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Pollution of four river-water surrounding Dhaka city and the effects of heavy metals on the yield and their concentrations in rice and cabbage

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ABSTRACT

The river-water of Dhaka city is polluting day by day because of increasing level of industrialization, poor water use practice and wastewater management inefficiency. Heavy metals present in river-water are uptaken by food crops when it is used as irrigation purposes which ultimately causing health risks. A pot experiment was conducted to assess the extent of pollution of four rivers water surrounding Dhaka city and to evaluate their effects on the yield and heavy metal concentrations and their uptake by rice and cabbage. Ten water samples of each river *viz.,* Buriganga, Shitalakshya, Turag and Bangshi were collected and analyzed. Crop growth experiment was laid out following completely randomized design with three replicates. The pH, electrical conductivity (EC), total dissolved solids (TDS) and dissolved oxygen (DO) ranged from 5.45 to 7.60, 170 to 1374 (µS cm^{-1}), 451 to 1827 (mg L^{-1}) and 1.8 to 6.5 (mg L^{-1}), respectively. The highest Pb (72.5 mg L^{-1}), Zn (675.8 mg L^{-1}) and Cd (1.08 mg L^{-1}) concentrations were found in Buriganga water whereas the highest Cr concentration (95.2 mg L^{-1}) was found in the water of Turag river. The concentrations of the heavy metals in those rivers were above the permissible limit with the exception of Shitalakshya river-water. In terms of heavy metal pollution, water of four rivers were of the following order: Buriganga > Turag > Bangshi > Shitalakshya. River-water irrigation reduced the yield up to 27% for rice and 38% for cabbage compared to freshwater. The lowest yield of rice and cabbage (3.2 and 25.3 t ha^{-1}, respectively) was found with Buriganga river-water irrigation. The highest Pb (3.72 mg kg^{-1}), Cd (0.08 mg kg^{-1}) and Zn (8.90 mg kg^{-1}) concentrations in rice grain were recorded in the plants grown with Buriganga river-water, whereas the highest Cr concentration (2.34 mg kg^{-1}) was obtained from Turag river-water irrigated rice plant. In cabbage, the highest concentrations of Pb, Cd and Zn were 4.38, 0.012 and 8.86 mg kg^{-1}, respectively recorded from the irrigation of Buriganga river-water, whereas the highest Cr concentration (3.02 mg kg^{-1}) was recorded from Turag river-water irrigation. The overall results suggested that the studied river-water may not be used directly without proper treatment for rice and cabbage production.

Introduction

Bangladesh is a low-lying flat country with big inland water bodies including some of the biggest rivers in the world and is extremely vulnerable because of its geographical characteristics (Matin and Kamal, 2010). The river-water pollution in major cities has been increased day by day. The ecosystem of the country is highly dependent on the river system and any upset in the supply of water is sure to bring about changes in the existing living facilities. About 33,400 m^3 of water is available for drinking, agriculture, domestic and industrial consumption out of the total 1,011 million km^3 of water found on the earth (Dara, 2007). The increasing urbanization and industrialization of Bangladesh have negative implications for water quality as the industrial effluents are directly discharged into the rivers without any consideration (BCAS, 2000). There has been a growing concern over the possible contamination of soils, sediments and water bodies around many of the industrial areas of the country (Chowdhury *et al*., 2007).

The surface water along these peripheral rivers including Buriganga, Turag and Shitalakshya of Dhaka city is known to be highly polluted due to municipal and industrial untreated waste waters that are discharged into these rivers (Karn and Harada, 2001; Ahmed *et al*., 2009; Khan *et al*., 2007; Rahman, 2005). The major sources of this pollution include the effluents from tanneries, textiles, pharmaceuticals, fertilizer factories, cement, dyeing and plastic industries (Kibria *et al*., 2016; Banu *et al*., 2013; Rahman *et al*., 2012) which affect the growth, reproduction and abundance of aquatic biodiversity increasing diseases incidence along

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with heavy metal pollution (Kibria *et al*., 2016). Human life and aquatic biodiversity become endangered along with disastrous consequences because of anthropogenic disturbance to environmental composition (Sunny *et al*., 2017). According to the Department of Environment (DoE), water quality of the peripheral rivers in Dhaka city has failed to comply the environmental quality standard and the rivers are grossly polluted throughout their courses except in monsoon (DoE, 2013). The recent report shows that the level of dissolved oxygen (DO) in several points of Buriganga river is "zero" (DoE, 2013) which is very threatening for the aquatic life and surrounding environment. Other important water quality parameters such as biological oxygen demand (BOD) and pH level were also proved problematic (DoE, 2013). Hence, the water of many rivers became restricted for the use of irrigation, drinking, livestock and washing as reported previously (Chowdhury *et al*., 2014; Hossain *et al*., 2015). More than 80% of the Dhaka metropolitan area is still used river-water for agriculture and fisheries as documented by the World Bank. The use of these polluted rivers water in crop production can affect the public health in this mega city (Chaudhary *et al*., 2016; Hossain *et al*., 2015; Lu *et al*., 2015). It was reported that in polluted areas, about 45% of persistent losses are found in rice production, and more than 20% are experiencing production losses in vegetable crops (Islam *et al*., 2019). Some reports showed that the farmers grow cabbage, red amaranth, radish, carrot, gourd, pumpkin gourd, and other leafy vegetables by using the wastewater in the urban and peri-urban areas, which is the common reason for the presence of harmful toxic substances in those vegetables (Islam *et al*., 2014; Mohiuddin *et al*., 2016; Sarkar *et al*., 2015; Uddin *et al*., 2016). Few studies from different parts of the country reported that exposure of high river-water pollution may result in environmental degradation posing a serious health effect for surrounding vicinity (Kibria *et al*., 2016; Banu *et al*., 2013; Rahman *et al*., 2012; Ahmad *et al*., 2010; Ahmed *et al*., 2009; Rahman, 2005). Therefore, it is an urgent need to examine the water quality of different rivers of Dhaka city along with their effects on crops cultivation. This experiment was conducted to assess the extent of pollution of four river-waters *viz.* Buriganga, Shitalakshya, Turag and Bangshi surrounding Dhaka city and to evaluate the comparative effects of polluted and freshwater irrigation on the yield and heavy metal concentrations in rice and cabbage.

