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Public health risk assessment of chromium intake from vegetable grown in the wastewater irrigated site in Bangladesh

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ABSTRACT: There are many potential risks to human health from heavy metal contamination of vegetables resulting from wastewater irrigated sites. This study was carried out to assess the concentration of chromium (Cr) and the risk to human health by chromium through the intake of locally grown vegetables collected from wastewater irrigated agricultural fields. Twenty-seven samples of 9 (nine) different types of vegetables were analyzed by an Atomic Absorption Spectrometer (AAS) (Varian AAS 240 F S). The range of chromium concentration in wastewater irrigated vegetables was ND (Not detected) - 4.14 mg/kg. The highest mean concentration of chromium (4.14 mg/kg) was detected in radish. The mean concentration of chromium in all the vegetables was within the safe limits of WHO/FAO except radish which was much higher than the standard. Health risk index for chromium contamination in all vegetables was less than 1 for both adults and children which cause no risk to the local population. Among all vegetables tested, the highest intake value of chromium was from consumption of radish for both adults and children. The lower values of health risk index indicated chromium contamination in the wastewater irrigated vegetables that cause less negative impact on human health.

Keywords: Bangladesh, chromium, daily intake, health risk assessment, vegetable.

INTRODUCTION

Due to its easy accessibility, disposal problems, and scarcity of fresh water, nowadays industrial or municipal wastewater is mostly used for the irrigation of crops (Hossain et al., 2015). Irrigation with wastewater is one of the best mediums or routes for heavy metals uptake through soil (Arora et al., 2008). Because of diverse composition of wastewater and types of activities, various heavy metals compound like Zn, Cu, Pb, As, Ni, Cr, and Cd exist in the wastewater (Hossain et al., 2015). Heavy metals in soil and vegetables can be accumulated through perpetual irrigation of agricultural land with sewage and industrial

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wastewater (Singh et al., 2004; Marshall et al., 2007; Sharma et al., 2007).

Non-biodegradable nature, long biological half-lives, and their potential to accumulate in different body parts, heavy metals are very detrimental and most of the heavy metals are extremely toxic because of their solubility in water (Hossain et al., 2015). As cited in the literature, because of the lack of elimination mechanism in the body, heavy metals cause damage to the body system even in very low concentration (Arora et al., 2008). Intake of heavy metals through the food chain by human populations has been widely reported throughout the world (Muchuweti et al., 2006). The damaging nature of the heavy metals varies according to the individual metals toxicity and nature of the heavy metal. Detrimental effects can be toxic (acute, chronic, or sub-chronic), neurotoxic, carcinogenic, mutagenic, or teratogenbecause of their accretion or disposition in the body tissue and persist long over the time which leads to death at the end (European Union, 2002).

In our food stuff, most vital component is vegetables because of their nutritional content like protein, vitamin, iron, calcium, and dietary fiber (Bahemuka and Mubofu, 1999). However, nutritional value and consumer acceptance must be taken into consideration when vegetables are being considered as food, because vegetables can contain both essential and nonessential elements over a wide range of concentrations (Chien et al., 2002; Gupta et al., 2008). Different scientific studies have already established that daily intake of heavy metal contaminated vegetables may pose a risk to the human health. Daily intake of low concentration of heavy metals like chromium can possess serious damage to the health because chromium is capable of accumulating in living organism and causing toxicity and damaging specific organs of the body.

It has been stated that continued consumption of elevated concentrations of heavy metals through food stuffs may lead to the chronic accumulation of the metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney, and bone diseases (Jarup, 2003). Chromium is a potent toxic metal and daily intake through vegetable at low concentration can be a great health concern in both adults and children. For this reason, the present study was carried out: (1) to determine concentrations of chromium in vegetables collected from the agricultural fields, (2) to calculate daily intake of chromium by the consumption of vegetables for both adults and children, and (3) to evaluate the potential health risk of the local consumers for both adults and children.

