Changes of heavy metal concentrations in Shitalakhya river water of Bangladesh with seasons

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ABSTRACT

Heavy metal concentrations in water and fish of the Shitalakhya river was measured to find out the suitability of its water for drinking and irrigation purposes. The concentrations of Pb, Cu, Cr, Zn, Cd and Hg in water were 0.0065; 0.0240; 0.0069; 0.8170; 0.0044; and 0.0057 mg/L, respectively in pre-monsoon, 0.0029; 0.0151; 0.0019; 0.4270; 0.0015; and 0.0020 mg/L, respectively in monsoon, and 0.0040; 0.0212; 0.0039; 0.6520; 0.0029; and 0.0031 mg/L, respectively in post-monsoon season. The heavy metal concentrations were found higher in pre-monsoon followed by post-monsoon and monsoon. The results also depicted that over the three seasons heavy metal pollution index and heavy metal evaluation index for all metals were lower than the critical pollution index value and low heavy metal contamination, respectively, and the degree of contamination in pre-monsoon season stated medium level pollution, followed by post-monsoon and monsoon season. The concentrations of Pb, Cu, and Cr in fish were found less than the lower detection limit, while the Zn were found 25.42; 18.30; and 29.34 mg/kg during the pre-monsoon, monsoon and post-monsoon, respectively. The study concluded that the Shitalakhya river water was not safe for the aquatic environment, especially for aquatic biota.

1. INTRODUCTION

Pollution of heavy metals in the aquatic environment is now a serious attention for human civilization because currently, it has reached an alarming rate (Mahfuza et al., 2012). These metals mostly raise from human activities like draining of sewerage, industrial waste and effluents, dumping of hospital wastes, municipal waste and recreational operations (Alam et al., 2007; Malik et al., 2010), conversely, metals are also occur in trace amounts naturally and may reached into aquatic ecosystem through leaching of rocks, airborne dust, forest fires and vegetation (Ishaq et al., 2011). As heavy metals are highly persistent and have potential to be toxic to living organisms, incessantly being deposited and incorporated in water, causing heavy metal pollution in the aquatic ecosystem (Fernandes et al., 2008; Ebrahimpour & Mushrifah, 2008; Storelli et al., 2005). The availability of heavy metals in water may have an intense effect on the micro algae which forge the main food source for mollusks in all their growth stages, zooplankton and for larval stages of some crustacean and fish species (Seshan et al., 2010). Moreover, bio-accumulation, as well as bio-magnification, could lead to high toxicity in organisms, even when the exposure level is low and under such position, the toxicity of a moderately toxic metal could be enhanced by synergism and fish population may decline (Haque et al., 2004). Apart from destabilizing the aquatic ecosystem, the bio-accumulation of these toxic metals in the aquatic food web is an impendence to public health and thus their potential large scale effects on ecosystem integrality cannot be disregarded (Rashid et al., 2012).

The river is very important for aquatic species especially for fish and also plays a significant role in assimilating or carrying off industrial and municipal effluents, residential waste water and runoff from agricultural fields which are accountable for river pollution (Alam 2003; Reza & Singh, 2010; Subramanian, 2004). Due to the swift population growth, unplanned urbanization, profound agricultural and industrial production, some rivers and water bodies has reached terrible levels in Bangladesh (Ghafoor et al., 2004). Pollution of the fresh aquatic ecosystem, especially the rivers are no longer within safe limits for human dealings and this can be measured through the heavy metal analysis in water and fishes (Haque et al., 2007). The environments of Bangladesh are particularly influenced by its regional and seasonal emergence and quality of water (MacFarlane & Burchett, 2000). In modern times Bangladesh holds 1176 industries that release almost 0.4 million m^3 of untreated waste water and effluents into the rivers per day (Rabbani & Sharif, 2005). Among the environmental pollutants, metals are of special concern due to their dynamic toxic effect and ability to bio-accumulation in fishes (Censi et al., 2006; Lohani et al., 2008). Discharge of waste water into a water body could reduce the biological oxygen demand (BOD) to such a massive scale that the entire oxygen may be shifted and this would cause the death of all aerobic groups along with fishes (Bhuiyan et al., 2011).

The Narsingdi town is one of the most vital industrial zones of the country and the Shitalakhya river flows through this town, various types of industries have been established on the bank of the river and most of these industries directly or indirectly discharging a huge quantities of wastes and effluents into the river without any treatment, and also municipal and domestic waste water from Narsingdi urban area, find their way untreated into this river (Mottalib et al., 2016; Islam et al., 2014). A significant volume of industrial raw materials for production and processed products are also transported through this river continuously by ships and other water vehicles (Islam et

al., 2008). Therefore, the risks of aquatic pollution impact are rising upwards sequentially (Mokaddes *et al.,* 2013). Thus, the present study was an attempt to assessing the present heavy metals pollution condition of the Shitalakhya river. The objectives of the study were as: (i) to investigate the heavy metal concentrations in water of the Shitalakhya river using pollution indices, and (ii) to assess the level of heavy metals contaminations in fish (*Notopterus notopterus*) of the Shitalakhya river.

