. PMID: 16618505.
5. Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environ Pollut. 2008 Apr;152(3):686-92. doi: 10.1016/j.envpol.2007.06.056. Epub 2007 Aug 27. PMID: 17720286.
6. Sekabira K, Oryem Origa H, Basamba TA, Mutumba G, Kakudidi E. Assessment of heavy metal pollution in the urban stream sediments and its tributaries. Int J Environ Sci Technol. 2010; 7:435-446.
7. Zhang C, Qiao Q, Piper JD, Huang B. Assessment of heavy metal pollution from a Fe-smelting plant in urban river sediments using environmental magnetic and geochemical methods. Environ Pollut. 2011 Oct;159(10):3057-70. doi: 10.1016/j.envpol.2011.04.006. Epub 2011 May 10. PMID: 21561693.
8. Grigoratos T, Samara C, Voutsa D, Manoli E, Kouras A. Chemical composition and mass closure of ambient coarse particles at traffic and urban-background sites in Thessaloniki, Greece. Environ Sci Pollut Res Int. 2014 Jun;21(12):7708-22. doi: 10.1007/s11356-014-2732-z. Epub 2014 Mar 14. PMID: 24627204.
9. Rodríguez Martín JA, De Arana C, Ramos-Miras JJ, Gil C, Boluda R. Impact of 70 years urban growth associated with heavy metal pollution. Environ Pollut. 2015 Jan;196:156-63. doi: 10.1016/j.envpol.2014.10.014. PMID: 25463709.
10. Ahmad MK, Islam S, Rahman S, Haque MR, Islam MM. Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. Int J Environ Res. 2010; 4:321-332.
11. Alexander DE, Fairbridge WR. Encyclopedia of environmental science. Kluwer Academic Publishers, Dordrecht, The Netherlands. 1999.
12. USEPA. Risk based Concentration Table. United States Environmental Protection Agency, Philadelphia, PA; Washington DC. 2000.
13. Giaccio L, Cicchella D, De Vivo B, Lombardi G, De Rosa M. Does heavy metals pollution affect semen quality in men? A case of study in the metropolitan area of Naples (Italy). J Geochem Explor. 2012; 112:218–225.
14. Morton-Bermea O, Hernandez E, Martinez-Pichardo E, Soler-Arechalde AM, Lozano Santa-Cruz R, Gonzalez-Hernandez G, Beramendi-Orosco L, Urrutia-Fucugauchi J. Mexico City topsoil: Heavy metals vs. magnetic susceptibility. Geoderma. 2009; 151:121-125.
15. Mielke HW, Wang G, Gonzales CR, Powell ET, Le B, Quach VN. PAHs and metals in the soils of inner-city and suburban New Orleans, Louisiana, USA. Environ Toxicol Pharmacol. 2004 Dec;18(3):243-7. doi: 10.1016/j.etap.2003.11.011. PMID: 21782755.
16. Santos-Francés F, García-Sánchez A, Alonso-Rojo P, Contreras F, Adams M. Distribution and mobility of mercury in soils of a gold mining region, Cuyuni river basin, Venezuela. J Environ Manage. 2011 Apr;92(4):1268-76. doi: 10.1016/j.jenvman.2010.12.003. Epub 2011 Jan 6. PMID: 21215510.
17. Santos-Francés F, García-Sánchez A, Alonso-Rojo P, Contreras F, Adams M. Distribution and mobility of mercury in soils of a gold mining region, Cuyuni river basin, Venezuela. J Environ Manage. 2011 Apr;92(4):1268-76. doi: 10.1016/j.jenvman.2010.12.003. Epub 2011 Jan 6. PMID: 21215510.
18. Martínez-Graña AM, Goy JL, De Bustamante I, Zazo C. Characterization of environmental impact on resources, using strategic assessment of environmental impact and management of natural spaces of “Las Batuecas-

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

Sierra de Francia" and "Quilamas" (Salamanca, Spain). Environ. Earth Sci. 2014; 71:39-51.

19. Abdullah EJ. Quality assessment for Shatt Al-Arab River using heavy metal pollution index and metal index. J Environ Earth Sci. 2013; 3:114-120.

20. Zhou QX, Kong FX, Zhu L. Ecotoxicology: Principles and Methods. Science Press, Beijing, 2004; 161-217.

21. Sankar TV, Zynudheen AA, Anandan R, Viswanathan Nair PG. Distribution of organochlorine pesticides and heavy metal residues in fish and shellfish from Calicut region, Kerala, India. Chemosphere. 2006 Oct;65(4):583-90. doi: 10.1016/j.chemosphere.2006.02.038. Epub 2006 May 5. PMID: 16678236.