MATERIALS AND METHODS

Study area and sampling

Twenty-seven samples (three samples for each vegetable) of nine different types of vegetables (e.g., Red amaranth, Radish, Bottle gourd, Green Indian spinach, Green papaya, Pointed gourd, Stem Amaranth Leaf, Jute leaf, and Coriander) were collected during February to April, 2015, at randomly selected agricultural fields beside a large canal into which most of the industries discharge their wastewater with little or without treatment located in Savar upazila of Dhaka district, Bangladesh. The details of different vegetables sampled during experiment are given in Table 1. The edible portions of test vegetables were collected from sampling site. The sample size was at least 1kg. The samples were kept in sterile polyethylene bags, put into ice boxes, and immediately transferred to the laboratory (Bangladesh Council of Scientific and Industrial Research-BCSIR) and stored at 4°C until analysis within 24 hours. Then the samples were marked and labelled properly.

Table 1. Vegetable samples collected from the experimental sites

Edible part of vegetable	Common name	Botanical name	Family
Leaf	Red amaranth	*Amaranthus gangeticus*	Amaranthaceae
Root and Leaf	Radish	*Raphanus sativus* L.	Brassicaceae
Fruit and Leaf	Bottle gourd	*Lagenaria siceraria* Mol.	Cucurbitaceae
Leaf	Indian spinach (green)	*Basella alba*	Basellacease
Fruit	Green papaya	*Carica papaya*	Caricaceae
Fruit	Pointed gourd	Trichossanthes dioica	Cucurbitaceae
Leaf	Stem Amaranth Leaf	Amaranthus lividus	Amaranthaceae
Leaf	Jute leaf	Corchorus capsularies	Malvaceae
Leaf	Coriander	*Coriandrum sativum* L.	Apiaceae

Chemical analysis

All the collected samples of vegetables were washed with double distilled water to remove airborne pollutants. The edible parts of the vegetable samples were weighed and air-dried for a day to reduce water content. All the samples were then oven-dried in a hot air oven at 70–80˚C for 24 hours to remove all moisture. Dried samples were powdered using a pestle and mortar and sieved through muslin cloth.

For each vegetable sample, approximately 0.5g dried samples were acid digested in microwave digestion system (Berghof, Speed wave) using HNO_3: H_2O_2 (9:1) to prepare clear solution. HNO_3 and H_2O_2 were obtained from Merck, Germany. This clear solution was brought to volume (up to 50 ml) with de-ionized water, filtered and ready for heavy metal analysis. The working standard solution for chromium was prepared before every analysis. The samples were analyzed in Analytical Research Division, Bangladesh Council of Scientific & Industrial Research (BCSIR) Laboratories, Dhaka, using Atomic Absorption Spectrophotometer (AAS) (Varian AAS 240 F S).

Quality control analysis

Analytical reagent blanks were prepared with each batch of digestion set and then analyzed for the same element of the samples. The analytical procedures were verified with National Institute of Standards and Technology (NIST) traceable certified reference standards. Quality control measures were taken to assess contamination and reliability of data. Accuracy of the analytical method was performed as percent recoveries for each of the elements.

Daily intake of metals (DIM)

The daily intake of metals (DIM) was determined by the following equation.

$$\text{Daily intake of metal }(\text{DIM}) = \frac{Concentration\ of\ metal\left(\frac{mg}{kg}\right) \times Daily\ food\ intake}{Average\ body\ weight}$$

The average adult and child body weights were considered 55.9 and 32.7 kg, respectively, while average daily vegetable intakes for adults and children were considered 0.345 and 0.232 kg/ person/day, respectively (Ge, 1992; Wang et al., 2005).

Health risk index (HRI)

The health risk index was calculated from ratio of estimated exposure of test vegetable and oral reference dose (Cui et al., 2004). Oral reference dose was (RfD) 3×10^{-2} mg kg^{-1} day^{-1} for chromium (USEPA, 1997). Estimated exposure is obtained by dividing daily intake of heavy metals by their safe limits. An index more than 1 is considered as not safe for human health (USEPA, 2002).

$$\text{Health risk index }(\text{HRI}) = \frac{\text{DIM}}{\text{RfD}}$$

where DIM is daily intake of metal and RfD is the reference oral dose for chromium.