2.   MATERIALS AND METHODS
2.1. Study area

The study area was located in the Shitalakhya river at Narsingdi district of Bangladesh approximately within the latitude between 23°55'36" to 23°91'92" N and longitude between 90°43'54" to 90°71'76" E. The river flows through Gazipur district forming its border with Narsingdi for some distance and then through Narayanganj district and one the most prominent distributary of the Old Brahmaputra river in the flood plain region of Bangladesh (Ahmed *et al.,* 2010). The river is very much alive during the monsoon and carries the major discharge of the Old Brahmaputra river on its way down. The river is about 110.0 km long and widest 0.3 km across and remains navigable year round. The river's maximum depth is 21 m and the average depth is 10 m (Haque, 2008).

2.2. Sampling stations

Water samples were collected from five sampling stations namely as Saorait Bazar (St-1), Ghorashal Fertilizer Company (St-2), Jamalpur Bazar (St-3), Ghorashal Ferighat (St-4) and Fuleshawri Bazar (St-5), whereas fish samples were collected from only St-1, St-3 and St-5 stations along the Shitalakhya river of Bangladesh. Stations were selected depending upon the presumed water quality and extent of pollution by prior visiting the study area. St-1 (upstream) located at the 1 km upstream of the Ghorashal Fertilizer Company Limited, where agricultural runoff, animal manure and waste water from municipal drains were the main source of pollution. St-2 (upstream) situated just besides the fertilizer company. Waste water from this industry was the main pollution source at this station. St-3 (upstream) was dominated by cement, textile, pesticide, and fertilizer factory and food beverage industrial park. Heavy metal containing waste water from plant discharge and waste water drains that collect mixed domestic, municipal and industrial waste water were the major pollution source in St-2. St-4 (downstream) situated just near the Ghorashal Bridge and Railway Bridge. Waste water from township, cement, fertilizer and plastic industries were the significant source of pollution at tis station. St-5 (downstream) was severely dominated by large scale industries such as, paper and pulp industry, plastic industrial park, cement factory, pesticide and fertilizer factory and textile industry. Ghorashal Railway Bridge and ferry Ghat were 1 km upstream near the St-5. Waste water drains that collect plant discharge, municipal, industrial and agricultural runoff were the most significance sources of pollution in St-5.

2.3. Sample collection

Water samples were collected from 5 sampling stations during the period from March to November 2015, where pre-monsoon (March to April), monsoon (July to August) and post-monsoon (October to November), respectively. On the other hand, fish samples were collected at four months interval i.e. in April, August and December 2015, and these three months were

considered as pre-monsoon, monsoon and post-monsoon season, respectively. To analyze the water quality, 500 mL water was collected by plastic bottles with double stoppers from each sampling points. Before sampling, the bottle was cleaned and washed with the detergent solution and treated with 5% nitric acid (HNO_3) over night. The bottles were finally rinsed with deionized water and dried. At each sampling station, the sampling bottles were rinsed at least three times before sampling was done. Pre-prepared sampling bottles were immersed about 10 cm below the surface water (Tareq *et al.*, 2013). After sampling, the bottles were screwed carefully and marked with the respective identification number. Then the samples were acidified with 10% nitric acid (HNO_3), were placed in an ice bath and were brought to the laboratory. The samples were filtered through 0.45 µm micro pore membrane filter and were kept in freeze at 4°C to avoid further contamination until analysis. The 200gm fish samples were collected from each sampling stations for analysis and brought to the laboratory with ice box and kept at freeze for preservation (Ahmad *et al.*, 2010).

2.4. Sample analysis

For water sample, at first 50 mL water sample was taken in a beaker by using a pipette. The 2 mL of concentrated HNO_3 was added in the water sample and then for digestion, the beaker was put in the hot-plate. After proper digestion, the sample was taken in a 50 mL of volumetric flask and filled with distilled water up to the limit. Then through a filter paper, it was filtered and preserved in a beaker and this process was followed for every water samples. The concentrations of Pb, Cu, Cr, Cd, Zn and Hg in water samples were analyzed by atomic absorption spectrophotometer (AAS-Model: AA-7000, Shimadzu, Japan) following the procedure in the laboratory of the Soil Science, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh-2201, Bangladesh. The fish samples were at freeze until analysis, and a bit of muscle, the whole liver and two-gill arches from each fish were removed before analysis, and only tissues from each fish were weighed and dried. A microwave digestion against the first-rate method is the concise time, lower consumption of acid and keeping the volatile mixture in the solution (Karadedea *et al.*, 2004). After digestion, the residues diluted to 25 mL with 2.5% of HNO_3. Instrument calibrated standard solutions were prepared from mercantile ingredients accordingly manufacturers instruction (Hassan *et al.*, 2015). The metal analyses of samples (Cr, Cu, Pb, and Zn) were carried out by using UNICAM-929 atomic absorption spectrophotometer (AAS) in the Food Laboratory of Central Laboratory of Societe de Surveillance (SGS), Bangladesh Limited, Dhaka. The fish species were analyzed by AOAC 19th Edition, 2012 BY ICP-OES, where the lower detection limit was 0.05 ppm.

2.5 Heavy metal indexing approach for water

Pollution indices are applied to explore the pollution status of water, in this study, three well-documented methods such as heavy metal pollution index (HPI) stated by Prasad and Bose (2001), heavy metal evaluation index (HEI) stated by Edet and Offiong (2002), and degree of contamination (CD) stated by Brraich and Jangu (2015) were weighted. These indices are often used to investigate the quality of water for drinking as well as irrigation purposes and describe an overall water quality status in relation to heavy metals.

For calculating the HPI, Prasad and Bose (2001) considered unit weightage (Wi) as a value inversely proportional to the recommended standard (Si) of the corresponding parameter as proposed by Reddy (1995).

