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Research Paper

Accumulation of Heavy Metals in Water and Sediments of Different Lakes of Matlab Uttar Upazila of Chandpur District, Bangladesh

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Abstract: Contamination of heavy metals in the aquatic environment has been considered a global crisis due to their indestructible, toxic, and persistent characters. To evaluate the level of contamination of different lakes of Matlab Uttar Upazila of Chandpur district in Bangladesh, this study was conducted estimating the concentration of worldwide alarming heavy metals (*i.e.* Pb, Cd, Cr, Cu, As, Zn, and Fe) in both surface water and sediments. The concentrations of the selected metals were determined by atomic absorption spectrometry (AAS). The obtained results indicated that metal concentrations were higher in sediment samples than in the lake water samples. In both cases, the concentration of Fe was maximum whereas Zn and Cd were found in the lowest amount in water and sediment samples, respectively. Almost all the selected metals in water were found lower than the maximum permitted concentrations of drinking water standards proposed by Bangladesh Standard, EC, WHO, and USEPA excepting Fe in all the lake water and Pb in Borokinachok lake water suggested that the examined lake water samples were not fully safe for daily activities, though these lake water can be used for irrigation purposes as they retain standards. In sediment samples analysis, the concentrations of studied heavy metals followed the order of Fe> Zn> Pb> Cu> Cr>As>Cd. Comparing with the sediment quality guidelines of USEPA, it was found that the collected sediments were not polluted for Zn and Cd whereas concentrations of some metals (As, Cr, Cu, and Pb) in different sediments indicated moderate to a high level of pollution. From the overall findings, it can be proposed that the selected lakes of Matlab Uttar Upazila of Chandpur district were contaminated and might pose an adverse effect on the ecology of the studied lakes.

Keywords: *Heavy metals, Water, Sediments, AAS, Contamination, Lake, Chandpur,*

Introduction

Pollution of the natural environment by heavy metals, a special group of contaminants of aquatic systems, is an issue of growing concern worldwide due to their indestructible and toxic nature, and bioaccumulation effects in aquatic habitats exceeding a certain concentration (Burchettt, 2000). Metals may readily contaminate an environment from a variety of sources; either natural processes or anthropogenic activities. Natural processes that pollute the environment include volcanic eruptions, erosion of soils and rocks, and a large number of human activities such as mining, untreated and partially treated industrial discharges containing toxic metals, municipal, domestic and agricultural wastewaters from fields treated with heavy metal-containing fertilizer and pesticides are major sources for introducing of these pollutants into the aquatic systems (Steinnes, 1990). Metals undergo a global ecological cycle in which natural water is the main pathway and during this movement, these hazardous heavy metals are dispersed both in the aqueous phase and in the sediments of the aquatic environment. In surface water, insoluble heavy metals may rapidly bind with the particulate matter followed by prompt association with other compounds forming complexes which subsequently be incorporated into the bottom sediments (Odiete, 1999). It is estimated that more than 90% of the total heavy metals in the aquatic environment exist in bound form to varying degrees with the suspended particulate matter and sediments (Varol & Şen, 2012). The strength of the bond determines the severity of the toxicity of metals to aquatic life where substances with very low solubility in water can

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be tightly bound and persist for a long time in the sediments (Mucha, Vasconcelos, & Bordalo, 2003). Only a minor percentage of free metal ions stay dissolved in water, however, a large proportion of them tends to adsorb from the water column through different processes including adsorption, hydrolysis, and co-precipitation, and finally deposited in the sediments (Gaur, Gupta, Pandey, Gopal, & Misra, 2005a). Owing to the higher tendency of heavy metals to accumulate in bottom deposits, the concentrations of these toxic elements are found extremely high in sediments than in the water column (Sultan & Shazili, 2009). Since metals are not removed by natural degradation processes due to their long biological half-life, their concentrations are increased in sediments over time. This is the major pathway, metals in aquatic systems become part of the water-sediment system. Metal-contaminated sediments can influence the concentrations of trace metals in both the water column and biota by releasing heavy metals back to the overlying water column. Sediment contamination thus poses one of the worst environmental problems in ecosystems, acting as a sink and source of metals for aquatic pollutants. Immobilization of metals in the sediments constitutes a potential hazard to water quality, aquatic flora, and fauna which in turn, may enter into the human food chain and result in health problems. Aquatic organisms acquire heavy metals in the body directly from the water via gills which poses a severe threat to fish and other aquatic biota (Collinson & Shimp, 1972). Toxic metals may alter many physiological processes and biochemical parameters either in blood or in tissues including structural deformations in aquatic animals (Al-Yousuf, El-Shahawi, & Al-Ghais, 2000). Once at the sediment, metals are more likely to transport and therefore, can be concentrated through food chains and produce a significant magnification of the original concentration at the end of the chain. As a result, the toxic effects of non-biodegradable heavy metals are produced at points after far removed from the source of pollution (Thomilson, Wilson, Harris, & Jeffrey, 1980). All aspects of animal and human system including circulatory and cardiovascular systems, detoxification pathways (colon, liver, kidneys, skin), endocrine (hormonal) system, energy production pathways, enzymatic, gastrointestinal, immune, nervous (central and peripheral), reproductive and urinary systems are affected due to exposure of increased levels of heavy metals (Ogunfowokan, Adenuga, Torto, & Okoh, 2008).

