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Physicochemical Properties and Metallic Constituent Load in the Water Samples of the Buriganga of Bangladesh

K. M. Mohiuddin*, M. M. Alam, I. Ahmed, H. M. Zakir and A. K. Chowdhury

Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

*Corresponding author: mohiagchem@gmail.com

Abstract

The study was conducted to assess the level of Cu, Zn, Pb, Cr, Fe, Mn, Cd and Ni contamination in the water samples of the Buriganga river. Total 14 water samples were collected from different areas of upstream of the Buriganga river to determine the physicochemical properties, concentration of different metallic constituents and assess the heavy metal pollution load. Atomic Absorption Spectrometer was used for analyzing the heavy metals of the samples. The mean concentration of Ca, Mg, Na, K in water samples were 0.779, 0.889, 140.39, 26.9 µg mL^{-1}, respectively. The mean concentration of Cr, Pb, Fe, Cu, Zn and Mn in the water samples were 0.17, 0.05, 0.67, 0.22, 0.55 and 0.17 µg mL^{-1}, respectively. The amount of Cd in all samples and Pb in 10 samples was below detectable limit of the instrument (0.01 µg mL^{-1}). Water pH ranged from 4.09 to 7.41 and EC was 346 to 7720 µS cm^{-1}. Magnitude of heavy metal pollution in the Buriganga river system implies that the condition is very alarming and may severely affect the aquatic ecology of the river. To minimize the severe impact on city dwellers and aquatic ecology of the Buriganga river, sustainable steps and continuous monitoring on pollution prevention and cleanup operation is suggested.

Key words: Buriganga river, Heavy metal, Pollution load, Water quality

Introduction

Heavy metals exhibit extreme toxicity even at trace levels. Rivers are a dominant pathway for metals transport (Miller *et al.,* 2003) and heavy metals become significant pollutants of many riverine systems (Dassenakis *et al.,* 1998). In Bangladesh, river water are largely used for agricultural purposes. But presence of hazardous substances such as As, Cr, Cd, Pb, Cu, Ni, Fe, Zn, Mn, Hg and toxic microbes, consequently river water becomes polluted. The chemical characteristics of water determine its quality as well as its usefulness for irrigation, industrial and domestic usage. In Bangladesh, the research on the aspect of wastewater pollution is yet at an initial stage and literature in this connection is very scanty. In the distant past, a course of the Ganges river used to reach the Bay of Bengal through the Dhaleshwari river. This course gradually shifted and ultimately lost its link with the main channel of the Ganges and was renamed as the Buriganga. The river Buriganga is the main river flowing beside Dhaka, the capital of Bangladesh, which is a megacity of 12 million people. City dwellers largely depend on the Buriganga's water for cleaning utensils and other commodities, fishing and carrying merchandise. Unfortunately it is now considered as one of the dirtiest rivers of the world. The foul odour of the polluted blackish water of the Buriganga river can be sensed even from half a kilometer distance. Intensive human intervention, unplanned urbanization and population pressure have created the present unwanted situation of the river. As a result of insensible human actions on the one hand, and failure by the authority to enforce rules and regulations to save the river on the other, the Buriganga is dying biologically (Alam, 2008). Nowadays, no fish and other aquatic animals are found in the river during the dry season. According to the experts, one among the major reasons of pollution in the Buriganga is the Hazaribagh tannery. Although the tannery is 46 years old but no treatment plant has been introduced yet to neutralize the noxious materials it produces. That's why it continuously pollutes the water of the Buriganga. Most of the previous studies have been focused mainly on the Buriganga river water chemistry (Ali *et al.,* 2008; Moniruzzaman *et al.,* 2009; Alam *et al*, 2003; Ahmad *et al.,* 2010). Mohiuddin *et al.,* (2011) collected water samples from the Buriganga river to observe the seasonal and spatial distribution of heavy metals and reported extreme heavy metal pollution load in the water samples. However, in the mean time Govt. of Bangladesh has taken various steps to clean up Buriganga river. In 2010, Bangladesh Inland Water Transport Authority (BIWTA) began extracting hundreds of thousands of tonnes of garbage from the Buriganga river that being slowly choked by waste, mostly non-biodegradable polythene bags. In June 2011, The High Court of Bangladesh directed the chairman of Dhaka Water Supply and Sewerage Authority (WASA) to take steps to seal off the waste outlets and asked the Dhaka City Corporation to immediately start cleaning the riverbanks to stop dumping any more waste into or by the river. In 2012, BIWTA completed a mega project namely 'Construction of port facilities in order to prevent unauthorized encroachment of Buriganga river and its foreshore land'. To remove wastes from the Buriganga river, 'Deposited Polythene and Other Waste Removal from Buriganga and Turag Rivers' project was implemented by BIWTA in 2013. Considering the above facts, the present research was planned to carry out to follow up assessment of the heavy metal pollution load in the water samples of the Buriganga river, Bangladesh.

