Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer Reviewed Journal

Open Access
Research Article

Res. Agric. Livest. Fish.
Vol. 3, No. 1, April 2016: 53-65

EFFECT OF POLLUTED RIVER WATER ON GROWTH, YIELD AND HEAVY METAL ACCUMULATION OF RED AMARANTH

KM Mohiuddin*, Md. Mehediul Alam, Md. Shahinur Rahman, Md. Shafiqul Islam and Istiaq Ahmed

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

***Corresponding author:** KM Mohiuddin; E-mail: mohiagchem@gmail.com

ARTICLE INFO

Received
24.02.2016

Accepted
22.04.2016

Online
30 April 2016

Key words
Heavy metal,
Vegetable,
River water,
Irrigation

ABSTRACT

The present study was carried out to assess the levels of different heavy metals like chromium (Cr), lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) on red amaranth vegetable irrigated with polluted river water. Atomic Absorption Spectrometer was used for analyzing the heavy metals in the samples. The results indicated a substantial build-up of heavy metals accumulation in red amaranth irrigated with polluted river water. The ranges of various metals in red amaranth samples irrigated with polluted river water were 0.45–0.93, 0.147–0.175, 42.33–479.73, 1.31–12.04, 3.71–35.11 and 10.9–142.9 µg g^{-1} for Cr, Pb, Fe, Cu, Zn and Mn, respectively. Cadmium concentration was below the detection limit (0.01 µg g^{-1}) of the method used in the analysis. However, the regular monitoring of levels of these metals from effluents and sewage, in vegetables and in other food materials is essential to prevent excessive build-up of these metals in the food chain. In general, our results indicated that using polluted river water had no significant variation in growth and yield of red amaranth from the crops irrigated with fresh water.

To cite this article: Mohiuddin KM, MM Alam, MS Rahman, MS Islam and I Ahmed, 2016. Effect of polluted river water on growth, yield and heavy metal accumulation of red amaranth. Res. Agric. Livest. Fish. 3 (1): 53-65.

INTRODUCTION

River water is becoming contaminated for the disposal of sewages and municipal waste, medical, dying, tannery waste and from free flowing of pesticide and fertilizer and most of these effluents contain various hazardous metals like As, Cr, Cd, Pb, Cu, Ni, Fe, Zn, Mn, Hg etc which offer potential threats for both human being and environment even at trace levels. Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Now-a-days heavy metals are ubiquitous because of their excessive use in industrial applications. Wastewater contains substantial amounts of toxic heavy metals, which create problems (Chen, Wang, & Wang, 2005; Singh, Mohan, Sinha, & Dalwani, 2004). Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination, but also affect food quality and safety (Muchuweti *et al.,* 2006). Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda, Mangwayana, Nyamangara, & Giller, 2005). Vegetables take up heavy metals and accumulate them in their edible (Bahemuka & Mubofu, 1991) and non-edible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants (Alam, Snow, & Tanaka, 2003). A number of serious health problems can develop as a result of excessive uptake of dietary heavy metals.

Rivers around Dhaka city, Bangladesh are economically very important. River water is used for irrigation during dry season. Not only in Dhaka city, irrigation of crops with river water though it is contaminated, is a very common practice in Bangladesh due to its easy availability and scarcity of fresh water. Hundreds of industries had already been established along the rivers and are frequently used for dumping of industrial waste. As a result, rivers in Dhaka city and it's surrounding are under serious threat of toxic heavy metal contamination (Alam, 2008). Thus, when those rivers water used as irrigation purposes, it gets an easy way to alter the soil physical and chemical properties which may offer a potential risk for agricultural activities and become harmful for growth and yield of different agricultural crops especially on leafy vegetables. Vegetables constitute an important part of the human diet. Some vegetables are very rich with carbohydrates, proteins, vitamins and minerals. But, recently different heavy metals have been found on the surface and in the tissue of fresh vegetables with a mentionable concentration (Bigdeli and Seilsepour, 2008). Some experimental report suggested that, in addition to human health hazard about 6 µg mL^{-1} of Cu, Hg and Ni in water also seriously decrease germination of seed, shoot length, root length, leaf area, fresh and dry mass of leaves of cowpea (Joshi *et al.,* 1999).

