Available online at www.banglajol.info

Bangladesh J. Sci. Ind. Res. **50(2)**, 123-134, 2015

BCSIR

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Study of hydrochemistry and pollution status of the Buriganga river, Bangladesh

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Abstract

The hydrochemistry and pollution status of tannery effluent as well as the Buriganga River were studied. The water quality parameters namely temperature, pH, salinity, TDS, EC, DO, COD, Cr, Cd, Ni, Cu and Zn of tannery effluent were 22.8-31.5 ^oC, 7.4-10.6, 3920-6280 mg/l, 4680-7220 mg/l, 7070-10810 µs, 0.3-1.1 mg/l, 1020-3800 mg/l, 7.7656 mg/l, 0.0198 mg/l, 0.2070 mg/l, 0.0304 mg/l and 0.3021 mg/l, respectively whereas in water of the Buriganga River were 22.0-31.6 ^oC, 6.2-7.8, 69-642 mg/l, 97-871 mg/l, 146-1309 µs, 1.1-4.1 mg/l, 140-800 mg/l, 0.0306-0.2163 mg/l, 0.0018-0.0162 mg/l, 0.0663-0.2486 mg/l, 0.0112-0.0238 mg/l and 0.0878-0.2948 mg/l, respectively. According to the statistical analysis Salinity, EC, TDS, COD, Cr, Cd, Cu and Zn show positive correlations with each other and negative correlations with Temp. and DO. Ecological risk factor shows that Cr is the highest risk metal for ecosystem. The hydrochemistry has been revealed that the water is not safe for aquatic lives.

Keywords: Water quality parameters; Toxic metal; Aquatic lives; Ecosystem; Correlation; Risk assessment

Introduction

Water is one of the vital elements in the earth has a strong correlation between water and all kinds of life. Now-a-days worldwide, fresh water is the most concern. Bangladesh is not out of them. Bangladesh is the delta of the world with its 230 Rivers has flown all over the country like a net. These Rivers are the major source of surface water supply which is used in drinking, household, irrigation and industrial purposes. Most in the cases, all over the world, urbanization and industrial development has been performed by River or sea based. Therefore, surface water is most vulnerable to pollution due to its easy accessibility for disposal of municipal, industrial and different kinds of wastewater (Islam *et al.,* 2015). As a carrier of industrial and municipal wastage the Buriganga River has been running across the southern part of Dhaka is now going to be biologically death.

Tannery industry is one of the most potentially pollution causing industry for the Buriganga River as it process raw skin by chrome tanning. Tannery effluent contain hexavalent chromium is the potential carcinogenic and mutagenic source (Saranraj and Sujitha, 2013). Beside this raw wastes containing different types of toxic chemicals and heavy metals like cadmium, zinc, arsenic etc. discharged on street, sewers as well as in drain and finally mixed with surface and ground water. By consumption and using this polluted water the marginal people who are leaving on the bank of the Buriganga River especially children facing different types of water borne diseases, viz. skin sore, irritation in respiratory tract (Sultana *et al.,* 2009), typhoid, dysentery, cholera, viral hepatitis etc. and loss their life. Dhaka water supply authority (DWASA) is only the responsible body to supply the drinking water for about 15 millions of city dwellers. About 75% of the current demand has been provided of which only 22% comes from surface water treatment. But ground water level has declined at an alarming rate over the last couple of decades. Therefore, Earth has no alternative to utilize the surface water and recently, the Government of People's Republic of Bangladesh divulged their attempt for increasing rate of surface water use.

The Buriganga originated from Dholeshwori near kalatia flows through Dhaka**.** It is one of the most polluted River in Bangladesh as well as in the south Asia. Everyday huge amount of untreated agricultural, household, industrial, municipal, hospital and transportation wastes have been discharging into the Buriganga. Up to 40,000 tons of tannery waste has been flown into the Rivers daily along with sewage from Dhaka (Anonymous, 2003). It is a city of more than15 million people and human waste is responsible for 60% of pollution in the River, industrial

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waste of 30% and the rest is solid waste. The ecosystem of the Buriganga is now going to be demolished. Thus the Buriganga River is now biologically lamb and its water is flabby for safe using of industrial, household, irrigation and drinking purposes. Some previous studies investigated the concentration of heavy metal in water, sediment and some fishes (Ahmad *et al*., 2010), Shah and Hossain, (2011) observed the heavy metal concentration in the Buriganga River. However, there is no vast work by establishing correlation among the sources of pollution and the distribution of hazardous materials beneath the Buriganga River has been performed yet. But the assessment of physicochemical water quality parameters plays an important role to classify the water quality (Sahin *et al*., 2014), hydrochemistry and ecology. The assessment of water quality evaluation is very much necessary for safe and sound health, environment and ecosystem.

