TOXICITY ANALYSES OF SURFACE WATER IN SELECTED INDUSTRIAL AREAS OF BOGURA SADAR, BANGLADESH

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A B S T R A C T

An investigation was carried out to assess the extent of ionic toxicity of surface water samples for agricultural usage in the Karatoya-Bangali Floodplain (2,577 sq. km). Fifteen water samples were collected from five industrial areas of Bogura sadar upazila to assess the dissolved chemical constituents and also to classify them on the basis of their comparative stability for agricultural usage. Water samples were collected from surface water sources viz., rivers, canals and ponds at Bogura sadar upazila. The chemical analyses included pH, electrical conductivity (EC), total dissolved solids (TDS), Ca, Mg, K, Na, Zn, Cu, Fe, Mn, Cd, Pb, B, As, CO_3, HCO_3, PO_4, SO_4 and Cl. The pH indicated that surface water samples were acidic to alkaline in nature (pH = 6.5-8.8). The electrical conductivity (EC) and sodium absorption ratio (SAR) revealed that all the surface samples were categorized as 'medium salinity' and 'low alkalinity' hazards with 'excellent' and 'good' in quality combining expressed as C2S1. Considering TDS all the surface waters were as 'freshwater'. Soluble sodium percentage (SSP) indicated that all the surface water samples were 'excellent' and 'good' classes. Residual sodium carbonate (RSC) categorized the surface water samples as 'suitable' in quality for irrigation. The status of Ca, Mg, Na, K, Zn, Cu, As, B, Fe, CO_3, SO_4, PO_4, and Cl were not hazards in the investigated area. In all surface water samples, HCO_3 ion was considered as pollutant for irrigating crops. Rest ionic constituents were suitable for irrigation purposes. As, B, SO_4, Cl and TDS were not problematic for drinking, TDS, Cd, Cu and Zn were not hazardous for livestock usage and SO_4 and hardness (H_T) were not problematic for aquaculture. But rest ionic constituents for these respective usages were toxic.

INTRODUCTION

Toxicity can be termed as a degree to which a substance can damage an organism. Toxicity can refer to the effect on a whole organism, such as an animal, bacterium, or plant, as well as the effect on a substructure of the organism, such as a cell or an organ such as the liver. The main purpose of the study was to analyse toxicity of surface water of some industrial areas of Bogura sadar upazila. Now-a-days industries are growing like fungus in the whole world. Our country, Bangladesh is not an exception. The national profile shows that Bangladesh now has 30,000 industrial units of which 24,000 units are small and cottage. The remaining 6,000 are large and medium industries (DOE, 2011). In Bangladesh, industries are building up their positions at a high rate and with a costly result to the environment. Amongst the environmental components water and soil are mostly affected. The contamination of water with toxic effluents is a major environmental problem. River water quality monitoring is necessary especially where the water serves as drinking water sources and threatened by pollution resulting from various human activities along the river course (Ahmad et al. 2010; Amadi 2011). Heavy metals contamination in river is one of the major quality issues in many fast growing cities, because maintenance of water quality and sanitation infrastructure did not increase along with population and urbanization growth especially for the developing countries (Karbassi et al. 2007; Akoto et al. 2008; Ahmad et al. 2010). Some of these are carcinogenic at high concentrations and can cause serious health hazard if they enter into the food chain. Metallic effluents such as Cu, Zn, Mn, Fe, Cd, Pb, B, As etc. are usually present in water at low concentration, but enhanced concentration of these metals have found as a result of human activities. Metals enter into water bodies from variety of sources; it can be either natural or anthropogenic (Wong et al. 2003; Adaikpoh et al. 2005; Akoto et al. 2008). Investigations have been made in different countries by different researchers on the extent of heavy metals pollution in surface water, ground water, soil, sediments and vegetation (Zakir et al., 2006; Mohiuddin et al., 2010; Akbal et al., 2011; Zakir et al., 2011; Shikazono et al., 2012).