Materials and Methods

Total forty water samples, ten of each river surrounding Dhaka city *viz.,* Buriganga, Shitalakshya, Turag and Bangshi were randomly collected (Table 1) maintaining the distance of one kilometer at least following the sampling techniques as outlined by Hunt and Wilson (1986) and APHA (2012). The collected samples were tightly sealed immediately to avoid exposure to air. Physico-chemical parameters of the water samples were analyzed in the Laboratory of the Department of Agricultural University, Mymensingh. Water samples were filtered with filter paper (Whatman No. 1) to remove undesirable solid and suspended materials. The pH of the water samples was determined electrometrically following the procedure mentioned by Ghosh *et al.* (1983). The electrical conductivity (EC) of the water samples were determined electrometrically using conductivity meter according to the method mentioned by Tandon (1995). Total dissolved solids (TDS) were determined by using TDS meter following the methods proposed by Gupta (2013). Heavy metal concentrations (Zn, Pb, Cr and Cd) were analyzed by atomic absorption spectrophotometer (model no.: Shimadzu, AA-7000) in the laboratory of the Department of Agricultural Chemistry of Bangladesh Agricultural University, Mymensingh, Bangladesh.

Table 1. Different sampling locations of four rivers surrounding Dhaka city

Sample	Buriganga River	Shitalakshya River	Turag River	Bangshi River
1.	*Sadarghat*-BIWTA launch terminal	*Demra*	*Bindan*	*Sutrapur*
2.	*Hazaribag* tannery main drain	*Shitalakshya* near ACI factory	*Thermog*	*Jatio Smriti Soudho, Savar*
3.	*Sowari Ghat*	*Sayedabad WTP*	*Istema field*	*Tongi*
4.	*Shmashan Ghat*	*Majhipara Khal*	*Tiebpur*	*Gazipur*
5.	*Wachpur Ghat*	*Killarpul Khal*	*Amin Bazar*	*Kalikoir*
6.	*Kolatiya Para*	*Kalibazar Khal*	*Ashulia*	*Noyarhat*
7.	*Kamrangirchar*	*Tanbazar Khal*	*Chapai*	*Kolagachia*
8.	*Chandni Ghat*	*Norai Khal*	*Baimile*	EPZ Area
9.	*Badamtoli Ghat*	DND *Khal*	*Boroibari*	*Mirzapur*
10.	*Mitford Ghat*	*B.K.* Road *Khal*	*Goran Chatbari*	*Saturia*

Legend: BIWTA = Bangladesh Inland Water Transport Authority; ACI = Advanced Chemical Industries; WTP = Water Treatment Plant; DND = Dhaka-Narayanganj-Demra.

Crop growth experiment was carried out in the Soil Science division of Bangladesh Agricultural Research Institute (BARI), Gazipur. Rice *cv.* BRRI dhan29 and cabbage *cv.* Atlas 70 were used as test crops for the experiment. Collected river-water of four rivers and fresh water were used as experimental treatments. The experiment was laid out following completely randomized design (CRD) with three replications. Total fifteen experimental pots were used having five treatments for each test crop. Soils were collected from Agronomy farm of Bangladesh Agricultural University, Mymensingh at a depth of 15 cm for the pot experiment.

After collection, soils were cleaned, air dried, ground, sieved using 2 mm sieve and labeled carefully. Ten kgs of processed soil was taken in each plastic pot. About 500 g of soil was preserved for laboratory analyses. Irrigation was done using polluted river-water after making it bulk of collected samples of each river, and freshwater @ 2.5 L pot^{-1} at 10 days interval from planting of the test crops. Intercultural operation and pest management was done as and when necessary. In mature stage (110 days after transplanting of rice and 95 days after sowing of cabbage) the crops were harvested and cleaned for chemical analyses. Rice grain and cabbage plant were digested using di-acid mixture (conc. HNO_3 and 60% $HClO_4$ at a ratio of 2:1) as mentioned by Singh *et al*. (1999). Heavy metal concentrations were determined by atomic absorption spectrophotometer (model no.: Shimadzu AA-7000) using flame emission in the Department of Agricultural Chemistry of Bangladesh Agricultural University, Mymensingh, Bangladesh. Analysis of variance (ANOVA) was done following the principal of F-statistics and the mean values were separated by Duncan's Multiple Range Test using statistical software SPSS (version 20.0) (Gomez and Gomez, 1984).