22. Kumar Sharma R, Agrawal M, Marshall F. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicol Environ Saf. 2007 Feb;66(2):258-66. doi: 10.1016/j.ecoenv.2005.11.007. Epub 2006 Feb 7. PMID: 16466660.

23. Yi Y, Yang Z, Zhang S. Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River basin. Environ Pollut. 2011 Oct;159(10):2575-85. doi: 10.1016/j.envpol.2011.06.011. Epub 2011 Jul 14. PMID: 21752504.

24. Vieira, C., Morais, S., and Ramos, S. 2011. Mercury, cadmium, lead and arsenic levels in three pelagic fish species from the Atlantic Ocean: intra- and inter-specific variability and human health risks for consumption. Food Chem. Toxicol. 49:923-932. http://dx. doi.org/10.1016/j.fct.2010.12.016.

25. Forti E, Salovaara S, Cetin Y, Bulgheroni A, Tessadri R, Jennings P, Pfaller W, Prieto P. In vitro evaluation of the toxicity induced by nickel soluble and particulate forms in human airway epithelial cells. Toxicol In Vitro. 2011 Mar;25(2):454-61. doi: 10.1016/j.tiv.2010.11.013. Epub 2010 Nov 25. PMID: 21111804.

26. Banerjee N, Nandy S, Kearns JK, Bandyopadhyay AK, Das JK, Majumder P, Basu S, Banerjee S, Sau TJ, States JC, Giri AK. Polymorphisms in the TNF-α and IL10 gene promoters and risk of arsenic-induced skin lesions and other nondermatological health effects. Toxicol Sci. 2011 May;121(1):132-9. doi: 10.1093/toxsci/kfr046. Epub 2011 Feb 25. PMID: 21357384; PMCID: PMC3115675.

27. Alhashemi AH, Sekhavatjou MS, Kiabi BH. Bioaccumulation of trace elements in water, sediment, and six fish species from a freshwater wetland, Iran. Microchem J. 2012; 104:1-6.

28. Pan K, Wang WX. Trace metal contamination in estuarine and coastal environments in China. Sci Total Environ. 2012 Apr 1;421-422:3-16. doi: 10.1016/j.scitotenv.2011.03.013. Epub 2011 Apr 5. PMID: 21470665.

29. Rahman MM, Asaduzzaman M, Naidu R. Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh. J Hazard Mater. 2013 Nov 15;262:1056-63. doi: 10.1016/j.jhazmat.2012.06.045. Epub 2012 Jun 30. PMID: 22939573.

30. Fang Y, Sun X, Yang W, Ma N, Xin Z, Fu J, Liu X, Liu M, Mariga AM, Zhu X, Hu Q. Concentrations and health risks of lead, cadmium, arsenic, and mercury in rice and edible mushrooms in China. Food Chem. 2014 Mar 15;147:147-51. doi: 10.1016/j.foodchem.2013.09.116. Epub 2013 Oct 1. Erratum in: Food Chem. 2014 May 15;151:379. PMID: 24206698.

31. Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Hoque MF. Preliminary assessment of heavy metal contamination in surface sediments from a river in Bangladesh. Environ. Earth Sci. 2015; 73:1837-1848. http://dx.doi.org/10.1007/s12665-014-3538-5.

32. Ahmed MK, Baki MA, Islam MS, Kundu GK, Habibullah-Al-Mamun M, Sarkar SK, Hossain MM. Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. Environ Sci Pollut Res Int. 2015 Oct;22(20):15880-90. doi: 10.1007/s11356-015-4813-z. Epub 2015 Jun 6. PMID: 26044144.

33. Rainbow PS, Amiard-Triquet C, Amiard JC, Smith BD, Langston WJ. Observations on the interaction of zinc and cadmium uptake rates in crustaceans (amphipods and crabs) from coastal sites in UK and France differentially enriched with trace metals. Aquat Toxicol. 2000 Sep 1;50(3):189-204. doi: 10.1016/s0166-445x(99)00103-4. PMID: 10958954.

34. Shuhaimi-Othman M, Pascoe D. Bioconcentration and depuration of copper, cadmium, and zinc mixtures by the freshwater amphipod Hyalella azteca. Ecotoxicol Environ Saf. 2007 Jan;66(1):29-35. doi: 10.1016/j.ecoenv.2006.03.003. Epub 2006 May 2. PMID: 16647753.

35. Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Islam KN, Ibrahim M, Masunaga S. Arsenic and lead in foods: a potential threat to human health in Bangladesh. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2014;31(12):1982-92. doi: 10.1080/19440049.2014.974686. Epub 2014 Nov 17. PMID: 25396285.