The surface water resource is an indispensable part of a country because of its use for drinking, bathing, fishing, irrigation, household, and livestock watering. Enrichment of metals destroys its water quality and hampers the aquatic flora and fauna living in this aquatic ecosystem. Sediments are the carrier of contaminants which may act as the potential secondary sources of contaminants in the aquatic system (Calmano, Ahlf, & Förstner, 1990). The presence of heavy metals in water and sediments provide significant information for environmental pollution status for the area of the aquatic ecosystem (Aremu, Atolaiye, Shagye, & Moumouni, 2007). Therefore, monitoring the concentration of metals in water and sediments is necessary to study the metal pollution in an area. A good number of studies for heavy metal analysis were performed in different lakes, ponds, and rivers of Bangladesh contaminated from industries, domestic wastes, and agrochemicals (Ali, Ali, Islam, & Rahman, 2016; Barmon, Islam, & Kabir, 2018; M. S. Islam, Ahmed, Habibullah-Al-Mamun, & Hoque, 2015; Kibria, Hossain, Mallick, Lau, & Wu, 2016; Mohuya, Bhuiyan, & Hoque, 2010; Mokaddes, Nahar, & Baten, 2012). To our knowledge, there has been no study reported on the pollution of heavy metals in different lakes in the Chandpur district, particularly Matlab Uttar Upazila, a rural area that is contaminated with domestic wastes and agrochemicals. Moreover, a previous study on Meghna River which flows through the selected district showed high level of contamination for some metals in water and sediment (Bhuyan et al., 2017). The threat of arsenic contamination is very high all over the country. About 40 million people are at risk due to arsenic whereas a study reported a huge number (9136) of deaths in every year in Bangladesh due to arsenic-related diseases (M. Alam, Snow, & Tanaka, 2003). Elements such as Cr, Fe, Cu, Zn, Cd, and Pb are also a great concern due to a variety of adverse health effects. Excess copper accumulation can cause hepatic cirrhosis, kidney damage, and hemolytic anemia (Tuzen, 2009); ingestion of acute zinc can cause vomiting, diarrhea, neurological damage; high intake of chromium is responsible for a variety of pulmonary adverse health effects; and overdosing of iron leads to cause diabetes, lung and heart disease (M. K. Hasan, Shahriar, & Jim, 2019). Lead has been associated with pathological changes in the central nervous system which results in hindrance of the cognitive development and intellectual performance in children. Cadmium toxicity leads to damage to the cardiovascular system, kidneys, and bones (Fang et al., 2014). The inhabitants of the selected Upazila of Chandpur district largely depend on the lake water for drinking, bathing, cooking, and many other household purposes, irrigation for agriculture and aquaculture. Hence, the present study was designed to assess the concentrations of different heavy metals including As, Pb, Cd, Zn, Cr, Cu, and Fe in surface water and sediments collected from a different number of lakes of Matlab Uttar Upazila in Chandpur district.

Materials and Methods

Sampling sites

Our study sites were in the Matlab Uttar Upazila of Chandpur district, which lies between the geographical location of 23°N to 23°30′N and 90°32′E to 91°2′E, about 65 km southeast of Dhaka, the capital of Bangladesh. The total area of the district is about 1704.06 square Km and the River Meghna flows through the district from north to south. The study area is rural, and agriculture is the principal economic activity. Surface water and sediment samples from five important lakes of the district were collected in August 2019. Figure 1 shows the sampling points of the present study.

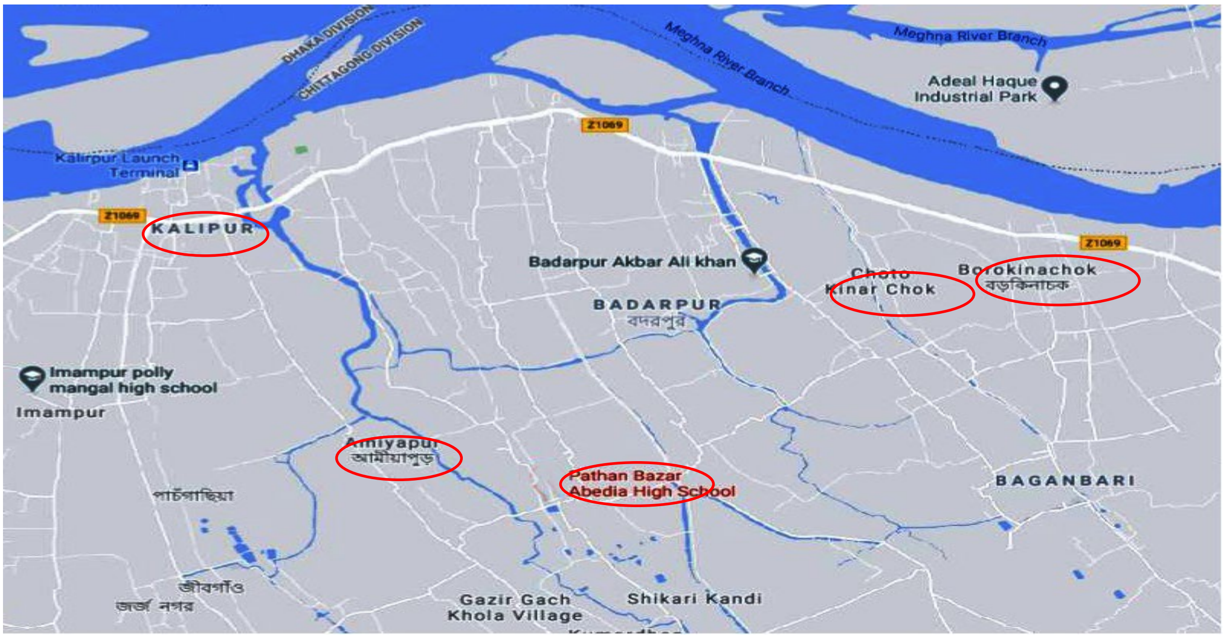

Figure 1. The map showing the location of different sampling sites of Matlab Uttar Upazila, Chandpur, Bangladesh.

Sample collection and preservation

Surface water and sediment samples from five different lakes of Matlab Uttar Upazila were collected. The five sampling sites with their Geographic Coordinate System (GCS) are presented in Table 1. From each lake area, four water and sediment samples were collected where representative samples (500 mL for water and 300–400 g wet weight for sediments) were added in plastic bottles for water and polyethylene bags were used for collecting the sediment samples. For avoiding any kind of contamination, samples were carefully handled and shipped to Agrochemical and Environmental Research Division, Institute of Food and Radiation Biology, Savar with rush delivery. Samples were properly labeled and preserved at -20ºC to avoid the risk of hydrolysis and oxidation.

Table 1. Geographic Coordinate System (GCS) for Sampling points of Matlab Uttar Upazila.