Results and Discussion

Physicochemical parameters of river-water samples

The pH of the collected river-water samples were within the range of 5.45 to 7.60 (Fig. 1A) indicating them as slightly acidic to slightly neutral. The highest average pH (7.12±0.61) was found in Buriganga river-water samples and lowest was obtained in the water samples collected from both Turag and Bangshi river. Out of 40 samples, the pH of 30% samples was found from 5.45 to 6.99 and the rest samples (70%) were found from 7.00 to 7.60. This result is in line with the previous studies conducted in river-water of Dhaka city (Ahammed *et al*., 2016; Hoque and Deb, 2016; Mokaddes *et al*., 2013). A higher pH value in Buriganga river water was reported by Fatema *et al.* (2018) who found the pH ranged from 7.61 to 8.97. According to ECR (1997), the standard level of pH for both fisheries and irrigation is ranged from 6.5 to 8.5. As shown in Fig. 1A, observed pH values of river-water samples were within the standard level (ECR, 1997). Previous researchers also found similar pH levels in Buriganga, Dhaleshwari, Turag, Shitalakshya and Balu rivers of Dhaka city as 4.9-7.2, 7.1, 5.9-7.5, 7.05-7.4 and 7.07-8.1, respectively (Ahmad *et al*., 2010; Ahmed *et al*., 2009; Rahman, 2005. Kibria *et al*., 2016, Rahman *et al*., 2012; Banu *et al*., 2013). Electrical conductivity (EC) of water samples was within the range of 170 to 1374 (µS cm^{-1}) (Fig. 1B). The highest EC (1374 µS cm^{-1}) was recorded from the Buriganga river and the lowest was obtained from Bangshi river (170 µS cm^{-1}). According to ADB (1994), the EC of Bangshi river was suitable for the use as irrigation water. Almost similar EC level (829 µS cm^{-1}; range: 604-1101 µS cm^{-1}) in Buriganga river-water was reported by Hoque and Deb (2016). The finding of this study was contrary to Mokaddes *et al.* (2013) who found EC ranging from 17.61 to 34.61 µS cm^{-1} in different rivers of Dhaka city. Fatema *et al.* (2018) found that the values of EC of Buriganga river water ranged from 180.0 to 598.0 µS cm^{-1}, which was lower than the present investigation. Another study (Mottalib *et al*., 2016) reported that the EC value of Shitalakshya river water were ranged from 131.6 to 2292.0 µS cm^{-1} and which were almost similar to the present study. Total dissolved solids (TDS) of water samples in the investigated river-water varied from 451 to 1827 mg L^{-1} (Fig. 1C). The highest TDS value (1827 mg L^{-1}) was detected in the Buriganga river and the lowest value (684 mg L^{-1}) was found in Bangshi river. Almost all the samples exceeded the standard limit of TDS as proposed by ADB (1994) and United States Public Health domestic water supplies standard (De, 2005). The result of this study exceeded the previous studies of different rivers of Dhaka city and found TDS levels of 420-840, 240, 342-812, 192 and 280; and DO levels of 0.19-7.9, 3.0, 2.5-9.8, 1.2-6.8 and 0.25-7.4 in Buriganga, Dhaleshwari, Turag, Shitalakshya and Balu rivers, respectively (Ahmad *et al*., 2010; Ahmed *et al*., 2009; Rahman, 2005. Kibria *et al*., 2016. Rahman *et al*., 2012; Banu *et al*., 2013). Hossain *et al*. (2018) found the TDS value of Rupsha river-water samples ranged from 600.0 to 940.0 mg L^{-1} whereas Tareq *et al.* (2013) observed the range of 62.0 to 245.0 mg L^{-1} in Brahmaputra river-water which were lower than the current study. The concentration of dissolved oxygen (DO) in collected water samples ranged from 1.8 to 6.5 mg L^{-1} (Fig. 1D). The highest amount of DO (6.5 mg L^{-1}) was found in Bangshi river and the lowest from Buriganga river (1.8 mg L^{-1}). The observed DO level of rivers water was very lower except some samples of Bangshi and Shitalakshya river than the standard level for irrigation (≥5.0 mg L^{-1}) proposed by ECR (1997).

Heavy metal concentrations in the river-water samples

The average highest Pb (67.0±3.9 mg L^{-1}), Zn (402.8±134.3 mg L^{-1}) and Cd (0.89±0.12 mg L^{-1}) concentrations were found in Buriganga river-water and the lowest concentrations were obtained in Shitalakshya river except Cd which was lowest in Bangshi river (0.12 mg L^{-1}) (Fig. 2). Previous study conducted in different rivers of Dhaka reported Pb concentration (0.40 mg L^{-1}, range: 0.03-1.14 mg L^{-1}) which also exceeded the permissible limit (Mokaddes *et al*., 2013). They found Zn concentration varied from 0.08 to 3.065 mg L^{-1}. Khan *et al*. (2013) found Pb values as 0.224, 0.216, 0.04, 0.28 and 0.038 mg L^{-1} at Buriganga, Balu, Turag, Tongi khal and Shitalakshya, respectively during 2010. Zinc values in different five rivers were 1.103, 0.156, 2.055, 0.156 and 0.106 mg L^{-1} (Khan *et al*., 2013). In contrast, the highest Cr concentration (78.5 mg L^{-1}) was found in the water of Turag river and the lowest (0.023 mg L^{-1}) from Shitalakshya river-water (Table 1). Previously, Ahmad *et al*. (2010) found the concentration of Pb, Cd, and Cr in Buriganga river ranging from 58.17 to 72.45, 7.08 to 12.33 and 489.27 to 645.26 µg L^{-1}, respectively in Buriganga, Balu, Turag, Tongi khal and Shitalakshya river. Different values of Cr as 0.042, 0.020, 0.006, 0.024, 0.005 mg L^{-1}, respectively were found by Khan *et al*. (2013). Khan *et al*. (2013) found Cd concentration as 0.018, 0.011, 0.003, 0.015, 0.003 mg L^{-1} at Buriganga, Balu, Turag, Tongi khal and Shitalakshya river, respectively. Hoque and Deb (2016) found the concentrations of Cr, Pb and Cd in Buriganga river-water as 0.13, 0.003, 0.014 mg L^{-1}, respectively. Similar trends of Cd ion were detected in water samples of the Buriganga, Turag and Shitalakha rivers (Islam *et al*., 2014). The values of Cd of the present study was lower than the previous study (Das *et al*., 2011), where it was reported that Cd concentration in Buriganga river varied from 0.11 and 2.37 µg mL^{-1}. Comparatively higher Cd concentration (0.016 to 0.035 µg mL^{-1}) in Rupsha river-water samples was also found by Hossain *et al.* (2018).

Effect of polluted river-water on the yield of rice and cabbage

Yields of rice and cabbage were significantly influenced by polluted river-water irrigation and its pollution level (Fig. 3). Experimental results showed that polluted river-water had significant effect on the yield of rice and cabbage. In case of rice, the highest yield (4.4 t ha^{-1}) was found when irrigated with freshwater and the lowest (3.2 t ha^{-1}) was found with Buriganga river-water irrigation. The second highest yield was obtained from the pot irrigated with Shitalakshya river-water. The yield of rice varied considerably irrigated with different river-water showing the trend: freshwater > Shitalakshya > Bangshi > Turag > Buriganga (Fig. 3).

