Tech. J. River Res. Inst. 15(1): 48-58, 2020 (August), ISSN: 1606-9277

SPATIAL AND TEMPORAL DISTRIBUTION OF HEAVY METALS IN THE BURIGANGA RIVER

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Abstract

River pollution is identified as one of the top environmental issues during the couple of decades in Asian region. The Buriganga is considered the most important and polluted river in Dhaka. Disposal of untreated industrial and domestic waste, encroachment and dumping of solid waste have degraded the overall quality of the river Buriganga. The present study investigated the spatial distributions of heavy metals in water at sixteen different sites spread over whole stretch of the Buriganga River (27km). The concentrations of seven metals Cr, Cd, Pb, Ni, Fe, Zn and Cu were analyzed using an Atomic Absorption Spectrophotometer (Thermo-Scientific, 3000 series) in the RRI laboratory. The concentrations were compared with several standard Guideline values provided by different organizations like WHO, DoE, FAO and CCME. The visualization of the spatial pattern of individual metal throughout the Buriganga was primed using ArcGIS 10.3 software. The result showed that the surface water of the whole stretch of the Buriganga was severely polluted by these heavy metals in dry season except Cu and Zn. The statistical analysis showed that a wide variation of concentrations among Cr, Cd, Pb, Ni, Fe, Zn and Cu but slightly differed among the locations. Anthropogenic activities are mainly responsible for elevated levels of the measured metals in river water. The lower concentration of heavy metal was found in post rainy season compared to dry season. Even though the concentration has decreased in post rainy season some severe toxic heavy metals like Cr and Cd concentrations are far above than the safe recommended values. Prevention of metals entering in to the rivers should be enforced to save ecosystem of the watershed environment of the Buriganga.

Key words: *Heavy metal, Pollution, Buriganga River, ArcGIS, Spatial distribution, Seasonal variation, Environment, Industrial waste.*

Introduction

Unintended rapid urbanization and industrial growth have triggered serious concerns in environment. Heavy metal contamination in aquatic environments has received huge concern due to toxicity of metals, abundance and persistence in the environment and subsequent accumulation in aquatic habitats. Rivers are a dominant pathway for metals transport (Hasan, *et al*., 2014) and undergo a global ecological cycle (Afrin, *et al*., 2014). Heavy metals are naturally occurring metallic elements that have relatively high atomic weight and density compared to water (Tchounwou, *et. al.,* 2012) and usually non-biodegradable (Mahfuza, *et al*., 2012). It can concentrate along the food chain, producing toxic effect at points after far removed from the source of pollution (Tilzer and Khondker, 1993).

Metal pollution has harmful effect on biological systems and therefore, exposure to heavy metals has linked to several human diseases such as malformation, kidney damage, cancer, abortion, effect on intelligence and behavior, and even death in some cases of exposure to very high concentrations (Ghrefat and Yusuf, 2006). The toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of high degree of toxicity, cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), arsenic (As), mercury (Hg), cupper (Cu), zink (Zn) and iron (Fe) rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure (Pehlivan, *et al.,* 2009). The World Health Organization (WHO) as well as the Food and Agriculture Organization (FAO) of the United Nations state that monitoring of toxic heavy metals like Cr, Cd, Pb and Ni are mandatory and others are suggestive in aquatic system.

The Buriganga is subject to severe pollution and considered as one of the worst polluted rivers in the world. The dyeing factories and tanneries are the main polluters of the Buriganga. Department of Environment (DoE) reports that the tanneries collectively dump 22,000 liters of toxic waste including cancer-causing chromium into Buriganga every day (Barton, 2011). Waste from the industries is usually connected to the sewerage system that directly follows to the river

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without any treatment. Moreover, the river has become a dumping ground of all kinds of solid, liquid and other chemical waste. The river is losing natural flow due to river encroachment and dumping of solid waste. Therefore, the river Buriganga is increasingly being polluted everyday with heavy metals containing toxic wastes through city's thousands of industrial units and sewerage lines (Islam *et al*., 2006).

A number of studies have been reported on the pollution of the Buriganga River. Some of the previously studies described only the physicochemical properties and biochemistry of the river water (Ali *et Al*., 2008; Bhuiyan *et al*., 2011; Sikder *et al*., 2012) and few others have dealt with the distribution of heavy metals (Ahmad, *et al*., 2010; Islam *et al*., 2015). However, the study of heavy metals pollution of entire reach of the Buriganga hasn't been carried out so far. Besides, the study of individual metal distribution in surface water of the Buriganga in GIS platform has not yet been reported.

In view of the above circumstances, a comprehensive study has been done on the distribution of Cr, Cd, Pb, Ni, Fe, Zn and Cu at sixteen different sites spread over whole stretch (27 km) of the Buriganga River with the following objectives:

i) to determine the spatial distributions of heavy metals in surface water of the Buriganga River;
ii) to investigate the seasonal variation of heavy metal concentrations; and
iii) to assess heavy metal concentration in an inclusive and integrated way using ArcGIS

Methodology

Study area and sampling site

The Buriganga River was selected as a study area. The Buriganga is a tide-influenced river flowing west and then south of Dhaka City. It is only 27 km long and its average width and depths are 400 and 10 m, respectively (Islam *et al*., 2015). Due to rapid and unplanned urbanization and industrialization the Dhaka city's surrounding rivers, including Buriganga have gradually experienced undue and unbearable pressure to their existence. To investigate the spatial pollution pattern, sixteen different sites spread over the whole stretch of the Buriganga river were selected in this study and shown in Fig. 1 and Table 1.