This study depicts the pollution level of the Buriganga by Hazaribag tannery effluent. By observing the pollution level it has been tried to explain the source of pollution and the effects of pollution. Moreover, in this study the pollution effect of tannery effluent in the Buriganga River is observed with increasing distance and after that a statistical correlation is drawn among the Temp., pH. Salinity, conductivity, EC, TDS, DO, COD as well as Cr, Cd, Cu, Ni and Zn. Finally, we have tried to assess the ecological risks for the existent concentrations of toxic metals. Therefore, it could be a fruitful attempt to understand the correlation among water quality parameters with increasing distance and the hydrochemistry of the Buriganga River.

Materials and methods

Sampling

The water samples from the Buriganga River were collected for physicochemical parameters from 60 cm and for heavy metals from 2.5 meters deep from surface by grab method (Alam *et al.,* 2012). The samples are collected form 100 ± 5 m inner from the bank. For collecting sample from different selected stations 500 ml non-transparent plastic bottles were used. First, the bottles were washed by detergent solution and after that these were treated with 2% (v/v) nitric acid solution overnight and finally, washed with deionized water. After that the sample bottles have been dried in the air. During sampling the prior marked sample bottles were washed with sampling water and tightly screwed after sample collection. The samples were collected from the tannery effluent drain and from the River. After collection of sample, DO and pH were observed in the spot. Finally, they were carefully carried to laboratory by ice carrier and preserve in a refrigerator to prevent microbial decomposition of organic and inorganic materials present in the sample water. The samples were taken to the normal temperature before analysis.

Sampling stations

Four sampling stations were Kawtail (Br-1), Postagola (Br-2), Sodorghat (Br-3), Modinanagar (Br-4). Fifth one was from the tannery effluent drain (Br-5) at Hazaribagh which discharged into the Buriganga River without any treatment. All the sampling stations are shown in **Fig. 1.** The distance of other stations from Hazaribagh is shown in **Table I**.

Table I. Distance from Hazaribagh (Br-5) to other sampling stations

Sampling Stations	Distance from Hazaribagh (Br-5) Km
Modinanagar (Br-4)	2.0
Sodorghat (Br-3)	12.5
Postagola (Br-2)	16.0
Kawtail (Br-1)	24.5

Sample analysis

Samples were analyzed in the Inorganic Research laboratory, Department of Chemistry, Jagannath University. The salinity, conductivity, TDS, pH and DO were measured instrumentally. Salinity, EC and TDS were measured by 'CTS-406K' model meter, Taiwan, pH was measured by 'Twin, B-221' pH meter by Horiba, Japan and DO was measured by 'YK-22' model meter, Taiwan. COD was measured by condensation and potassium dichromate oxidation. All reagents were purchase from Merck, Analytical Grade (AR), Germany. Toxic metal concentrations were determined by 'SHIMADZU, AA-7000' model atomic absorption spectrometer. A high precision electrical balance 'KERN, ABS 220-4' was used for weighing. For toxic metal concentration determination samples were preconcentrated and then the sample was filtered through a nylon membrane filter (Whatman, pore size 0.8 μm, diam. 47 mm).

For toxic metal analysis an aliquot of 100 ml of each sample was taken into a 100 ml of pyrex volumetric flask. Then 1 M concentrated HCl (9 ml) was added followed by 1 M concentrated HNO_3 (3 ml). The content of the volumetric flask was carefully heated in sand bath nearly to dryness in fume hood. After cooling the volumetric flask at room temperature, deionized water was added to the sample up to the mark of flask. Then, the sample was filtered and the filtrate was collected in a 250 ml screw cap plastic bottle (Type- HDPE container, LDPE-lined polypropylene cap, Brand-Thermo scientific). Finally, they were preserved for the determination of metal concentration. The AAS was calibrated for all the metals by running different concentration of standard solutions. Average value of three replicates was taken for each data. The detection limit was 0.003 mg/l. Metal concentrations were measured using 'GAF-7000' furnace.