Kumar *et al*. (2016) found that rice yields varied from 4.38 to 7.85 kg ha^{-1} (mean: 6.58 kg ha^{-1}) in the study area of Pillaipally anicut with canal water irrigation compared to groundwater 2.64 -7.00 t ha^{-1} (mean: 5.03 t ha^{-1}). Freshwater produced highest cabbage yield (25.3 t ha^{-1}) and when irrigated with Buriganga river-water it produced lowest yield (15.3 t ha^{-1}) (Fig. 3). The yield of cabbage followed the same trend as rice yield. From the results, it was found that irrigation with freshwater produced average highest yield of both crops. On the other hand, irrigation with polluted water caused drastically lower yield up to 27% for rice and 38% for cabbage (Fig. 4). Liao *et al*. (2013) obtained increased fresh yield of Chinese cabbage by 4.25, 3.50 and 1.82% irrigated with waste water, clear water-waste water rotation and waste water treatments, respectively compared to control. Previously, the highest head weight of cabbage (984 g in the year 2010 and 1017 g in 2011) and total fresh yield (39.36 t ha^{-1} in 2010 and 40.67 t ha^{-1} in the year 2011) were obtained with wastewater treatment in both years (Tunc and Sahin, 2015). Kiziloglu *et al*. (2008) found the highest yields of cauliflower (28.534 t ha^{-1}) and red cabbage (46.865 t ha^{-1}) with untreated wastewater irrigation. Liao *et al*. (2013) obtained fresh yields ranged from 49.475 to 51.827 t ha^{-1} in Chinese cabbage irrigated with wastewater of dairy effluent.

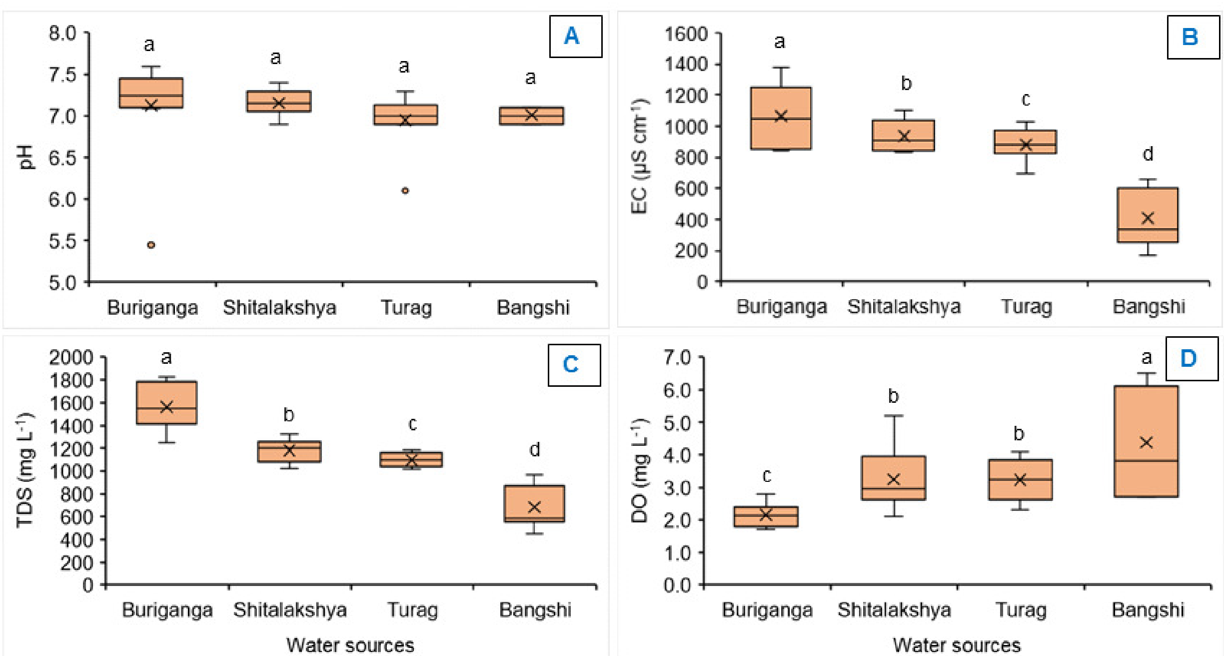

Fig. 1. Boxplot of pH, EC, TDS and DO concentrations of different river-water of Dhaka city. Median values are denoted by solid lines within the box while box boundaries show the 1st and 3rd quartiles. Box whiskers indicate the highest and lowest data values. Boxes with similar letters are statistically similar at 5% level using Tukey's method and vice versa.