Materials and Methods

Sampling

Water samples were collected from 14 sites of the Buriganga river in January 2014 (Table 1 and Fig. 1). About 200 mL water samples were collected from each location in two plastic containers, following the method as described by APHA (2005). These containers were cleaned with dilute HCl (1:1) and then washed with distilled water. Water samples were immediately filtered with ADVANTEC® 0.2 µm size sterile syringe filter. For the analysis of heavy metals 100 mL water sample was collected in separate clean bottle and acidified with 0.5 mL conc. nitric acid to maintain pH below 2, which will prevent the loss of metals by absorption and/ or ion exchange with the walls of glass containers.

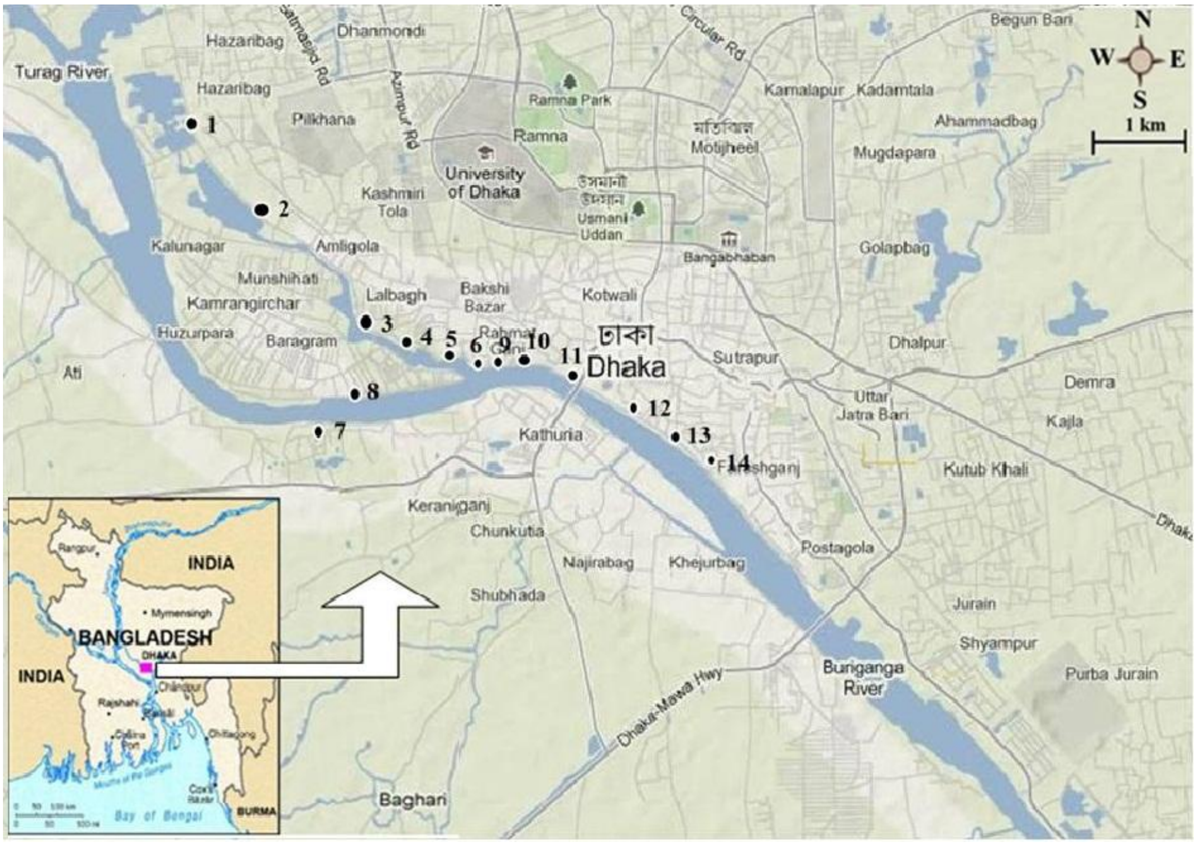

Fig. 1. Location of different sampling sites of Buriganga River, Dhaka, Bangladesh

Table 1. Name of the locations of different sampling sites of the river Buriganga, Dhaka, Bangladesh