Lake	Sample type	Geographic Coordinate System (GCS)	
		Latitude	Longitude
Choto Kinar Chok	Water and sediment	23.482662	90.664252
Amiyapur	Water and sediment	23.468168	90.632609
Pathan Bazar	Water and sediment	23.4649869	90.64321969
Kalipur	Water and sediment	23.48834152	90.624196968
Borokinachok	Water and sediment	23.482190	90.673940

Sample preparation (Water and Sediment)
To measure the concentration of heavy metals (As, Pb, Cd, Zn, Cr, Cu, and Fe) in water samples, 100 ml water samples were filtered using Whatman No. 1 filter paper followed by acidification with high-purity concentrated nitric acid (E. Merck, Germany) to make the pH of <2 that prevent the precipitation of metals and finally kept at 4ºC in the dark until analysis.
Sediment samples were dried at room temperature and ground into a fine powder using pestle and mortar. For metal analysis, about 2.0 g of dried sediment taken in porcelain crucible was treated with 15 mL of concentrated HNO_3 (E. Merck, Germany). Then the mixture was evaporated and pre-concentrated at a temperature of 130ºC on a hotplate. After cooling, the digested materials were passed through Whatman no. 1 filter paper. It was then transferred quantitatively to a 50 ml volumetric flask by adding distilled water (Ali, *et al.*, 2016). Analytical grade chemicals and reagents were used throughout the study. Blank digestion was also performed to quantify possible contamination during sample preparation and analysis. A blank solution was also treated as samples by the wet digestion procedure and then diluted with 50 ml distilled water.
Standard preparation
The metal standard solution of different concentrations for each element being determined was prepared for calibration of the instrument. Reference standard heavy metals arsenic, cadmium, copper, lead, chromium, iron, and zinc were obtained from inorganic ventures, USA. Then 50 ml of 0.1, 0.2, 0.5, 1.0, and 2.0 mg/l of working standards of each metal (Cu, Pb, Cd, Zn, Cr, Fe) was prepared from their stocks (1000 ppm). 10 ml of 1.0, 5.0, 10.0, and 20.0 µg/l of working standards of arsenic was prepared from arsenic stock solution (1000 ppm). A reagent blank was also prepared to avoid reagent contamination. All standards were prepared by the chemicals of analytical grade with distilled water.
Analysis of metals
Both flame and graphite furnace atomic absorption spectroscopy (AAS) (Model: AA-7000, Shimadzu Corporation, Japan) were used in this study. A deuterium-arc lamp was used for background correction. An aliquot of the digested sample was injected into the air acetylene flame for Pb, Cd, Zn, Cr, Cu, and Fe and graphite furnace containing a pyrolytic coating graphite tube atomizer for As using a Shimadzu autosampler ASC-7000. The instrument setting and operational conditions were followed according to the manufacturers' specifications. The operating conditions for AAS are summarized in Table 2. A blank reading was taken to allow background correction and necessary corrections were made during the calculation of the concentration of various elements. They were analyzed by AAS before the samples and their values were subtracted to ensure that the equipment read only the exact values of heavy metals.

Table 2:The operating conditions of AAS used for metal analysis.

Elements	Wavelength	Lamp current	Slit width	Correlation coefficient (r)	Gas flow	BGC Mode
As	193.7 nm	12 mA	0.7 nm	0.9987	1 L/min	BGC-D2
Cd	228.8 nm	8 mA	0.7 nm	0.9997	1.8 L/min	BGC-D2
Cr	357.9 nm	10 mA	0.7 nm	0.9998	2.8 L/min	BGC-D2
Pb	283.3 nm	10 mA	0.7 nm	0.9995	2 L/min	BGC-D2
Cu	324.8 nm	6 mA	0.7 nm	0.9997	1.8 L/min	BGC-D2
Fe	248.3 nm	12 mA	0.2 nm	0.9997	2.2 L/min	BGC-D2
Zn	213.9 nm	8 mA	0.7 nm	0.9977	2 L/min	BGC-D2

Statistical analysis
Data for different toxic metals of water and sediments from lakes were analyzed statistically using Microsoft Excel 2016 software. Data were expressed as mean±Standard Deviation (SD).

Results and Discussion
Metal concentration in water
The investigated heavy metals in water samples collected from five different lakes of Matlab Uttar Upazila of Chandpur include arsenic (As), iron (Fe), copper (Cu), lead (Pb), chromium (Cr), cadmium (Cd), and zinc (Zn). The concentrations of the selected metals obtained from the current

study and other studies around the world are summarized in Table 3 and Table 4 respectively. The results for heavy metals concentration from the selected water samples were compared with drinking water quality standards for both Bangladesh and different international regulatory authorities. The data was also evaluated for water irrigation standards of the World Health Organization (WHO) (Table 3). The mean concentration (mg/L) of studied metals in different lake water samples followed the decreasing order of Fe>Cu>Pb>Cr>As>Cd>Zn. Among all the metals examined in different lake water samples, Fe was detected in the highest amount with an average of 1.146 mg/L. The Zn concentration in all the collected water samples was found below the detection limit (BDL) whereas a significant amount of Zn was identified in many prior studies (Balkis, Aksu, Okuş, & Apak, 2010; Bhuyan, et al., 2017; S. J. Hasan, Tanu, Haidar, Ahmed, & Rubel, 2015; Karbassi, Monavari, Bidhendi, Nouri, & Nematpour, 2008; Lawson, 2011; Nazir et al., 2015). The range of Fe detected in lake water samples was 0.205±0.028 mg/L to 2.19±1.34 mg/L. The highest concentration of Fe was obtained in Pathan Bazar lake water with a mean and standard deviation of 2.19 and 1.34 mg/L, respectively. The average Fe concentration in Shur River and Bhavan's College Lake of Andheri city of Mumbai of India and the highest level of Fe in Meghna River water was found 10.98 mg/L, 5.19 mg/Land 3.68 mg/L respectively which were much higher than the maximum Fe level detected in the lake water sample of Matlab Uttar Upazila (Bhuyan, et al., 2017; Karbassi, et al., 2008; Singare, Talpade, Dagli, & Bhawe, 2013).

Table 3. Heavy metal concentration in lake water samples of Matlab Uttar Upazila, Chandpur and maximum permitted concentrations (mg/L) for drinking water quality and irrigation standards.