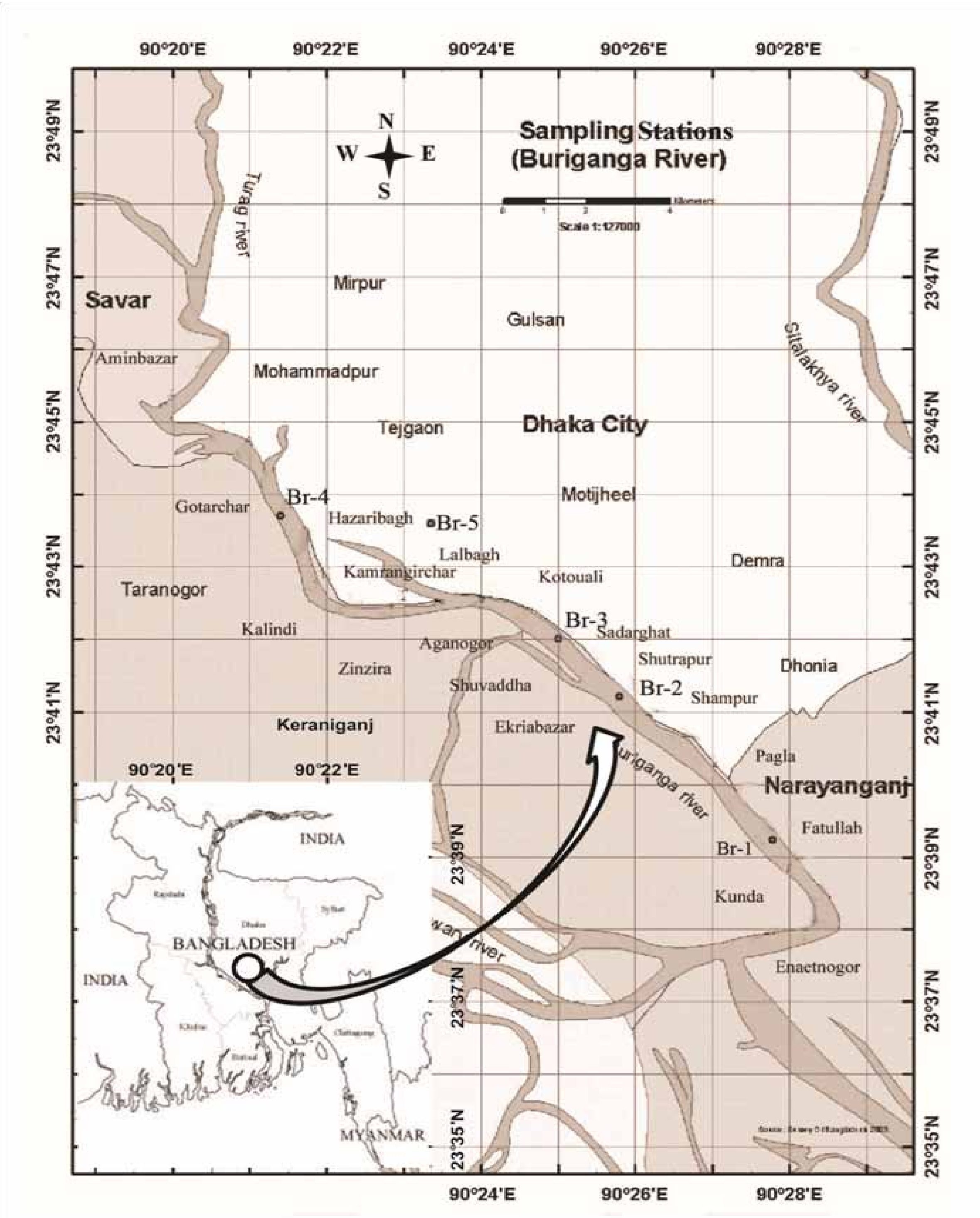

Fig. 1. Sampling stations of the Buriganga River

Statistical Analysis

Mean and standard deviation (SD) were computed to show the average behavior of the parameters and their dispersions. Pearson's correlation (r) represented the association among the parameters as well as between parameters and distance of sampling stations from the tannery area. One way Analysis of variance (ANOVA) test was used to show the equality of mean values of the water quality parameters. For further quest, Post Hoc Test, Duncun Multiple Range Test (DMRT) in particular, was performed to prevail extent of variations among the means by grouping the means into subgroups. All statistical analysis was performed with SPSS (16.0 version) software.

Results and discussion

To observe the pollution level of Hazaribagh tannery effluent as well as in water of the Buriganga River, some water quality parameters were measured bimonthly from October, 2012 to August, 2013. Observed data has been tabulated in Table II. Throughout the study period the color of water was dark and acrid in smell. Descriptive statistics including the maximum, minimum, mean and standard deviation values for the Buriganga River water and Hazaribagh tannery effluent are charted in Tables III. Water quality parameters revealed significant correlation with a strong affinity with each other shown in Table IV which indicates the significance of one parameter to predict the other (Davis, 1986).

Water quality parameters

Water temperature is an important parameter in assessing the water environment. The water temperature plays a profound impact on the chemical, physicochemical characteristics of water body (Simpi *et al.***,** 2011). Table II shows that the temperature varied from 22.8 to 31.5 ^{o}C in tannery effluent and 22.0 to 31.6 ^{o}C in water of the Buriganga River. It shows insignificant positive correlations ($P < 0.01$) with salinity, TDS and DO as r = 0.023, 0.018 and 0.167 and insignificant negative correlations with pH, EC and COD as r = -0.15, -0.005 and -0.187, respectively. During June, 2012 Br-1 shows the higher temperature (31.6 ^{o}C). The reason of higher temperature is a result of meteorological fact and solar radiation. Beside this, there are many mills and factories constructed in the both bank of Buriganga River and use Buriganga's water for the cooling purposes in different steps of manufacturing of their products. After cooling operations, they are draining out their effluents into the Buriganga River which increases the Temperature. The water of Buriganga River was dark in color and turbid. More heat content captured by turbid water than clean water which is another reason of increasing temperature (Mandal *et al.,* 2012).