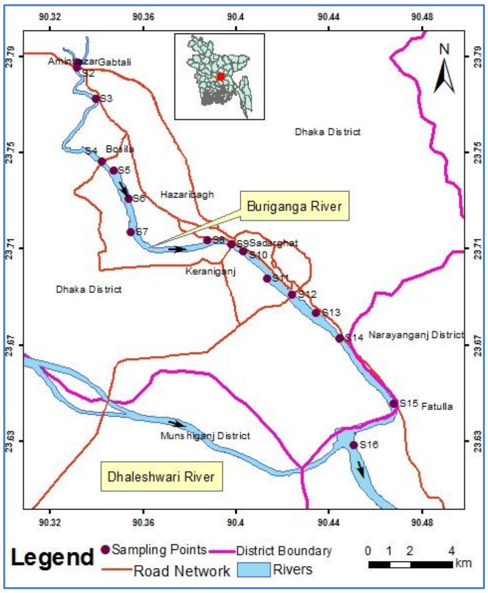


Fig. 1. Map of study area with sampling site

Sample collection procedure

Water samples were collected in 2015 in dry and post rainy seasons. The month of March is considered to be representative of dry season where as the October as treated as post rainy season assuming the river water become stable in this month after rainy season. In dry season, water samples were collected from 16 sites. However, to observe the seasonal variation of metals, water samples were collected only from 4 sites namely, Amin Bazar, Hazarribagh, Saderghat and Fatulla in post rainy season. The water samples were collected from 10 to 15 cm below the water surface using acid washed 1 litre HDP plastic bottle. Prior to sample collection, the bottles were rinsed with the river water to avoid contamination in the bottle. At each sampling site, a composite sample was collected by taking 3 numbers of samples at 1 m interval. The collected samples were immediately acidified with HNO_3 and the bottles were carefully closed to avoid contact with air. The water samples were transferred to the laboratory as early as possible and were stored at 4°C in a refrigerator.

Table 1. Locations and description of sampling sites along the Buriganga River (total reach 27 km).

Site	Location	Coordinates	Description (Reason for choosing location)
S1	Ishakha Badh	23°47'10.65"N 90°20'8.45"E	It is the confluence of Turag, Karnatoli and Buriganga river.
S2	Amin Bazar Bridge	23°47'1.69"N 90°20'8.28"E	It is the commencing point of the Buriganga river with the joint flow of Turag and Karnatoli Rivers. This point contains various quays of different types of transport.
S3	Adabor Sluice Gate	23°46'18.78"N 90°20'32.69"E	Buriganga river and Kallyanpur Canal get to meet here through a sluice gate.
S4	Bosila	23°44'38.61"N 90°20'46.27"E	At this point many drains are connected to the Buriganga river carrying municipal waste. There is tanneries waste disposal canals linked to the river.
S5	Hazaribagh Canal	23°44'24.52"N 90°21'5.00"E	A big canal carrying waste water of tanneries of Hazaribagh area runs into the Buriganga river at this site.
S6	Gazirghat	23°43'41.24"N 90°21'28.03"E	Some Canals carrying municipal wastes and untreated water of tanneries meets the river at this point.
S7	Kholamora boat terminal	23°42'51.54"N 90°21'31.39"E	A rivulet fall into the Buriganga river at this point. There is also many engine driven boats come and go.
S8	Sowarighat	23°42'38.27"N 90°23'30.26"E	A big canal carrying municipal and industrial waste of Kamrangirchar and Shahidnagar area gets joint to this point. There is a boat terminal present there.
S9	Babubazar Bridge	23°42'33.11"N 90°24'7.70"E	A storm water drain carrying municipal waste from old Dhaka area is connected to the Buriganga river at this point.
S10	Sadarghat	23°42'21.59"N 90°24'26.24"E	Sadarghat Launch terminal is the largest river port in Bangladesh. Oil and lube spillage happens during refueling of vessels and cargo handling. These vessels dump waste, including burnt oil, into the water.
S11	Mirerbag	23°41'40.06"N 90°25'2.82"E	There is a launch terminal and several dockyards at this point which is the reason to choose this point.
S12	Postogola	23°41'16.05"N 90°25'41.75"E	Some canals carrying municipal and industrial waste of Postogola area meet at this point with the Buriganga river.
S13	Monsikhola	23°41'0.63"N 90°26'2.48"E	It is the point where local brick traders run their business through loading and unloading bricks to ships of various sizes.
S14	Pagla	23°39'46.80"N 90°27'14.04"E	One of the biggest sewage treatment plants of Dhaka is situated about 1km away from this point and it lies in the middle of the quay used to transport bricks.
S15	Fatullah	23°38'26.15"N 90°28'21.33"E	Fatullah Bazar is one of the significant market places of Narayanganj district and contains a busy launch terminal. This point lies in the launch terminal.
S16	Dharmaganj	23°37'39.75"N 90°27'14.87"E	A branch of Dhaleswari river meets Buriganga river in this point and continues to flow further to meet Shitalakhya and Meghna river with several dockyards and brick fields around.