Location	As (mg/L)	Cd (mg/L)	Cr (mg/L)	Pb (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)
Choto Kinar Chok	0.0061± 0.0003	BDL	BDL	BDL	BDL	0.205± 0.028	BDL
Amiyapur	0.0080± 0.0003	BDL	BDL	BDL	0.00268± 0.005	0.968± 0.213	BDL
Pathan Bazar	0.0077± 0.00099	BDL	BDL	BDL	0.04508± 0.034	2.19± 1.34	BDL
Kalipur	0.0119± 0.0012	BDL	BDL	BDL	0.13545± 0.048	2.006± 0.277	BDL
Borokinachok	0.00548± 0.0025	0.0022± 0.0002	0.035± 0.014	0.115± 0.014	BDL	0.358± 0.419	BDL
Water quality guidelines							
Bangladesh Standard (DOE, 2002) (Ixtaina et al., 2010)	0.05	0.005	0.05	0.05	1	0.3	5
EC (1998) (Soto, Chamy, & Zuniga, 2007)	0.01	0.005	0.05	0.01	2	0.2	0.1
WHO (2004) (Oyen & Dung, 1999)	0.01	0.003	0.05	0.01	2	-	-
USEPA (2009) (Cos, Vlietinck, Berghe, & Maes, 2006)	0.01	0.005	0.1	0.015	1.3	0.3	5
Irrigation standards							
WHO (2006) (Duraipandiyan, Ayyanar, & Ignacimuthu, 2006)	0.1	0.01	0.1	5	0.2	5	2

BDL means Below the Detection Limit.

The main contributors of elevated level of Fe in the selected lakes may be natural geological sources, washing of cattle's, utensils, improper disposal of domestic and animal wastes. The permitted Fe concentration for drinking water in Bangladesh is 0.3 mg/L established by the Department of Environment (DOE), Bangladesh (2002). Most of the water samples (except Choto Kinar Chok) contained a high level of Fe than the national standard values (**Table 3**). Two international regulatory authorities, European Commission (EC) (1998) and the United States Environmental Protection

Agency (USEPA) (2009) had recommended 0.2 mg/L and 0.3 mg/L as standard Fe levels for drinking water. It was apparent from our present work that Fe concentration in all the sampled locations (Amiyapur, Pathan Bazar, Borokinachok, and Kalipur lakes) without Choto Kinar Chok area was higher than the suggested values provided by EC (1998) and USEPA (2009). Contamination of drinking water with a high level of Fe may pose threat to human health. The lowest amount of iron was noted in the Choto Kinar Chok lake area and the lake water was safe for drinking, fishing, and other household activities according to the standard set by USEPA (2009), though it could be remarked as contaminated if the result is compared with the limit set by EC (1998). A similar amount of Fe (0.299 mg/L) was identified in the Hazigonj Bazar Bridge site of the Dakatia River of Chandpur (Hasan, *et al.*, 2015).

Table 4. Heavy metal concentrations (mg/L) in water taken from other studies.

Location	Cr	Cu	As	Cd	Pb	Zn	Fe	Ref.
Korotoa River	-	-	0.041	0.010	0.031	-	-	(MS. Islam, A., Raknuzzaman, et al., 2015)
Dhalai Beel and Bangshi River	0.093	1.053	0.024	0.007	0.108	3.318	-	(M. S. Rahman, et al., 2014)
Ship breaking sites, Sitakunda	0.511	0.267	-	BDL	0.477	0.320	-	(Aktaruzzaman, et al., 2014)
Karnaphuli River, Bangladesh	0.046-0.112	-	0.013-0.053	0.025-0.018	0.005-0.027	-	-	(Ali, et al., 2016)
Meghna River, Bangladesh	0.02	0.027	-	0.018	0.01	0.04	0.18-3.68	(Bhuyan, et al., 2017)
Buriganga River, Bangladesh	0.587	0.163	-	0.0093	0.065	-	-	(Ahmad, et al., 2010)
River Ganges, India	0.00-0.018	0.00-0.03	-	0.00-0.012	0.018-0.086	0.026-0.122	-	(Gupta, et al., 2009)
Hindon River, India	0.031-0.330	BDL-4.37	-	0.0024-0.024	0.030-0.902	0.005-0.837	BDL-1.247	(Suthar, Nema, Chabukdhara, & Gupta, 2009)
Shur River, India	-	0.771	-	0.026	0.116	0.688	10.98	(Karbassi, et al., 2008)
Khoshk River, Iran	0.19	0.03	-	0.03	0.07	1.7	-	(Salati & Moore, 2010)
Tigris River, Turkey	<0.005	0.165	0.0024	0.0014	0.00342	0.037	0.388	(Varol & Şen, 2012)
Okumeshi River, Nigeria	0.09	-	-	0.03	0.01	-	-	(Ekeanyanwu, et al., 2010)

Three different heavy metals Pb, Cr, and Cd were not detected in any lake water samples of the studied areas except for the Borokinachok area. The concentration was 0.115±0.014 mg/L, 0.035±0.014 mg/L and 0.0022±0.0002 mg/L for the metals Pb, Cr, and Cd respectively. Lake water from Borokinachok showed the Cr concentration of 0.035±0.014 mg/L which was lower than the standard value (0.05 mg/L) provided by the Bangladesh Standard (DOE, 2002), EC (1998) and WHO (2004) as well the maximum permitted value 0.1 mg/L for Cr in drinking water quality guidelines of USEPA (2009). The Cr concentration in Meghna River (flows through the Chandpur district) water was recorded 0.02 mg/L which is slightly lower while Korotoa River, Karnaphuli River, Buriganga River, and Khoshk River had a high level of Cr than the present work documented (Ahmad, Islam, Rahman, Haque, & Islam, 2010; Ali, et al., 2016; Bhuyan, et al., 2017; M. S. Islam, Ahmed, Raknuzzaman, Habibullah-Al-Mamun, & Islam, 2015; Salati & Moore, 2010). Chromium was not detected in Dhanmandi and Gulshan lake water (S. L. Rahman, 2020). The permissible Cd value of drinking water standard was set 0.005 mg/L and 0.003 mg/L by EC (1998) and USEPA (2009) respectively. Cd was found within the above acceptable limit whereas Pb level was found about eight times higher than the standard concentration of 0.015 mg/L set by USEPA (2009) and more than eleven times higher than 0.01 mg/L recommended by the international authorities EC (1998) and WHO (2004) for drinking water quality. The maximum permitted concentration of lead is 0.05 mg/L set by Bangladesh Standard (DOE, 2002) which is lower than the detected Pb level in Borokinachok. This indicated that the lake water is not consumable for safe and sound health. The probable source of high level of Pb in the lake is agricultural activities in the Borokinachok region. Indiscriminate and reckless application of heavy metal-containing fertilizers and pesticides in the farming area can accelerate the rate at which these heavy metals are added to the water bodies (Ntakirutimana, Du, Guo, Gao, & Huang, 2013). Water from the Gulshan and Dhanmondi lake also contained high level of Pb (S. L. Rahman, 2020).