The previous studies on the river water were focused on the river water chemistry and physicochemical properties in the river water (e.g. Ali *et al.,* 2008; Moniruzzaman *et al.,* 2009) and some studies on seasonal and spatial distribution of heavy metals (Alam, 2003; Mohiuddin *et al.,* 2011). But, no detailed study on growth, yield and quality of different leafy vegetables has so far been conducted. The present study was conducted to observe the concentration of accumulated metals and also effects of irrigation with polluted river water on the growth, yield and quality of winter vegetable such as Red amaranth *(Amaranthus tricolor* L.).

MATERIALS AND METHODS

Collection and preparation of water sample

About 16 river water samples were collected from 16 different sites around the Dhaka city (Table 1) following the method as described by APHA (2005). About 20 L water samples from each location were collected in plastic container for irritation. About 100 mL of water samples from each location were collected separately for chemical analysis, in which 0.5 mL conc. nitric acid were added to avoid any microbial growth. The chemical analyses of water were done as quickly as possible on arrival at the Laboratory of Agricultural Chemistry, BAU, Mymensingh-2202.

Test crop used for the study

Red amaranth (*Amaranthus tricolor L.*) was used as test crop to determine the effects of chemical constituents of river water on the growth, yield and quality of a winter vegetable. The seeds of Red amaranth were collected from the Bangladesh Agricultural Development Corporation (BADC), Mymensingh before 5 days of planting. The fresh soils were thoroughly mixed and air dried separately in a clean room to avoid contamination and ground to pass through 2 mm sieve. 10 kg of soil was taken into each of the plastic pot labeled earlier. Individual pot size was 30 cm diameter at the top and 20 cm diameter at the bottom with 25 cm depth. The top surface area of each pot was 0.07071 m^2. All the pots were filled with processed soil leaving 5 cm from the top. The seeds were sown by hand into the pot at 24 February, 2014 keeping uniform distance as far as possible and then the seeds were covered by soils. The seeds were germinated uniformly after 6 to 8 days of sowing. The seedlings were irrigated with the water samples collected from 16 different sampling sites around the Dhaka city. Irrigation with distilled water was considered as control treatment. The experimental design was randomized complete block design (RCBD) with three replications

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

Sample No.	Location
1	Tongi Bazar Boat Mooring
2	Sluice Gate Area
3	Noyanichala Bailey Bridge
4	Asulia Highway Bridge
5	Uttara Sector 16
6	Sinnirtak
7	Gabtoli
8	Aminbazar
9	Hazaribag – ZH Sikder MC
10	Nobabgonj Bara Masjid
11	Shohid Nagar Beribadh
12	Kellarmor Truck Stand
13	Raghunathpur
14	Swarighat
15	Nowab Barir Ghat
16	Mererbag

Data collection

Plant height (cm), shoot length (cm), root length (cm), no. of leaves $plant^{-1}$, total no. of plant pot^{-1}, fresh and dry weight of plant were recorded and their mean values were calculated from the sample plants after harvesting. The plant was harvested after 50 days of sowing on 14 April, 2014.

Digestion of the vegetable samples

All the collected vegetable samples were thoroughly washed with double distilled water to get rid of air born pollutants. All the samples were then oven-dried in a hot air oven at 70–80 ºC for 24 h, to remove all moisture. Dried samples were powdered using a pestle and mortar and sieved. All reagents were of analytical reagent grade, 69–72% HNO_3, 30% H_2O_2, and 70% $HClO_4$ were used for digestion of samples. Double deionized water was used for all dilutions. During the experiments, all glasswares and equipment were carefully cleaned starting with 2% HNO_3 and ending with repeated rinsing distilled deionized water to prevent contamination. Samples (0.6 g) were digested with 10 mL of HNO_3, 2 mL of H_2O_2, and 4 mL of $HClO_4$ in block digester system maintained temperature 180-200ºC until white fumes are evolved and finally diluted to 50 mL with 2% nitric acid. All sample solutions were clear. A blank digest was carried out in the same way.

Determination of metals

Titration using 0.02N EDTA was applied to analyze Ca and Mg (Page *et al.,* 1982). Heavy metals (Cr, Pb, Cd, Fe, Cu, Zn and Mn) concentration in the extract were determined by atomic absorption spectrophotometer (SHIMADZU AA-7000), using a deuterium background correction. Sodium and potassium were determined by flame emission spectrophotometer (JENWAY, PFP7).