36. Rodríguez Martín JA, De Arana C, Ramos-Miras JJ, Gil C, Boluda R. Impact of 70 years urban growth associated with heavy metal pollution. Environ Pollut. 2015 Jan;196:156-63. doi: 10.1016/j.envpol.2014.10.014. PMID: 25463709.

37. Islam MS, Ahmed MK, Raknuzzaman M, Habibullah-Al-Mamun M, Islam MK. Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. Ecol Indic. 2015; 48:282-291. http://dx. doi.org/10.1016/j.ecolind.2014.08.016.

38. Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Masunaga S. Assessment of trace metals in fish species of urban rivers in Bangladesh and health implications. Environ Toxicol Pharmacol. 2015 Jan;39(1):347-57. doi: 10.1016/j.etap.2014.12.009. Epub 2014 Dec 22. PMID: 25553576.

39. Ahmed MK, Shaheen N, Islam MS, Habibullah-al-Mamun M, Islam S, Mohiduzzaman M, Bhattacharjee L. Dietary intake of trace elements from highly consumed cultured fish (Labeo rohita, Pangasius pangasius and Oreochromis mossambicus) and human health risk implications in Bangladesh. Chemosphere. 2015 Jun;128:284-92. doi: 10.1016/j.chemosphere.2015.02.016. Epub 2015 Mar 3. PMID: 25747154.

40. Saha PK, Hossain MD. Assessment of heavy metal contamination and sediment quality in the Buriganga river, Bangladesh. Proceedings of the 2nd International Conference on Environmental Science and Technology, (EST' 11), IACSIT Press, Singapore, 2011; 384-388.

41. Miller CV, Foster GD, Majedi BF. Baseflow and stormflow metal fluxes from two small agricultural catchments in the coastal plain of Chesapeake Bay Basin, United States. Appl Geochem. 2003; 18(4):483-501.

42. Mohiuddin KM, Zakir HM, Otomo K, Sharmin S, Shikazono N. Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int J Environ Sci Technol. 2010; 7:17-28.

43. Barakat A, Baghdadi ME, Rais J, Nadem S. Assessment of heavy metal in surface sediments of Day river at Beni-Mellal Region, Morocco. Res. J Environ Earth Sci. 2012; 4:797-806.

44. Gao X, Chen CTA, Wang G, Xue Q, Tang C, Chen S. Environmental status of day a bay surface sediment inferred from a sequential extraction technique. Estuar. Coast. Shelf Sci. 2009. 86:369-378. http://dx.doi.org/10.1016/j.ecss.2009.10.012.

45. Bhuyan MS, Bakar MA, Nabi MRU, Senapathi V, Chung SY, Islam MS. Monitoring and assessment of heavy metal contamination in surface water and sediment of the Old Brahmaputra River, Bangladesh. App Water Sci. 2019; 9: 125.

46. Guo Y, Yang S. Heavy metal enrichments in the Changjiang (Yangtze River) catchment and on the inner shelf of the East China Sea over the last 150 years. Sci Total Environ. 2016 Feb 1;543(Pt A):105-115. doi: 10.1016/j.scitotenv.2015.11.012. Epub 2015 Nov 12. PMID: 26580732.

47. Forstner U, Wittman GTW. Metal Pollution in the Aquatic Environment. Springer, Berlin, 2nd ed. 1981; 486.

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

48. Salomons W, Forstner U. Metals in the Hydrocycle. Springer, Berlin, 1984; 169.

49. Helios Rybicka E. Phase-specific bonding of heavy metals in sediments of the Vistula River, Poland. 1992.

50. Selvaraj K, Ram Mohan V, Szefer P. Evaluation of metal contamination in coastal sediments of the Bay of Bengal, India: geochemical and statistical approaches. Mar Pollut Bull. 2004 Aug;49(3):174-85. doi: 10.1016/j.marpolbul.2004.02.006. PMID: 15245982.

51. Esslemont G. Heavy Metals in Seawater, Marine Sediments and Corals from the Townsville Section, Great Barrier Reef Marine Park, Queensland. Mar. Chem. 2000; 71:215-231.

52. Xu J, Wang H, Liu Y, Ma M, Zhang T, Zheng X, Zong M. Ecological risk assessment of heavy metals in soils surrounding oil waste disposal areas. Environ Monit Assess. 2016 Feb;188(2):125. doi: 10.1007/s10661-016-5093-x. Epub 2016 Jan 29. PMID: 26832722.

53. Ogbeibu AE, Omoigberale MO, Ezenwa I, Eziza JO, Igwe JO. Using Pollution Load Index and Geoaccumulation Index for the Assessment of Heavy Metal Pollution and Sediment Quality of the Benin River, Nigeria. Nat Environ. 2014; 2:1-9.