Both Pb and Cd levels were also found below the detection limit in Nallihan Bird Paradise, Turkey (Ayas, Ekmekci, Yerli, & Ozmen, 2007). Cd was not detected in previous many other studies completed on water samples from Buriganga River, Gomti River, Kushtia industrial zone, and ship breaking site of Sitakunda (Aktaruzzaman et al., 2014; A. S. ALAM, ISLAM, & RAHMAN, 2003; Gaur, Gupta, Pandey, Gopal, & Misra, 2005b; R. Islam, Al Foisal, Rahman, Lisa, & Paul, 2016). The Cd concentration in a water sample collected from Hazigonj Bazar Bridge site of Dakatia River of Chandpur was reported 0.0022 mg/L which is similar to our present Cd level in the detected area of Matlab Uttar Upazila (S. J. Hasan, et al., 2015), though the value was found lower than the Meghna River, Korotoa River and Okumeshi River water (Bhuyan, et al., 2017; Ekeanyanwu, Ogbuinyi, & Etienajirhevwe, 2010; M. S. Islam, Ahmed, Raknuzzaman, et al., 2015). Tigris River of Turkey contained a lower level of Cd (0.0014 mg/L) than Borokinachok lake water (Varol & Şen, 2012). Among five studied lake areas, most of the lake water samples did not show any Pb content like mangrove swamps of Lagos Lagoon in Nigeria and Hazigonj Bazar Bridge area of Dakatia River (Lawson, 2011). Shur River of India was identified with the heavy metal Pb at a concentration of 0.116 mg/L which is the same for documented Pb amount in Borokinachok lake water and the level was found lower than ship breaking site of Sitakunda and Kushtia industrial zone in Bangladesh (Aktaruzzaman, et al., 2014; R. Islam, et al., 2016), though the value was noted higher than River Ganges of India, Bangshi River, and Puranbazar and Eachali site of Dakatia River (Gupta, Rai, Pandey, & Sharma, 2009; S. J. Hasan, et al., 2015; M. S. Rahman, Saha, & Molla, 2014).

All the studied lake water samples from Matlab Uttar Upazila of Chandpur district showed the presence of As with the range between 0.00548±0.0025 mg/L and 0.0119±0.0012 mg/L. The As level was found in the following order: Kalipur>Amiyapur> Pathan Bazar>Choto Kinar Chalk>Borokinachok. The variations of the concentration are mainly due to different collection spots. The Kalipur lake water samples were detected with a high level of As (0.0119±0.0012 mg/L) which exceeded the international drinking water quality guidelines (0.01 mg/L) whereas the level was within Bangladesh standards (Bangladesh Standard (DOE, 2002)) 0.05 mg/L. Both Korotoa and Bangshi Rivers of Bangladesh had a high level of As at 0.041 mg/L and 0.024 mg/L respectively (M. S. Islam, Ahmed, Raknuzzaman, et al., 2015; M. S. Rahman, et al., 2014). Though the four remaining lakes were identified with As content, no water samples crossed the safe limit.

The Cu was not detected in any water samples of Choto Kinar Chok and Borokinachok lake areas. In Amiyapur, Pathan Bazar, and Kalipur lakes the concentration was recorded 0.00268±0.005 mg/L, 0.04508±0.034 mg/L, and 0.13545±0.048 mg/L respectively. The maximum permitted concentration of Cu in drinking water is 2.0 mg/L, set by EC (1998), WHO (2004), and 1.3 mg/L recommended by USEPA (2009). 1.0 mg/L is the safe limit provided by Bangladesh Standard (DOE, 2002). All the samples from the three mentioned studied areas were far below the limit provided by both national and international regulatory bodies. The examined data, therefore, indicated that the five lakes of Matlab Uttar Upazila were not contaminated with Cu. The Cu metal content from this current investigation was compared with recent past findings. Water samples collected from Tanda Dam Kohat were also found safe (Nazir, et al., 2015). The detected levels of Cu in the present study were found lower than the previous studies reported (Ahmad, et al., 2010; R. Islam, et al., 2016). The maximum level of Cu obtained in Kalipur lake water had a lower value recorded by (Singh, Malik, Sinha, Singh, & Murthy, 2005) whereas Eachali site of the Dakatia River had a higher level of Cu (0.067±0.114 mg/L) than the present studied areas Amiyapur and Pathan Bazar (S. J. Hasan, et al., 2015).

Matlab Uttar Upazila of Chandpur district is a rural area and the main occupation of the local people is agriculture. Irrigated agriculture is largely dependent on an adequate water supply of usable quality. The demand for an enormous amount of water requirements in agricultural fields for irrigation is met from the natural lake water resource of Chandpur. The quality of the lake water must be tested before applying to agricultural field areas as it may contain a huge amount of unnecessary and unwanted harmful substances dissolved in the water which subsequently may decrease crop production and show a significant negative role on the quality of the soil. These undesirable elements such as metals may be originated from natural or man-made sources and their severity depends upon the type of substance and its quantity which resulted in deteriorated water quality (Arshad & Shakoor, 2017). The metal concentrations in examined water samples were also compared with irrigation water quality standards of WHO (2006) (Table 3). All the heavy metals investigated in the present study were within the acceptable limit for irrigation water standards of WHO (2006) (**Table 3**). Hence, based on metal contents, the water from the selected lakes can be recommended as suitable for irrigation purposes.

Findings from this study have clearly shown that the concentration of the studied metals Cd, Cr, Cu, and Zn for the examined lake water samples of Matlab Uttar Upazila were below the admissible limit of drinking standards set by both national and international regulatory authorities. On the other hand, Fe content has exceeded the maximum permitted level in studied lake water samples resulted in water contamination. Water from the Borokinachok lake area showed a high level of Pb that exceeded the safe limit. From the above observations, it can be suggested that the water collected from five different lakes of Matlab Uttar Upazila of Chandpur district was not safe for drinking, cooking, or any other household activities in terms of its Fe content, but may be proposed for agricultural use.

