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Potential health risk of heavy metals accumulation in vegetables irrigated with polluted river water

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Abstract

Heavy metals contamination in food crops is of increasing concern worldwide due to food safety issues and potential health risk. The present study has been undertaken to evaluate potential health risk due to the consumption of vegetables that grown in agricultural soil irrigated with polluted water of the Shitalakhya river in Narayangonj, Bangladesh. Agricultural soil and vegetables were analyzed for copper (Cu), nickel (Ni), cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) using Flame Atomic Absorption Spectrophotometer (FAAS). The mean concentrations of heavy metals found in the agricultural soil were in the order of Ni (96.343 mg/kg) > Cr (69.746 mg/kg) > Cu (69.013 mg/kg) > Zn (45.726 mg/kg) > Pb (28.129 mg/kg) > Cd (0.9654 mg/kg). The mean concentrations of heavy metals in edible parts of selected vegetables were in the order of Zn (19.762 mg/kg) > Cu (9.373 mg/kg) > Pb (3.699 mg/kg) > Ni (2.92 mg/kg) > Cr (1.127 mg/kg) > Cd (0.168 mg/kg). The transfer factor (TF) values showed that there were no significant transfer of heavy metals from soil to vegetables. Comparing daily intake metals (DIM) values with oral reference dose, suggested that the consumption of vegetables grown in agricultural soil is nearly free of risks. Health risk index (HRI) values of the studied heavy metals were <1, indicating that there is a relative absence of health risks.

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Introduction

Heavy metals pollution is one of the most pressing environmental issues now days. Heavy metals are ubiquitous in environment and it has been exceeded due to both natural and anthropological sources (Harmanescu *et al*., 2011). Heavy metals pollution of agricultural soil and vegetables is one of the most severe ecological problems on a world scale and also in Bangladesh (Ahmad and Goni, 2010) because of their toxicity for plant, animal and human beings, and their lack of biodegradability (Li *et al*., 2006; Jang *et al*., 2006; Zhuang *et al*., 2009). It poses potential threats to the environment and can damage human health through various absorption pathways such as direct ingestion, dermal contact, diet through the soil-food chain, inhalation and oral intake (Park *et al*., 2004; Al-Saleh *et al*., 2004; Komárek *et al*., 2008; Lu *et al*., 2011). The food chain contamination is the major pathway of heavy metals exposure for humans (Khan *et al*., 2008). Agricultural soil pollution through irrigation with polluted water is one of the major sources of soil pollution and accumulation of heavy metals in soil and plants (Nagajyoti *et al*., 2010). Excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Muchuweti *et al*., 2006; Sharma *et al*., 2007; Ahmad and Goni, 2010).

Long term irrigation through wastewater results in build-up of heavy metals in soil that can restrict soil functioning resulting in toxicity to plants and contamination of the food chain affecting food quality and safety (He *et al*., 2005; Muchuweti *et al*., 2006; Chen *et al*., 2010; Singh *et al*., 2010; Ghosh *et al*., 2012;). Plant species differ in their efficiency to absorb heavy metals (Mapanda *et al*., 2005). Bioaccumulation of metal by plants is affected by many factors. In general, variations in plant species, the growth stage of the plants and element characteristics control absorption, accumulation and translocation of metals. Furthermore, physiological adaptations also control toxic metal accumulations by sequestering metals in the roots (Nouri *et al*., 2009). Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals and trace elements (Abdola *et al*., 1990; Bigdeli and Seilsepour, 2008). Metal

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accumulation in vegetables may pose a direct threat to human health (Damek-Poprawa and Sawicka-Kapusta, 2003). Heavy metals contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defenses, intrauterine growth retardation, impaired psychosocial faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar and Nair, 2000; Türkdogan *et al*., 2003; Arora *et al*., 2008; Ghosh *et al*., 2012).