54. Manoj K, Kumar B, Padhy PK. Characterization of metals in water and sediments of Subarnarekha River along the projects' sites in Lower Basin, India. Universal J Environ Res Technol. 2012; 2:402-410.

55. Arnason JG, Fletcher BA. A 40+ year record of Cd, Hg, Pb, and U deposition in sediments of Patroon Reservoir, Albany County, NY, USA. Environ Pollut. 2003;123(3):383-91. doi: 10.1016/s0269-7491(03)00015-0. PMID: 12667766.

56. Li M, Yang W, Sun T, Jin Y. Potential ecological risk of heavy metal contamination in sediments and macrobenthos in coastal wetlands induced by freshwater releases: A case study in the Yellow River Delta, China. Mar Pollut Bull. 2016 Feb 15;103(1-2):227-239. doi: 10.1016/j.marpolbul.2015.12.014. Epub 2015 Dec 22. PMID: 26719069.

57. Alshahri F, El-Taher A. Assessment of Heavy and Trace Metals in Surface Soil Nearby an Oil Refinery, Saudi Arabia, Using Geoaccumulation and Pollution Indices. Arch Environ Contam Toxicol. 2018 Oct;75(3):390-401. doi: 10.1007/s00244-018-0531-0. Epub 2018 Apr 30. PMID: 29713742.

58. Begüm A, Amin MDN, Kaneco S, Ohta K. Selected elemental composition of the muscle tissue of three species of fish, Tilapia nilotica, Cirrhina mrigala and Clarius batrachus, from the fresh water Dhanmondi Lake in Bangladesh. Food Chem. 2005; 93: 439-443.

59. Fernandes C, Fontaínhas-Fernandes A, Cabral D, Salgado MA. Heavy metals in water, sediment and tissues of Liza saliens from Esmoriz-Paramos lagoon, Portugal. Environ Monit Assess. 2008 Jan;136(1-3):267-75. doi: 10.1007/s10661-007-9682-6. Epub 2007 Apr 20. PMID: 17447151.

60. Öztürk M, Özözen G, Minareci O, Minareci E. Determination of heavy metals in of fishes, water and sediment from the Demirköprü Dam Lake (Turkey). J App Biol Sci. 2008; 2(3):99-104.

61. Poté J, Haller L, Loizeau JL, Garcia Bravo A, Sastre V, Wildi W. Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the Bay of Vidy, Lake Geneva, Switzerland. Bioresour Technol. 2008 Oct;99(15):7122-31. doi: 10.1016/j.biortech.2007.12.075. Epub 2008 Feb 13. PMID: 18276131.

62. Praveena SM, Radojevic M, Abdullah MH, Aris AZ. Application of sediment quality guidelines in the assessment of mangrove surface sediment in Mengkabong lagoon, Sabah, Malaysia. Iran J Environ Health Sci Eng. 2088; 5(1): 35-42.

63. Ali MM, Ali ML, Islam MS, Rahman MZ. Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. Environ Nanotechnol Monit Manag. 2016; 5:27-35. https://doi.org/10.1016/j.enmm.2016.01.002.

64. Kibria G, Hossain MM, Mallick D, Lau TC, Wu R. Monitoring of metal pollution in waterways across Bangladesh and ecological and public health implications of pollution. Chemosphere. 2016 Dec;165:1-9. doi: 10.1016/j.chemosphere.2016.08.121. Epub 2016 Sep 8. PMID: 27614397.

65. Khadse GK, Patni PM, Kelkar PS, Devotta S. Qualitative evaluation of Kanhan river and its tributaries flowing over central Indian plateau. Environ Monit Assess. 2008 Dec;147(1-3):83-92. doi: 10.1007/s10661-007-0100-x. Epub 2007 Dec 22. PMID: 18157651.

66. Venugopal T, Giridharan L, Jayaprakash M. Characterization and risk assessment studies of bed sediments of river Adyar, an application of speciation study. Int J Environ Res. 2009; 3:581-598.

67. Mokaddes MAA, Nahar BS, Baten MA. Status of heavy metal contaminations of river water of Dhaka Metropolitan City. J Environ Sci Nat Res. 2013; 5:349-353.

68. Shil SC, Islam MS, Irin A, Tusher TR, Hoq ME. Heavy Metal Contamination in Water and Sediments of Passur River near the Sundarbans Mangrove of Bangladesh. J Environ Sci Nat Res. 2017; 10(1):15-19.

69. Sikder D, Islam MS. Heavy metal contamination assessment of the Buriganga River bed sediment. Proceedings of 3rd International Conference on Advances in Civil Engineering, 21-23 December 2016, CUET, Chittagong, Bangladesh. 2016.