Metal concentration in Sediments

The concentration of heavy metals investigated in the sediment samples of five different lakes of Matlab Uttar Upazila of Chandpur district in Bangladesh are displayed in Figure 2. The contaminations in the sediments were also evaluated by comparison with the USEPA sediment quality guidelines **(Table 6)**. The concentration was determined on a dry weight basis and expressed as mg/kg. The obtained metal contents were ranging over following intervals: Pb: 10.36±4.77-61.21±45.01 mg/kg; Cd: 0.0-1.079±0.68 mg/kg; Cr: 14.57±3.73-25.21±7.16 mg/kg; Cu: 14.99±12.41-29.65±11.70 mg/kg; Zn: 38.33±7.03-88.41±12.31 mg/kg, Fe: 1202.85±18.92-1396.63±33.47 mg/kg dry weight. The relative order of the studied heavy metals in sediments was Fe> Zn> Pb> Cu> Cr>Cd. The data indicated that among all the metals studied in lake sediment samples, Fe was maximally accumulated in the sediments whereas Cd was least concentrated which is nearly relatable with the metal contents detected in ship breaking yards in Bangladesh, Coastline of Erongo Region of Western Namibia, and Tigris River of Turkey (Aktaruzzaman, et al., 2014; Onjefu, Kgabi, & Taole, 2016; Varol & Şen, 2012). The Cd concentration was not detected in any sediment samples collected from Pathan Bazar lake and the four other lakes showed its presence with a range of 0.0008±0.0016 to 1.079±0.68 mg/kg. The highest level of Cd was found in the Borokinachok lake sediment followed by Choto Kinar Chok, Amiyapur, and Kalipur. As per USEPA sediment quality guidelines, Cd in the Matlab Uttar Upazila belongs to the not polluted category which is similar to the previously reported results in Turag River, Meghna River, Paira River, Bongshi River, and Dakatia River **(Table 5)** (Banu, Chowdhury, Hossain, & Nakagami, 2013; Bhuyan, et al., 2017; S. J. Hasan, et al., 2015; M. S. Rahman, et al., 2014). The results obtained from the study showed that the Fe was recorded in the highest amount in all the investigated lake sediments of Chandpur district. The detected Fe concentration was ranged from 1202.85±18.92 to 1396.63±33.47 mg/kg and the analysis of the data followed a decreasing order of Amiyapur>Kalipur> Pathan Bazar>Choto Kinar Chok>Borokinachok. The maximum mean±SD value was recorded 1396.63±33.47 mg/kg in the Borokinachok lake area that is lower than the value obtained in Passur River, Dakatia River, and Gokova Bay (Balkis, et al., 2010; S. J. Hasan, et al., 2015; M. T. Rahman et al., 2011).

Table 5: Heavy metal levels (mg/kg) in sediments observed in other studies.

Location	Cr	Cu	As	Cd	Pb	Zn	Fe	Ref
Bangladesh								
Korotoa River	109	76	25	1.2	58	-	-	(MS. Islam, Ahmed, Raknuzzaman, et al., 2015)
Passur River	2.80-31.90	11.48-29.25	-	0.80-2.70	5.33-18.42	26.25-71.93	16500-31900	(MT. Rahman, et al., 2011)

Ship breaking sites, Sitakunda	106.806	50.0932	BDL	-	55.936	70.715	-	(Aktaruzzaman, et al., 2014)
Turag River	43.02	50.40	-	0.28	32.78	139.48	-	(Banu, et al., 2013)
Buriganga River	177.53	27.85	-	3.3	69.75	-	-	(Ahmad, et al., 2010)
Buriganga River	101.2	184.4	-	0.8	79.8	502.3	-	(Saha & Hossain, 2011)
Bangshi River	98.10	31.01	1.93	0.61	59.99	117.15	-	(M. S. Rahman, et al., 2014)
Karnaphuli River	20.3	-	81.09	2.01	43.69	-	-	(Ali, et al., 2016)
Paira River	45	30	12	0.72	25	-	-	(MS. Islam, A. Habibullah-Al-Mamun, et al., 2015)
Other countries								
River Ganges, India	1.8-6.4	0.98-4.4	-	0.14-1.4	4.3–8.4	10.48-20.40	-	(Gupta, et al., 2009)
Gomti River, India	8.15	5	-	2.42	40.33	41.67	-	(Singh, et al., 2005)
Hindon River, India	42.9-250.4	9.42-195.1	-	1.15-3.47	5.07-59.1	3.98-85.0	221.2-237.9	(Suthar, et al., 2009)
Tigris River, Turkey	158.35	2860.25	12.44	7.90	660.112	1061.54	-	(Varol & Şen, 2012)
Yeşilırmak River, Turkey	–	38.7	–	0.55	17.3	45.5	3566	(Mendil, et al., 2010)
River Po, Italy	–	90.1	–	3.7	98.5	645	-	(Farkas, et al., 2007)
Yilong Lake, China	86.73	31.40	15.46	0.76	53.19	86.82	-	(Bai et al., 2011)
Baihua Lake, China		74.97	53.34	0.88	16.04	283.58	-	(Huang et al., 2009)
Yellow River, China	41.49-128.30	29.72-102.22	13.68-48.11	NA	26.39-77.66	89.80-201.88	-	(Liu, et al., 2009)
Okumeshi River, Nigeria	0.87	-	-	1.32	0.45	-	-	(Ekeanyanwu, et al., 2010)
Cheliff River, Algeria	1.68	102	-	-	122	288	-	(Abdelmalek, Ouddane, & Addou, 2006)
Khoshk River, Iran	181.87	42.25	-	1.23	121.01	64.81	-	(Salati & Moore, 2010)
Shur River, Iran	-	9174	-	6.85	162	522	-	(Karbassi, et al., 2008)