The water was seriously affected by contamination of heavy metals originating from different industries and spoils, leaching of heavy metals, organic enrichment and silting by sand particles. Pollution of the water is evident by the color of the water which in most of the rivers and streams in the industrial area varies from brownish to reddish orange. The experimental water samples were collected from the major polluting areas of midstream of the river Karotoa under sadar district of Bogra, Bangladesh. There are several types of industrial units including textile, dying, pharmaceuticals, leather and others present in Bogra. From the different industrial zones of the area, contamination of river water by various metallic and non-metallic chemicals are very common. Ittefaq (2010) reported that the toxic waste, sewerages and effluents of more than hundred factories are being discharged to Karatoa River. Nowadays, offensive odor from this river are making nuisance to the people living surrounding areas. Huge amount of untreated municipal wastewater, industrial effluents and others may associate with the heavy metal contamination in water of Karatoa River, which has been used by nearby villagers for irrigation, animal watering, bathing and washing etc. for the last several decades, and may have a significant contribution to increase heavy metal content of the surrounding water. As a result, environmental hazards are occurring and this leads to degradation of water health and contamination of food chain mainly through the crops produced using contaminated irrigation water.

Water of the river Nagor flowing besides Bogura sadar also is becoming badly polluted by untreated effluent from Azad Pulp and Paper Mill situated at BISIC industrial area and Matidali in sadar upazila. People of both the sides generally avoid the river as contact of its polluted water makes one-fall sick, especially due to skin diseases. Many children from both sides of the river are also suffering from different waterborne diseases following the river pollution. Fish and insects are found dead in about 20 km of the river from Bogra sadar upazila to the downstream. The effluent from the mill has changed color of the river water in last three and a half years.

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MATERIALS AND METHOD

The sampling sites were selected for five industrial areas of Bogra sadar upazila under the district of Bogra. Exactly 15 surface water samples were randomly collected to cover most of the study areas during 6 September 2013 to 8 September 2013 following the instructions as outline by Hunt and Wilson (1986) and APHA (2005).Out of 15 surface water samples, 5 water samples were collected from Karatoa river, 5 water samples were collected from sewages and 5 water samples were collected from ponds. All the water samples were collected in 1L plastic bottle previously washed with distilled water followed by dilute hydrochloric acid and was sealed immediately to avoid air exposure. Surface water samples were taken from depth of 0.5 to 1.5 feet. The water samples were carried to the Soil Science Laboratory of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. All the water samples were filtered through filter paper (Whatman No. 1) to remove undesirable solids and suspended materials before chemical analysis.

Analytical techniques

The major chemical constituents of water and its quality factors were considered for analyses as follows:
1) pH: pH value of water samples was measured by taking 50 mL of water in a beaker and then placing the electrode of the pH meter (Model-WTW pH 522) into water samples as mentioned by Singh et at. (1999).
2) Electrical Conductivity (EC): Electrical conductivity of water was estimated by taking 100 mL of collected water in a beaker and then immersing the electrode of conductivity meter (Model: WTW LF 521) into water sample according to the technique as described by Ghosh et al. (1983).
3) Total Dissolved Solids (TDS): TDS were measured by evaporating 100 mL water sample to dryness and then were weighed following the method as suggested by Chopra and Kanwar (1980).
4) Ionic Constituents; like Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Cadmium (Cd), Lead (Pb), Boron (B), Arsenic (As), Carbonate (CO_3), Bicarbonate (HCO_3), Phosphate (PO_4), Sulphate (SO_4) and Chloride (Cl).

Calcium concentration of water samples was analyzed by EDTA titrimetric method at pH 12 in the presence of calcon indicator. Magnesium content of water samples was determined by EDTA titrimetric method at pH l0 in the presence of eriochrome black T (EBT) indicator (Page *et al.,* 1982 and Singh *et al.,* 1984). Sodium and potassium contents were determined from water samples separately by flame photometer (Model Jenway PEP7) using sodium and potassium filters, respectively. Zinc, copper, iron and manganese were analyzed by atomic absorption spectrophotometer (Model AAS, UNICAM 969) at the wavelengths of 213.9, 324.7, 248.3 and 278.5 nm, respectively following the procedure as described by APHA (2005).

Cadmium and lead were analyzed by atomic absorption spectrophotometer (Model Hitachi 170-30) following the procedure as stated by APHA (1998). Carbonate content of water samples was determined by acidimetric titration using phenolphthalein as indicator. Bicarbonate concentration of water samples was determined by acidimetric titration using methyl orange as indicator.