70. Bhuyan MS, Bakar MA, Rashed-Un-Nabi M, Senapathi V, Chung SY, Islam MS. Monitoring and assessment of heavy metal contamination in surface water and sediment of the Old Brahmaputra River, Bangladesh. Applied Water Sci. 2019; 9:125.

71. Kabir MH, Islam MS, Tusher TR, Hoq ME, Muliadi, Mamun SA. Changes of heavy metal concentrations in Shitalakhya river water of Bangladesh with seasons. Indonesian J Sci Tech. 2020; 5(3):395-409.

72. Islam MM, Rahman SL, Ahmed SU, Haque MKI. Biochemical characteristics and accumulation of heavy metals in fishes, water and sediments of the river Buriganga and Shitalakhya of Bangladesh. J Asian Sci Res. 2014; 4:270-279.

73. Saimon MK, Mustafa MG, Sarker BS, Hossain MB, Rahman MM. Marketing channels of Indian carp fry collected from Halda River and livelihood of the fry traders. Asian J Agric Res. 2016; 10:28-37.

74. Tsai CF, Islam MN, Karim R, Rahman KUMS. Spawning of major carps in the lower Halda River, Bangladesh. Estuaries. 1981; 4:127-138.

75. Patra RWR, Azadi MA. Limnology of the Halda river. J Noami. 1985; 2: 31-38.

76. Kabir MH, Kibria MM, Jashimuddin M, Hossain MM. Economic valuation of tangible resources from Halda-the carp spawning unique river located at southern part of Bangladesh. Int J Water Res. 2013; 1:30-36.

77. Sharawy ZZ, Ashour M, Labena A, Alsaqufi AS, Mansour AT, Abbas E. Effects of dietary Arthrospira platensis nanoparticles on growth performance, feed utilization, and growth-related gene expression of Pacific white shrimp, Litopenaeus vannamei. Aquaculture 2022; 551: 737905.

78. Metwally AS, El-Naggar HA, El-Damhougy KA, Bashar MAE, Ashour M, Abo-Taleb HAH. GC-MS analysis of bioactive components in six different crude extracts from the Soft Coral (Sinularia maxim) collected from Ras Mohamed, Aqaba Gulf, Red Sea, Egypt. Egypt. J Aquat Biol Fish. 2020; 24: 425–434.

79. Bhuyan MS, Bakar MA. Assessment of water quality in Halda River (the Major carp breeding ground) of Bangladesh. Pollution . 2017; 3(3):429-441.

80. Praveen S. Analysis of Wastewater for Metals using ICP-OES. PerkinElmer, Inc. Shelton, CT 06484 USA. 2010.

81. Guan Y, Shao C, Ju M. Heavy metal contamination assessment and partition for industrial and mining gathering areas. Int J Environ Res Public Health. 2014 Jul 16;11(7):7286-303. doi: 10.3390/ijerph110707286. PMID: 25032743; PMCID: PMC4113876.

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

82. Müller G. Index of geo-accumulation in sediments of the Rhine River. Geol J. 1969; 2:108-118.

83. Chowdhury R, Favas PJ, Pratas J, Jonathan MP, Ganesh PS, Sarkar SK. Accumulation of Trace Metals by Mangrove Plants in Indian Sundarban Wetland: Prospects for Phytoremediation. Int J Phytoremediation. 2015;17(9):885-94. doi: 10.1080/15226514.2014.981244. PMID: 25581820.

84. Varol M. Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. J Hazard Mater. 2011 Nov 15;195:355-64. doi: 10.1016/j.jhazmat.2011.08.051. Epub 2011 Aug 22. PMID: 21890271.

85. Müller G. The heavy metal pollution of the sediments of Neckars and its tributary. Chemiker Zeitung. 1981; 105:157-164.

86. Hakanson L. An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res. 1980; 14:975-1001.

87. Abrahim GM, Parker RJ. Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environ Monit Assess. 2008 Jan;136(1-3):227-38. doi: 10.1007/s10661-007-9678-2. Epub 2007 Mar 17. PMID: 17370131.

88. Sakan SM, Dordević DS, Manojlović DD, Predrag PS. Assessment of heavy metal pollutants accumulation in the Tisza river sediments. J Environ Manage. 2009 Aug;90(11):3382-90. doi: 10.1016/j.jenvman.2009.05.013. Epub 2009 Jun 9. PMID: 19515481.

89. Franco-Uría A, López-Mateo C, Roca E, Fernández-Marcos ML. Source identification of heavy metals in pastureland by multivariate analysis in NW Spain. J Hazard Mater. 2009 Jun 15;165(1-3):1008-15. doi: 10.1016/j.jhazmat.2008.10.118. Epub 2008 Nov 7. PMID: 19070956.