The Zn concentration varied between 38.33±7.03 mg/kg and 88.41±12.31 mg/kg where the Amiyapur lake showed the highest value. The Zn concentrations of the present study were compared to other studies conducted in Bangladesh and other countries. The Zn concentration was far below the maximum amount detected in the Tigris River of Turkey, Axios River, River Po, Yangtze River, Danube River, and Almendares River (Farkas, Erratico, & Vigano, 2007; Karageorgis, Nikolaidis, Karamanos, & Skoulikidis, 2003; Olivares-Rieumont et al., 2005; Varol & Şen, 2012; Woitke et al., 2003; Yang, Wang, Shen, Niu, & Tang, 2009). The EPA heavy metal guideline for sediments defines these levels as not polluted for Zn. The Dakatia River, Ship breaking yards in Bangladesh, and the theYeşilırmak River in Tokat of Turkeywere also found unpolluted for Zn (Aktaruzzaman, et al., 2014; S. J. Hasan, et al., 2015; Mendil, Ünal, Tüzen, & Soylak, 2010) whereas the Turag River was moderate to highly polluted at different sites for the selected metal content (Banu, et al., 2013).The studied lake sediments were detected with Cr (14.57±3.73-25.21±7.16 mg/kg) where the tested sediments from the Kalipur site contained a much higher level of Cr than other sites and the concentration was found in the moderate pollution range (25-75 mg/kg) when compared with USEPA sediment standards. All the detected values in five selected lakes were far below the concentration of the tested sediments reported in various studies (Ahmad, et al., 2010; Datta & Subramanian, 1998; M. S. Islam, Ahmed, Raknuzzaman, et al., 2015; M. S. Rahman, et al., 2014).

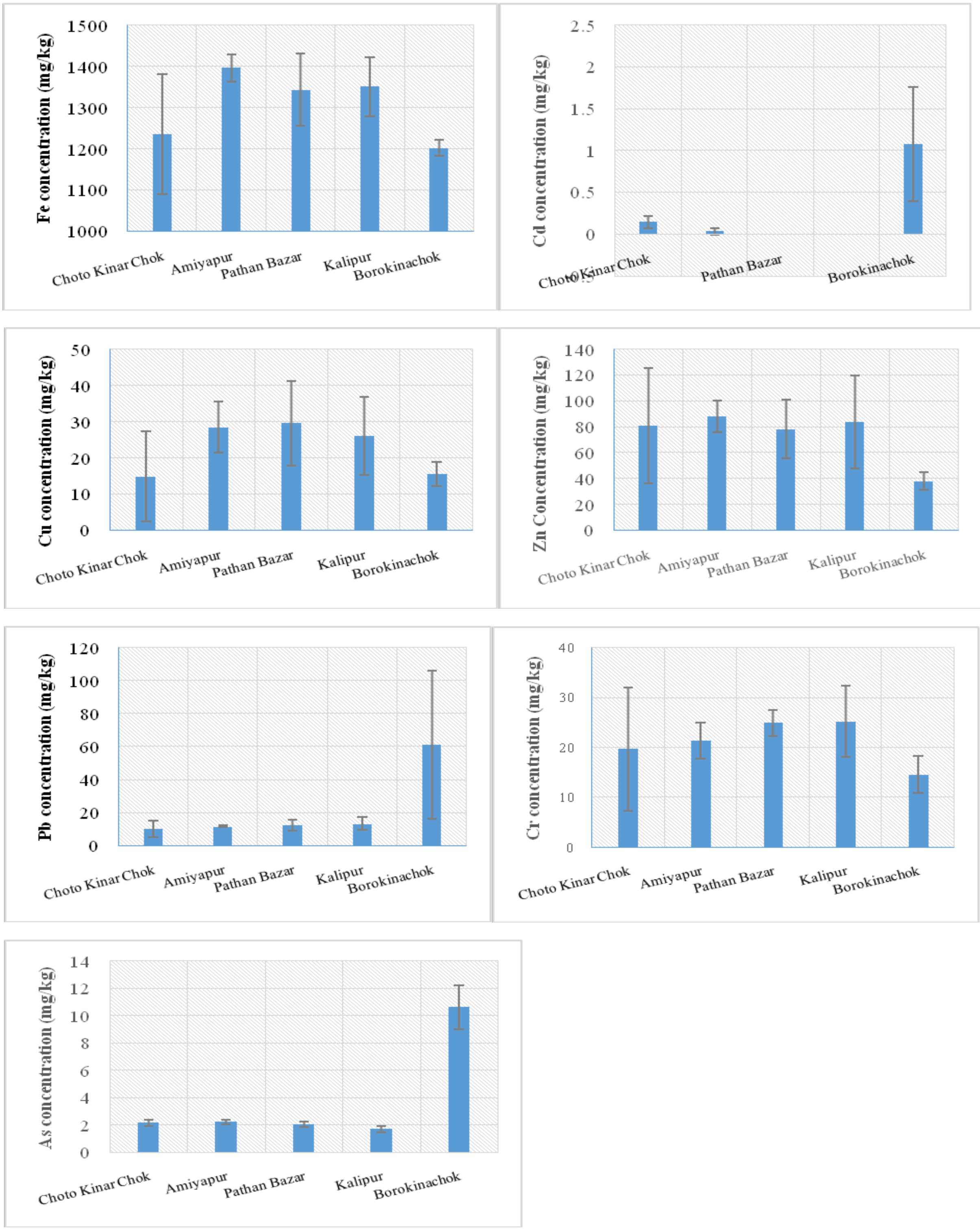

Figure 2. Metal concentration(±SD) in sediments of different lakes of Matlab Uttar Upazila.

Table 6. Comparisons of heavy metal concentrations(mg/kg) with USEPA guidelines for sediments.

Metal	Not polluted	Moderately polluted	Heavily polluted
Pb	<40	40-60	>60
Cr	<25	25-75	>75
Cd	NA	NA	>6
Cu	<25	25-50	>50
Zn	<90	90-200	>200
As	<3	3-8	>8
Fe	NA	NA	NA

NA- Not Available

The Cu concentration for five lake sediments was ranged from 14.99±12.41 to 29.65±11.70 mg/kg dry weight. The lowest concentration was detected in Choto Kinar Chok lake and the Pathanpur lake showed a high level of Cu which was much lower than the maximum amount observed in Paira River (65 mg/kg), Yellow River (102 mg/kg), and Axios River (93 mg/kg) (M. S. Islam, Ahmed, Habibullah-Al-Mamun, et al., 2015; Karageorgis, et al., 2003; Liu, Xu, Liu, Zhang, & Dai, 2009). River Ganges and Gomti of India were identified with very low Cu concentration than the present investigation done on Matlab Uttar Upazila of Chandpur (Gupta, et al., 2009; Singh, et al., 2005). According to USEPA guidelines for Cu in sediments, the range of 25-50 mg/kg dry weight indicates moderate pollution and from the analyzed data of Amiyapur (28.54±7.09 mg/kg), Pathan Bazar (29.65±11.70 mg/kg), Kalipur lake area (26.10±10.69 mg/kg), it can be said that these sites are grouped into moderate pollution area. All the sampling sites of the Turag River and ship breaking yards in Bangladesh were also found moderately to heavily polluted for Cu (Aktaruzzaman, et al., 2014; Banu, et al., 2013). A study on sediment samples collected from the Buriganga River showed a high level of Cu which was found above the USEPA guidelines for heavily polluted sediments (Saha & Hossain, 2011).