The HPI model (Mohan *et al.,* 1996) is given by:

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} \mathrm{WiQi}}{\sum_{i=1}^{n} \mathrm{Wi}}$$

Where Qi is the sub-index of the ith parameter. Wiis is the unit weightage of the ith parameter and *n* is the number of parameters considered. The sub-index (Qi) of the parameter is calculated by:

$$\mathrm{Qi} = \sum_{i=1}^{n} \frac{\{\mathrm{Mi}(-)\mathrm{Ii}\}}{(\mathrm{Si} - \mathrm{Ii})} \times 100$$

where Miis is the monitored value of heavy metal of ith parameter and the sign (−) indicates numerical difference of the two values, ignoring the algebraic sign. In computing the HPI for the present study, Pb, Cu, Zn, and Cd were used. The weightage (Wi) was taken as the inverse of MAC, Si the WHO standard for drinking water in ppb and Ii the guide value for the chosen element in ppb, and MAC the maximum admissible concentration/upper permissible.

Heavy metal evaluation index (HEI) method gives an overall quality of the water with respect to heavy metals (Edet & Offiong, 2002) and is computed as:

$$\mathrm{HEI} = \sum_{i=1}^{n} \frac{\mathrm{Hc}}{\mathrm{Hmac}}$$

where Hcis is the monitored value of the ith parameter and Hmac is the maximum admissible concentration of the ith parameter.

The contamination index (CD) summarizes the combined effects of several quality parameters considered harmful to domestic water (Backman *et al.,* 1998) and the contamination index is calculated from equation below

$$CD = \sum_{i=1}^{n} Cfi$$
$$\mathrm{Cfi} = \frac{\mathrm{Cai}}{\mathrm{Cni}} - 1$$

Where Cfi, Cai, and Cni represent the contamination factor, the analytical value, and the upper permissible concentration of the ith component, respectively.

2.6. Statistical analysis

The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. The MS office excel 2010 and IBM statistics 20.0 software were used to analyze the collected data. The findings of the study were presented as charts and tabular forms.

3. RESULTS AND DISCUSSION
3.1 Heavy metal contamination in water

The mean concentration of Pb, Cu, Cr, Zn, Cd, and Hg in water were found 0.0065; 0.0240; 0.0069; 0.8170; 0.0044; and 0.0057 mg/L, respectively in pre-monsoon, 0.0029; 0.0151; 0.0019; 0.4270; 0.0015; and 0.0020 mg/L, respectively in monsoon, and 0.0040, 0.0212; 0.0039; 0.6520; 0.0029; and 0.0031 mg/L, respectively in post-monsoon season. The concentration of investigated heavy metals was found higher in pre-monsoon followed by post-monsoon and monsoon, due to the presence of higher level of pollutants into the river water with the lack of heavy rainfall for dilution of pollutants (Ahmad *et al.,* 2010). Moreover, the mean concentrations were observed in decreasing order of Zn > Cu > Pb > Cr > Hg > Cd whereas all the studied heavy metals concentrations were found lower than the standard level

reported by Environment Conservation Rules (ECR, 1997) except Hg (**Table 1**). The season, might be presence of electroplating, fertilizer, paper and pulp, plastic and cement industry in the bank of the river which discharged a large amount of waste water into the river water (Mottalib *et al.*, 2016). The Hg concentrations in Turag river water was greatly exceeded the standard level of the surface water quality (Zakir *et al.*, 2006), which is similar to the present study. The study found that concentration of heavy metals was varied from stations to stations and found in order of St-5 > St-3 > St-4 > St-2 > St-1, this might be due to river water flow, locations of industries, municipal and commercial drainage system and agricultural runoff (Hassan *et al.*, 2015). The level of Pb, Cd, and Zn of the Turag river water were found 0.0021, 0.0136 and 0.0191 mg/L, respectively (Mokaddes *et al.*, 2013), almost similar to the present study. The mean concentrations of heavy metal found in the Buriganga river water were observed Pb (0.0654 mg/L), Cu (0.1630 mg/L), Cr (0.5872 mg/L) and Cd (0.0093 mg/L) (Ahmad *et al.*, 2010) reported higher concentrations of heavy metals than the present study. In relation to, the Toxicity Reference Value (TRV) proposed by USEPA (1999) for fresh water, the concentration of Pb, Cu, Zn, Cd, and Hg in water were exceeded the TRV value in great extent whereas Cr found lower than the TRV value (**Table 1**).

Pearson correlation coefficients (r) was determined to reveal the relationships highest Hg (0.0080 mg/L) in water was found at St-5 during the pre-monsoon among the studied heavy metals in the samples during different seasons (**Table 2**), which may provide notable information on the sources and pathways of these heavy metals into the study area. The coefficient values determined for all the seasons showed significant positive correlation between the studied heavy metals which clearly supported the fact that these heavy metals are from similar pollution sources and pathways into the aquatic environment of the study area (Armah *et al.*, 2010; Hassan *et al.*, 2015).

The concentrations of heavy metal in water of the Shitalakhya river were compared with other major rivers of Bangladesh (**Tables 3-5**). The study depicted that Buriganga river water was contaminated with lead, chromium, and cadmium in large extent. The Turag, Balu, Meghna, Padma, Dakatia, Passur and Bangshi river showed that the studied heavy metals concentrations were below the permissible level. The Dhaleshwari river water was contaminated by the Pb and Cr pollution; on the other hand, chromium and Hg contents in Shitalakhya river (Islam *et al.*, 2008) water were severely contaminated in large extent. From the overall discussions, the study concluded that the Buriganga river water was contaminated by heavy metals followed by Shitalakhya (Islam *et al.*, 2008) and Dhaleshwari river (Ahmed *et al.*, 2012).