pH varied from 7.4 to 10.6 in tannery effluent and 6.2 to 7.8 in water of the Buriganga River. It shows significant positive correlations ($P < 0.01$) with salinity, TDS, EC and COD as r = 0.595, 0.606, 0.625 and 0.603 and a negative correlation with DO as r = -0.674. Br-5 shows higher pH resulted from tannery industries effluent discharged without any treatment. pH is an important parameter for assessing the water quality. The organism which can persist in a specific pH level cannot adapt with slight pH variation (Mandal *et al.,* 2012). Photosynthesis quantity of water body depends on the pH value of water. By the decrease of photosynthesis rate the incorporation of carbon dioxide and bicarbonates is increases which are eventually responsible for increase in pH (Simpi *et al., 2011*)**.**

Salinity varied from 3920 to 6280 mg/l in tannery effluent and 69 to 642 mg/l in water of the Buriganga River which shows significant positive correlations ($P < 0.01$) with pH, TDS, EC and COD as r = 0.595, 1.0, 0.997 and 0.832 and a negative correlation with DO as r = -0.742. Br-4 shows the higher salt content (642 mg/l) resulted from the untreated tannery effluent. Beside this residuals pesticide and fertilizer used by farmer in their crop land are washed out through rain and increasing the saline content in the Buriganga River water. A study (Ahmed *et al.,* 2011) observed only 0.56 mg/l saline content in Buriganga. Higher saline content water also affects the soil construction, permeability and aeration which affect the growth of seedlings (Rao**,** 2006)**.** Various species of fish cannot get suitable environment for reproduction in high concentrated saline water. Therefore, fish diversity decline at an alarming rate which affect on biodiversity that correlated with ecosystem (Sengupta, 2001) as well as human food chain. High saline content drinking water has a detrimental effect on the blood pressure, kidney as well as menstrual process of women.

TDS varied from 4680 to 7220 mg/l in tannery effluent and 97 to 871 mg/l in water of the Buriganga River. It shows significant positive correlations ($P < 0.01$) with pH, salinity, EC and COD as r = 0.606, 1.0, 0.997 and 0.832 and a negative correlation with DO as r = -0.754. TDS is the measure of dissolve matter (Organic matter and inorganic salt) in water. Br-4 shows the higher value of TDS (871 mg/l) as a result of tannery effluent is discharged without treatment into the Buriganga River near this station. The increase of TDS from its permissible limit (1000 mg/l) make the water more turbid (Tabata *et al.,* 2007; Srivastava and Sinha, 1996) and saline that has a detrimental effect on aquatic lives (Simpi *et al.,* 2011) which has ultimate effect on crop, livestock and human. TDS value in Buriganga observed almost same (789 mg/l) in the study period that recorded by Hasan *et al.,* (2009).

Table II. water quality parameters of the Buriganga River from October, 2012 to Augast, 2013

	Stations	Temp °C	P^H	Salinity mg/L	TDS mg/L	EC µs	DO mg/L	COD mg/L
October	Br-1	28.6	7.0	72	100	150	4.1	180
	Br-2	29	7.2	71	98	148	3.6	260
	Br-3	26.9	7.2	95	132	200	3.6	220
	Br-4	29.2	7.2	80	111	167	3.3	460
	Br-5	31.5	10.6	3920	4680	7070	0.3	1260
December	Br-1	26.6	7.5	295	410	615	2.7	340
	Br-2	22.0	7.7	307	428	642	2.6	400
	Br-3	22.5	7.5	268	373	562	1.6	560
	Br-4	22.5	7.5	263	366	549	2.8	460
	Br-5	22.8	10.2	4060	4820	8250	0.5	3460
February	Br-1	22.5	7.7	446	620	933	1.7	480
	Br-2	22.8	7.5	597	814	1223	1.6	560
	Br-3	23.3	7.6	592	806	1210	1.1	800
	Br-4	24.8	7.7	642	871	1309	1.5	620
	Br-5	24.0	7.4	4890	5720	8580	0.3	3800
April	Br-1	31.2	7.7	309	430	644	1.8	260
	Br-2	31.1	7.8	510	694	1042	1.5	460
	Br-3	30.8	7.5	560	764	1150	1.3	760
	Br-4	29.7	7.8	603	820	1231	1.9	580
	Br-5	27.7	8.6	4710	5500	7960	0.3	3340
June	Br-1	31.6	6.9	272	378	566	2.6	140
	Br-2	31.3	6.7	264	367	551	2.8	200
	Br-3	30.7	6.7	268	373	561	2.1	200
	Br-4	30.4	6.8	259	360	540	2.7	380
	Br-5	30.3	8.8	4430	5290	7230	0.6	2940
August	Br-1	29.6	7.2	72	100	151	3.4	180
	Br-2	29.6	7.2	69	97	146	3.7	220
	Br-3	29.5	7.0	71	98	148	3.1	260
	Br-4	30.9	6.9	96	134	202	3.2	280
	Br-5	30.3	7.4	6280	7220	10810	1.1	1020