The concentration of boron (B) in water samples was determined by azomethine-H method. This spectrophotometric method by using azomethine-H as the reagent to form a stable colored complex at pH 5.1 in aqueous media. Phosphate was analyzed colorimetrically by stannous chloride method as per Jackson (1973). In this method, stannous chloride ($SnCl_2.2H_2O$) was used as a reducing agent which developed molybdophosphate blue color complex with the reduction of heteropolycomplex formed by co-ordination of molybdate and phosphorous ions. Sulphate concentration of water was analyzed turbidimetrically with the help of a spectrophotometer. Chloride content of water sample was estimated by argentometric method of titration (Tandon, 1995 and APHA, 2005).

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Assessment of water quality or toxicity

The concentrations of major ions present in water samples affect water quality. The following water quality factors were considered in judging water pollution or toxicity by the interpretation of analytical results of waters:

I. Sodium absorption ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

II. Soluble sodium percentage (SSP)

$$SSP = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

III. Residual sodium carbonate (RSC)

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

IV. Hardness (H_T)

$$H_T = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$$

Whereas, all the ionic concentrations were expressed as meL^{-1} but in case of hardness cationic concentrations were expressed as mg L^{-1}.

Statistical analyses

The statistical analyses of the analytical results obtained from water samples were performed (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Water quality rating or toxicity for irrigation usage

The pH value of surface water samples ranged from 6.5 to 8.8 reflecting acidic to alkaline in nature (Table 1). All the waters were alkaline in nature except one sample (No. 7). Ayers and Westcot (1985) mentioned that the normal pH for irrigation is usually from 6.0 to 8.5. According to this, water samples having pH>8.5 (sample no. 1, 4, 13, 23) were not suitable for long-term irrigation.

The average value of electrical conductivity (EC) of all the collected surface water samples was 463.27 µS cm-1 (Table 1). According to Richards (1968), all the water samples were classified as 'medium' salinity (EC = 250 - 270 µS cm-1) hazard. Therefore, waters of such qualities can be used for irrigation purpose without harmful effects on soils and crops but moderate leaching will be required.

The average value of measured total dissolved solids (TDS) of surface water samples was 334.79 mg L-1 (Table 1). The computed standard deviation (SD) and co-efficient of variation were 71.82 and 21.45%, respectively. According to Freeze and Cherry (1979), all the water samples under investigation contained less than 1000 mg L-1 TDS and were classified 'freshwater' in quality. These water would not be affected the osmotic pressure of soil solution and cell sap of the plants when applied to soil as irrigation water.

Table 1. p^H, EC, TDS and anionic constituents of surface water samples

Value	pH	EC	TDS	CO₃	HCO₃	PO₄	SO₄	Cl
		µS cm L⁻¹	mg L⁻¹	mg L⁻¹	me L⁻¹	mg L⁻¹	mg L⁻¹	me L⁻¹
Min	6.5	259.50	194.90	Trace	2.00	0.04	Trace	0.10
Max	8.8	667.20	439.60		4.00	0.49	5.48	2.00
Mean		463.27	334.79		3.16	0.22	1.36	0.98
SD		104.72	71.82		0.61	0.13	1.89	0.50
CV%		22.60	21.45		19.17	59.76	139.08	51.48

Traces of CO₃ and SO₄ were considered as <0.05 mg L⁻¹ and <0.01 mg L⁻¹, respectively

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Table 2. Cationic constituents of surface water samples

Value	Ca me L^{-1}	Mg me L^{-1}	Na me L^{-1}	K me L^{-1}	Zn mg L^{-1}	Cu mg L^{-1}	Fe mg L^{-1}	Mn mg L^{-1}	Cd mg L^{-1}	Pb mg L^{-1}	B mg L^{-1}	As mg L^{-1}
Min	0.80	0.90	0.26	0.02	0.005	0.006	0.25	0.02	Trace	Trace	0.10	Trace
Max	2.00	3.60	1.36	0.16	0.073	0.021	0.85	0.52	0.041	0.50	0.48	
Mean	1.45	2.43	0.80	0.05	0.034	0.013	0.63	0.095	0.017	0.26	0.27	
SD	0.29	0.74	0.29	0.04	0.019	0.004	0.20	0.12	0.013	0.16	0.11	
CV%	19.61	30.62	35.86	76.26	58.13	31.49	32.26	128.4	73.87	63.22	42.24	

T=Trace, Traces of K, Cd, Pb and As were <0.01 me L^{-1}, <0.005 mg L^{-1}, <0.01 mgL^{-1}, and <0.05 mg L^{-1}, respectively.