Determination of protein

The protein content of the samples was estimated by the micro Kjeldhal method, in which the sample was digested with a known quantity of concentrated sulphuric acid in the block digester. The digested material was distilled after the addition of alkali. The released ammonia was collected in 4% boric acid in the distillation unit. The resultant boric acid, now contained the ammonia released from the digested material, was then titrated against 0.1 N HCl, manually. The nitrogen content thus determined was multiplied by a factor of 6.25 to arrive at the amount of protein.

Statistical analysis

Data obtained were subjected to statistical analysis by using the software package SPSS 12 (SPSS Inc., Chicago, IL, USA). The statistical tests performed were analysis of variance (ANOVA; P = 0.05) and Duncan's multiple-range test (P = 0.05).

RESULT

The analysis of river water is given in Table 1 and 2. The application of polluted river water generally led to changes in the physicochemical characteristics of soil and consequently heavy metal uptake by red amaranth. The table reports a relative enrichment of that water by Cr, Fe, Cu, Zn and Mn,

Table 2. Concentration of major nutrients in water samples collected from different sites of the river around the Dhaka city, Bangladesh

Sample no.	Ca (µg mL^{-1})	Mg (µg mL^{-1})	Na (µg mL^{-1})	K (µg mL^{-1})
1	0.64	1.07	29.51	135.8
2	0.32	0.68	21.14	132.7
3	0.48	0.58	20.30	282.6
4	0.64	0.68	21.98	263.7
5	0.48	0.78	21.98	62.4
6	0.64	0.68	29.51	172.1
7	0.32	0.87	14.44	165.0
8	0.48	1.17	18.63	153.2
9	0.80	0.97	30.3	80.6
10	0.64	0.78	38.7	142.1
11	0.96	1.07	28.7	61.6
12	0.96	0.87	35.4	101.9
13	0.96	0.87	22.8	135.8
14	0.80	0.58	27.8	151.6
15	0.64	1.07	20.3	152.4
16	0.96	1.17	17.0	146.1
Mean	0.67	0.86	24.9	146.2
Range	**0.32-0.96**	**0.58-1.17**	**14.44-38.7**	**61.6-282.6**

Effect of polluted river water on growth and yield of red amaranth

Plant growth parameters such as plant height (cm), shoot length (cm), root length (cm), no. of leaves plant^{-1}, total no. of plant pot^{-1}, fresh and dry weight of plant were not significantly affected by the river water application (Table 4). Total no. of plants among the all treatments varied from 16 to 45 with an average of 30. On the other hand, the maximum no. of plant (58.0) was observed in pot where normal water used for irrigation. These observed results might be due to use of river water for irrigation which contaminated with different heavy metals. The plant height of the red amaranth were ranging from 10.7 to 24 cm and the average height of the control plants were 22.2 cm and average height of the 16 treatments were 18.6 cm. Root and shoot length of red amaranth were decreased due to application of polluted river water ranging from 1.9 to 5.2 cm 8.8 to 18.8 cm, respectively. The average root and shoot length of 16 treatments were 3.6 cm and 14.7 cm, respectively but 4.72 cm and 17.48 cm were in control treatment, respectively. The average leaf no. of five plants per pot ranged from 4 to 9.4 with an average of 6.8.The average no. of leaf in control of five plants per pot was 7.6.Fresh and dry weights of 10 plants per pot were observed among all treatments ranging from 5.60 to 18.40 g and 0.54 to 1.50 g, respectively with an average of 10.11 and 1.01 g, respectively and 12.20 g and 1.50 g, respectively, in control. Similar result was also observed in tomato and cucumber plants (Qaryouti *et al.,* 2015).Subsequently, these authors suggested that the reclaimed river polluted water can replace fresh water in irrigation of vegetables during dry season but the water quality is continuously monitored to avoid heavy metal accumulation and microbial contamination.