Table 1. Concentration (mg/L) of heavy metals in water of the Shitalakhya

Seasons	Stations	Pb	Cu	Cr	Zn	Cd	Hg
Pre-monsoon	St-1	0.0045	0.0210	0.0055	0.685	0.0025	0.0015
	St-2	0.0060	0.0235	0.0060	0.700	0.0035	0.0055
	St-3	0.0075	0.0250	0.0075	0.910	0.0055	0.0075
	St-4	0.0060	0.0240	0.0065	0.820	0.0045	0.0060
	St-5	0.0085	0.0265	0.0090	0.970	0.0060	0.0080
Monsoon	St-1	0.0025	0.0110	0.0010	0.300	0.0010	0.0010
	St-2	0.0025	0.0120	0.0010	0.350	0.0010	0.0010
	St-3	0.0035	0.0175	0.0025	0.475	0.0015	0.0030
	St-4	0.0025	0.0145	0.0015	0.430	0.0020	0.0015
	St-5	0.0035	0.0205	0.0035	0.580	0.0020	0.0035
Post-monsoon	St-1	0.0025	0.0200	0.0020	0.540	0.0020	0.0015
	St-2	0.0035	0.0205	0.0035	0.500	0.0020	0.0020
	St-3	0.0045	0.0215	0.0055	0.675	0.0035	0.0040
	St-4	0.0045	0.0205	0.0025	0.730	0.0025	0.0030
	St-5	0.0050	0.0235	0.0060	0.815	0.0045	0.0050
	Maximum	0.0075	0.0265	0.0090	0.970	0.0060	0.0080
	Minimum	0.0025	0.0110	0.0010	0.300	0.0010	0.0010
	Mean	0.0044	0.0201	0.0042	0.6320	0.0029	0.0036
	SD	0.0018	0.0045	0.0025	0.2005	0.0015	0.0023
	ECR (1997)	0.0500	1.0000	0.0500	5.0000	0.0050	0.0010
	TRV (USEPA, 1999)	0.0025	0.0090	0.0110	0.1180	0.0022	0.0007

Table 2. Pearson correlation coefficients (r) among heavy metals in water samples

Pre-monsoon	Pb	Cu	Cr	Zn	Cd	Hg
Pb	1					
Cu	0.978**	1				
Cr	0.965**	0.932*	1			
Zn	0.929*	0.911*	0.955*	1		
Cd	0.963**	0.967**	0.938*	0.977**	1	
Hg	0.933*	0.972**	0.833	0.852	0.943*	1
Monsoon	**Pb**	**Cu**	**Cr**	**Zn**	**Cd**	**Hg**
Pb	1					
Cu	0.906*	1				
Cr	0.926*	0.987**	1			
Zn	0.839	0.990**	0.962**	1		
Cd	0.456	0.764	0.692	0.823	1	
Hg	0.973**	0.977**	0.983**	0.936*	0.640	1
Post-monsoon	**Pb**	**Cu**	**Cr**	**Zn**	**Cd**	**Hg**
Pb	1					
Cu	0.761	1				
Cr	0.737	0.889*	1			
Zn	0.872	0.775	0.581	1		
Cd	0.807	0.966**	0.900*	0.846	1	
Hg	0.913*	0.925*	0.887*	0.890*	0.975*	1

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

The result of the study found that the HPI for all studied metals in three seasons were much lower the critical pollution index value for drinking water of 100. The computed HPI showed that in pre-monsoon, monsoon and post-monsoon season varied between -11.663 to 43.958 (mean = 18.421), -35.619 to -19.858 (mean = -27.661) and -20.635 to 18.765 (mean = -5.989), respectively. According to Prasad and Bose (2001), low heavy metal pollution (HPI<100), heavy metal pollution on the threshold risk (HPI=100) and high heavy metal pollution (i.e. critical pollution index) (HPI > 100), and if the samples have HPI greater than 100, water is not potable. Overall, result stated that the Shitalakhya river water was contaminated with respect to heavy metal but the pollution level was not significant based on HPI analysis. The analyzed HEI of Shitalakhya river water showed that in pre-monsoon, monsoon and post-monsoon season varied from 4.101 to 8.067 (mean = 5.995); 2.101 to 3.237 (mean = 2.7308); and 2.500 to 5.139 (mean = 3.842), respectively, which revealed that low heavy metal contamination for all sampling stations over the three seasons. Edet et al. (2003) stated the water quality index into three categories which include: low (HEI<400), moderate (400 < HEI < 800) and high (HEI > 800). Thus, the computed HEI of Shitalakhya river water showed that the water quality falls under the lower level of pollution. The CD was used as the reference to estimate the extent of metal pollution and CD may be grouped into three categories as follows: low (CD < 1), medium (CD = 1-3) and high (CD > 3) (Brraich and Jangu 2015). The mean CD in pre-monsoon, monsoon and post-monsoon season were 1.477; -2.429; and -0.6542, respectively, indicated that CD values in pre-monsoon season were higher, fall in the medium category pollution, followed by post-monsoon (low to medium pollution) and monsoon season (lower level of pollution). The overall CD value suggesting that water was low to medium polluted.