Chemical analysis of water samples

All reagents using in the laboratory were analytical grade. Deionized (DI) water was used for the preparation of all solutions. All glassware used in this study were cleaned by soaking in dilute acid for at least 24 h and rinsed abundantly in deionized water and dried before use.

For heavy metal analysis, water samples were prepared and analyzed according to Sharma and Tyagi, 2013. Briefly: Transferred 100 ml of well mixed acid preserved sample into a beaker and added 2 ml of concentrated HNO_3 + 5 ml of concentrated HCl. The beaker was placed on a hot plate at 90 to 95 ^{0}C and reduced the volume up to 10-20 ml. Then the beaker was removed and allowed to cool. The beaker was washed with deionized water (3 times) and filtered through a Whatman filter paper no. 42. Then the sample was poured into 100 ml volumetric flask and made it up 100 ml mix thoroughly. The sample was poured to HDP plastic bottle and kept in refrigerator for Heavy metals analysis.

The standard solution of the elements Cr, Pb, Cd, Ni, Cu, Fe and Zn were prepared by pouring the required amount of the solution from the stock solution, manufactured by Fisher Scientific Company, USA. The standard solution was prepared before every analysis of the current work. The samples were analyzed by using air acetylene flame with combination, as well as, single element hollow cathode lamps into an atomic absorption spectrophotometer (Thermo-Scientific, 3000 series). During quantifying metals, at least three concentrations were prepared of standard solution of a particular metal. Blank solution was aspirated and adjusted to zero. Each standard solution was aspirated into flame and prepared a calibration curve for absorbance versus concentration of standard solution. The appropriate dilution factor was used for the samples having higher concentration of metal ions. Average values of three replicates were taken for each measurement.

Statistical analyses

Statistical analysis has been done using GENSTAT 12th Edition (VSN International, Hemel Hempstead, England) for heavy metals.

Mapping procedures

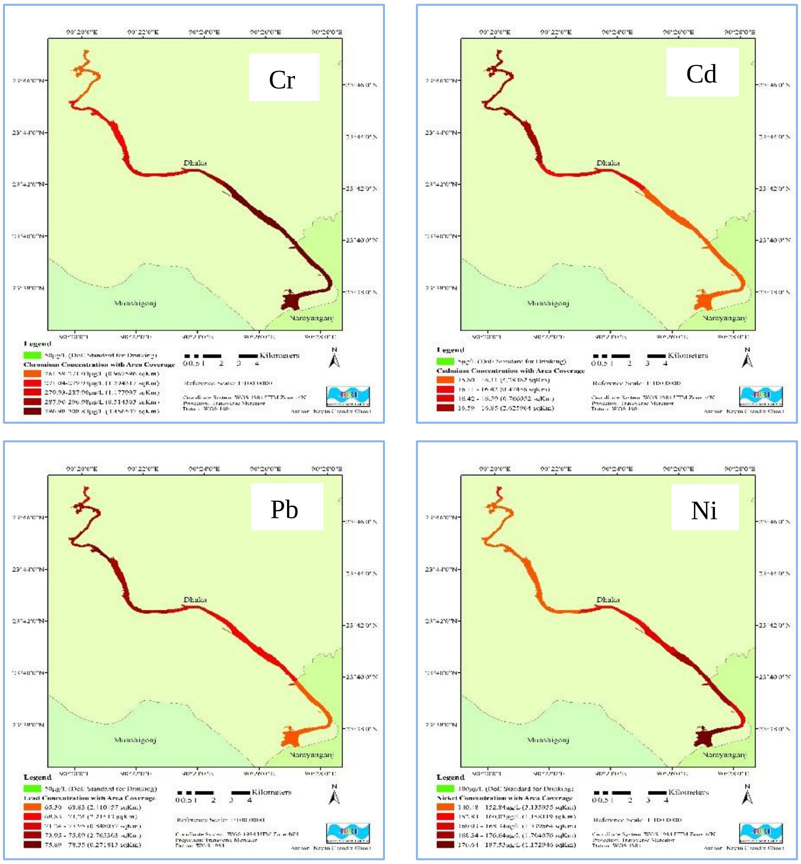
Distribution of heavy metal concentrations to the whole river reach was done by kriging ordinary interpolation method using ArcGIS 10.3. The interpolated data were reclassified into 5 classes with natural breaks (jenks) for convenience. The color of the class was choosen depending on the DoE standard with green and red for below and above respectively. The intensity of the color with lower to higher represents dark to light for green and light to dark for red respectively.

Results and discussions

Spatial distribution of metals in the Buriganga River water in dry season

The spatial pollution pattern by seven heavy metals at sixteen different sites spread over the whole stretch of the Buriganga river in dry season are visualized in Fig. 2 and Fig. 3. The whole stretch of the Buriganga was severely contaminated by four toxic metals Cr, Cd, Pb and Ni in dry season (Fig. 2). The concentration of Cu and Zn were acceptable level whereas Fe concentration was fluctuated in dry season at different sites of the Buriganga stretch (Fig. 3).