The range of Pb concentration(±SD) in different lakes in the present study was 10.36±4.77 to 61.21±45.01 mg/kg which were quite similar to the range (9.1-58 mg/kg) detected in the Paira River of Bangladesh (M. S. Islam, Ahmed, Habibullah-Al-Mamun, et al., 2015). The detected Pb level followed the order of Borokinachok>Kalipur>Pathan Bazar>Amiyapur>Choto Kinar Chok. The mean concentration of the heavy metal Pb at the Borokinachok lake area was quite higher than other studied lake sediments and this maximum value showed a similar amount in Pasvik River and Wachpur Ghat of Buriganga River (Dauvalter & Rognerud, 2001; Saha & Hossain, 2011). Domestic wastes, agricultural runoff and atmospheric deposition may be the major sources of the observed high levels of Pb. The Pb level was found about six times lower in Choto Kinar Chok lake sediment than Borokinachok lake sediment. The lowest Pb concentration obtained in this investigation was far below the results reported in (Datta & Subramanian, 1998; Liu, et al., 2009; M. S. Rahman, et al., 2014; Singh, et al., 2005) and higher than the studies (Ekeanyanwu, et al., 2010; Gupta, et al., 2009; S. J. Hasan, et al., 2015). No lakes for this current study were polluted comparing the data with USEPA guidelines with an exception of Borokinachok lake which was highly polluted. The As was found in all the sediment samples of Choto Kinar Chok, Amiyapur, Pathan Bazar, Kalipur, and Borokinachok lake areas in a concentration of 2.17±0.24 mg/kg, 2.23±0.18 mg/kg, 2.046±0.19 mg/kg, 1.68±0.24 mg/kg and 10.62±1.59 mg/kg respectively. Higher than 8 mg/kg concentration of As directs highly polluted category whereas the concentration falls into not polluted if does not exceed 3.0 mg/kg proposed by USEPA. Comparing the data with the present study for As, only Borokinachok lake sediment was found in the highly polluted zone. Some researchers have reported that the elevated As level in the area might be attributed to naturally or the anthropogenic sources such as excessive use of a variety of mineral fertilizers and arsenical pesticides on agricultural land (Fu et al., 2014; Renner, 2004). However, all the sediment samples showed As concentration, far below than the previous studiesreported by different authors on sediments (Varol & Şen, 2012; Woitke, et al., 2003; Yang, et al., 2009).

Overall findings on sediment samples analysis demonstrate that Cd and Zn in all studied sediments of Matlab Uttar Upazila of Chandpur district belong to unpolluted. Amiyapur, Pathan Bazar, Kalipur were found in the moderately polluted category for Cu. Kalipur was also moderately polluted for Cr. The Pb and As the level of Borokinachok were fall within the highly polluted section. In Choto Kinar Chok lake, all the examined metals in collected sediments were recorded below the limit compared to USEPA guidelines.

Heavy metal contaminated sediments demonstrate a large impact on aquatic ecosystems. To predict the adverse biological effects caused by polluted sediments, sediment quality guidelines (SQGs) were established that can expose sediment contamination by comparing the metal concentrations in sediments with the standard quality guidelines. To evaluate the contamination level and ecological risk using SQGs, the heavy metal concentrations of the current investigation were compared with MacDonald *et al*. (2000) derived threshold effect level (TEL) which denotes the concentration below which adverse biological effects are unlikely to occur, probable effect level (PEL) representing the concentration above which adverse effects are expected to occur more often and severe effect level (SEL) that shows chronic, long-term effects of contamination to benthic organisms (**Table 7**) (MacDonald, Ingersoll, & Berger, 2000). Sediment contamination concentrations below the TEL are considered acceptable whereas concentrations above the PEL are unacceptable. If the concentration obtained from sediments was found between the PEL and SEL, it is supposed to moderate pollution resulting from a moderate ecological risk. If the concentration exceeds the SEL, it was categorized into severe pollution with high ecological risk (Wu, Li, Wang, & Zheng, 2012). In our present study, the concentration of As, Pb, and Cd in Borokinachok lake sediments samples were observed higher than the TEL limit, though the value was within the PEL when compared with SQGs, indicating moderate pollution and posing a moderate ecological risk. Other than those mentioned metals in the selected lake, all four investigated lakes in Matlab Uttar Upazila displayed a lower level of metal contents than TEL value.

Table 7. Guidelines for metals contamination in sediment (MacDonald, et al., 2000)**.**

Metals	Pb	Cd	Cr	Zn	As	Cu
TEL (Threshold effectlevel)	35	0.596	37.3	123	5.9	35.7
PEL (Probable effectlevel)	91.3	3.53	90	315	17	197
SEL (Severe effect level)	250	10	110	820	33	110

Conclusion

The metal concentration observed in water samples of five different lakes of Matlab Uttar Upazila of Chandpur district, Bangladesh was in good agreement with the toxicity reference values proposed by Bangladesh Standard (DOE, 2002), EC (1998), WHO (2004), USEPA (2009) with an exception of Fe level. Fe has greatly exceeded the limit for drinking water quality standards which suggests that water from the selected lakes of Matlab Upazila is not fully safe for drinking, cooking, and other household activities, though lake water can be applied for agricultural purposes as it maintains the quality for irrigation standard. From the heavy metal analysis in sediments of different lakes of Chandpur, it was reported that concentrations of most of the metals in all the lakes except Choto Kinar Chok lake exceeded the well-recognized regulatory authority USEPA's sediment standard values. As a whole, it can be concluded that the selected lakes were partly heavy metal polluted and might create an adverse effect on the ecosystem excluding Choto Kinar Chok lake.

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