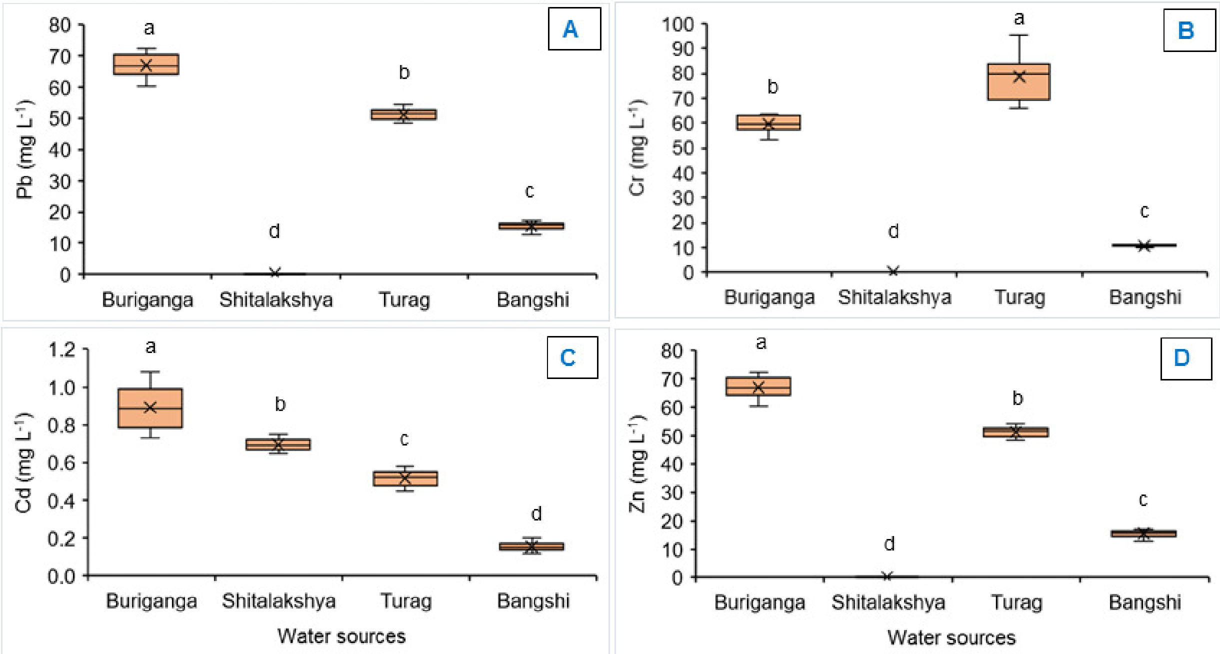

Fig. 2. Boxplot of the concentration of heavy metals (Pb, Cr, Cd and Zn) of different river-water of Dhaka city. Median values are denoted by solid lines within the box while box boundaries show the 1st and 3rd quartiles. Box whiskers indicate the highest and lowest data values. Boxes with similar letters are statistically similar at 5% level using Tukey's method and vice versa.

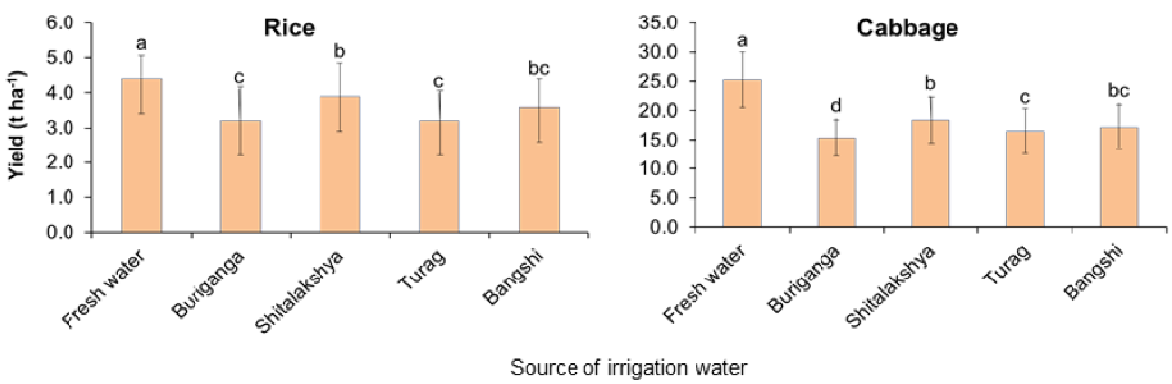

Fig. 3. Effects of polluted river-water irrigation on the yield of rice and cabbage.

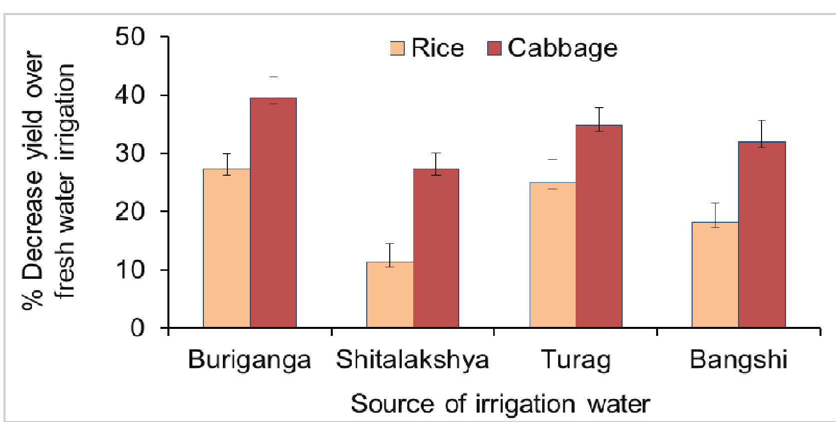

Fig. 4. Percent decreased yield of rice and cabbage over freshwater irrigation

Tunc and Sahin (2017) found similar result in the curd yield of cauliflower as 48.37 and 48.84 t ha^{-1} in the year 2010 and 2011, respectively by using wastewater as irrigation water. Moreover, higher cauliflower yields under wastewater irrigation conditions were stated many studies (Kiziloglu *et al*., 2008; Khurana and Singh, 2012; Majeed *et al*., 2014, Tunc and Sahin, 2017). Previously, Chowdhury *et al*. (2019) found cabbage yield ranging from 0.72 to 1.54 t ha^{-1} produced in polluted soils of Dhaka regions.

Heavy metal concentrations in rice grain and cabbage irrigated with river-water

Heavy metal concentrations of both test crops was also significantly affected by the wastewater irrigation. Heavy metal concentrations of rice grain and cabbage grown with polluted water as irrigation of different rivers surrounding Dhaka city are presented in Table 2 and 3. Irrigation water of different rivers significantly influenced the heavy metal concentrations of rice grain and cabbage. The highest concentrations of Pb, Cd and Zn in rice grain were 3.72, 0.08 and 8.90 mg kg^{-1}, respectively recorded in the plants irrigated with Buriganga river-water, whereas the highest Cr concentration (2.34 mg kg^{-1}) was obtained from Turag river-water Table 2. Rahman *et al*. (2019) found maximum concentration of Pb and Zn as 0.48 and 0.13 mg kg^{-1}, respectively in rice seedlings irrigated with wastewater of dyeing industries. Previously Huonga *et al*. (2008) reported the average concentration of heavy metals in the rice grain irrigated with wastewater as the following order: Zn (14.4 mg kg^{-1}) >Cu (6.9 mg kg^{-1}) >Cr (3.1 mg kg^{-1}) >Pb (2.1 mg kg^{-1}) >Ni (1.4 mg kg^{-1}) >Cd (0.1 mg kg^{-1}).