Nutritive quality of red amaranth

Protein and total nutrient uptake of Ca, Mg, K and Na are summarized in Table 5 and were not significantly affected by the river water application except Na. The maximum protein content was (13%) observed in sample no. 15 and the minimum value of N was (6.5 %) in treatment no. 10. Mean value of protein content was found 9.0 % of 16 treatments. Control treatment contains (9.8%) in which normal water was used. The content of potassium varied from 1.1% to 2.6%. The maximum value of K content was (2.63%) observed in control treatment and minimum (1.1%) in treatment no. 14. The average content of K was 2.0 %. Aykroyd (1963) observed that K in red amaranth was 341 mg l00g^{-1} in edible portion. The content of Ca varied from 0.3% to 1.0%. The maximum value of Ca content was (1.0%) observed in sample no. 1, 5, 12, and 15; and minimum (0.3%) was observed in sample no. 2 and 7. The average content of Ca was (0.7%) but in control it was 0.96%. Begum (2006) reported that the Ca content of red amaranth was 374 mg 100g^{-1} of the edible portion. The content of Mg was ranging from 0.1% to 0.27%. The maximum and minimum value of Mg was observed 0.27% and 0.1%, respectively with the average value of 0.21% and control treatment contains 0.17% Mg. Aykroyd (1963) observed that Mg in red amaranth was 247 mg 100g^{-1} of the edible portion. Statistical analysis showed that Na content was increased significantly in all treatments except sample no. 2, 6, 7, 8 and 11 as compared with control treatment. The highest (182.2 ppm) Na was found in sample no. 3 and the lowest (69.3 ppm) in sample no. 2 and 8. The average content of Na was observed 126.7 ppm and in control treatment where 81.64 ppm Na was found.

Table 3. Concentration of heavy metals in water samples collected from different sites of the river around the Dhaka city, Bangladesh

Sample no.	Heavy metal concentration (µg mL^{-1})						
	Cr	**Pb**	**Cd**	**Fe**	**Cu**	**Zn**	**Mn**
1	0.022	BDL	BDL	0.832	0.135	0.243	0.125
2	0.014	BDL	BDL	0.921	0.172	0.262	0.201
3	0.031	BDL	BDL	0.812	0.211	0.252	0.163
4	0.123	BDL	BDL	0.235	0.166	0.392	0.017
5	0.089	BDL	BDL	0.364	0.182	0.390	0.066
6	0.101	BDL	BDL	0.275	0.183	0.278	0.012
7	0.173	BDL	BDL	0.285	0.189	0.204	0.109
8	0.166	BDL	BDL	0.492	0.215	0.334	0.103
9	0.135	BDL	BDL	1.446	0.203	0.243	0.283
10	0.142	BDL	BDL	0.912	0.209	0.591	0.167
11	0.139	BDL	BDL	1.312	0.217	0.821	0.241
12	0.152	BDL	BDL	0.605	0.219	0.575	0.229
13	0.169	BDL	BDL	0.639	0.215	0.399	0.192
14	0.163	BDL	BDL	0.372	0.220	0.572	0.171
15	0.192	0.025	BDL	0.321	0.217	0.483	0.165
16	0.179	0.082	BDL	0.373	0.242	0.342	0.132
Range	0.014-0.192	BDL-0.082	-	0.235-1.446	0.135-0.242	0.204-0.821	0.012-0.283
Mean	0.124	0.0535	BDL	0.637	0.200	0.399	0.149
DWGV*		**2[a]**		**0.3[b]**	**0.05[a]**		**0.4[a]**
IWGV*		**0.011[d]**		**0.75[c]**	**0.2[c]**		**2[c]**

BDL: Below Detectable Limit; DWGV: Drinking Water Guideline Value; IWGV: Irrigation Water Guideline Value
*a - WHO (2008); b - USEPA (2009); c - Ayers and Westcot (1985); d- ADB (1994)

Table 4. Effect of Waste Water on Morphological and Physiological attributes of red amaranth

Sample no.	Total No. of plant	Average plant height (cm) of 05 plant per pot	Average shoot length (cm) of 05 plant per pot	Average root length (cm) of 05 plant per pot	Average of 05 plant leaf No. per pot	Fresh weight (g) of 10 plant per pot	Dry weight (g) of 10 plant per pot	Moisture content (%) of 10 plant
1	45.0	24.0	18.8	5.2	9.4	13.10	1.40	89.3
2	17.0	13.6	11.2	2.4	6.2	8.18	1.21	85.2
3	52.0	21.4	16.9	4.5	8.6	10.10	1.32	86.9
4	26.0	18.2	14.6	3.6	6.9	8.50	0.89	89.5
5	41.0	18.8	15.8	3.0	7.2	11.10	1.00	91.0
6	43.0	18.9	15.1	3.8	7.2	13.00	1.10	91.5
7	24.0	10.7	8.8	1.9	4.7	7.43	0.60	91.9
8	31.0	21.8	17.9	3.9	6.4	11.60	1.25	89.2
9	32.0	18.4	14.8	3.6	7.0	10.80	1.13	89.5
10	29.0	21.0	17.1	3.9	6.8	7.30	1.00	86.3
11	26.0	21.2	16.4	4.8	7.4	18.40	1.50	91.8
12	16.0	18.0	14.3	3.7	6.4	5.60	0.54	90.4
13	31.0	18.8	12.3	2.0	4.0	8.51	0.81	90.5
14	29.0	23.6	18.0	5.6	8.2	12.40	1.40	88.7
15	21.0	14.9	12.5	2.4	6.8	7.35	0.54	92.7
16	17.0	13.8	11.1	2.7	6.4	8.31	0.41	95.1
Average of (16) sample	**30.0**	**18.6**	**14.7**	**3.6**	**6.8**	**10.11**	**1.01**	**90.0**
Range	**16.0-45.0**	**10.7-24**	**8.8-18.8**	**1.9-5.2**	**4-9.4**	**5.60-18.40**	**0.54-1.50**	**85.2-91.9**
Control	58.0	22.20	17.48	4.72	7.6	12.20	1.50	87.7