Sample No.	*Location*	*Sample No.*	*Location*
1	Hazaribag – ZH Sikder MC	8	Kamrangirchor Tara Masjid
2	Nobabgonj Bara Masjid	9	Swarighat
3	Shohid Nagar Beribadh	10	Razar ghat
4	Kellarmor Truck Stand	11	Badamtoli Bridge
5	Islambag Alir ghat	12	Nowab Barir Ghat
6	Raghunathpur	13	Sadar Ghat
7	Borishur Lonch Terminal	14	Mererbag

Analysis of water samples

The pH value of water samples was measured by taking 90 mL of water in 100 mL beaker and immersing the electrode of pH meter (SensION+EC5, HACH, USA) into samples as mentioned by Singh *et al.* (1999). EC of the samples was measured with the help of EC meter (SensION™+EC5, HACH, USA) following the method as outlined by Singh *et al*. (1999). Calcium and magnesium were determined from water samples by titrimetric method using Na_2EDTA as a chelating agent at pH 12 (Page *et al*., 1982). Potassium and Na contents determined by flame emission spectrophotometer (Model: JENWAY PFP7, UK). Heavy metals such as chromium (Cr), lead (Pb), cadmium (Cd), iron (Fe), zinc (Zn), copper (Cu), nickel (Ni) and Manganese (Mn) in acidified water samples were analyzed by Atomic Absorption Spectrophotometer (AA-7000; SHIMADZU, Japan).

Results and Discussion

Physicochemical properties of water

The pH value of all water samples varied from 4.09 to 7.41 (Table 2). Out of 14 samples, 10 samples varied from 4.09 to 5.74 and rest of 04 samples ranged from 6.73 to 7.41. These might be due to the presence of higher amount of industrial waste in water. According to Ayers and Westcot (1985), the acceptable range of pH for irrigation water is from 6.0 to 8.4. So, the measured pH of 10 samples under the investigation area was problematic for long-term irrigation. On the other hand, according to US EPA (2009), the guideline value of pH for drinking water is from 6.5 to 8.5. Out of 14 samples, 04 samples were within the permissible value. These waters were suitable for drinking but 10 samples were below the permissible limit and found unsuitable for drinking. The EC is the total concentration of soluble salts in the sample. In this study, EC of the water samples ranged from 346 to 7720 µS cm^{-1} with an average value of 2798 µS cm^{-1} (Table 3). The highest EC (7720 µS cm^{-1}) was recorded in the sample no. 10 and the lowest (346 µS cm^{-1}) was obtained in the sample no. 08. Higher EC value reflected the higher amount of salt concentration which affected irrigation water quality related to salinity hazard (Agarwal *et al.*, 1982). The acceptable limit of EC for irrigation water is 750 µS $cm^{-1}$and fishing water is 500 to 1000 µS cm^{-1} (ADB, 1994). On the basis of measured EC, out of 14 samples 09 water samples exceeded the acceptable limit of irrigation water quality. According to Richards (1968), 05 samples under test were rated in the category C2 (EC = 250-750 µS cm^{-1}), 01 sample in the category C3 (EC =751-2250 µS cm^{-1}) and the rest 08 samples in the category C4 (EC = >2251 µS cm^{-1}) indicating medium to very high salinity. Medium salinity class water might be applied with moderate leaching. High salinity class waters were treated as unsuitable for irrigation purpose (Agarwal *et al.*, 1982).

Table 2. Physicochemical properties (pH and EC) of water samples collected from different sites of Buriganga River, Bangladesh

Sample No.	pH	EC (µS cm^{-1})
1	5.74	947
2	4.09	3490
3	4.89	3960
4	5.08	2850
5	5.05	2860
6	6.73	524
7	7.27	492
8	5.02	346
9	4.82	5790
10	4.66	7720
11	4.78	5630
12	4.95	3500
13	7.41	594
14	6.87	474
Range	**4.09-7.41**	**346-7720**
Mean	**5.5**	**2798**
DWGV	**6.5-8.5[a]**	**-**
IWGV	**6.0~8.4[b]**	**750[c]**

DWGV: Drinking Water Guideline Value;
IWGV: Irrigation Water Guideline Value
[a] - US EPA (2009); [b] - Ayers and Westcot (1985); [c]- ADB (1994)