**Br-1= Kawtail, Br-2= Postogola, Br-3= Sadarghat, Br-4= Modinanagar, Br-5= Hazaribagh tannery effluent

Table III. Descriptive Statistics of the water quality parameters in the Buriganga River

Paramete	N	Minimun	Maximum	Mear	Std. Deviation
Temp.	30	22.00	31.60	27.86	3.442
P^H	30	6.20	10.60	7.59	0.922
Salinity	30	69.00	6280	1179.03	1841.208
TDS	30	97.00	7220.00	1432.47	2135.914
EC	30	146.00	10810.00	2151.33	3205.849
DO	30	0.30	4.10	2.11	1.134
COD	30	140.00	3800.00	836.00	1054.794

Table IV. Correlation matrix among water quality parameters in the Buriganga River

Parameters	Temp.	P^H	Salinity	TDS	EC	DO	COD
Temp.	1						
P^H	-0.150	1					
Salinity	0.023	0.595**	1				
TDS	0.018	0.606**	1.000**	1			
EC	-0.005	0.625**	0.997**	0.997**	1		
DO	0.167	-0.674**	-0.742**	-0.754**	-0.755**	1	
COD	-0.187	0.603**	0.827**	0.832**	0.836**	-0.735**	1

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

EC varied from 7070 to 10810 µs in tannery effluent and 146 to 1309 µs in water of the Buriganga River. It shows significantly positive correlations ($P < 0.01$) with pH, salinity, TDS and COD as r = 0.625, 0.997, 0.997 and 0.836 and a negative correlation with DO as r = -0.755. Br-4 shows the higher value of EC (1309 µs) resulted from untreated tannery effluent. EC is an important water quality parameter. According to FAO, the value of EC of a water body greater than 1000 mg/l is not suitable for agricultural, household, bathing, industrial and drinking purpose. EC increases due to the discharge of tannery effluent and metal plating industries. There are a number of ship repairing workshop developed in the bank of the Buriganga and discharging different heavy metals which is a potential source of EC. Textile and dyeing industries also discharge heavy metals. Chromium mixed into River from pottery industry which constructed near Br-2. Beside this fertilizer and pesticide residue washed out into the water body which increases the EC.

DO varied from 0.3 to 1.1 mg/l in tannery effluent and 1.1 to 4.1 mg/l in water of the Buriganga River. It shows significantly negative correlations ($P < 0.01$) with pH, salinity, TDS, EC and COD as r = -0.674, -0.742, -0.754, -0.755 and -0.735, respectively. DO is very essential for the aquatic life. It correlates with water body by giving direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. (Vikal, 2009). DO value declines rapidly by the presence of biodegradable wastes from industrial and domestic sources by stimulating the growth of micro-organisms in the water body. Br-3 shows lower value of DO (1.1 mg/l) during February, 2013 because of higher micro-organisms grown in lower level stagnant water at this dry season. Br-3 sampling station is also a BIWTA launch terminal. Therefore, every day a large number of launches anchor at this terminal and are discharging their untreated oil and passengers wastes. Beside this there is a fruit and vegetables market situated near this station and huge numbers of rotten fruits as well as vegetables are discharged into this point. It is suitable for growing micro-organism which consumes the dissolve oxygen from water body thereby declines the DO value at this station.

COD is an important parameter for assessing the water quality. Higher COD value refers to the higher organic pollutants. In this study, COD varied from 1020 to 3800 mg/l in tannery effluent and 140 to 800 mg/l in water of the Buriganga River. It shows significantly positive correlations ($P < 0.01$) with pH, salinity, TDS and EC as r = 0.603, 0.827, 0.832 and 0.836 and a negative correlation with DO as r = -0.735. The household and industrial wastages are drained into the River which stimulates the micro-organisms growth and thereby increasing the COD value in the water body. Br-3 shows higher value of COD (800 mg/l) during February, 2013 resulted from higher micro-organisms grown in lower level stagnant water at this dry season. Br-3 is a BIWTA

Table V. DMRT for sample collection time

Sample collection time	Temperature	DO
	Mean±SD	Mean±SD
October, 2012	29.04±1.65[b]	2.98±1.53[a]
December, 2012	23.28±1.88[c]	2.04±0.99[ab]
February, 2013	23.48±0.93[c]	1.24±0.57[b]
April, 2013	30.50±0.74[ab]	1.36±0.64[b]
June, 2013	30.86±0.57[a]	2.16±0.91[ab]
August, 2013	29.98±0.61[ab]	2.90±1.03[a]

**Means containing the same letters do not differ significantly at 0.05 level of significance DMRT = Duncun Multiple Range Test , DO = dissolved oxygen, SD = Standard deviation,