Bangladesh is a country with large interconnected rivers on the banks of which there are many agricultural fields. In this fields farmers usually use river water for irrigation. But present emphasis of Bangladesh government is on industrialization (Islam *et al*., 2014). It is very common to establish industries on the bank of riverside due to easy availability of water and easy transportation facility. The existing tendency of industrialization and urbanization may contribute greatly to the poor quality of water through indiscriminate disposal of solid waste, industrial effluents and other toxic wastes which are the major environmental issues, posing threats to the existence of human being. The concentration of chemical parameters of industrial effluent were above the allowable limits and also tended to accumulate at the downstream area (Islam *et al*., 2012). Industrial activities, domestic wastes, urbanization and land development all contribute to the heavy metals pollution of rivers (Manoj *et al*., 2012). Wastewaters carry toxic heavy metals that get introduced into the soil and aquatic system through various processes, prominent among them being irrigation (Khan *et al*., 2008). So it is needed to study the heavy metals on plants and soil in the agricultural fields to assess the health risk due to the consumption of those vegetables which are grown in the field where polluted river water has been used for irrigation. The present study has been conducted at agricultural site of Rupganj upzila (sub-district) under Narayanganj district on the bank of Shitalakhya river. Shitalakhya is one of the most polluted rivers due to improper discharge of untreated wastewater from various industries which deteriorate river water quality (Kamal *et al*., 1999; Subramaniam, 2004; Rahman and Hossain, 2007). The polluted Shitalakhya river water is used for irrigation in the selected study area. The objective of the study was to assess soil and vegetable contamination and associated health risk in exposure to heavy metals due to the consumption of vegetables.

Materials and Methods

Study area

The study area is located in Rupganj upzila (sub-district) under Narayanganj district besides the Shitalakhya river of Bangladesh. The Shitalakhya river is one of the most prominent rivers in the flood plain region of Bangladesh. It is located in Narayanganj City, the second most vital industrial zone of the country. Various types of industrial units have been established on the bank of the Sitalakhya river; most of these industries directly or indirectly discharging a huge quantities of wastes and effluents into the river without any treatment and also municipal and domestic sewage sludge's from Narayanganj urban area (Alam *et al*., 2006). The wastes, effluents and agrochemicals contain heavy metals, toxic substances, germs and nitrogen containing toxic substances. These waste materials are tremendously deteriorating water and sediment quality of the river (Islam *et al.*, 2014). The river water is the only source of irrigation for agriculture activity around the study area. The soil and vegetable samples in this study were taken from the selected agricultural land irrigated with polluted water of the Shitalakhya river.

Sample collection and preparation

Five surface soil (0-20 cm) samples were collected using a stainless steel grab sampler. The sampler was inspected for possible cross contamination and cleaned with ambient water for individual sample collection. The soil was sampled from the central part of the grab sampler by avoiding contact with the inside materials of the sampler and transferred to a pre-cleaned plastic container (Rahman *et al.*, 2012). The surface soil samples were collected in pre-cleaned zipper polythene bags, which was kept in airtight large plastic containers (Iqbal and Shah, 2011). Soil samples were air-dried, ground into fine powder and passed through 2-mm mesh sieve and stored at ambient temperature prior to analysis. Samples of some commonly grown vegetables, i.e., Malabar spinach *(Basella alba)*, pumpkin *(Cucurbita moschata)*, amaranth *(Amaranthus lividus)*, snake gourd *(Trichosanthes cucumerina)* and spinach *(Spinacea oleracea)* were collected by pre-cleaned zipper bags from the same sites where soils were collected. For metal analysis, only the edible parts of vegetable samples were used. The freshly harvested mature vegetables were brought to the laboratory and thoroughly washed with running tap water and rinsed with deionized water to remove any soil particles attached to the plant surfaces. Samples were cut into small pieces and dried in oven at 70^{0}C for 48 h (Gupta *et al*., 2012), ground into fine powder, sieved through 2 mm mesh and kept in pre-cleaned zipper bags at ambient temperature till further analysis.