Statistical analysis

All analyses were performed in triplicate. Results were expressed by means of $\pm$SD.

Statistical software packages of SPSS 16.0 (Statistical Package for Social Sciences Version 16.0) were used for the data analysis.

RESULTS AND DISCUSSION

Heavy metal concentrations of vegetables

The mean concentrations of chromium in edible parts of various vegetables collected from wastewater irrigated agricultural fields in Savar Upazila of Dhaka District, Bangladesh, are shown in Table 2. The results generally reveal significant levels ($P<0.05$) of identified chromium in different vegetable samples. The application of wastewater generally led to changes in the physicochemical characteristics of soil and consequently heavy metal uptake by vegetables (Arora et al., 2008). In general, leafy vegetables (Red amaranth, Radish, Indian spinach (green), Stem Amaranth Leaf, Jute leaf, and Coriander) accumulated much higher concentration of chromium compared to non-leaf vegetables (Bottle gourd, Green papaya, and Pointed gourd) grown on wastewater irrigated soils at the same site. Leafy vegetables are generally found to accumulate metal to a higher extent than roots/tuberous vegetables (Li et al., 2006), which is due to the fact that leafy vegetables have high translocation, high transpiration, and also fast growth rates (Itanna, 2002; Muchuweti et al., 2006).

Table 2. Mean concentration of Chromium (mean ± standard deviation, $mgkg^{-1}$) in vegetable samples (fresh weight basis)

Vegetable	Chromium (mg/kg)	FAO/WHO permissible levels (FAO/WHO, 2011)	Permissible levels in China (Bugang, 2010)
Red amaranth	ND		
Radish	4.14 ±0.01		
Bottle gourd	ND		
Indian spinach (green)	ND		
Green papaya	ND		
Pointed gourd	0.32±0.01	2.3 mg/kg	0.5 mg/kg
Stem amaranth leaf	0.85 ±0.09		
Jute leaf	0.66±0.01		
Coriander	1.18±0.01		

*ND-not detected

Generally, the mean concentration range of chromium in all vegetables analyzed was ND (Not detected) to 4.14 mg/kg, with the highest concentration (4.14 mg/kg) in radish and the lowest concentration ND (less than 0.001mg/kg) in red amaranth, green papaya, bottle gourd, and Indian spinach (green). Islam and Hoque (2014) also found that the mean concentration of chromium (0.61-3.04 mg/kg) in different vegetables were almost similar to the present study. In radish, the mean concentration of chromium (4.14 mg/kg) was much higher than the values 0.273 mg/kg obtained from the vicinity of an industrial area (Farooq et al., 2008). Farooq et al. (2008) also reported the mean concentration of chromium (0.369 mg/kg) in coriander was much lower than the chromium concentration detected in coriander in present study.

Kananke et al. (2014) reported that the mean concentration of chromium was 1.79 mg/kg in green leafy vegetables which was similar to the present study. The mean concentration of chromium was found 1.12 mg/kg in leafy vegetables (Rahman et al., 2013). The mean chromium concentration in vegetables of this study was considerably higher than the mean chromium concentrations detected in vegetables 0.005 mg/kg -0.071 mg/kg (González-Weller et al., 2013). The mean concentrations of chromium was compared with safe limits given by FAO/WHO (FAO/WHO, 2011; Table 2) then it was found that detected chromium concentrations were within the safe limits in all vegetables except radish which was much higher than the standard. When the present study was compared with the China national standard set for vegetables (Bugang, 2010), it was revealed that detected chromium concentrations were higher than the permissible limits in all vegetables except pointed gourd.