Heavy metals in water samples

The concentration of Cr in water samples ranged from 0.130 to 0.209 µg mL^{-1} with a mean value of 0.172 µg mL^{-1} (Table 3). The US EPA regulates total Cr in drinking water and has set a Maximum Contaminant Level (MCL) of 0.1 µg mL^{-1}. The World Health Organization (WHO) guideline is 0.05 µg mL^{-1} for total Cr. In all the collected water samples concentration of Cr was recorded above the Maximum Contaminant Level (MCL) of US EPA. Out of 14 samples, 06 samples were below the mean value. The concentration of Pb in water samples collected from different sites of Buriganga river varied from Below detectable limit of the instrument AA7000 to 0.097 µg mL^{-1} with a mean value of 0.054 µg mL^{-1} (Table 3). The standard of Pb for domestic water supplies is <0.05 µg mL^{-1} as reported by USPH and 0.01 µg mL^{-1} as stated by ISI (De, 2002). The standard of Pb for drinking water is 0.05 µg mL^{-1}; fishing water is 0.05 µg mL^{-1}; industrial water is 0.01 µg mL^{-1}; irrigation water is 0.05 mg L^{-1} and livestock water is 0.05 µg mL^{-1} (ADB, 1994). According to international standards for inland surface water, tolerance limit of Pb for public supply and bathing is 0.1 µg mL^{-1} (Ayers and Westcot, 1985**).** According to Bangladesh Standards, Pb content for irrigation water is 0.01 µg mL^{-1} (DoE, 2005).

Considering these limits, Pb concentrations in 10 water samples collected from the study area were found suitable and other samples were unsuitable for drinking, fishing, industrial and irrigation purposes in respect of Pb content. Similar observations were reported by Rahman *et al*. (2012) for Turag river and Bakali *et al*. (2014) for Tongi area water quality. The concentration of Pb in water samples collected from different sites of Buriganga river contained below detectable limit (BDL) of the instrument AA7000 (Table 3), which indicates that all of these waters can safely be used for different purposes in respect of Cd. All the water samples collected from different sites of the Buriganga river contained comparatively different amount of iron (Fe) and the amount varied from 0.301 to 1.549 µg mL^{-1} with a mean value of 0.671 µg mL^{-1} (Table 3). The recorded Fe concentrations of all the samples were far below the acceptable limit (5.00 µg mL^{-1}) for irrigation as reported by Ayers and Westcot (1985), and could safely be used for long term irrigation without any detrimental effect on soil. According to US EPA (2009), the guideline value of Fe for drinking water is 0.30 µg mL^{-1} (Table 4). From the results mentioned above it can be inferred that all water samples were unsuitable for drinking in respect to Fe content.

Table 3. Concentration of heavy metal in water samples collected from different sites of Buriganga River, Bangladesh

Sample No.	Heavy metal concentration (µg mL^{-1})						
	Cr	Pb	Cd	Fe	Cu	Zn	Mn
1	0.130	BDL	BDL	1.549	0.197	0.239	0.276
2	0.136	BDL	BDL	0.940	0.214	0.601	0.174
3	0.147	BDL	BDL	1.426	0.210	0.818	0.235
4	0.140	BDL	BDL	0.519	0.213	0.569	0.235
5	0.176	BDL	BDL	0.888	0.209	0.594	0.170
6	0.174	BDL	BDL	0.651	0.219	0.415	0.185
7	0.209	BDL	BDL	0.920	0.208	0.547	0.105
8	0.203	BDL	BDL	0.440	0.223	0.780	0.175
9	0.162	BDL	BDL	0.363	0.226	0.566	0.167
10	0.167	BDL	BDL	0.368	0.232	0.638	0.057
11	0.181	0.023	BDL	0.347	0.230	0.594	0.198
12	0.198	0.016	BDL	0.301	0.226	0.491	0.172
13	0.194	0.082	BDL	0.363	0.236	0.522	0.041
14	0.188	0.097	BDL	0.323	0.232	0.346	0.136
Range	**0.13-0.209**	**BDL-0.097**	**BDL**	**0.301-1.549**	**0.197-0.236**	**0.239-0.818**	**0.041-0.276**
Mean	**0.172**	**0.054**	BDL	**0.671**	**0.219**	**0.551**	**0.166**

BDL refers to Below Detectable Limit of the instrument AA7000 (0.01 µg mL^{-1})