Sample digestion

Two (2) g of dry homogenized soil samples were weighed into beakers (100 ml) and digested according to Jan et al. (2010) with 15 ml aqua-regia (HCl:HNO_3 = 3:1) for approximately 4 hours using hotplate maintaining heating temperature approximately 110^{0}C in such a way that mixture was neither evaporate nor too much dry in a fume chamber. During digestion, the beakers were covered with watch glass. After cooling at room temperature, the digestion mixtures were diluted to 100 ml in a 100 ml volumetric flask with deionized water. Then the solution was filtered using Whatman No. 41 (0.45 µm pore size) into plastic bottle and kept the solution in the refrigerator until analysis.

One (1) g of plant samples powders were weighed into beakers (100 ml) and digested according to Cao *et al*. (2010) with 10 ml 65% concentrated HNO_3 and 4 ml 20% H_2O_2. The beakers were covered with watch glass, and the suspensions were boiled on a hot plate at 200^{0}C for 4 hours. After cooling at room temperature, the suspensions were diluted to 50 ml in a 50 ml volumetric flask with deionized water. Then the solution was filtered using Whatman No. 41 (0.45 µm pore size) into plastic bottle and kept the solution in the refrigerator until analysis. Blanks were prepared to check for background contamination by the reagents used.

Sample analysis

Soil pH and electrical conductivity (EC) were measured by making a solution of soil sample (1:5 ratio) with deionized water (Nouri *et al*., 2009) by using portable multiparameter meter (Model: SensION 156, HACH, USA). To assess the concentration of heavy metals (Cu, Ni, Cd, Cr, Pb and Zn), the digested soil and vegetable samples were analyzed by Flame Atomic Absorption Spectrophotometer (Model: AA240FS; Varian Inc., USA). Series of reference standards 1, 2 and 3 ppm for these metals were prepared from the purchased stock solution. The standards were prepared by pipetting 0.1, 0.2 and 0.3 ml respectively of the metal reference standards and made up to 100 ml for standard calibration curve measurement. All chemicals used were of analytical reagent grade and all solutions were prepared by deionized water.

Transfer factor (TF)

Metal transfer factor (TF) denoting transfer of metals from soil to plant and which is computed as the ratio of the concentration of metals in plants to the concentration in soil, on dry weight basis (Ghosh *et al.*, 2012). TF values of metals were calculated as follows.

$$TF = \frac{C_{vegetable}}{C_{soil}} \quad (1)$$

Where Cvegetable and Csoil represent the concentration of heavy metals in extracts of vegetables and soils on dry weight (DW) basis, respectively (Xue *et al.*, 2012).

Daily intake of metal (DIM)

Daily intake of metals was calculated using the following equation (Khan *et al*., 2013):

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{food\ intake}}{B_{average\ weight}} \quad (2)$$

Where, C_{metal}, C_{factor}, D_{food} intake and $B_{average}$ weight represent the heavy metals concentrations in plants (mg/kg), conversion factor, daily intake of vegetables and average body weight, respectively. The conversion factor 0.085 was used to convert fresh green vegetable weight to dry weight as described by (Rattan *et al*., 2005; Wang *et al*., 2013). The average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 kg (Ge, 1992; Wang *et al.*, 2005).

Health risk index (HRI)

Health risk assessment of consumers from the intake of metal contaminated vegetables is characterized by using HRI (Xue *et al*., 2012). The HRI > 1 for any metal in food crops means that the consumer population faces a health risk. The following formula was used for the calculation of HRI (Khan *et al*., 2013):

$$HRI = \frac{DIM}{RfD} \quad (3)$$

Where, DIM is the daily intake of metals and RfD is the reference dose. The RfD values for Zn, Cd, Pb, Ni, Cu and Cr are 0.30, 0.001, 0.004, 0.02, 0.04 and 1.5 mg/kg bw/day, respectively (Jan *et al.*, 2010).