The highest concentrations of Pb, Cd and Zn in cabbage were 4.38, 0.012 and 8.86 mg kg^{-1} recorded in the plants grown in Buriganga river-water, whereas the cabbage plant grown with Turag river-water gave the highest Cr concentration (3.02 mg kg^{-1}) (Table 3). The lowest concentrations of the metals were found from cabbage grown with freshwater. Mohamed *et al*. (2003) observed Cd concentration in tomatoes as 0.77 mg kg^{-1}. Aktaruzzaman *et al*. (2013) found the concentrations of Cr and Cd ranging between 1.17−3.83 and 0.180−2.305 mg kg^{-1}, respectively in leafy vegetables. In another study, Cd concentration in red cabbage heads found above the safe limit, and wastewater treatment had the highest value (0.168 mg kg^{-1}) (Tunc and Sahin, 2015). Kiziloglu et al. (2008) found Cd, Zn and Pb as 0.16 mg kg^{-1}, 3.36 mg kg^{-1} and 0.22 mg kg^{-1} dry weight, respectively in red cabbage. Mensah *et al*. (2008) also found Cd and Pb concentrations for cabbage ranging between 0.09 to 1.11 and 0.18 to 15.2 mg kg^{-1}, respectively.

Table 2. Heavy metals concentrations (mg kg^{-1}) in rice grain after freshwater irrigation and polluted water irrigation

Heavy metals	Freshwater	River-water				Maximum limit*
		Buriganga	Shitalakshya	Turag	Bangshi	
Pb	0.03d	3.72a	0.08c	3.12a	1.35b	0.2
Cr	0.02d	1.60b	0.01d	2.34a	0.82c	1.0
Cd	0.003c	0.08a	0.06ab	0.05b	0.02c	0.1
Zn	0.049d	8.90a	0.057d	6.33b	5. 12c	50

*World Health Organization standard for heavy metal concentration in rice grain (Cheng *et al.,* 2004)

Table 3. Heavy metals concentrations (mg kg^{-1}) in cabbage after freshwater irrigation and polluted water irrigation

Heavy metals	Freshwater	River-water				Maximum limit*
		Buriganga	Shitalakshya	Turag	Bangshi	
Pb	0.031d	4.38a	0.06d	3.89b	1.81c	0.3
Cr	0.021e	1.82b	0.07d	3.02a	0.70c	2.3
Cd	0.004c	0.012b	0.08a	0.011b	0.08a	0.2
Zn	0.046d	8.86a	0.063d	6.12b	4.92c	99.4

*WHO/FAO (1989): Guidelines for heavy metals concentration in leafy vegetables

Conclusion

The heavy metal concentrations varied considerably in different river-water samples which exceeded the permissible limit in most of the samples. Yield of both test crops were also highly influenced by the river samples. Heavy metal concentrations in rice and cabbage were above the permissible limits in case of using irrigation water of Buriganga, Turag and Bangshi. The overall heavy metal pollution in the four rivers was of the following order: Buriganga > Turag > Bangshi > Shitalakshya. It can be concluded that the river-water of these three rivers were not suitable to use them as irrigation water for growing rice or cabbage. After proper treatment water of these rivers can be used.

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References

ADB. 1994. Training Manual for Environmental Monitoring, USA: Engineering Science Inc., 2-16 and 10.

Ahammed, S., Tasfina, S., Rabbani, K. and Khaleque, M., 2016. An investigation into the water quality of Buriganga -a river running through Dhaka. *International Journal of Scientific and Technology Research*, 5: 3.

Ahmad, M.K., Islam, S., Rahman, M.S., Haque, M.R. and Islam, M.M., 2010. Heavy Metals in Water, Sediment and Some Fishes of Buriganga River, Bangladesh. *International Journal of Environmental Research*, 4(2): 321-332.

Ahmed, K.M., Ahamed S. and Rahman, S., 2009. Heavy metals concentration in water, sediments and their bioaccumulations in some freshwater fishes and muscle in Dhaleshwari river, Bangladesh. Terrestrial aquatic toxicology, Global science book.

Aktaruzzaman, M., Fakhruddin, A.N.M., Chowdhury, M.A.Z., Fardous, Z. and Alam, M.K., 2013. Accumulation of heavy metals in soil and their transfer to leafy vegetables in the Region of Dhaka Aricha highway, Savar, Bangladesh. *Pakistan Journal of Biological Sciences*, 16: 332–338. https://doi.org/10.3923/pjbs.2013.332.338

APHA. 2012. Standard Methods for the Examination of Water and Wastewater, 22nd Edn. American Public Health Association, Washington, DC, USA.

Ayers, R.S. and Westcot, D.W., 1976. Water Quality for Agriculture, FAO Irrigation and Drainage Paper, 29(1).

Banu, Z., Chowdhury, M.S.A., Hossain, M.D. and Nakagami, K., 2013. Contamination and ecological risk assessment of heavy metal in the sediment of Turag River, Bangladesh: An index analysis approach. *Journal of Water Resource and Protection*, 5: 239-248. https://doi.org/10.4236/jwarp.2013.52024

BCAS. 2000. Pollution Study. Bangladesh Center for Advance Studies. Management of Aquatic Ecosystem through Community Husbandry (MACH), Dhaka, Bangladesh.

Chaudhary, M., Mishra, S. and Kumar, A., 2016. Estimation of water pollution and probability of health risk due to imbalanced nutrients in River Ganga, India. *International Journal of River Basin Management*, 1–8. https://doi.org/10.1080/15715124.2016.1205078

Cheng, W., Zhang, G., Yao, H., Dominy, P., Wu, W. and Wang, R., 2004. Possibility of predicting heavy-metal concentrations in rice grains based on DTPA-extracted levels in soil. *Communications in soil science and plant analysis*, 35(19-20): 2731-2745. https://doi.org/10.1081/CSS-200036424

Chowdhury, A.M.S., Rahman, M.A., Rahman, M.M., Mohiuddin, A.S.M. and Zaman, M.B., 2007. Nature and the extent of industrial pollution in river-water around Dhaka city. *Bangladesh Journal of Environmental Science,* 13(1): 46-49.