The water samples collected from different sites of the Buriganga river contained 0.197 to 0.236 µg mL^{-1} Cu (Table 3). Among the total 14 water samples, only one sample was found within the recommended limit for irrigation (0.20 µg mL^{-1}) as described by Ayers and Westcot (1985). Similarly, the National Academy of Science has recommended that for continuous use irrigation effluent water should not contain more than 0.20 µg mL^{-1} Cu (Gibeault and Cockerham, 1985). The standard limit of Cu for domestic water supplies is 1.0 µg mL^{-1} as described by USPH (De, 2002). According to ADB (1994) the standard limit of Cu for drinking water is 1.0 µg mL^{-1} and livestock drinking water is 5.00 µg mL^{-1}. Considering these limits, Cu concentrations in all water samples were found within the suitable range (Table 3). A similar observation was reported by Meghla *et al.* (2013), for the waters collected from the Turag river in Dhaka city, Bangladesh. The water samples collected from different sites of Buriganga river contained different amount of Zn and the amount varied from 0.239 to 0.818 µg mL^{-1} with a mean value of 0.551 µg mL^{-1} (Table 3). According to Ayers and Westcot (1985), the maximum permissible limit of Zn in irrigation water is 2.00 µg mL^{-1}. Considering this limit as standard, all samples were found suitable for irrigation. The standard of Zn for domestic water supplies is 5.5 µg mL^{-1} as described by USPH (De, 2005). The standard of Zn for drinking water is 5.0 µg mL^{-1} (ADB, 1994). Considering these limits, Zn concentrations in all samples were within the suitable range for all purposes (Table 4). Similar observation was reported by Rahman *et al*. (2012) and Bakali *et al*. (2014), for the seasonal variations in the Turag river and Tongi area water quality, respectively. The concentration of Mn in water samples collected from Buriganga river ranged from 0.041 to 0.276 µg mL^{-1} with a mean value of 0.166 µg mL^{-1} (Table 3). According to Ayers and Westcot (1985), the highest recommended concentration of Mn for irrigation water is 0.20 µg mL^{-1}. Considering this limit, Mn concentration in 21.43% samples (03 water samples out of 14 samples) exceeded the maximum acceptable level indicating Mn toxicity in water of the study area and for this reason those samples are not permissible for long term irrigation. On the other hand, according to WHO (2008), the guideline value of Mn for drinking water is 0.40 µg mL^{-1}. It is evident from the results mentioned above that all the water samples were suitable for drinking purpose as regards to Mn content in waters. The standard of Mn for domestic water supplies is <0.05 mg L^{-1} as reported by USPH (De, 2002). Therefore, 92.86% samples for the study area were found unsuitable for domestic water supplies in respect of Mn content.

Table 4. Comparison of heavy metal concentration (µg ml^{-1}) in the water samples of the Buriganga with different standard values and with the previous report on the Buriganga

Trace metal	This study average (µg mL^{-1})	Standard values (µg mL^{-1})				Report on Buriganga[e]	
		DWS as MCL[a]	DWGV[b]	TRV[c]	DWSB[d]	Summer	Winter
pH	3.38	6.5 – 8.5	6.5 – 9.5	-	6.5-8.5	-	-
EC	5264.35	-	-	-	2250	-	-
Ca	0.78	-	-	-	75	-	-
Mg	0.89	-	-	-	35	-	-
K	27	-	-	-	12	-	-
Na	140.4	-	-	-	200	-	-
Cr	0.17	0.1	0.05	0.011	0.05	1.43	1.96
Pb	0.05	0.015	0.01	0.0025	0.05	0.50	0.23
Cd	BDL	0.005	0.003	0.0022	0.005	0.16	0.22
Fe	0.67	0.3	-	-	0.3-1	-	-
Cu	0.22	1.3	2.0	0.009	1.0	1.71	2.74
Zn	0.09	5	-	0.118	5.0	0.26	0.22
Mn	0.17	0.05	0.4	-	0.1	-	-

[a] drinking water standard (DWS) as maximum contaminant level (MCL) proposed by US EPA
[b] drinking water guideline values WHO (2008)
[c] TRV for fresh water proposed by US EPA (1999)
[d] drinking water standard for Bangladesh proposed through ECR (1997)
[e] Mohiuddin *et al.,* (2011)

Heavy metal concentration in the water samples of different sites of the Buriganga is compared with different standard values and with the previous report on the Buriganga and presented in Table 4. The average concentration of Cr, Pb and Cu the Buriganga is about 10 times lower than the samples of same river presented by Mohiuddin *et al.,* 2011. The average concentration Zn is also much lower than the previous report and Cd content this time is below the detectable range of the instrument (<0.01 µg mL^{-1}).

Conclusions

The pH of water ranged from 4.09 to 7.41 and EC was 346 to 7720 µS cm^{-1}. The mean concentration of Ca, Mg, Na, K in water samples were 0.779, 0.889, 140.39, 26.9 µg mL^{-1}, respectively. The mean concentration of Cr, Pb, Fe, Cu, Zn and Mn in water samples were 0.17, 0.05, 0.67, 0.22, 0.55 and 0.17 µg mL^{-1}, respectively; while the amount of Cd in all samples and Pb in 10 samples was below detectable limit of the instrument. Chromium content in Buriganga river water sample was thirteen to twenty times higher than that of toxicity reference value (TRV) for fresh water proposed by US EPA.

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