Table VI. DMRT for sample collection stations

Stations	p^H	Salinity	TDS	EC	DO	COD
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Br-1	7.33±0.35[b]	244.33±146.68[b]	339.67±203.98[b]	509.83±439.83[b]	2.72±0.92[a]	263.33±128.01[b]
Br-2	7.35±0.40[b]	303.00±218.82[b]	416.33±297.02[b]	625.33±445.92[b]	2.63±0.94[a]	350.00±145.74[b]
Br-3	7.25±0.35[b]	309.00±223.11[b]	424.33±302.74[b]	638.50±454.53[b]	2.13±1.01[a]	466.67±275.87[b]
Br-4	7.20±0.61[b]	323.83±244.31[b]	443.67±329.80[b]	666.33±495.29[b]	2.57±0.72[a]	463.33±125.49[b]
Br-5	8.83±1.35[a]	4715.00±851.14[a]	5538.33±913.99[a]	8315.67±1352.98[a]	0.52±0.31[b]	2636.67±1193.88[a]

**Means containing the same letters do not differ significantly at 0.05 level of significance, DMRT= Duncun Multiple Range Test TDS= Total dissolved solids, EC= Electrcal conductivity, DO= Dissolved oxygen, COD= Chemical oxygen demand, SD= Standard deviation.

Table VII. Metal concentration in the Buriganga River water during June, 2013

Stations	Cr in mg/l	Cd in mg/l	Ni in mg/l	Cu in mg/l	Zn in mg/l
Br-1	0.0306	0.0018	0.0663	0.0112	0.1471
Br-2	0.2163	0.0148	0.2294	0.0142	0.0878
Br-3	0.1430	0.0162	0.2486	0.0238	0.1544
Br-4	0.0453	0.0090	0.0834	0.0160	0.2948
Br-5	7.7656	0.0198	0.2070	0.0304	0.3021

Table VIII. Descriptive Statistics of the metal concentration in the Buriganga River water

Metal	N	Min.	Max.	Mean	Std. Deviation
Cr	5	30.60	7765.60	1640.1000	3425.09487
Cd	5	1.80	19.80	12.3200	7.05067
Ni	5	66.30	248.60	166.9400	85.55956
Cu	5	11.20	30.40	19.1200	7.83913
Zn	5	87.80	302.10	197.2400	95.96871

**Min.= Minimum, Max. = Maximum, Std. = Standard.

Table IX . Correlation matrix among toxic metals in the Buriganga River

Metal	Cr	Cd	Ni	Cu	Zn
Cr	1				
Cd	0.608**	1			
Ni	0.281	0.873**	1		
Cu	0.808**	0.832**	0.591**	1	
Zn	0.599**	0.203	-0.281	0.536**	1

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

Table X. Correlation matrix among water quality parameters and toxic metals in the Buriganga River

Parameters	Cr	Cd	Ni	Cu	Zn	Temp.	p^H	Salinity	TDS	EC	DO	COD
Cr	1											
Cd	0.608**	1										
Ni	0.281	0.873**	1									
Cu	0.808**	0.832**	0.591**	1								
Zn	0.599**	0.203	-0.281	0.536**	1							
Temp.	-0.549**	-0.622**	-0.227	-0.766**	-0.834**	1						
p^H	0.994**	0.517**	0.179	0.764**	0.630**	-0.520**	1					
Salinity	1.000**	0.592**	0.262	0.804**	0.610**	-0.549**	0.996**	1				
TDS	1.000**	0.592**	0.262	0.804**	0.609**	-0.549**	0.996**	1.000**	1			
EC	1.000**	0.592**	0.262	0.804**	0.609**	-0.549**	0.996**	1.000**	1.000**	1		
DO	-0.955**	-0.650**	-0.374	-0.915**	-0.572**	0.599**	-0.944**	-0.956**	-0.956**	-0.956**	1	
COD	0.997**	0.599**	0.242	0.809**	0.660**	-0.601**	0.992**	0.997**	0.997**	0.997**	-0.947**	1

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

launch terminal. Therefore, every day a large number of launches anchor at this station and are discharging their untreated oil and passengers wastes. Beside this there is a fruit and vegetables market situated near this station and huge numbers of rotten fruits as well as vegetables are discharged into this station. Also untreated sewerage lines meet from both sides of the River at this point. Thus COD shows higher value at this station.

Seasonal variation of water quality parameters was analyzed by Analysis of Variance (ANOVA). Table V shows that only temp. and DO are seasonally variable parameters ($p < 0.05$). Rest of the parameters like pH, Salinity, TDS, EC and COD did not vary over seasons ($p < 0.05$).

Results from ANOVA shows the water quality parameters in different sample collection stations prevailed that except temp. ($p < 0.05$), all other parameters are significantly different at different sampling stations, shown in Table VI.

Toxic metals

The toxic metal concentrations in the Buriganga River and in the tannery effluent were measured during June, 2013 and tabulated in the Table VII. Descriptive statistics of toxic metals including the maximum, minimum, mean and standard deviation values for the Buriganga River water and Hazaribagh tannery effluent are tabulated in Tables VIII. Toxic metals of water revealed significant correlation with each other as shown in Table IX.