Table 3. Comparisons of heavy metals concentrations (mg/L) in the Shitalakhya river water in relation to other rivers of Bangladesh

River	Pb	Cu	Cr	Zn	Cd	Hg	References
Shitalakhya	0.0044	0.0201	0.0042	0.6320	0.0029	0.0036	Present Study
Buriganga	0.1119	-	0.1140	0.3320	0.0590	-	Bhuiyan et al. (2015)
Turag	0.0027	0.0722	0.0138	-	0.0033	0.0001	Afrin et al. (2014)
Balu	0.0010	0.0060	-	0.0101	0.0137	-	Mokaddes et al. (2013)
Meghna	-	-	0.0346	0.0364	0.0030	-	Hassan et al. (2015)
Padma	0.0015	0.0200	0.0030	0.0072	0.0020	-	Jolly et al. (2013)
Dakatia	0.0063	0.0326	0.0030	0.1140	0.0013	-	Hasan et al. (2015)
Passur	-	0.0200	0.0200	0.0100	-	-	Shil (2013)
Bangshi	0.0135	0.0700	-	2.1050	0.0012	-	Rehnuma et al. (2016)
Dhaleshwari	0.2010	-	0.1300	-	0.0010	-	Ahmed et al. (2012)
Shitalakhya	0.0060	0.0200	4.7700	0.0200	-	0.0069	Islam et al. (2008)

Table 4. Heavy metal pollution indices (HPI, HEI and CD) of water

Seasons	Stations	HPI	HEI	CD
Pre-monsoon	St-1	-11.663	4.101	-0.899
	St-2	4.558	5.449	2.209
	St-3	35.689	6.54	2.19
	St-4	19.565	5.818	0.818
	St-5	43.958	8.067	3.067
Monsoon	St-1	-35.619	2.119	-2.909
	St-2	-34.841	2.101	-2.898
	St-3	-27.349	2.996	-2.005
	St-4	-20.636	3.237	-2.537
	St-5	-19.858	3.201	-1.794
Post-monsoon	St-1	-20.635	2.500	-2.499
	St-2	-19.859	3.189	-1.809
	St-3	3.393	4.433	0.157
	St-4	-11.603	3.949	-1.019
	St-5	18.765	5.139	1.899

Three reported indices CD, HPI and HEI were analyzed for their propriety for contamination exploring of underground water from Medias city and found low, as well as water samples, do not present heavy metal pollution (Hoaghia *et al.*, 2013). Investigation showed that the metal pollution in southern Caspian Sea basin water of two indices namely the HPI and HEI were found below the critical values (Nasrabadi, 2015). Due to the rising pollution of water resources, tow pollution indices HPI and HEI were weighed and found low contamination levels (Sobhanardakani *et al.*, 2014).

3.2. Heavy metals contamination in fish

The concentration of Pb, Cu and Cr in fish (*Notopterus notopterus*) of the Shitalakhya river were found below the lower detection limit (LOD) < 0.05 mg/kg during the pre-monsoon, monsoon and post-monsoon, respectively in the all St-1, St-3, and St-5 sampling stations. On the other hand, concentration of Zn in fish (*Notopterus notopterus*) were found 25.42, 18.30 and 29.34 mg/kg during the pre-monsoon, monsoon and post-monsoon,

respectively, whereas the highest level of Zn was found 35.59 mg/kg at St-3 during post-monsoon, while the lowest was found 15.82 mg/kg at St-1 during the monsoon season (**Table 6**).

Moreover, the study also showed that Zn concentration was below the permissible level in fish over the three seasons in all stations except St-5 during the post-monsoon as well as the study stated that fish was safe for human consumption. It might be due to the lower level of metal concentrations in water and low bioaccumulation rate of small fish species. Bio-accumulation also depends on geography, trophic level, size, foraging method and the propensity of metals to undergo bio-magnification in the food chain (Ahmad *et al.*, 2010). A study in the Khiru river revealed that in fish, average bioaccumulation of Cu, Zn, Mn, Pb, and Cd was found 3.65 ± 1.04; 106.39 ± 34.93; 27.52 ± 11.27; 0.0016 ± 0.002; and 0.0043 ± 0.01111 mg/kg, respectively which was within the permissible limit (Rashid *et al.*, 2012). A considerable amount of Pb, Zn and Cr were recorded in fishes sampled from both the Buriganga and Shitalakhya

(Narayanganj) rivers. In Buriganga, Pb, Zn, and Cr were found 4.32-31.51; 3.95-51.50; and 7.83-21.72 mg/kg, respectively whereas in Shitalakhya, 11.44-17.03, 6.29-62.02 and Cr 7.83-21.72 mg/kg were found, respectively, and this finding indicated a major threat to human health in relation to consumption of fishes (Islam *et al.,* 2014).

The comparative study depicted that concentration of Pd in Passur and Shitalakhya river fish were within standard level whereas the Buriganga Dhaleshwari and Sundarbans Reserved Forest (SRF) river fish largely exceeded the permissible level set by FAO (1984), whereas all the river fish observed the lower level of Cu, within the permissible level. The Buriganga and Dhaleshwari river fish were highly contaminated by Cr that exceeded the permissible level than Passur, SRF and Shitalakhya river (**Table 7**). The highest level of Zn was found 24.35 mg/kg in *Notopterus notopterus* fish of present studied Shitalakhya river followed by SRF and Passur river (**Table 7**) and all the values show that the Zn content was within the permissible limit 30.00 mg/L (FAO, 1984). From the overall analysis, it can be stated that the heavy metals contamination in fish species of Dhaleshwari river is much worse than the others.