Chowdhury, R.A., Rashid, T. and Hoque, S., 2014. Assessing surface water quality using landsat TM and In situ Data: An exploratory analysis in Dhaka megacity, pp. 301–318. https://doi.org/10.1007/978-94-007-6735-5_16

Chowdhury, M.A.H., Chowdhury, T. and Rahman, M.A., 2019. Heavy metal accumulation in tomato and cabbage grown in some industrially contaminated soils of Bangladesh. *Journal of Bangladesh Agricultural University*, 17(3): 288–294. https://doi.org/10.3329/jbau.v17i3.43198

Dara, S.S., 2007. A Textbook of Environmental Chemistry and Pollution Control. 7th Edn., Chand S. (eds.) Company Ltd., Ram Nagar, New Delhi, India, pp.44–75.

Das, M., Ahmed, M.K., Islam, M.S., Islam, M.M. and Akter, M.S. 2011. Heavy metals in industrial effluents (tannery and textile) and adjacent rivers of Dhaka city, Bangladesh. *Terrestrial and Aquatic Environmental Toxicology*, 5: 8-13.

De, A.K., 2005. Environmental Chemistry, Fifth Edition. India: New Age International Publishers, 242.

DoE (Department of Environment). 2013. Surface Water Quality Report- 2013. Dhaka.

DoE (Department of Environment). 1997. Environmental quality standards (EQS) for Bangladesh, Dhaka: GOB.

ECR. 1997. Government of the People's Republic of Bangladesh. Ministry of Environment and Forest, Department of Environment, Dhaka, Bangladesh, pp: 212–214.

Fatema, K., Begum, M., Zahid, A. and Hossain, M.E. 2018. Water quality assessment of the river Buriganga, Bangladesh. *Journal of Biodiversity, Conservation, Bioresources Management*, 4: 47-53. https://doi.org/10.3329/jbcbm.v4i1.37876

Ghosh, A.B., Bajaj, J.C., Hasan, R. and Singh, D., 1983. Soil and Water Testing Methods. A laboratory Manual, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi- 1100012. pp. 1–48.

Gomez, K.A. and Gomez, A.A., 1984. Statistical Procedure for Agricultural Research. 2nd Edn. International Rice Research Institute. Los Banos, Philippines. pp. 207–215.

Gupta, P.K., 2013. Soil, Plant, Water and Fertilizer Analysis. 2nd Edn., Agrobios Jodhpur, India, pp. 254–263.

Hoque, M.M.M. and Deb, P.P., 2016. Assessment of physicochemical water quality parameters and heavy metals concentration in water samples from Buriganga River adjacent to Dhaka city. *Journal of Environmental Science and Natural Resources*, 9(2): 97-104. https://doi.org/10.3329/jesnr.v9i2.32164

Hossain, M.S., Ahmed, F., Abdullah, A.T.M., Akbor, M.A. and Ahsan, M.A., 2015. Public health risk assessment of heavy metal uptake by vegetables grown at a waste-water-irrigated site in Dhaka, Bangladesh. *Journal of Health and Pollution*, 5(9): 78–85. https://doi.org/10.5696/2156-9614-5-9.78

Hossain, M.K., Rahman, M.M. and Haque, S. 2018. Quantitative assessment of water contaminants in the Rupsha river of Khulna region for irrigation usage. *Journal of Environmental Science and Natural Resources*, 11: 145-151. https://doi.org/10.3329/jesnr.v11i1-2.43381

Hunt, D.T.E. and Wilson, A.L., 1996. The Chemical Analysis of Water-General Principles and Techniques. 2nd Edn., Published by the Royal Society of Chemistry. Thomas Graham Home. The Science park, Cambridge CB 44 WF. pp. 1-2.

Islam, M.S., Ahmed, M.K., Habibullah-Al-Mamun, M. and Masunaga, S., 2014. Trace metals in soil and vegetables and associated health risk assessment. *Environmental Monitoring and Assessment*, 186(12): 8727–8739. https://doi.org/10.1007/s10661-014-4040-y

Islam, M.A., Ahmad, S.A. and Islam, R., 2019. The valuation of water quality: A conceptual framework for households' and producers' willingness to pay in Dhaka, Bangladesh. *Journal of Economics and Sustainable Development*, 10(2): 162–168.

Karn, S.K. and Harada, H., 2001. Surface water pollution in three urban territories of Nepal, India, and Bangladesh. *Environmental Management*, 28(4): 438–496. https://doi.org/10.1007/s002670010238

Khan, M.A.I., Hossain, A.M., Huda, M.E., Islam M.S. and Elahi, S.F., 2007. Physico- chemical and biological aspects of monsoon waters of Ashulia for economic and aesthetic applications: preliminary studies. *Bangladesh Journal of Science and Industry Research,* 42(4): 377–396. https://doi.org/10.3329/bjsir.v42i4.747

Khan, M.T.R., Rahman, S., Akib, S. and Biswas, S.K., 2013. Investigation of heavy metal pollution in peripheral river-water around Dhaka city. *Pensee Journal*, 75(10): 421–435.

Khurana, M.P.S. and Singh, P., 2012. Waste water use in crop production: A review. *Resources and environment*, 2: 116–131. https://doi.org/10.5923/j.re.20120204.01

Kibria, G., Hossain, M.M., Mallick, M., Lau, T.C. and Wu, R. 2016. Monitoring of metal pollution in waterways across Bangladesh and ecological and public health implications of pollution. *Chemosphere*, 165: 1–9. https://doi.org/10.1016/j.chemosphere.2016.08.121

Kiziloglu, F.M., Turan, M., Sahin, U., Kuslu, Y. and Dursun, A., 2008. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica olerecea* L. *var.* botrytis) and red cabbage (*Brassica olerecea* L. *var.* rubra) grown on calcareous soil in Turkey. *Agricultural Water Management*, 95: 716–724. https://doi.org/10.1016/j.agwat.2008.01.008

Kumar K.A., Devi, M.U., Rao V. P., Ramulu V., Narender N. and Krishnaveni., 2016. Waste water irrigation effect on rice yields in Musi river command area in India – A case study. 2nd World Irrigation Forum. 1–11.