Results and Discussion

heavy metals in agricultural soil

The pH, EC and heavy metals concentrations

Table 1. pH, EC and heavy metals concentrations in agricultural soil irrigated with polluted river water

Sites	pH	EC (µS/cm)	Heavy metals concentrations in soil (mg/kg)					
			Cu	Ni	Cd	Cr	Pb	Zn
S1	8.18	43.2	28.4	39.386	0.713	46.066	16.666	57.922
S2	8.55	35.0	94.067	144.1	1.028	103.4	43.00	34.74
S3	8.66	27.5	84.766	113.7	0.951	82.3	35.666	46.99
S4	8.19	70.1	64.6	88.8	0.69	57.9	20.567	38.051
S5	8.21	50.4	73.233	95.733	1.445	59.066	24.749	51.67
Mean	8.35	45.24	69.013	96.343	0.9654	69.746	28.129	45.726
SD	0.23	16.34	25.311	38.351	0.305	22.941	10.931	9.554

SD-Standard Deviation

Table 2. Heavy metals concentrations in vegetables irrigated with polluted river water

Sites	Vegetables	Heavy metals concentrations in vegetable (mg/kg)					
		Cu	Ni	Cd	Cr	Pb	Zn
S1	*Basella alba*	7.05	2.65	0.116	2.27	2.833	21.096
S2	*Cucurbita moschata*	14.35	4.8	0.233	1.052	5.333	12.792
S3	*Trichosanthes cucumerina*	11.7	3.5	0.095	0.266	2.166	17.02
S4	*Spinacea oleracea*	3.45	1.55	0.116	1.1	2.667	20.674
S5	*Amaranthus lividus*	10.316	2.1	0.283	0.95	5.5	27.226
Mean		9.373	2.920	0.168	1.127	3.699	19.762
SD		4.229	1.274	0.084	0.722	1.587	5.348

SD-Standard Deviation

of the agricultural soil irrigated with polluted Shitalakhya river water are given in Table 1. Soil pH is a major factor that influences the migration and transformation of heavy metals (Zhao *et al*., 2012). The range (8.18-8.66) and mean (8.35) values for soil pH, indicating that the soil environment is basic in the study area. Higher pH values in soil result in greater retention and lower heavy metals solubility and mobility due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Smith *et al*., 1996; Malik *et al*., 2010; Sekabira *et al.,* 2010). Soil electrical conductivity (EC) is a useful indicator in managing agricultural systems. EC directly affects plants growing in the soil or media. The impact of EC on plants is also directly affected by water management (Narsimha *et al*., 2013). The range (27.5-70.1 µS/cm) and mean (45.24 µS/cm) values for soil EC, indicating that soil environment is good of the study area as EC range of 0-1 dS/m indicates good soil health (Doran, 2005).

The heavy metals concentrations found in the agricultural soil were in the range of Cu: 28.4-94.067 mg/kg; Ni: 39.386-144.1 mg/kg; Cd: 0.69-1.445 mg/kg; Cr: 46.066-103.4 mg/kg; Pb: 16.666-43 mg/kg; Zn: 34.74-57.922 mg/kg. The mean concentrations of Cu, Ni, Cd, Cr, Pb and Zn were 69.013, 96.343, 0.9654, 69.746, 28.129 and 45.726 mg/kg, respectively, having the order of Ni > Cr > Cu > Zn > Pb > Cd. The agricultural soil of the study area is contaminated with heavy metals through the repeated use of polluted river water which polluted from industries and other sources as well as application of chemical fertilizers and pesticides. Heavy metals occur in effluents of industries and in many fertilizers and pesticides (Ahmed and Goni, 2010). Aucejo *et al*. (1997) and Facchinelli *et al.* (2001) suggested that wastewater is the main source for metal elements in agricultural soils. The mean concentrations of Cu, Ni, Cd, Cr and Pb in agricultural soil in the present investigation were higher than world soil average (Kabata-Pendias, 2011) (except Zn). But the mean concentrations of all studied heavy metals were lower than the safe limits of European Union standard (EU, 2002), Indian standard (Awshthi, 2000) and State Environmental Protection Administration, China (SEPA, 1995) (except Ni and Cd). The mean concentrations of all studied heavy metals were found higher in the present investigation than reported by Jolly *et al.* (2013) (except Ni), Rahman and Naidu (2010) (except Ni), Khan *et al*. (2008) (except Pb), Singh *et al*. (2010) (except Zn), Rattan *et al.* (2005), Bigdeli and Seilsepour (2008) (except Pb and Zn) and Liu *et al.* (2005) (except Cr and Zn) but found lower than reported by Gupta *et al.* (2008) in agricultural soil. The mean concentrations of Cu, Ni and Cr were found higher but Cd, Pb and Zn were lower than reported by Ahmed and Goni (2010).