Table 5. Standard used for the indices computation(Brraich & Jangu, 2015)

Metal	Unit	W	S	I	MAC
Pb	ppb	0.7	100	10	1.5
Cu	ppb	0.001	1000	2000	1000
Cr	ppb	0.02	50	-	50
Zn	ppb	0.0002	5000	3000	5000
Cd	ppb	0.3	5	5	3
Hg	ppb	-	-	-	-

Table 6. Heavy metal concentrations in fish (*Notopterus notopterus*) species

Season	Sampling Stations	Heavy metal concentrations (mg/kg)			
		Pb	Cu	Cr	Zn
Pre-monsoon	St-1	<0.05	<0.05	<0.05	21.77
(April)	St-3	<0.05	<0.05	<0.05	27.24
	St-5	<0.05	<0.05	<0.05	27.24
Monsoon	St-1	<0.05	<0.05	<0.05	15.82
(August)	St-3	<0.05	<0.05	<0.05	16.85
	St-5	<0.05	<0.05	<0.05	22.22
Post-monsoon	St-1	<0.05	<0.05	<0.05	26.12
(December)	St-3	<0.05	<0.05	<0.05	26.30
	St-5	<0.05	<0.05	<0.05	35.59
Permissible level (FAO, 1984)		0.30	30.00	1.00	30.00

Table 7. Comparisons of heavy metals concentrations (mg/kg) in the Shitalakhya river fish in relation to other rivers of Bangladesh

River	Species	Pb	Cu	Cr	Zn	References
Shitalakhya	_Notopterus notopterus_	<0.05	<0.05	<0.05	24.35	Present Study
Buriganga	_Channapunctatus_	9.11	5.31	5.66	-	Ahmad _et al._ (2010)
Dhaleshwari	_Cirrhinusreba_	9.61	9.53	14.56	-	Ahmad _et al._ (2010)
SRF	_Cirrhinusreba_	3.40	2.26	0.18	16.62	Haque _et al._ (2006)
Passur	_Liza parse_	0.19	0.78	0.38	9.17	Shil (2013)

4. CONCLUSION

The study found that except Hg rest of the studied heavy metals concentrations were found below than the standard level in water whereas, apart from Cr all the metals were exceeded the TRV in significantly. The HPI and HEI values for all studied metals were satisfactory level but the CD was varied markedly over the three seasons. The Zn was the only dominant metals found in fish whereas concentrations of Pb, Cu, and Cr in fish were found below LOD. The study concluded that the Shitalakhya river water was contaminated by means of heavy metals which undoubtedly revealed that the water of the river is not safe for aquatic environment, especially for aquatic biota. Moreover, the study stated that fish in the Shitalakhya river was safe for human consumption in terms of heavy metal contamination. In this point of view, straightforward management approach along with continuous monitoring and assessment is obvious for protecting the water quality and fish species as well as aquatic biota of the Shitalakhya river.

5. ACKNOWLEDGEMENTS

6. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest. Authors confirmed that the data and the paper are free of plagiarism.

7. REFERENCES

Afrin, R., Mia, M. Y., Ahsan, M. A., Akbor, M. A., & Akter, S. (2015). Status of water pollution in respect of physicochemical parameters and anions in the Turag river of Bangladesh. _Bangladesh Journal of Environmental Science_, _28_, 113-118.

Ahmad, M.K., Islam, S., Rahman, S., Haque, M.R., & Islam, M.M. (2010). Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. _International Journal of Environmental Research, 4_(2),321-332.

Ahmed, A. T. A., Mandal, S., Chowdhury, D. A., Tareq, A. R. M., & Rahman, M. M. (2012). Bioaccumulation of some heavy metals in Ayre Fish (Sperata Aor Hamilton, 1822), sediment and water of Dhaleshwari River in dry season. _Bangladesh Journal of Zoology, 40_(1), 147-153.

Ahmed, M., Bhowmik, A. C., Rahman, S., & Haque, M. (2010). Heavy metal concentration in water, sediments, freshwater mussels and fishes of the river shitalakhya, Bangladesh. *Asian Journal of Water, Environment and Pollution*, *7*(1), 77-90.

Alam, A.M.S., Islam, M.A., Rahman, M.A., Ahmed, A., Islam, S., Sultana, K.S., & Siddique, M.N. (2004). Transport of toxic metal through the major river system of Bangladesh. *Journal of Chemical Society of Pakistan*, *26*(3), 328-332.

Alam, M. J., Islam, M. R., Muyen, Z., Mamun, M., & Islam, S. (2007). Water quality parameters along rivers. *International Journal of Environmental Science and Technology*, *4*(1), 159-167.

Armah, F. A., Obiri, S., Yawson, D. O., Onumah, E. E., Yengoh, G. T., Afrifa, E. K., & Odoi, J. O. (2010). Anthropogenic sources and environmentally relevant concentrations of heavy metals in surface water of a mining district in Ghana: a multivariate statistical approach. *Journal of Environmental Science and Health Part A*, *45*(13), 1804-1813.

Backman, B., Bodiš, D., Lahermo, P., Rapant, S., & Tarvainen, T. (1998). Application of a groundwater contamination index in Finland and Slovakia. *Environmental Geology*, *36*(1-2), 55-64.