Toxic metals are significant threatening source on ecosystem. Chromium (Cr) is an important one. The concentration of Cr at four stations in water of the Buriganga River were in the range 0.0306 to 0.2163 mg/l as well as in the tannery effluent 7.7656 mg/l which shows significantly positive correlations with Cd, Zn and Cu ($P < 0.01$) as $r = 0.608$, 0.808 and 0.599, respectively. The highest Cr concentration was shown at Br-5 (7.7656 mg/l) resulted from the tannery industries effluent which is much higher than permissible level by WHO (0.05 mg/l). Beside this, Cr concentration exceed the permissible limit at Br-2 (0.2163 mg/l) which is situated near industrial area at Kaliganj. In Kaliganj, different types of cooling tower are operated at different industries. From cooling towers additives chromium could be mixed into the River water. Pottery industry also discharged Cr into River which is constructed near Br-2 area. The long term exposure of Cr above permissible limit causes allergic dermatitis (EPA, 2013) . However, Br-4 area is situated near the Hazaribagh tannery effluent discharging area but at this station the observed Cr concentration is very low (within the permissible level). This is because during the sampling period, water hyacinths (*E. crassipes*) were grown around the sampling station. Water hyacinth is considered being a chromium adsorber (Shama *et al.,* 2010).

The concentrations of cadmium (Cd) at the four stations in water of the Buriganga River were in the range 0.0018 to 0.0162 mg/l as well as in tannery effluent 0.0198 mg/l. It shows significantly positive correlations with Cr, Ni and Cu ($P < 0.01$) as $r = 0.608$, 0.873 and 0.832, respectively which lie above the permissible level by DoE (as 0.01 mg/l). The use of Cd in batteries, pigment and plating industries can be the source of Cd in the Buriganga River water. A study (El-Ebiary *et al*., 2013) found the highest mortality relation as a consequence of high dose of Cd on red tilapia which also affects on the decrease of sperm number.

The concentration of Nickel (Ni) at four different stations in water of the Buriganga River were in the range 0.0663 to 0.2486 mg/l as well as in tannery effluent 0.2070 mg/l which shows significantly positive correlations with Cd and Cu ($P < 0.01$) as $r = 0.873$ and 0.591, respectively. The concentration of Ni was above the permissible level by WHO (as 0.1 mg/l) at Br-2, 3 and 5 because of some paper mills are operated at the bank of Buriganga River near Br-2 and 3 stations. Nickel is a carcinogenic metal and long term exposure to it can cause heart and liver damage, decreased body weight and skin irritation (Homady *et al.,* 2002). There are some dockyards constructed in the bank of the Buriganga River and a launch terminal situated at station Br-3. These might be a source of high concentration of nickel in the stations Br-2 and Br-3.

The concentration of copper (Cu) at four different stations in water of the Buriganga River were in the range 0.0112 to 0.0238 mg/l as well as in tannery effluent 0.0304 mg/l. Copper is emitted from the tannery effluent, industrial wastewaters as well as from the sewerage pipe lines. It is also used for the purpose of metal cleaning and plating (Aksu and Isoglu, 2005). The concentrations of Cu in all stations were lie beneath the permissible level by WHO (1.5 mg/l) which means that biological effects are rarely observed. It shows significantly positive correlations with Cr, Cd, Ni and Zn ($P < 0.01$) as $r = 0.808$, 0.832, 0.591 and 0.536, respectively.

The concentration of Zinc (Zn) at four different stations in water of the Buriganga River were in the range 0.0878 to 0.2948 mg/l as well as in tannery effluent 0.3021 mg/l. Zinc is discharged through the industrial wastewaters into the River. Hamed *et al*., (2009) reported that Zn can be precipitated as $ZnCO_3$ which is suspected for lower concentration of Zn in surface water. The concentrations of Zn lie beneath the permissible level by WHO (15 mg/l). Zinc

Table XI. Ecological risk factor and potential ecological risk index for toxic metals in the Buriganga River

Station	E_r^i					E_{RI}
	Cr	Cd	Ni	Cu	Zn	
Br-1	1.224	5.400	3.315	0.037	0.010	9.986
Br-2	8.652	44.400	11.470	0.047	0.006	64.575
Br-3	5.720	48.600	12.430	0.079	0.010	66.840
Br-4	1.812	27.000	4.170	0.053	0.020	33.055
Br-5	310.624	59.400	10.350	0.101	0.020	380.496
Min	1.224	5.400	3.315	0.037	0.006	9.986
Max	310.624	59.400	12.430	0.101	0.020	380.496
Average	65.606	36.96	8.347	0.063	0.013	110.990
±SD	137.002	21.152	4.278	0.026	0.006	152.490

** $E^i r$ = ecological risk factor, E_{RI} = potential ecological risk index

is one of the most important metals for enzyme and protein production (Valle, 1978). It shows significantly positive correlations with Cr and Cu ($P < 0.01$) as $r = 0.599$ and 0.536, respectively.