90. Turekian KK, Wedepohl KH. Distribution of the elements in some major units of the earth's crust. Geo Soci Am Bullet. 1961; 72:175-192.

91. Al Rashdi S, Arabi AA, Howari FM, Siad A. Distribution of heavy metals in the coastal area of Abu Dhabi in the United Arab Emirates. Mar Pollut Bull. 2015 Aug 15;97(1-2):494-498. doi: 10.1016/j.marpolbul.2015.05.052. Epub 2015 Jun 13. PMID: 26081249.

92. El-Sammak AA, Aboul-Kassim TA. Metal pollution in the sediments of Alexandria region, southeastern Mediterranean, Egypt. Bull Environ Contam Toxicol. 1999 Aug;63(2):263-70. doi: 10.1007/s001289900975. PMID: 10441645.

93. Tomlinson DC, Wilson JG, Harris CR, Jeffrey DW. Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. Helgoland Marine Res. 1980; 33: 566-575.

94. Harikumar PS, Nasir UP, Mujeebu RMP. Distribution of heavy metals in the core sediments of a tropical wetland system. Int J Environ Sci Tech. 2009; 6:225-232. DOI: 10.1007/BF03327626.

95. Lin Y, Han P, Huang Y, Yuan GL, Guo JX, Li J. Source identification of potentially hazardous elements and their relationships with soil properties in agricultural soil of the Pinggu district of Beijing, China: multivariate statistical analysis and redundancy analysis. J Geochem Explor. 2017; 173:110-118. http://dx.doi.org/10.1016/j.gexplo.

96. Abdullah MZ, Louis VC, Abas MT. Metal pollution and ecological risk assessment of Balok River Sediment, Pahang Malaysia. Am J Environ Eng. 2015; 5:1-7. http://dx.doi.org/10.5923/c.ajee.201501.01.

97. Maanan MM, Saddik M, Chaibi M, Assobhei O, Zourarah B. Environmental and ecological risk assessment of heavy metals in sediments of Nador lagoon, Morocco. Ecol Indic. 2015; 48:616-626. http://dx.doi.org/10.1016/j.ecolind.2014.09.034.

98. Soliman NF, Nasr SM, Okbah MA. Potential ecological risk of heavy metals in sediments from the Mediterranean coast, Egypt. J Environ Health Sci Eng. 2015 Oct 10;13:70. doi: 10.1186/s40201-015-0223-x. PMID: 26457189; PMCID: PMC4600254.

99. Tang Z, Zhang L, Huang Q, Yang Y, Nie Z, Cheng J, Yang J, Wang Y, Chai M. Contamination and risk of heavy metals in soils and sediments from a typical plastic waste recycling area in North China. Ecotoxicol Environ Saf. 2015 Dec;122:343-51. doi: 10.1016/j.ecoenv.2015.08.006. Epub 2015 Sep 20. PMID: 26318969.

100. Zhuang W, Gao X. Distributions, sources and ecological risk assessment of arsenic and mercury in the surface sediments of the southwestern coastal Laizhou Bay, Bohai Sea. Mar Pollut Bull. 2015 Oct 15;99(1-2):320-7. doi: 10.1016/j.marpolbul.2015.07.037. Epub 2015 Jul 21. PMID: 26209128.

101. Krishna AK, Mohan KR. Distribution, correlation, ecological and health risk assessment of heavy metal contamination in surface soils around an industrial area, Hyderabad, India. Environ Earth Sci 2016; 75: 1-17.

102. Sun G, Chen Y, Bi X, Yang W, Chen X, Zhang B, Cui Y. Geochemical assessment of agricultural soil: a case study in Songnen-Plain (Northeastern China). Catena. 2013; 111: 56-63. http://dx.doi.org/10.1016/j.catena.2013.06.026.

103. Long ER, Field LJ, MacDonald DD. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environ Toxico Chem. 1998; 17: 714-727.

104. Wang YB, Liu CW, Liao PY, Lee JJ. Spatial pattern assessment of river water quality: implications of reducing the number of monitoring stations and chemical parameters. Environ Monit Assess. 2014 Mar;186(3):1781-92. doi: 10.1007/s10661-013-3492-9. Epub 2013 Nov 16. PMID: 24242081.

105. WHO. Guidelines for drinking water quality. World Health Organization, Geneva, Switzerland. 1993

106. WHO. Guidelines for Drinking Water Quality. 3rd Edn., World Health Organization, 2004; 515.

107. USEPA. National primary drinking water standards. United States Environmental Protection Agency. 2008.

108. DoE. Environment conservation rules, E. C. R schedule 3, standards for water. Department of Environment of Bangladesh. 1997.