Heavy metals in vegetables

The heavy metals concentrations in edible parts of vegetables grown in agricultural land irrigated with polluted water of the Shitalakhya river in Narayangonj are shown in Table 2. The application of wastewater generally led to changes in the physico-chemical characteristics of soil and consequently

Table 3. Transfer factor (TF) values for heavy metals in selected vegetables

Sites	Vegetables	Cu	Ni	Cd	Cr	Pb	Zn
S1	*Basella alba*	0.2482	0.0672	0.1626	0.0492	0.1699	0.3642
S2	*Cucurbita moschata*	0.1525	0.0333	0.2266	0.0102	0.1240	0.3682
S3	*Trichosanthes cucumerina*	0.1380	0.0307	0.0998	0.0023	0.0607	0.3622
S4	*Spinacea oleracea*	0.0534	0.0174	0.1681	0.0189	0.1296	0.5433
S5	*Amaranthus lividus*	0.1408	0.0219	0.1958	0.0161	0.2222	0.5269

heavy metals uptake by vegetables (Arora *et al*., 2008). The mean concentrations of heavy metals in edible parts of selected five vegetables were 9.373, 2.92, 0.168, 1.127, 3.699 and 19.762 mg/kg for Cu, Ni, Cd, Cr, Pb and Zn, respectively, having the order of Zn > Cu > Pb > Ni > Cr > Cd. Considering all measured heavy metals, the accumulation trend in plant species were in the order of *Amaranthus lividus* > *Cucurbita moschata* > *Basella alba* > *Trichosanthes cucumerina* > *Spinacea oleracea*. The studied data showed that the heavy metals contents varied among different vegetables at the different sites. The variations in heavy metals concentrations in vegetables may be ascribed to the differences in their morphology and physiology for heavy metals uptake, exclusion, accumulation and retention (Singh *et al*., 2010).