Among the 16 sites, the maximum Cr concentration was 346.76 μgL^{-1} at Postogola which is approximately seven times and the minimum was 223.82 μgL^{-1} in Adabor Sluice Gate which is approximately four times greater than standard value (50 µg/ L) provided by WHO & DoE (Table 2 and Table 3). The concentration of Cr was 236.06 and 289.90 μgL^{-1} at Ishakha Badh and Amin Bazar Bridge respectively, which are the commencing point of the Buriganga River indicates the Buriganga initiates with the Cr polluted water flow. The concentration of Cr was slowly increased throughout the flow of water of the river (Fig. 2). The Cr concentration was not significantly differed among the locations indicating whole stretch of the river is Cr polluted. According to CCME (2007), required Cr concentration is 0.02 μgL^{-1} to protect fish and 2.0 μgL^{-1} to protect aquatic life including zooplankton and phytoplankton (Table 3). Therefore, according to CCME (2007), aquatic life awkward in this severe Cr polluted river water. For the reasons of this high level of Cr that the Hazaribagh Tannery industries discharging their solid wastes and liquid effluent containing rotten flesh, fat, blood and skin, toxic chemicals, dissolved lime, chromium sulfate and alkali, hydrogen sulfide, heavy metals, suspended solids, etc., in most cases without any treatment directly to the river Buriganga (Zahid, 2004) at different places such as Basila, Hazaribagh, Kamrangir char etc. Moreover, Turag and Bongshi are situated up stream of the Buriganga and these rivers also carries considerable amount of Cr which flowing through the Buriganga. In this study, the excess amount of Cr found in the Buriganga is due to upstream Cr containing water flow along with Cr containing tannery and other industries wastes connecting to the Buriganga. Islam, *et al.* (2015) showed that Cr concentration in Buriganga 110 μgL^{-1} in summer which is lower than this study. However, Ahmad, *et al.* (2010) revealed that Cr concentration were 645.26, 605.87, 613.25 μgL^{-1} at Balughat, Shawaryghat, Foridabad, respectively, in the Buriganga in Pre monsoon which were greater than this study. Difference in concentration was possibly due to the difference in collection season, time, places, amount of wastage discharge and measurement method in different studies.



Note: Red and green colour indicate above and below DoE standard level respectively for water. Intensity of color is proportional to concentrations.

Fig. 2. Concentration of toxic heavy metals Cr, Cd, Pb, and Ni in μgL^{-1} at different locations of the whole reach of the Buriganga in dry season.

The Cd concentration of first location (Ishakha Badh) was 15.48 μgL^{-1} which indicates oncoming flow of Briganga severely Cd polluted (Table 2). The highest Cd concentration was 22.25 at Sadarghat and the lowest was 11.67 μgL^{-1} at Munshikhola that are far above the standard value as the standard value of Cd provided by WHO is 3 μgL^{-1} and Provided by DoE is 5 μgL^{-1}. However, different studies showed that variation in Cd concentration in Buriganga. For example Ahmed, *et al.* (2010) found that Cd concentration varied from 9.21 to 10.03 μgL^{-1} and Islam, *et al*. (2015) found 10 μgL^{-1} in Buriganga which are far below than this study. The Cd pollution mainly attributed by upstream flow and different Cd containing wastes and dockyard besides the Buriganga.

Bosila was the highest Pb contaminated site among the sites. The concentration of Pb fluctuated from 52.24 to 97.30 μgL^{-1} through the whole pathway of the Buriganaga (Ishakha Badh to Dharmaganj) which is approximately five to limit and one to two fold greater value provided by DoE (ECR, 1997). At the Ishakha Badh Pb concentration was 75.21 µgL^{-1} which represents upstream of the Buriganga contaminated by Pb containing many different industrial, agricultural

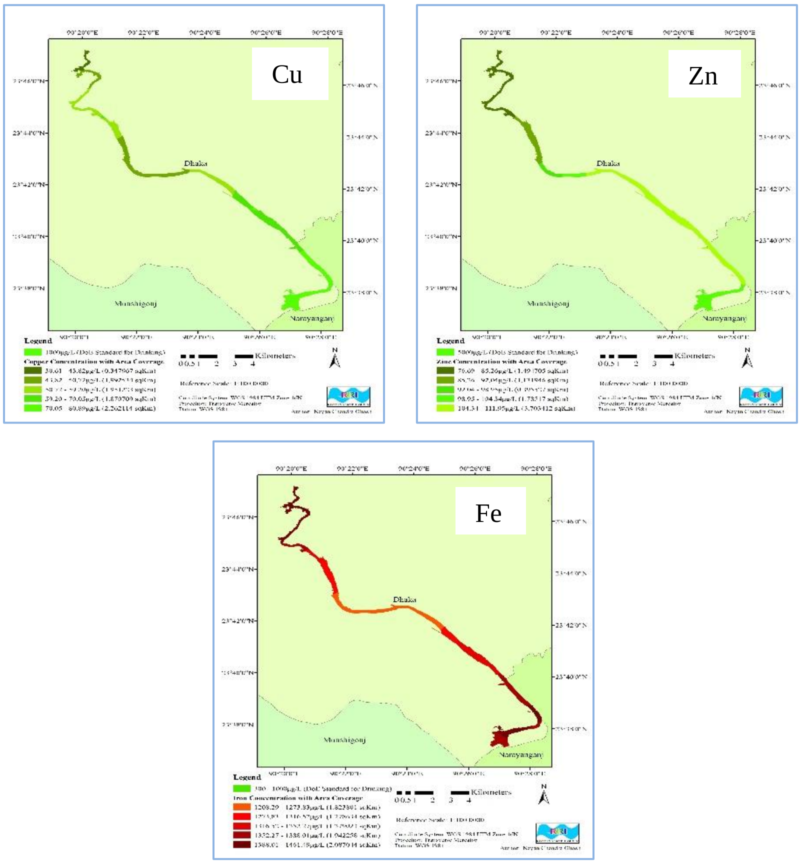
nine fold greater than WHO (2011) standard and domestic wastes. Similar findings were observed Ahmed, *et al.* (2010) in some places like Swaryghat, Gazirghat, Balughat in Buriganga in Pre-Monsoon.