Table 5. Concentration of protein and major nutrients in red amaranth

Sample No.	Protein (%)	Ca (%)	Mg (%)	K (%)	Na (ppm)
1	8.2	1.0	0.17	2.6	170.4
2	9.2	0.3	0.23	2.6	69.3
3	8.0	0.5	0.17	2.4	182.8
4	9.0	0.7	0.20	2.1	124.0
5	10.2	1.0	0.25	2.0	131.0
6	8.2	0.6	0.25	2.0	71.8
7	9.3	0.3	0.12	2.6	81.6
8	8.7	0.8	0.10	2.6	69.3
9	8.8	0.5	0.27	1.6	145.8
10	6.5	0.6	0.17	2.0	145.8
11	8.0	0.6	0.10	2.1	98.9
12	10.5	1.0	0.23	1.6	150.7
13	7.8	0.8	0.27	1.6	135.9
14	8.2	0.8	0.21	1.1	131.0
15	13.0	1.0	0.25	1.3	170.4
16	10.2	0.6	0.27	2.4	148.2
Average of (16) sample	**9.0**	**0.70**	**0.21**	**2.0**	**126.7**
Range	**6.5-13.0**	**0.3-1.0**	**0.10-0.27**	**1.1-2.6**	**69.3-182.8**
Control	9.8	0.96	0.17	2.63	81.64

Heavy metal accumulation in red amaranth

The application of polluted river water generally led to changes in the physicochemical characteristics of soil and consequently heavy metal uptake by vegetable. The heavy metals concentrations in edible part of red amaranth are shown in Fig. 1. It can be clearly observed that the concentration of all the heavy metals is higher in polluted river water-irrigated than freshwater-irrigated except Pb and Zn. Heavy metals concentration was in the order of Fe > Mn > Zn > Cu > Cr > Pb > Cd in the polluted river water irrigated vegetable.

Table 6. Concentration of heavy metal (μg g^{-1}) in red amaranth samples

No. of Sample	Concentration (μg g^{-1})						
	Cr	**Pb**	**Cd**	**Fe**	**Cu**	**Zn**	**Mn**
1	0.519	0.0147	BDL	139.99	9.47	11.60	84.0
2	0.448	0.0161	BDL	81.92	1.31	5.24	16.7
3	0.489	0.0153	BDL	272.32	6.29	9.04	93.5
4	0.532	0.0159	BDL	245.66	7.83	3.81	89.6
5	0.485	0.0156	BDL	176.53	7.01	9.48	86.7
6	0.487	0.0150	BDL	128.16	8.75	9.76	70.6
7	0.769	0.0170	BDL	42.33	7.11	3.71	10.9
8	0.837	0.0152	BDL	142.11	8.55	8.98	72.0
9	0.918	0.0153	BDL	298.50	11.32	10.26	104.1
10	0.899	0.0159	BDL	368.92	6.08	10.45	114.1
11	0.899	0.0160	BDL	199.91	12.65	8.95	78.2
12	0.907	0.0159	BDL	388.85	12.04	9.45	140.5
13	0.893	0.0175	BDL	344.87	9.47	9.17	103.0
14	0.933	0.0164	BDL	341.81	11.93	8.64	124.7
15	0.880	0.0166	BDL	326.67	12.04	7.61	117.4
16	0.933	0.0163	BDL	479.73	6.08	35.11	142.9
Average	**0.74**	**0.02**	BDL	**248.64**	**8.62**	**10.08**	**90.56**
Range	**0.448-0.933**	**0.147-0.175**		**42.33-479.73**	**1.31-12.04**	**3.71-35.11**	**10.9-142.9**
Control	0.10	0.0159	BDL	197.92	1.92	13.63	74.51