Liao, L., Cai, W., Shao, X. and Tan, J., 2013. Yields, quality and metal accumulation of Chinese cabbage irrigated with diary effluent. *Advance Journal of Food Science and Technology*, 5(7): 941–945. https://doi.org/10.19026/ajfst.5.3187

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A.J., Jenkins, A., Ferrier, R.C., Li, H., Luo, W. and Wang, T., 2015. Impacts of soil and water pollution on food safety and health risks in China. *Environment International*, 77: 5–15. https://doi.org/10.1016/j.envint.2014.12.010

Mokaddes, M.A.A., Nahar, B.S. and Baten, M.A., 2013. Status of heavy metal contaminations of river-water of Dhaka metropolitan city. *Journal of Environmental Science and Natural Resources,* 5(2): 349–353. https://doi.org/10.3329/jesnr.v5i2.14842

Majeed, M., Chaudhry, M.S., Zehra, S.S., Gillani, S.M.N. and Ajmal, F., 2014. Impact of waste water irrigation on cauliflower yield in Punjab, Pakistan. *International Journal of Science and Research*, 3: 2107–2110.

Matin, M.A. and Kamal, R., 2010. Impact of climate change on river system. In The International Symposium on Environmental Degradation and Sustainable Development (ISEDSD), Dhaka, Bangladesh, pp. 61–65.

Meade, J.W., 1998. Aquaculture Management, India: CBS Publishers & Distributors: 9.

Mensah E., Allen H.E., Shoji R., Odai S.N., Kyei-Baffour N., Ofori E. and Mezler D., 2008. Cadmium (Cd) and lead (Pb) concentrations effects on yields of some vegetables due to uptake from irrigation water in Ghana. *International Journal of Agricultural Research*, 3: 243–251. https://doi.org/10.3923/ijar.2008.243.251

Mohamed, A.E., Rashed, M.N. and Mofty, A., 2003. Assessment of essential and toxic elements in some kinds of vegetables. *Ecotoxicology and environmental safety,* 55: 251–260. https://doi.org/10.1016/S0147-6513(03)00026-5

Mohiuddin, K.M., Alam, M.M., Rahman, M.S., Islam, M.S. and Ahmed, I., 2016. Effect of polluted river-water on growth, yield and heavy metal accumulation of red amaranth. *Research in Agriculture Livestock and Fisheries*, 3(1): 53–65. https://doi.org/10.3329/ralf.v3i1.27858

Mottalib, M.A., Al-Razee, A.N.M., Abser M.N. and Aman E.U.M. 2016. Assessment of physico-chemical properties of surface water of Shitalakhya river near Polash, Narsingdi, Bangladesh. *International Journal of Advanced Research,* 4: 915-924. https://doi.org/10.21474/IJAR01/1288

Huonga, N.T.L., Ohtsuboa, M., Lib, L., Higashia, T. and Nakanoa, M.K.A., 2008. Heavy metal contamination of soil and rice in wastewater-irrigated paddy field in a suburban area of Hanoi. *Vietnam Clay Science,* 13: 205–215.

Rahman, A., Zafor, M.A. and Kar, S., 2012. Analysis and comparison of surface water quality parameters in and around Dhaka city. *International Journal of Civil Engineering and Technology,* 3 (2): 7–15.

Rahman, M.D., 2005. Pollution status and trends in water quality of the Shitalakshya and Balu rivers. MS thesis. Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Rahman, M.A., Rahman, M.S., Mohiuddin, K.M., Chowdhury, M.A.H. and Chowdhury, M.A.K., 2019. Germination and seedling growth of rice (*Oryza sativa* L.) as affected by varying concentrations of loom-dye effluent. *Journal of Bangladesh Agricultural University*, 17(2): 153–160. https://doi.org/10.3329/jbau.v17i2.41938

Sarkar, M., Rahman, A.K.M.L., Islam, J.B., Ahmed, K.S., Uddin, M.N. and Bhoumik, N.C., 2015. Study of hydrochemistry and pollution status of the Buriganga river, Bangladesh. *Bangladesh Journal of Scientific and Industrial Research,* 50(2): 123–134. https://doi.org/10.3329/bjsir.v50i2.24353

Singh, D., Chhonkar, P.K. and Pandey, R.N., 1999. Soil, Plant and Water Analysis: A Method Manual. IARI, New Delhi. India.

Sunny, A.R., Naznin, S., Rahman, M.J., Nahiduzzaman, M. and Wahab, M.A., 2017. Assessment of the river-water quality parameters and pollution: An insight from Dhaka city. International Symposium on Sustainable Urban Environment, Tezpur University, Assam, 23-24 June, 2017.

Tandon, H.L.S., (eds.) 1995. Methods of Analysis of Soils, Plants, Waters and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi. pp. 84–90.

Tareq, S.M., Rahaman, M.S., Rikta, S.Y., Islam, S.M.N. and Sultana, M.S. 2013. Seasonal variations in water quality of the Ganges and Brahmaputra River, Bangladesh. *Jahangirnagar University Environmental Bulletin,* 2: 71-82. https://doi.org/10.3329/jueb.v2i0.16332

Tunc, T. and Sahin, U., 2017. Yield and heavy metal concentration of wastewater-irrigated cauliflower and soil chemical properties. *Communications in Soil Science and Plant Analysis*, 48(10): 1194–1211. https://doi.org/10.1080/00103624.2017.1341910

Tunc, T. and Sahin, U., 2016. Red cabbage yield, heavy metal concentration, water use and soil chemical characteristics under wastewater irrigation. *Environmental Science and Pollution Research*, 23(7): 6264-6276. https://doi.org/10.1007/s11356-015-5848-x

Uddin, M.J., Khanom, S., Al Mamun, S. and Parveen, Z., 2016. Effects of irrigation water on some vegetables around industrial areas of Dhaka. *Bangladesh Journal of Scientific Research*, 28(2): 151–159. https://doi.org/10.3329/bjsr.v28i2.26785

USEPA. 1999. US Environmental Protection Agency, Screening Level Ecological Risk Assessment Protocol. Appendix E: Toxicity Reference values U.S. EPA Region 6. Office of Solid waste.

WHO/FAO. 1989. Report of 33rd meeting of Joint WHO/FAO Expect Committee on foods additives. Toxicological evaluation of certain foods additives and contaminants. No. 24, International Program on Chemical Safety, WHO, Geneva.