Table 2. Level of heavy metals in µgL^{-1} in Buriganga River water at different locations in dry season

Site	Location	Cr	Cd	Pb	Ni	Fe	Zn	Cu
S1	Ishakha Badh	236.06	15.48	75.21	170.15	1601.27	58.75	58.79
S2	Amin Bazar	289.90	19.82	53.94	158.91	1706.23	70.33	54.30
S3	Adabor Sluice Gate	223.82	16.35	81.12	129.87	1461.91	73.15	54.07
S4	Bosila	314.36	18.77	97.30	158.40	1499.36	89.04	78.38
S5	Hazaribagh	282.46	13.42	84.23	135.69	1022.34	104.01	46.03
S6	Gazirghat	256.82	16.66	60.84	130.84	1507.68	61.93	44.57
S7	Kholamora Boat Ghat	285.50	14.74	83.10	146.74	1058.89	66.86	48.45
S8	Swaryghat	296.28	13.54	74.50	172.89	1219.73	141.69	68.18
S9	Babubazar Bridge	270.82	13.61	52.24	157.03	995.55	94.06	55.06
S10	Sadarghat	332.53	22.25	63.74	153.60	1166.57	98.98	54.22
S11	Mirerbag, Balighat	269.25	14.79	85.85	161.07	1216.96	111.77	49.73
S12	Postogola	346.76	18.83	74.01	155.75	1909.19	78.84	89.89
S13	Munshikhola	300.41	11.67	79.09	175.21	1273.56	151.48	62.18
S14	Pagla	324.14	21.83	68.02	182.14	1188.59	118.41	62.62
S15	Fatulla	262.72	13.06	42.87	135.40	1612.55	118.39	86.32
S1 6	Dharmaganj	334.61	16.87	79.16	208.15	1568.41	76.61	77.39

Table 3. Guideline value for heavy metals in µgL^{-1}set by different organizations for Drinking water, Irrigation water and Aquatic life Purposes

Parameter	Drinking water			Irrigation water	Aquatic Life
	WHO (2011)	DoE (ECR,1997)	CCME (2007)	FAO (1994)	CCME (2007)
Cr	50	50	50	100	0.02 µgL^{-1}, To protect fish 2.0 µgL^{-1}, To protect aquatic life including zooplankton and phytoplankton
Cd	3	5	5	10	0.2 µgL^{-1} for Hardness 0–60 mg/l ($CaCO_3$) 0.8 µgL^{-1} for Hardness 60–120 mg/l ($CaCO_3$) 1.3 µgL^{-1} for Hardness 120–180 mg/l ($CaCO_3$) 1.8 µgL^{-1} for Hardness > 180 mg/l ($CaCO_3$)
Cu	2000	1000	1000	200	2.0 µgL^{-1} for Hardness 0–120 mg/l ($CaCO_3$) 3.0 µgL^{-1} for Hardness 120–180 mg/l ($CaCO_3$) 4.0 µgL^{-1} for Hardness > 180 mg/l ($CaCO_3$)
Fe	300	300–1000	300	5000	300 µgL^{-1}
Pb	10	50	50	5000	1.0 µgL^{-1} for Hardness 0–60 mg/l ($CaCO_3$) 2.0 µgL^{-1} for Hardness 60–120 mg/l ($CaCO_3$) 4.0 µgL^{-1} for Hardness 120–180 mg/l ($CaCO_3$) 7.0 µgL^{-1} for Hardness > 180 mg/l ($CaCO_3$)
Ni	70	100	-	200	25 µgL^{-1} for Hardness 0–60 mg/l ($CaCO_3$) 65 µgL^{-1} for Hardness 60–120 mg/l ($CaCO_3$) 110 µgL^{-1} for Hardness 120–180 mg/l ($CaCO_3$) 150 µgL^{-1} for Hardness > 180 mg/l ($CaCO_3$)
Zn	-	5000	5000	2000	300 µgL^{-1}



Note: Red and green colour indicate above and below DoE standard level respectively for water. Intensity of color is proportional to concentrations.

Fig. 3. Level of Cu, Zn and Fe in μgL^{-1} at different locations of the whole reach of the Buriganga in dry season.