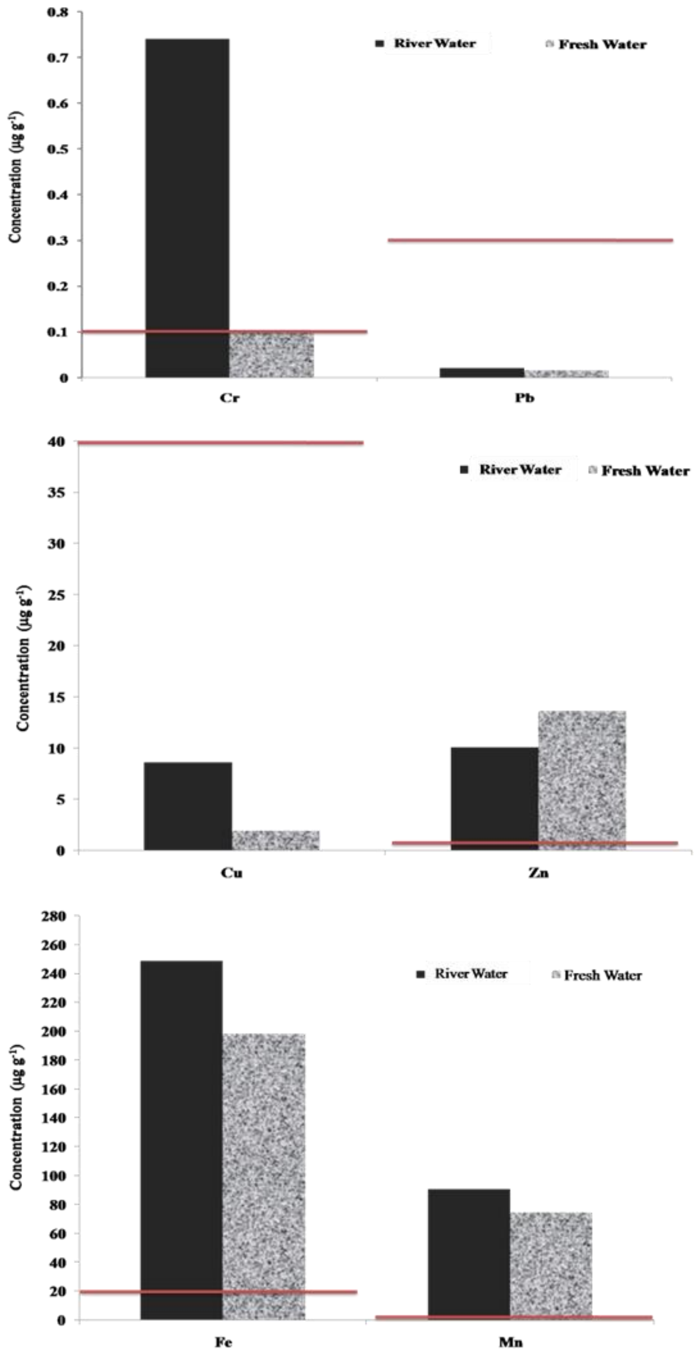

Figure 2. Heavy metal concentration in different red amaranth samples irrigated with contaminated river water and fresh water [Red line showing the standard acceptable limit for consumption proposed by FAO/WHO]

The concentration of Cr in red amaranth samples ranged from 0.45 to 0.93 µg $g^{-1}$with a mean value of 0.74µg g^{-1} (Table 6) of 16 samples and control treatment contains 0.10 µg g^{-1} Cr which is much below with the previous report, where the concentration of this metal was found to be 6.4 µg g^{-1} (Salvatore, Carratù, and Carafa, 2009). However this value is higher than 0.1 µg g^{-1} limit set by FAO/WHO (1993) and SEPA (2005), and 0.002 µg g^{-1} by Bose and Bhattacharyya (2008).