As a consequence of unavailable metal data finally, we correlated all the parameters in June, 2013. Table X shows that there are perfect correlations among Cr, Salinity, TDS, EC. Cr, pH, and COD which indicate they are originated from the same sources. Chromium has strong positive correlation with Cu, pH, and COD ($P < 0.01$) as r=0.808, 0.994 and 0.997, respectively but a strong negative correlation with DO as r = -0.955. Cadmium shows significantly positive correlations ($P < 0.01$) with Ni and Cu as r = 0.873 and 0.832, respectively. Copper shows significantly positive correlations ($P < 0.01$) with salinity, TDS, EC and COD as r = 0.804 but the relation is negative with DO as r = -0.650. Finally, DO have very high correlations with opposite direction.

Ecological risk assessment

To estimate the ecological risk by toxic metals to the Buriganga River ecosystem, potential ecological risk factor and risk index was used. Ecological risk index introduced by Hakanson (1980), was obtained by following equations.

$$E^i_r = T^i_r \frac{C^i}{C^i_o}$$

$$E_{RI} = \Sigma E^i_r$$

Where E^i_r is the ecological risk factor, C^i and C^i_o are the concentration of specific metal and its permissible reference value in waste water, respectively. T^i_r is the toxicity factor (Cr = 2, Cd = 30, Ni = 5, Cu = 5 and Zn = 1) of respective metals (Wang *et al*., 2011). E_{RI} is the potential ecological risk of a region based on the sensitivity of biological communities to various metals.

The calculated values of E^i_r and E_{RI} for metals in the five studied stations are presented in Table XI. Higher the value of E^i_r and E_{RI} indicates the higher risk for ecosystem. There is no standard value available for the assessment of waste water ecological risk. According to Gen *et al*., (2000), the potential ecological risk of sediment exposed by toxic metals can be classified as:

Low risk: $E^i_r < 30$, $E_{RI} < 100$

Moderate risk: $30 \le E^i_r < 50$, $100 \le E_{RI} < 150$

Considerable risk: $50 \le E^i_r < 100$, $150 \le E_{RI} < 200$

Very high risk: $100 \le E^i_r < 150$, $200 \le E_{RI} < 300$

Disastrous risk: $E^i_r \ge 150$, $E_{RI} \ge 300$

Among the toxic metals observed, Cr is the highest ecological risk metal. The average value of E^i_r for Cr is 65.606 ± 137.002 which indicates that Cr concentration highly varied through station to station. The station Br-5 is the ecologically highest risk station (E^i_r = 310.624, E_{RI} = 332.976). The other four metals have lower ecological risk than Cr (average E^i_r value as Cd = 36.960 ± 21.152, Ni = 8.347 ± 4.278, Cu = 0.063 ± 0.026 and Zn = 0.013 ± 0.006).

Conclusion

This work reveals the present pollution status of the Buriganga River by observing temp., pH, salinity, EC, TDS, DO and COD. These parameters show significantly correlations ($P < 0.01$) with each other. Temp. and DO show seasonal variations ($p < 0.05$). Rest of the parameters like pH, Salinity, TDS, EC and COD did not vary over seasons ($p < 0.05$). Except Temp. ($p < 0.05$), all other parameters are significantly different in different sampling stations. During February, 2013 Br-4 showed the higher inorganic pollution by value of salinity, TDS and EC as 642 mg/l, 871 mg/l and 1309 µs, respectively. At the same time tannery effluent showed 4890 mg/l, 5720 mg/l and 8580 µs, respectively. But tannery effluent shows the highest EC value during the August, 2013 as 10810 µs. According to the organic pollution Br-3 is more polluted station during February, 2013 by DO and COD as 1.1 mg/l and 800 mg/l, respectively. At the same time tannery effluent showed DO and COD as 0.3 mg/l and 3800 mg/l, respectively. According to the above data water of the Buriganga River is polluted by the DoE suggested values for EC, DO and COD and the water is not safe for drinking, household, industrial and irrigation purpose. Br-2 and 3 are contaminated by Cr as 0.2163 mg/l and 0.143 mg/l, by Cd as 0.0148 mg/l and .0162 mg/l, by Ni as 0.2294 mg/l and 0.2486 mg/l, respectively during June, 2013. Based on inorganic pollution Br-4 (at February 2013, TDS = 871 mg/l, EC = 1309 µs) is most polluted station and both are unsuitable for drinking, household and industrial use. According to ecological risk index Cr is the highest risk metal for ecosystem. During dry season there is no fish in

Buriganga according to the fisherman's statement. Thus the authorities should take necessary steps to prevent the untreated industrial and municipal discharge by installing effluent treatment plant (ETP) and no permission should be given to setup new industries without setting effluent treatment plant.

Acknowledgment

We gratefully acknowledge the support of Inorganic research laboratory, Jagannath University and financial support of the Jagannath University Development Project on the Pollution of the Buriganga River, Bangladesh.

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Received: 29 September 2014; Revised: 16 February 2015; Accepted: 26 March 2015.