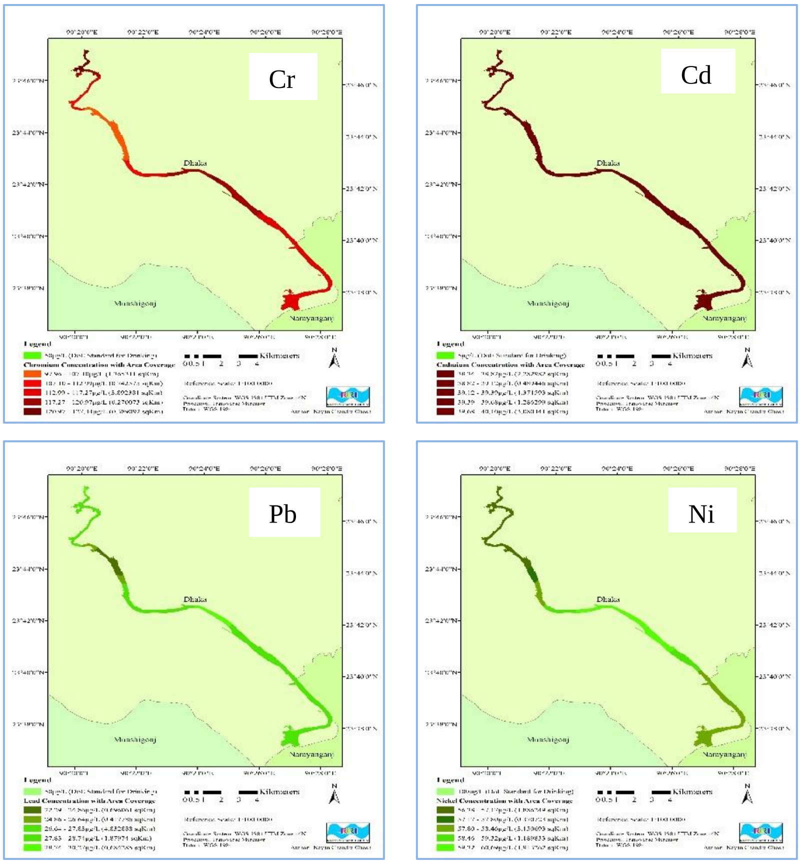
Concentration of Ni varied from 129.87 to 208.15 μgL^{-1} which are exceeded the recommended value provided by WHO (2011) and DoE (ECR, 1997). The highest level of Ni was found in Dharmaganj and it is likely because of several dockyards are present there. The higher level of Ni was also found in Ishakha Badh, Swaary ghat, Pagla and Dharmaganj indicating Ni containing industries such as alloys, stainless steel, batteries etc. are located around the places and discharging their wastes directly to the river. However, Ahmed, *et al*. (2010) observed far lower Ni concentration than this study in the Buriganga.

The surface water of the Buriganga was free from Cu and Zn pollution. Concentration of Cu varied from 44.57 to 89.89 μgL^{-1} and Zn varied from 58.75 to 151.48 μgL^{-1} which were lower that the recommended value provided by WHO (2011) and DoE (1997). Concentration of Cu at Swaryghat was 68.18 μgL^{-1} whereas Ahmed, *et al.* (2010) observed that Cu concentration was 132.18 μgL^{-1} at Swaryghat in Pre monsoon.

The concentration of Fe was fluctuated at different locations and varied from 995.55 to 1909.19 μgL^{-1}. The standard value provided by DoE (ECR, 1997) is 300 to 1000 μgL^{-1} for drinking water and 300 μgL^{-1} for aquatic life (CCME, 2007) which is lower than the values found in this study indicating iron pollution occurs. However, Fe concentration was much lower than this study observed by Sikder, *et al.* 2012. In this study, the higher level of Fe in Postogola, Fatulla and Dharmaganj is attributed by water vehicle and dockyard. Similarly, the greater Fe level in Ishakha Badh, Amin Bazar and Basila is also likely as Fe discharging metal industries such as the iron pipes, stailless still and water vehicle are available surroundings of these locations.

The concentration of Cr, Cd, Pb, Ni, Zn, Cu, and Fe showed a wide variation of concentration among the metals but slightly differed among the locations of the river (Table 2). The concentration of metals was significantly differed among them ($P < 0.001$) and was found in order of Fe> Cr > Ni > Zn > Pb > Cu > Cd. Among the investigated metals, Cr, Cd, Pb and Ni which are very toxic, exceeded the standard levels provided by WHO (2011), DoE (ECR, 1997) and CCME (2007) in all locations of the river. This findings may be related to the adsorption of the heavy metals by metal oxides or hydroxides. Major sources of these elements in river water include industrial wastes, tanneries, manufacturing processes related to chemicals and metals, contamination of water in natural geologic deposits, discharges of municipal waste, domestic wastes and atmospheric deposition.