Bhuiyan, M. A. H., Suruvi, N. I., Dampare, S. B., Islam, M. A., Quraishi, S. B., Ganyaglo, S., & Suzuki, S. (2011). Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka, Bangladesh. *Environmental monitoring and assessment*, *175*(1-4), 633-649.

Bhuiyan, M. A. H., Dampare, S. B., Islam, M. A., & Suzuki, S. (2015). Source apportionment and pollution evaluation of heavy metals in water and sediments of Buriganga River, Bangladesh, using multivariate analysis and pollution evaluation indices. *Environmental monitoring and assessment*, *187*(1), 4075.

Brraich, O. S., & Jangu, S. (2015). Evaluation of water quality pollution indices for heavy metal contamination monitoring in the water of Harike Wetland (Ramsar Site), India. *International Journal of Scientific and Research Publications*, *5*(2), 1-6.

Censi, P. A. O. L. O., Spoto, S. E., Saiano, F. I. L. I. P. P. O., Sprovieri, M., Mazzola, S., Nardone, G., Geronimo, S.I.D., Punturo, R., & Ottonello, D. (2006). Heavy metals in coastal water systems. A case study from the northwestern Gulf of Thailand. *Chemosphere*, *64*(7), 1167-1176.

Ebrahimpour, M., & Mushrifah, I. (2008). Heavy metal concentrations in water and sediments in Tasik Chini, a freshwater lake, Malaysia. *Environmental monitoring and assessment*, *141*(1-3), 297-307.

ECR (1997). *Environment Conservation Rules*. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

Edet, A. E., & Offiong, O. E. (2002). Evaluation of water quality pollution indices for heavy metal contamination monitoring. A study case from Akpabuyo-Odukpani area, Lower Cross River Basin (southeastern Nigeria). *GeoJournal*, *57*(4), 295-304.

Edet, A. E., Merkel, B. J., & Offiong, O. E. (2003). Trace element hydrochemical assessment of the Calabar Coastal Plain Aquifer, southeastern Nigeria using statistical methods. *Environmental Geology*, *44*(2), 137-149.

FAO (1984). *Food and Agricultural Organization.* List of maximum levels recommended for contaminants by the Joint FAO/WHO Codex Alimentarius Commission. Series 2nd CAC/FAL, Rome.

Fernandes, C., Fontaínhas-Fernandes, A., Cabral, D., & Salgado, M. A. (2008). Heavy metals in water, sediment and tissues of Liza saliens from Esmoriz–Paramos lagoon, Portugal. *Environmental monitoring and assessment*, *136*(1-3), 267-275.

Ghafoor, A., Qadir, M., Sadiq, M., Murtaza, G., & Brar, M. S. (2004). Lead, copper, zinc and iron concentrations in soils and vegetables irrigated with city effluent on urban agricultural lands. *Journal of the Indian Society of Soil Science*, *52*(1), 114-117.

Haque, M. R., Ahmad, J. U., Chowdhury, M. D. A., Ahmed, M. K., & Rahman, M. S. (2004). Seasonal variation of heavy metals concentration in sediments of the rivers and estuaries of Sundarban mangrove forest. *Asian Journal of Microbiology Biotechnology and Environmental Sciences*, *6*(2), 175-185.

Haque, M. R., Ahmed, M. K., Ahmad, J. U., & Chowdhury, M. D. A. (2007). Seasonal variation of heavy metals in some molluscs of Sundarban mangrove forest, Bangladesh. *Pakistan Journal of Oceanography*, *2*(2), 81-98.

Haque, M. R., Ahmed, M. K., Mannaf, M. A., & Islam, M. M. (2006). Seasonal variation of heavy metals concentrations in Gudusia chapra inhabiting the Sundarban mangrove forest. *Journal of NOAMI*, *23*(1), 1-21.

Haque, M.I. (2008). *Water resources management in Bangladesh*. Anushilan Publishers, Chuadanga and Dhaka

Hasan, S.J., Tanu, M.B., Haidar, M.S., Ahmed, T., Rubel, A.K.M.S.A. (2015). Physiochemical characteristics and accumulation of heavy metals in water and sediments of the river Dakatia, Bangladesh. *International Journal of Fish Aquatic Studies*, *2*(5), 300-304.

Hassan, M., Rahman, M. A. T., Saha, B., & Kamal, A. K. I. (2015). Status of heavy metals in water and sediment of the Meghna River, Bangladesh. *American Journal of Environmental Sciences*, *11*(6), 427.

Hoaghi, M. A., Roman, C., Ristoiu, D., Popita, G., & Tanaselia, C. (2013). Assessing of water quality pollution indices for heavy metal contamination. a study case from medias city groundwaters. *Agricultura*, *87*(3-4).

Eneji, I. S., Sha'Ato, R., & Annune, P. A. (2011). Bioaccumulation of heavy metals in fish (Tilapia zilli and Clarias gariepinus) organs from River Benue, North-Central Nigeria. *Pakistan Journal of Analytical Environmental Chemistry*, *12*(1), 25-31.

Islam, M. M., Rahman, S. L., Ahmed, S. U., & Haque, M. K. I. (2014). Biochemical characteristics and accumulation of heavy metals in fishes, water and sediments of

the river Buriganga and Shitalakhya of Bangladesh. *Journal of Asian scientific research*, *4*(6), 270-279.