Ionic constituents

Anions
The amount of carbonate was not detected higher than trace amount (<0.10 mg L^{-1}) in all the water samples. The mean concentration of HCO$_3$, PO$_4$, SO$_4$, Chloride in surface water samples were 3.16 me L^{-1}, 0.22 mg L^{-1}, 1.36 mg L^{-1}, 0.98 me L^{-1}, respectively. The calculated SD was 0.61, 0.13, 1.89, 0.50, respectively. The calculated CV was 19.17%, 59.76%, 139.08%, 24.15%, respectively (Table 1).

Cations
The amount of cations present in water samples have been illustrated in Table 2. The major cations were expressed as me L^{-1} and other cations in minor quantities were expressed as mg L^{-1} . The mean concentration of Ca, Mg, Na, K, Zn, Cu, Fe, Mn, Cd, Pb, B in surface water samples was found to be 1.45 me L^{-1}, 2.43 me L^{-1}, 0.80 me L^{-1}, 0.05 me L^{-1}, 0.034 mg L^{-1} ,0.013 mg L^{-1}, 0.63 mg L^{-1}, 0.095 mg L^{-1} , 0.017 mg L^{-1} , 0.26 mg L^{-1} , 0.27 mg L^{-1}, respectively. The standard deviation (SD) was 0.29, 0.74, 0.29, 0.04, 0.019, 0.002, 0.20, 0.12, 0.013, 0.16, 0.11, respectively. The co-efficient of variation (CV) were 19.61%, 30.62%, 35.86%, 76.26%, 58.13%, 31.49%, 32.26%, 128.40%, 73.87%, 63.22%, 42.24%, respectively (Table 2).

Water quality determining indices
The average of sodium absorption ratio (SAR) of surface water samples was 0.57. The SD and CV were 0.18 and 31.48%, respectively. The present investigation expressed that a good proportion of Ca and Mg existed in waters which was 'suitable' for good structure and tilth condition of soil and also the improvement of soil permeability. The irrigation water with SAR less than 10.00 might not be harmful for agricultural crops (Todd, 1980). The mean value of soluble sodium percentage (SSP) value of all the collected surface water samples was 17.69% (Table-3). According to the water classification proposed by Wilcox (1955), 10 samples were classified as 'excellent' (SSP<20%) and the rest 5 samples were rated as 'good' class (SSP=20%-40%). The mean value of residual sodium carbonate (RSC) was -0.72 me L^{-1} (Table 3). The standard deviation (SD) and co-efficient of variation (CV) were 0.44 and -61.71%, respectively. According to Eaton (1950) and Ghosh *et al.* (1983), all the water samples were found to be 'suitable' class (RSC<1.25 me L^{-1}) except one surface water sample (no. 2) valued -1.80 me L^{-1}. For this reason, all the water samples might not be problematic for irrigation purposes.

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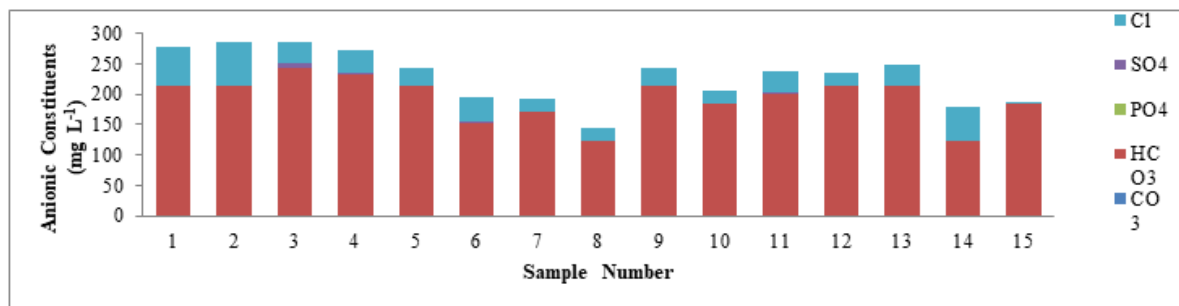
Figure 1. Bar diagram for representing major anionic constituents of surface water samples
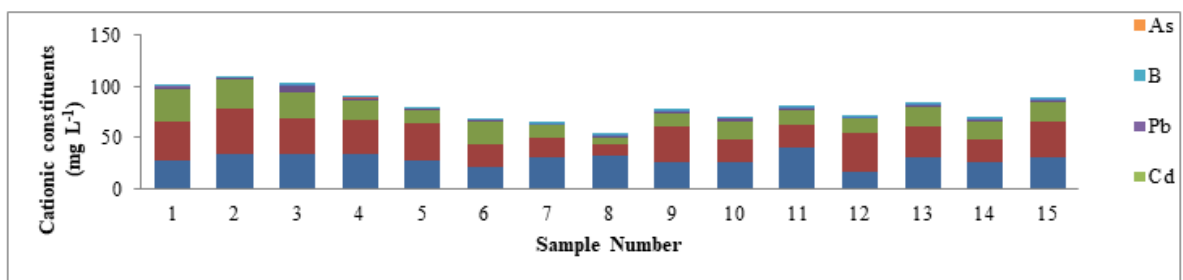