Seasonal variation of metals

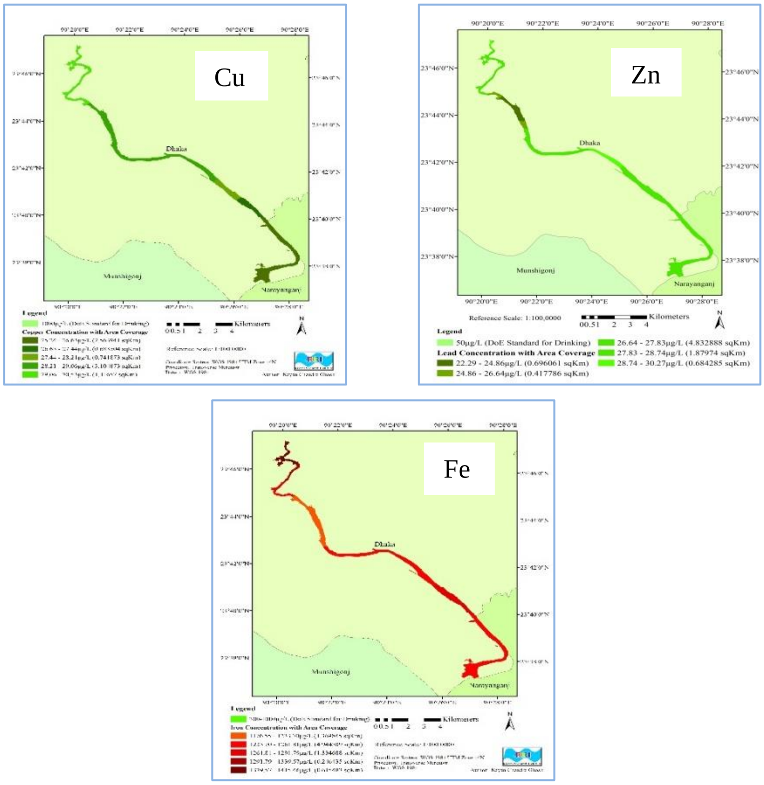


Note: Red and green indicate above and below DoE standard level respectively for water. Intensity of color is proportional to concentrations.

Fig. 4. Concentration of toxic metals Cr, Cd, Pb, and Ni in μgL^{-1} at different locations of the whole reach of the Buriganga in post rainy season.

Concentrations of heavy metals were greater in dry season compared to post rainy season (Table 2 and Table 4). The lower concentration of metals in post rainy season was because of dilution of water due to influx of rain water and flood water from surrounding areas. The dilution during higher water flow washed away much of the pollutants and decreased the concentration.

The reason could be that, during the monsoon season, polluted sediment particles may be suspended in the bottom sediment layer, which could lead to lower concentrations of heavy metals. Most of the suspended materials, which were not complex and precipitated with soil, organic matter and other compounds, were flushed out through the canal into the adjoining vast flood zone. However, the concentration of Cr, Cd and Fe were far above than the standard level provided by WHO and DoE in post rainy season. The level of Cr varied from 262.72 to 332.53 μgL^{-1} in dry season whereas 97.49 to 127.70μgL^{-1} in post rainy season. Concentration of Cr in dry season was significantly different ($P < 0.05$) than that of post rainy season. Even though Cr concentration was much lower in post rainy season than the dry season, it was approximately double than the standard level provided by WHO and DoE. The concentration of Cr at Amin Bazar, Hazaribagh, Sadarghat and Fatulla was 289.90, 282.46, 332.53 and 262.72 μgL^{-1}, respectively in dry season whereas 127.70, 97.49, 121.22 and 116.60 μgL^{-1} in post rainy season at same places. The levels of Pb, Ni, Cu and Zn were below the than the standard level provided by WHO and DoE (Fig. 4, Fig. 5 and Table 3). It is remarkable that the level of Cd is greater in post rainy season compared to the dry season. The lower concentration of the Cd in dry season also observed Islam et.al. (2015). Deviations of the results could be attributed to site-specific activities, source of waste and the flow of the river.



Note: Red and green indicate above and below DoE standard respectively for water.

Fig. 5. Level of Cu, Zn and Fe in μgL^{-1} at different locations of the Buriganga in post rainy season.

Table 4. Concentration of metals in μgL^{-1} in the water of Buriganga River in post rainy season

Season	Location	Cr	Cd	Pb	Ni	Fe	Zn	Cu
Post rainy	Amin Bazar	127.70	39.28	28.94	56.37	1418.59	38.12	34.29
	Hazaribagh	97.49	39.75	21.97	56.72	1174.02	41.99	24.75
	Sadarghat	121.22	40.12	30.47	60.75	1249.41	43.60	33.23
	Fatulla	116.60	38.33	28.67	57.87	1239.97	34.97	21.19

In post rainy season, two toxic metals Cr and Cd were found in significant amount throughout the river in this study (Fig. 4). As heavy metals are non-degradable and not decomposable it is likely to be present with the flow of water in post rainy season. During July to November rivers are full of water in Dhaka and generally the water seems good in terms of odor and color. Therefore, it is very disquieting that the river water is polluted by Cr and Cd during this period too and these two toxic metals still prevailing into the aquatic environment.

Conclusions

The present investigation demonstrates that the whole stretch of the Buriganga River is harshly contaminated by toxic heavy metals. At all 16 sites, the surface water of the Buriganga is severely polluted by metals except Cu and Zn in dry season. At the commencing point of the Buriganga, the concentration of Cr, Cd, Pb, Ni and Fe are far above level recommended by DoE (ECR, 1997) and WHO (2011) indicating the river pollution is largely dependent on the upstream river flow. Among these metals Cr, Cd, Pb and Ni toxicity are severe in the water possibly due to the discharge of high amount of these metals concentrated wastewater from industries and from surface runoff. Moreover, the level of heavy metal is lower in the post rainy season compared to the dry season perhaps due to the dilution of water and river flow. However, even though the concentration has decreased in the post rainy season some noxious heavy metals like Cr and Cd are two to five times greater than the safe recommended values. As heavy metals are non-biodegradable and not decomposable the high level of metals occurs at points are far from the source of pollution with the flow of water.