The concentration of Cu was measured higher among the studied heavy metals in the range of 3.45-14.35 mg/kg. Highest Cu was found in *Cucurbita moschata* (14.35 mg/kg) and the trend of accumulation in vegetables in the decreasing order of *Cucurbita moschata* > *Trichosanthes cucumerina* > *Amaranthus lividus* > *Basella alba* > *Spinacea oleracea*. Cu in normal plant is 3-15 mg/kg and toxic level to plant is 20 mg/kg (Pivic *et al*., 2013). Cu is an essential trace element for normal biological activities of aminoxide and tryosinase enzymes but excessive intake of Cu may cause haemolysis, hepatotoxic and nephrotoxic effects (Hasmi *et al*., 2005). Ni was found in the range of 1.55-4.8 mg/kg and the trend of accumulation of Ni concentration in vegetables in the decreasing order of *Cucurbita moschata* > *Trichosanthes cucumerina* > *Basella alba* > *Amaranthus lividus* > *Spinacea oleracea.* Ni in normal plant is 0.1-5 mg/kg and toxic level to plant is 30 mg/kg (Pivic *et al*., 2013). Ni exposure causes formation of free radicals in various tissues in both human and animals which lead to various modifications to DNA bases, enhanced lipid peroxidation, and altered calcium and sulphhydryl homeostasis (Das *et al*., 2008). The range of Cd concentration in the studied vegetables was from 0.095 to 0.283 mg/kg and the trend of accumulation of Cd concentration in the decreasing order of *Amaranthus lividus* > *Cucurbita moschata* > *Spinacea oleracea* = *Basella alba* > *Trichosanthes cucumerina.* When the concentration in the human body reaches levels considered to be harmful (> 200 µg/gm) cadmium-induced kidney damage, skeletal disorders as well as other diseases may result (Page *et al*., 1987). The accumulated Cr concentration was found in the studied vegetables in decreasing order of *Basella alba* > *Spinacea oleracea* > *Cucurbita moschata* > *Amaranthus lividus* > *Trichosanthes cucumerina* with the range of 0.266-2.27 mg/kg. Up to 200 µg/day of Cr is essential for human beings and animals to metabolize carbohydrates and lipid. Exceeding normal limit, Cr creates toxicity which can result in hepatitis, gastritis, ulcers and lung cancer (Parvin *et al*., 2014). Pb was found in the range of 2.166-5.5 mg/kg and the trend of accumulation of Pb concentration in vegetables in the decreasing order of *Amaranthus lividus* > *Cucurbita moschata* > *Basella alba* > *Spinacea oleracea* > *Trichosanthes cucumerina.* Pb in normal plant is 1-5 mg/kg and toxic level to plant is 20 mg/kg (Pivic *et al*., 2013). The introduction of Pb into the food chain may affect human health and creates toxicity which can result in nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances, coordination loss and neurological effect (Ansari *et al*., 2004; Bigdeli and Seilsepour, 2008). Zn was found in the range of 12.792-27.226 mg/kg and the trend of accumulation of Zn concentration in vegetables in the decreasing order of *Amaranthus lividus* > *Basella alba* > *Spinacea oleracea* > *Trichosanthes cucumerina* > *Cucurbita moschata.* Zn is essential nutrients for plants, but concentrations higher than 50.0-60.0 mg/kg for Zn can be toxic, and lead to the plant growth inhibition (Chao *et al*., 2007). The symptoms that an acute oral Zn dose may include: tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatic is and damage of hepatic parenchyma (Bigdeli and Seilsepour, 2008).

The mean concentrations of Cu, Cd and Zn in vegetables in the present investigation were below the safe limits of European Union Standard (EU, 2006), FAO/WHO (2007), Indian Standard (Awshthi, 2000) and State Environmental Protection Administration, China (SEPA, 2005). Ni mean concentration was found higher than the safe limit of Indian Standard (Awshthi, 2000) but lower than SEPA (2005). The mean concentration Cr was found higher than

Table 4. Daily intake of heavy metals (DIM) (mg/kg bw/day) arising out of consumption of vegetables irrigated with polluted river water

Sites	Vegetables	Individuals	Cu	Ni	Cd	Cr	Pb	Zn
S1	*Basella alba*	Adult	3.7E-03	1.3E-03	6.1E-05	1.2E-03	1.5E-03	1.1E-02
		Children	4.2E-03	1.6E-03	7.0E-05	1.3E-03	1.7E-03	1.2E-02
S2	*Cucurbita moschata*	Adult	7.5E-03	2.5E-03	1.2E-04	5.5E-04	2.8E-03	6.7E-03
		Children	8.6E-03	2.8E-03	1.4E-04	6.3E-04	3.2E-03	7.7E-03
S3	*Trichosanthes cucumerina*	Adult	6.1E-03	1.8E-03	4.9E-05	1.4E-04	1.1E-03	8.9E-03
		Children	7.1E-03	2.1E-03	5.7E-05	1.6E-04	1.3E-03	1.0E-02
S4	*Spinacea oleracea*	Adult	1.8E-03	8.1E-04	6.1E-05	5.7E-04	1.4E-03	1.1E-02
		Children	2.1E-03	9.3E-04	7.0E-05	6.6E-04	1.6E-03	1.2E-02
S5	*Amaranthus lividus*	Adult	5.4E-03	1.1E-03	1.4E-04	4.9E-04	2.8E-03	1.4E-02
		Children	6.2E-03	1.2E-03	1.7E-04	5.7E-04	3.3E-03	1.6E-02