Figure 2. Bar diagram for representing major cationic constituents of surface water samples

Table 3. Quality rating and suitability of surface water used for irrigation

Sl. No.	SAR	SSP %	RSC me L^{-1}	H$_T$ mg L^{-1}	Water class based on				Alkalinity and salinity hazard[5]
					SAR[1]	SSP[2]	RSC[3]	H$_T$[4]	
1.	0.91	23.73	-1.00	224.69	Ex.	Good	Suit.	Hard	C2S1
2.	0.76	19.33	-1.80	264.65	Ex.	Ex.	Marginal	Hard	C2S1
3.	0.73	21.50	-0.60	229.75	Ex.	Good	Suit.	Hard	C2S1
4.	0.59	16.98	-0.60	219.78	Ex.	Ex.	Suit.	Hard	C2S1
5.	0.42	12.78	-0.80	214.72	Ex.	Ex.	Suit.	Hard	C2S1
6.	0.79	25.26	-0.40	144.85	Ex.	Good	Suit.	MH	C2S1
7.	0.43	15.30	-0.30	154.92	Ex.	Ex.	Suit.	Hard	C2S1
8.	0.23	11.66	-0.50	125.03	Ex.	Ex.	Suit.	MH	C2S1
9.	0.39	12.50	-0.70	209.71	Ex.	Ex.	Suit.	Hard	C2S1
10.	0.60	21.12	-0.10	154.87	Ex.	Good	Suit.	Hard	C2S1
11.	0.44	14.10	-0.60	194.93	Ex.	Ex.	Suit.	Hard	C2S1
12.	0.45	14.47	-0.40	194.63	Ex.	Ex.	Suit.	Hard	C2S1
13.	0.60	18.37	-0.50	199.79	Ex.	Ex.	Suit.	Hard	C2S1
14.	0.64	21.12	-1.10	154.87	Ex.	Good	Suit.	Hard	C2S1
15.	0.59	17.14	-1.40	219.73	Ex.	Ex.	Suit.	Hard	C2S1
Range									
Min	0.23	11.66	-1.80	125.03					
Max	0.91	25.26	-0.10	264.65					
Mean	0.57	17.69	-0.72	193.80					
SD	0.18	4.24	0.44	38.74					
CV%	31.48	23.99	-61.71	19.99					

Ex = Excellent, MH = Moderately hard, Suit = Suitable, C2 = Medium salinity and S2=Low alkalinity

The calculated mean value of hardness of all the surface water samples was 193.80 mg L^{-1} (Table 3). The standard deviation (SD) and the co-efficient of variation (CV) were 38.74 and 19.99%, respectively. Hardness of water samples resulted due to the abundant presence of divalent cations like Ca^{2+} and Mg^{2+}.

CONCLUSION

From the present investigation, it can be concluded that all the collected surface water samples would create problem for irrigating crops grown in the study areas and in most cases, HCO$_3$ ion would exhibit as pollutant for irrigation. Considering drinking purpose for human and livestock, Fe, Mn, Pb and Cl ions were treated as pollutants in most of the collected water samples. And in case of aquaculture, Fe, Mn, Pb, Cl, Cd and TDS measured were treated as pollutants in maximum collected water samples. It may be suggested that water samples should be treated to remove the pollutants before the use of water for specific purpose. Regarding this aspect, appropriate sustainable technology should be established for the chemical quality of waters. The biological and radiological qualities of waters should be assessed in future for the appropriate management of water use.

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CONFLICT OF INTEREST

There are no conflicts of research interest in this study.

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