Islam, M. Z., Azim, M. A., Islam, R., & Quraishi, S. B. (2008). Seasonal Variation of Heavy metals in water samples from the Sitalakhya River. *Journal of Bangladesh Academy of Sciences*, *32*(1), 13-22.

Jolly, Y. N., Akter, J. S., Kabir, A. I., & Akbar, S. (2013). Trace elements contamination in the river padma. *Bangladesh Journal of Physics*, *13*, 95-102.

Karadede, H., Oymak, S. A., & Ünlü, E. (2004). Heavy metals in mullet, Liza abu, and catfish, Silurus triostegus, from the Atatürk Dam Lake (Euphrates), Turkey. *Environment International*, *30*(2), 183-188.

Lohani, M. B., Singh, A., Rupainwar, D. C., & Dhar, D. N. (2008). Seasonal variations of heavy metal contamination in river Gomti of Lucknow city region. *Environmental Monitoring and assessment*, *147*(1-3), 253-263.

MacFarlane, G. R., & Burchett, M. D. (2000). Cellular distribution of copper, lead and zinc in the grey mangrove, Avicennia marina (Forsk.) Vierh. *Aquatic Botany*, *68*(1), 45-59.

Sultana, M. S. (2012). Toxic Metal Contamination on the River near Industrial Area of Dhaka. *Universal Journal of Environmental Research & Technology*, *2*(2), 56-64.

Malik, N., Biswas, A. K., Qureshi, T. A., Borana, K., & Virha, R. (2010). Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. *Environmental monitoring and assessment*, *160*(1-4), 267.

Mohan, S. V., Nithila, P., & Reddy, S. J. (1996). Estimation of heavy metals in drinking water and development of heavy metal pollution index. *Journal of Environmental Science & Health Part A*, *31*(2), 283-289.

Mokaddes, M. A. A., Nahar, B. S., & Baten, M. A. (2012). Status of heavy metal contaminations of Drain water of Dhaka Metropolitan city. *Journal of Environmental Science and Natural Resources*, *5*(2), 11-14.

Jannat, N., Mottalib, M. A., & Alam, M. N. (2019). Assessment of Physico-chemical Properties of Surface Water of Mokeshbeel, Gazipur. *Bangladesh Journal of Environmental Science and Current Research*, *2*, 014.

Nasrabadi, T. (2015). An IndexApproach toMetallic Pollution in RiverWaters. *International Journal of Environmental Research*, *9*(1), 385-394.

Prasad, B., & Bose, J. (2001). Evaluation of the heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. *Environmental Geology*, *41*(1-2), 183-188.

Rabbani, G., & Sharif, M.I. (2005). *Dhaka city-state of environment* (SoE)-2005. UNEP in collaboration with BCAS and DoE, Bangladesh.

Rashid, H., Hasan, M. N., Tanu, M. B., Parveen, R., Sukhan, Z. P., Rahman, M. S., & Mahmud, Y. (2012). Heavy metal pollution and chemical profile of Khiru river, Bangladesh. *International Journal of Environment*, *2*(1), 57-63.

Reddy, S.J. (1995). *Encyclopedia of environmental pollution and control*. India: Environmental Media.

Rehnuma, M., Islam, M.S., Meghla, N.T., & Kabir, M.H. (2016). Heavy metal exploration in water and fish from Bangshi river at Mirzapur area under Tangail district of Bangladesh. *Bangladesh Journal of Environmetal Science, 30*, 7-12.

Reza, R., & Singh, G. (2010). Heavy metal contamination and its indexing approach for river water. *International Journal of Environmental Science and Technology, 7*(4), 785-792.

Seshan, B. R. R., Natesan, U., & Deepthi, K. (2010). Geochemical and statistical approach for evaluation of heavy metal pollution in core sediments in southeast coast of India. *International Journal of Environmental Science & Technology*, *7*(2), 291-306.

Shil, S.C. (2013). *Investigation of heavy metal contamination in water, sediment and fishes from the Mongla port area near Sundarbans mangrove, Bangladesh*. MS Thesis, Mawlana Bhashani Science and Technology University, Bangladesh

Sobhanardakani, S., Jamali, M., Maànijou, M. (2014). Evaluation of As, Zn, Cr and Mn concentrations in groundwater resources of Razan Plain and preparing the zoning map using GIS. *Journal of Environmental Science and Technology, 16*(2), 25-38.

Storelli, M.M., Storelli, A., D'ddabbo, R., Marano, C., Bruno, R., & Marcotrigiano, G.O. (2005). Trace elements in loggerhead turtles (*Carettacaretta*) from the eastern Mediterranean Sea: overview and evaluation. *Environmental Pollution*, *135*(1), 163-170.

Subramanian, B. (2004). Water quality in south Asia. *Asian Journal of Water Environmental Pollution, 1*(1-2), 41-54.

Tareq, S. M., Rahaman, M. S., Rikta, S. Y., Islam, S. N., & Sultana, M. S. (2013). Seasonal variations in water quality of the Ganges and Brahmaputra River, Bangladesh. *Jahangirnagar University Environmental Bulletin*, *2*, 71-82.

USEPA (1999) *United States Environmental Protection Agency*, Screening level ecological risk assessment protocol for hazardous waste combustion facilities, Appendix E: Toxicity reference values. Washington DC, USA

Zakir, H.M., Sharmin, S., & Shikazono, N. (2006). Heavy metal pollution assessment in water and sediments of Turag River at Tongi area in Bangladesh. *International Journal of Lake and River, 1*(1), 85-96.