Table 5. Health risk index (HRI) arising out of consumption of vegetables irrigated with polluted river water

Sites	Vegetables	Individuals	Cu	Ni	Cd	Cr	Pb	Zn
S1	*Basella alba*	Adult	9.2E-02	6.9E-02	6.1E-02	7.9E-04	3.7E-01	3.6E-02
		Children	1.1E-01	7.9E-02	7.0E-02	9.1E-04	4.2E-01	4.2E-02
S2	*Cucurbita moschata*	Adult	1.8E-01	1.2E-01	1.2E-01	3.6E-04	6.9E-01	2.2E-02
		Children	2.1E-01	1.4E-01	1.4E-01	4.2E-04	8.0E-01	2.5E-02
S3	*Trichosanthes cucumerina*	Adult	1.5E-01	9.1E-02	4.9E-02	9.3E-05	2.8E-01	2.9E-02
		Children	1.7E-01	1.1E-01	5.7E-02	1.1E-04	3.2E-01	3.4E-02
S4	*Spinacea oleracea*	Adult	4.5E-02	4.1E-02	6.1E-02	3.8E-04	3.5E-01	3.6E-02
		Children	5.2E-02	4.6E-02	7.0E-02	4.4E-04	4.0E-01	4.1E-02
S5	*Amaranthus lividus*	Adult	1.3E-01	5.5E-02	1.4E-01	3.3E-04	7.2E-01	4.7E-02
		Children	1.5E-01	6.3E-02	1.7E-01	3.8E-04	8.2E-01	5.4E-02

the safe limits of EU (2006) and SEPA (2005) but lower than Indian Standard (Awshthi, 2000) and on the other hand, Pb mean concentration was found higher than the safe limits of EU (2006) and Indian Standard (Awshthi, 2000) but lower than FAO/WHO (2007) and SEPA (2005). The mean concentrations of heavy metals measured in vegetables in the present investigation were lower than reported by Ahmed and Goni (2010) (except Cu), Rahman *et al. (*2013) (Except Ni, Cd and Cr), Islam and Hoque (2014) (except Pb) in the different areas of Bangladesh, Bigdeli and Seilsepour (2008) (except Pb and Ni), Liu *et al*. (2005), Gupta *et al*. (2008) and Rattan *et al.* (2005).

Transfer factor (TF) from soil to vegetables

Metal transfer factor from soil to plants is a key module of human exposure to heavy metals via food chain. Transfer factor of metals is essential to investigate the human health risk index (Cui *et al.*, 2004; Mahmood and Malik, 2014). Table 3 summarizes the TF values for selected heavy metals in selected vegetables collected from the study areas. The range of TF values for vegetables irrigated with polluted river water were from 0.0534 to 0.2482, 0.0174 to 0.0672, 0.0998 to 0.2266, 0.0023 to 0.0492, 0.0607 to 0.2222 and 0.3622 to 0.5433 for Cu, Ni, Cd, Cr, Pb, and Zn, respectively. The result showed that TF values for Cu, Ni, Cd, Cr, Pb and Zn for various vegetables are not significantly high. The trend of TF for heavy metals in different vegetable species was in order of Zn > Cd > Cu > Pb > Ni > Cr. The result showed that TF values for all studied heavy metals were lower than those reported by Khan *et al.* (2008), Rattan *et al*. (2005), Liu *et al.* (2005) and Jan *et al.* (2010) (except Pb and Cd). TF values for Cu, Ni and Cr were lower but for Cd, Pb and Zn were higher in this study than those reported by Mahmood and Malik (2014).