The level of Pb in red amaranth ranged from 0.0147 to 0.0175 µg g^{-1}, having an average value of 0.02 µg g^{-1} (Table 6) of 16 treatments. Control treatment contains 0.02 µg g^{-1} Pb. The permissible limit in plants recommended by FAO/WHO (1993) is 0.3 µg g^{-1} and SEPA (2005) limit is 9.0 µg g^{-1} but in all the plant were below these limit. Lead is a serious cumulative body position which enters into the body system through air, water and food and cannot be removed by washing fruits and vegetables (Kumar Sharma *et al.,* 2007).

The permissible limit of Cd in vegetables, recommended by FAO/WHO (1993) and SEPA (2005), is 0.02 µg g^{-1} and our values of Cd in all samples were below 0.01 µg g^{-1} (below detectable limit by flame AAS method). Cadmium is highly toxic metal not known to have any beneficial effects for plants and animals. Many Cd compounds are also believed to be carcinogenic.

From the results it was observed that the concentration of Fe in red amaranth samples varied from 42.33 to 479.73 µg g^{-1} having an average value of 248.64 µg g^{-1} (Table 6) and this value is greater than the concentration of Fe in control treatment which is 197.92 µg g^{-1} and it is much higher than the recommended value by FAO/WHO (20 µg g^{-1}). Excess amount of Fe (more than 10 mg kg^{-1}) causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. Fe toxicity in plants occurs when they accumulate greater than 300 µg g^{-1} of Fe, at soil pH less than 5.0 (Li, Wang, Gou, Su, & Wang, 2006). However, high concentration of iron reported from all vegetables analyzed, coupled with its lowest percentage loss from plants can be attributed to its role in chlorophyll synthesis in plants in addition to its relative abundance in the earth crust.

The concentration of Cu in red amaranth ranged from 1.31 to 12.04 µg g^{-1}, having an average value of 8.62 µg g^{-1} (Table 6). Out of 16 plant samples, 04 samples exceed the mean value. In control treatment where normal water was used for irrigation purpose contain 1.92 µg g^{-1} Cu which was less than the mean value. The permissible limit of copper for plants is 40 µg g^{-1} recommended by FAO/WHO. All plant samples concentration was recorded below the permissible limit.

Among all the heavy metals, Zn is the least toxic and an essential element in human diet as it is required to maintain the functioning of the immune system. Zinc deficiency in diet may be highly detrimental to human health than too much Zn in diet. The recommended dietary allowance for Zn is 15 mg/day for men and 12 mg/day for women but high concentration of Zn in vegetables may cause vomiting, renal damage, cramps (Alexander, Alloway, & Dourado, 2006). According to this study, the level of Zn in vegetable was found in the range of 3.71 to 35.11 µg g^{-1}, having an average value of 10.08 µg g^{-1} (Table 6), which is in close agreement to 22.7 µg g^{-1} reported by Zakir *et al.* (2009). The value of zinc found in this study is far higher than 0.3 µg g^{-1} (FAO/WHO, 1993). The value of Zn in control treatment was 13.63 µg g^{-1}(Table 6). However, Zn concentration was substantially lower than the SEPA limit (100 µg g^{-1}).

The concentration of Mn in vegetable samples varied from 10.9 to 142.9 µg g^{-1} with a mean value of 90.56 µg g^{-1} (Table 6). Control treatment contains74.51µg g^{-1}which was less than from mean value. This value is higher than 0.2 µg g^{-1} (Pennington *et al.,* 1995) which is a safe limit according to WHO/EU (1990). Sridhara Chary, Kamala, and Raj (2008) reported the accumulation of Mn in *Allium cepa* to a level of 5.39 µg g^{-1}. High concentration of Mn causes hazardous effects on lungs and brains of humans.

CONCLUSIONS

It may be concluded that irrigation by untreated river water are the main reasons for accumulation of heavy metals in vegetables around the Dhaka city. In addition, crop parameters were not significantly influenced by river water with the replacement of fresh water. Hence, it is imperative to treat sewage water and industrial effluents before their discharge into water bodies. Awareness should be created among the farmers of the area regarding the serious consequences of using polluted river water for irrigation purpose. Therefore, continuous monitoring of wastewater irrigated crops is needed to control the dangerous accumulation of various toxic metals in plant parts and to prevent the possible health hazards due to the consumption of toxic metal contaminated agricultural products. Further research is needed on the accumulation of heavy metals in different vegetable crops cultivated in different types of soils irrigated with wastewater and their health risk after consumption.

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