109. Ahmed MJ, Nizamuddin M. Physicochemical assessment of textile effluents in Chittagong Region of Bangladesh and their possible effects on environment. Inter J Res Chem Environ. 2012; 2: 220-230.

110. Ahmed G, Uddin MK, Khan GM, Rahman MS, Chowdhury DA. Distribution of trace metal pollutants in surface water system connected to effluent disposal points of Dhaka Export Processing Zone (DEPZ), Bangladesh: a statistical approach. J Nat Sci Sustain Technol. 2009; 3:293-304.

111. Islam F, Rahman M, Khan SSA, Ahmed B, Bakar A, Halder M. Heavy metals in water, sediment and some fishes of Karnofuly River, Bangladesh. Pollut Res. 2013; 32:715-721.

112. Banu Z, Chowdhury MSA, Hossain MD, Nakagami K. Contamination and ecological risk assessment of heavy metal in the sediment of Turag River, Bangladesh: an index analysis approach. J Water Res Prot. 2013; 5:239-248.

113. Hassan M, Mirza ATM, Rahman T, Saha B, Kamal AKI. Status of heavy metals in water and sediment of the Meghna River, Bangladesh. Am J Environ Sci. 2015; 11:427-439.

114. Islam SMD, Bhuiyan MAH, Rume T, Mohinuzzaman M. Assessing heavy metal contamination in the bottom sediments of Shitalakhya River, Bangladesh; using pollution evaluation indices and geo-spatial analysis. Pollution. 2016; 2: 299-312.

115. Bhuyan MS, Bakar MA. Seasonal variation of heavy metals in water and sediments in the Halda River, Chittagong, Bangladesh. Environ Sci Pollut Res Int. 2017 Dec;24(35):27587-27600. doi: 10.1007/s11356-017-0204-y. Epub 2017 Oct 5. PMID: 28980109.

116. Datta DK, Subramanian V. Distribution and fraction of heavy metals

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080

in the surface sediments of the Ganges-Brahmaputra-Meghna River system in the Bengal Basin. Environ Geol. 1998; 36:93-101. DOI: 10.1007/s002540050324.

117. Balkis N, Aksu A, Okus E, Apak R. Heavy metal concentrations in water, suspended matter, and sediment from Gokova Bay, Turkey. Environ Monit Assess. 2010; 167:359-370.

118. Ergul HA, Topcuoglu S, Olmez E, Kırbaşoglu C. Heavy metals in sinking particles and bottom sediments from the eastern Turkish coast of the Black Sea. Estuar Coast Shelf Sci. 2008; 78:396-402.

119. Zhang Z, Juying L, Mamat Z. Sources identification and pollution evaluation of heavy metals in the surface sediments of Bortala River, Northwest China. Ecotoxicol Environ Saf. 2016; 126:94-101. http://dx.doi.org/10.1016/j.ecoenv.2015.12.025.

120. Malvandi H. Preliminary evaluation of heavy metal contamination in the Zarrin-Gol River sediments. Iran Mar Pollut Bullet. 2017; 117: 547-553.

121. Rahman MS, Saha N, Molla AH. Potential ecological risk assessment of heavy metal contamination in sediment and water body around Dhaka export processing zone, Bangladesh. Environ Earth Sci. 2014; 71:2293-2308.

122. Akbor MA, Rahmana MM, Bodrud-Doza M, Haque MM, Siddique MAB, Ahsan MA, Bondad SEC, Uddin MK. Metal pollution in water and sediment of the Buriganga River, Bangladesh: an ecological risk perspective. Desal Wat Treat. 2020; 193:284-301.

123. Islam MM, Akhtar MK, Masud MS. Prediction of environmental flow to improve the water quality in the river Buriganga. Proceedings of the 17th IASTED International Conference on Modelling and Simulation, Montreal, QC, Canada. 2006.

124. Chakravarty M, Patgiri AD. Metal Pollution Assessment in Sediments of the Dikrong River, N.E. India. J Human Ecol. 2017; 27(1):63-67. DOI: 10.1080/09709274.2009.11906193.

125. Rodríguez-Barroso MR, García-Morales JL, Coello Oviedo MD, Quiroga Alonso JM. An assessment of heavy metal contamination in surface sediment using statistical analysis. Environ Monit Assess. 2010 Apr;163(1-4):489-501. doi: 10.1007/s10661-009-0852-6. Epub 2009 Apr 25. PMID: 19396559.