The present investigation agrees with previous studies by revealing the chromium contamination in edible parts of vegetables produced in wastewater irrigated sites (Liu et al., 2005; Khan et al., 2008). However, Table 3 shows the comparison of the results of some other study in Bangladesh and other countries indicating the contamination of vegetables by chromium. Studies conducted by (Liu et al., 2005; Muchuweti et al., 2006; Sharma et al., 2006) demonstrate that the plants grown on wastewater-irrigated soils are generally contaminated with chromium which pose a major health concern.

Health risk assessment of chromium

To assess the health risk associated with chromium contamination of vegetables grown locally, daily intake of chromium and health risk index were calculated. There are several possible pathways of exposure to humans but amongst them food chain is the most important pathway. The daily intake of chromium was calculated according to the average vegetable consumption for both adults and children (Table 4). Among all vegetables tested, the highest intake values of chromium were from consumption of radish, coriander, and stem amaranth leaf for both adult and children. The daily intake amount of chromium in present study is almost similar to the provisional tolerable daily intake for adults (PTDI) set by WHO/FAO **(**JECFA, 1999; 2010**)**. The daily intake of chromium from vegetables in this study was 0.002-0.029 mg/kg/day for both adults and children which were similar to the previous study 0.003-0.005 mg/kg/day (González-Weller et al., 2013).

Table 3. Comparison of studies of chromium concentrations in vegetables

District (Country)	Sampling site description	Cr (mg/kg)	References
Dhaka (Bangladesh)	Industrial area	0.32-4.14	This Study
Dhaka (Bangladesh)	Industrial area	1.44 (0.61-3.04)	Islam and Hoque, 2014
Dhaka (Bangladesh)	Industrial area	1.66	Ahmad and Ghani, 2010
Noakhali (Bangladesh)	Arsenic contaminated area	0.64 (0.18-1.91)	Rahman *et al.*, 2013

*ND-not detected. All values are presented as (mg/kg fw).

Table 4. Daily intake of chromium (Cr) in different vegetables for adults and children

Vegetable	Adults	Children
Red amaranth	ND	ND
Radish	0.0256	0.0294
Bottle gourd	ND	ND
Indian spinach (green)	ND	ND
Green papaya	ND	ND
Pointed gourd	0.0020	0.0023
Stem amaranth leaf	0.0053	0.0060
Jute leaf	0.0041	0.0047
Coriander	0.0073	0.0084

*ND-not detected. Units of daily intake are expressed as mg/kg/day.

Table 5. Health risk index of chromium from intake of vegetables for adults and children

Vegetable	Adults	Children
Red amaranth	ND	ND
Radish	0.85	0.98
Bottle gourd	ND	ND
Indian spinach (green)	ND	ND
Green papaya	ND	ND
Pointed gourd	0.07	0.08
Stem amaranth leaf	0.18	0.20
Jute leaf	0.14	0.16
Coriander	0.24	0.28

*ND-not detected

Health risk index of chromium from consumption of vegetables for both adults and children is presented in Table 5.

The results revealed that health risk index for chromium contamination in all vegetables was less than 1 for both adults and children which causes no risk to the local population. Highest risk index was measured 0.85 and 0.98 in radish for adults and children, respectively. Singh et al. (2010) showed health risk index was less than 1 for chromium in bottle gourd, radish, and pointed gourd which are similar to the present study.

CONCLUSION

The study shows a significant build-up of chromium contamination in vegetables with continuous irrigation with wastewater in the study area. The highest mean concentration of chromium was detected in radish. The mean concentration of chromium in all the vegetables was within the safe limits of WHO/FAO except for radish which was much higher than the WHO/FAO standard. In all vegetables, health risk index values for chromium contamination was less than 1 for both adults and children which causes no risk to the local population. Among all vegetables tested, the highest intake value of chromium was from consumption of radish for both adults and children. The lower values of health risk index indicated chromium contamination in the wastewater irrigated vegetables that cause less negative impact on human health. Regular monitoring of this toxic chromium from industrial effluents, in vegetables and in other food materials, is essential to prevent their excessive build-up in the food chain.

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