Bangladesh government has taken initiatives to reduce pollution and to increase navigation facility in dry season in the Buriganga through different projects. Flow of water would increase in dry season and the tannery industries are moving from Hazaribagh to Saver through these projects. However, this study shows that heavy metal pollution continues in post rainy season too with the increase of water flow. Moreover, the metals are easily moving with flow from upstream to downstream throughout the river and would move in to the other rivers as all rivers are interlinked in Dhaka. Therefore, it is mandatory to stop disposal of toxic metal containing wastes to rivers to protect Dhaka from pollutions otherwise any project wouldn't be successful. The enforcement of laws is very urgent to protect riverine ecosystem of Dhaka and should be achieved at any cost otherwise the situation in near future might be further worsened with the continuing development of industries.

References

Ahmad, M. K., Islam, S., Rahman, S., Haque, M. R. and Islam, M. M. (2010). Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. *Int. J. Environ. Res*. 4: 321–332.

Afrin, R., Mia, M. Y. and Akter, S. (2014). Investigation of Heavy Metals (Pb, Cd, Cr, Cu, Hg and Fe) of the Turag River in Bangladesh. *J. Environ. Sci. & Natural Resources*. 7(2): 133–136.

Ali, M.Y., Amin, M.N. and Alam, K. (2008). Ecological Health Risk of Buriganga River, Dhaka, Bangladesh. *Hydro Nepal J. Water Energy Environ*. 3: 25–28.

Barton, C. *Bangladesh's deadly leather industry.* A news report [Online]. Available: http:// thestar.com.my/lifestyle/story.asp? file=/2011/3/8/lifefocus/8094926&sec=lifefo [Accessed 8 March 2011].

Bhuiyan, M.A., Rakib, M.A., Dampare, S.B., Ganyaglo, S. and Suzuki, S. (2011). Surface water quality assessment in the central part of Bangladesh using multivariate analysis. *KSCE J. Civ. Eng.* 15: 995–1003.

CCME (2007). For the protection of aquatic life. In: *Canadian environmental quality guidelines, 1999*, Canadian Council of Ministers of the Environment (CCME), 1999, Winnipeg.

DoE (ECR, 1997)). ECR-Schedule-3 to 14. Bangladesh Gazette, Department of Environment (DoE), Government of the People's Republic of Bangladesh. SRO 197-Law/97: 3124-3145.

Ghrefat, H.A. and Yusuf, N. (2006). Assessing Mn, Fe, Cu, Zn and Cd pollution in bottom sediments of Wadi Al-Arab dam, Jordan. *Chemosphere.* 65(11): 2114- 2121. doi:10.1016/j.chemosphere.

Hasan, M. K., Happy, M. A., Nesha, M., Karimon, K. H. and Karim, R. (2014). Pollution status of Balu River due to industrial input at Dhaka, Bangladesh. *Open journal of water pollution and treatment*. 1 (1): 34-42. DOI: 10.15764/WPT.2014.01004.

Islam, M.M., Akhtar, M.K. and Masud, M.S. (2006). 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*.

Islam, M.S., Uddin M.K., Tareq, S.M., Shammi, M., Kamal, A.K.I., Sugano, T., Kurasaki, M., Saito, T., Tanaka, S. and Kuramitz, H. (2015). Alteration of water pollution level with the seasonal changes in mean daily discharge in three main rivers around Dhaka city, Bangladesh. *Environments*. 2: 280–294; doi: 10.3390/environments2030280.

Mahfuza, S.S., Kulsum, U., Shakila, A. and Islam, M.S. (2012). Toxic metal contamination on the river near industrial area of Dhaka. *Univers. j. environ. res. technol*. 2 (2): 56-64.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. and Sutton, D.J. (2012). Heavy Metal Toxicity and the Environment. *Molecular, Clinical and Environmental Toxicology*. 101: 133–164. doi: 10.1007/978-3-7643-8340-4_6

Pehlivan, E., Ozkan, A.M., Dinc, S. and Parlayici, S. (2009). Adsorption of Cu^{2+} and Pb^{2+} ion on dolomite powder. *J. Hazard. Mater*. 167 (1–3): 1044–1049.

Sikder, M.T., Yasuda, M., Yustiawati, Syawal, M.S., Saito, T., Tanaka, S. and Kurasaki, M. (2012). Comparative assessment of water quality in the major rivers of Dhaka and West Java. *Int. J. Environ. Protec.* 2: 8–13.

Tilzer, M.M. and Khondker, M. (1993). *Hypertrophic and polluted freshwater ecosystems: Ecological basis for water resource management*. Dept. of Botany, University of Dhaka, Bangladesh.

WHO, (World Health Organization), (2011). Guidelines for drinking water quality-1, recommendations. World Health Organization, Geneva, 4th edition.

Zahid, A., Balke, K.D., Hassan, M.Q. and Flegr, M. (2004). Evaluation of aquifer environment under Hazaribagh leather processing zone of Dhaka city. *Environ. Geol.* 50: 495-504.