Daily intake of metals (DIM) and health risk index (HRI)

The estimated DIM through the consumption of vegetables for adults and children is presented in Table 4. The daily intake of metals (DIM) is calculated to averagely estimate the daily metal loading into the body system of a specified body weight of a consumer (Jena *et al*., 2012). DIM may be the realistic estimate for the average intake of metals from vegetables. DIM for Cu, Ni, Cd, Cr, Pb and Zn ranged from 1.8E-03 to 7.5E-03, 8.1E-04 to 2.5E-03, 4.9E-05 to 1.4E-04, 1.4E-04 to 1.2E-03, 1.1E-03 to 2.8E-03 and 6.7E-03 to 1.4E-02 mg/kg bw/day, respectively, for adults, while ranged from 2.1E-03 to 8.6E-03, 9.3E-04 to 2.8E-03, 5.7E-05 to 1.7E-04, 1.6E-04 to 1.3E-03, 1.3E-03 to 3.3E-03 and

7.7E-03 to 1.6E-02 mg/kg bw/day respectively, for children. Trend of the metal intake by all vegetables are Zn > Cu > Pb > Ni > Cr > Cd. The DIM values suggested that the consumption of vegetables grown in agricultural soils irrigated with polluted river water is nearly free of risks, as the oral reference dose for Cu, Ni, Cd, Cr, Pb and Zn are 0.04, 0.02, 0.001, 1.5, 0.004 and 0.30 mg/kg bw/day, respectively (Jan *et al.*, 2010).

To assess the human health risk of heavy metals, it is necessary to calculate the level of human exposure to that metal by tracing the route of exposure of pollutant to human body. There are many exposures routes for heavy metals that depend upon a contaminated media of soil and vegetables on the recipients. Receptor population use the vegetables enriched with higher concentration of heavy metals which enters the human body leading to health risks (Khan *et al*., 2008). The estimated HRI for both adults and children for the consumption of vegetables for all measured heavy metals is given in Table 5. HRI for Cu, Ni, Cd, Cr, Pb and Zn ranged from 4.5E-02 to 1.8E-01, 4.1E-02 to 1.2E-01, 4.9E-02 to 1.4E-01, 9.3E-05 to 7.9E-04, 2.8E-01 to 7.2E-01 and 2.2E-02 to 4.7E-02, respectively, for adults, while ranged from 5.2E-02 to 2.1E-01, 4.6E-02 to1.4E-01, 5.7E-02 to 1.7E-01, 1.1E-04 to 9.1E-04, 3.2E-01 to 8.2E-01 and 2.5E-02 to 5.4E-02, respectively, for children. Trend of health risk of heavy metals for the consumption of vegetables are Pb > Cu > Cd > Ni > Zn > Cr. The result revealed that HRI for all measured heavy metals for all studied vegetables are lower than 1 indicating safe for the consumer.

Conclusion

Continuous irrigation with polluted river water has led to increase heavy metals contents in agricultural soil and which accumulated into food crops and create potential health risk through food chain. In this research, the mean concentrations of studied heavy metals in the agricultural soil irrigated with polluted water of the Shitalakhya river were higher than world soil average (Kabata-Pendias, 2011) (except Zn) but lower than the safe limits of European Union standard (EU, 2002), Indian standard (Awshthi, 2000) and State Environmental Protection Administration, China (SEPA, 1995) (except Ni and Cd). The heavy metals concentrations in the studied vegetables were varied in the different sampling sites and among vegetable species reflecting the differences in uptake capabilities and there further translocation into edible parts. The mean concentrations of Cu, Cd and Zn in vegetables were below the safe limits of EU (2006), FAO/WHO (2007), Indian Standard (Awshthi, 2000) and SEPA (2005). The mean concentration Cr was found higher than the safe limits of EU (2006) and SEPA (2005) but lower than Indian Standard (Awshthi, 2000) and on the other hand, Pb mean concentration was found higher than the safe limits of EU (2006) and Indian Standard (Awshthi, 2000) but lower than FAO/WHO (2007) and SEPA (2005). TF values for Cu, Ni, Cd, Cr, Pb, and Zn for various vegetables were not significantly high. DIM and HRI values indicated that vegetables grown in the agricultural soils were free of any risk for the consumers. Therefore, significant attention should be paid to prevent excessive build-up of heavy metals in the food chain by regularly monitoring in agricultural soil and vegetables.

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