126. Mohiuddin KM, Ogawa Y, Zakir HM, Otomo K, Shikazono N. Heavy metals contamination in the water and sediments of an urban river in a developing country. Int J Environ Sci Technol. 201; 8(4): 723-736.

127. Islam MS, Proshad R, Ahmed S. Ecological risk of heavy metals in sediment of an urban river in Bangladesh. Hum Ecol Risk Assess. 2018; 24:699-720.

128. Sivakumar S, Chandrasekaran A, Balaji G, Ravisankar R. Assessment of Heavy Metal Enrichment and the Degree of Contamination in Coastal Sediment from South East Coast of Tamilnadu, India. J Heavy Met Tox Dis. 2016; 1(2): 2473-6457.

129. Samlafo BV. Levels of Cadmium in Soil, Sediment and Water Samples from Tarkwa and Its Environs. Afri J Edu Stud Mathem Sci. 2006; 4.

130. Liu J, Yin P, Chen B, Gao F, Song H, Li M. Distribution and contamination assessment of heavy metals in surface sediments of the Luanhe River Estuary, northwest of the Bohai Sea. Mar Pollut Bull. 2016 Aug 15;109(1):633-639. doi: 10.1016/j.marpolbul.2016.05.020. Epub 2016 May 16. PMID: 27197763.

131. Rahman MS, Saha N, Molla AH. Potential ecological risk assessment of heavy metal contamination in sediment and water body around Dhaka export processing zone, Bangladesh. Env Ear Sci. 2013; 1866-6280.

132. Islam MS, Proshad R, Ahmed S. Ecological risk of heavy metals in sediment of an urban river in Bangladesh. Hum Ecol Risk Assess: An Inter J. 2017; 1080-7039 (Print) 1549-7860 (Online).

133. Li H, Kang X, Li X, Li Q, Song J, Jiao N, Zhang Y. Heavy metals in surface sediments along the Weihai coast, China: Distribution, sources and contamination assessment. Mar Pollut Bull. 2017 Feb 15;115(1-2):551-558. doi: 10.1016/j.marpolbul.2016.12.039. Epub 2016 Dec 20. PMID: 28007385.

134. Xia P, Meng X, Yin P, Cao Z, Wang X. Eighty-year sedimentary record of heavy metal inputs in the intertidal sediments from the Nanliu River estuary, Beibu Gulf of South China Sea. Environ Pollut. 2011 Jan;159(1):92-99. doi: 10.1016/j.envpol.2010.09.014. Epub 2010 Oct 18. PMID: 20961675.

135. Bilali LE, Rasmussen PE, Hall GEM, Fortin D. Role of sediment composition in trace metal distribution in lake sediments. Appl Geochem. 2002; 17:1171-1181.

136. Armah FA, Obiri S, Yawson DO, Onumah EE, Yengoh GT, Afrifa EK, Odoi JO. Anthropogenic sources and environmentally relevant concentrations of heavy metals in surface water of a mining district in Ghana: a multivariate statistical approach. J Environ Sci Health A Tox Hazard Subst Environ Eng. 2010 Nov;45(13):1804-13. doi: 10.1080/10934529.2010.513296. PMID: 20924925.

137. Hossain MB, Semme SA, Ahmed ASS, Hossain MK, Porag GS, Parvin A, Shanta TB, Senapathi V, Sekar S. Contamination levels and ecological risk of heavy metals in sediments from the tidal river Halda, Bangladesh. Arab J Geosci. 2021; 14:158.

138. Dou Y, Li J, Zhao J, Hu B, Yang S. Distribution, enrichment and source of heavy metals in surface sediments of the eastern Beibu Bay, South China Sea. Mar Pollut Bull. 2013 Feb 15;67(1-2):137-45. doi: 10.1016/j.marpolbul.2012.11.022. Epub 2012 Dec 11. PMID: 23245460.

139. Gu Y, Yang Y, Lin Q, Li Q, Wang Z, Wang X. Spatial, temporal, and speciation variations of heavy metals in sediments of Nan'ao Island, a representative mariculture base in Guangdong coast, China. J Environ Monit. 2012 Jul;14(7):1943-50. doi: 10.1039/c2em10970k. Epub 2012 Jun 7. PMID: 22673585.

140. USEPA. Environmental Protection Agency of Ground Water and Drinking Water Standards and Risk Management Division. Distribution System Indicators of Drinking Water Quality. Pennsylvania Ave., NW Washington DC. 2006.

Citation: Alam MA, Flura, Rahman MA, Ali A, Amin Chowdhury AI, et al. (2022) Ecological Risk of the River Halda: A Perspective from Heavy Metal Assessment Int J Aquac Fish Sci 8(3): 066-079. DOI: https://dx.doi.org/10.17352/2455-8400.000080