Levels Of Heavy Metals In Soil And Vegetables And Health Risk Assessment

Most Laboni Begum, Umme Habiba Bodrun Naher, Md. Razib Hosen, Ashiqur Rahaman

Abstract: This study was conducted for assessment of human health risks due to intake of heavy metal cont aminated vegetables through determination of the heavy metals' concentrations in soil and vegetables grown on it nearby Buriganga River, Dhaka, Bangladesh. Flame Atomi c Absorption Spectroscopy (AAS) was used to determine the concentrations of heavy metals. Moreover, Health Risk Index (HRI) of heavy metals was also calculated. The mean concentrations of heavy metals in soil were found in the decreasing order of Fe>Cr>Zn> Ni>Cu>Pb>Cd but in the case of roots and edible parts of vegetables, the mean concentrations of different heavy metals were as decreasing order of Fe>Cr>Zn>Pd>Ni>Cd>Cu and Fe>Cr>Zn>Pd>Ni>Cu>Cd respectively. In case of roots and edible parts of vegetables, except Cu and Ni all other heavy metal concentrations were higher than permissible limit. The HRI values of Cd, Cr, Fe, Pb and Zn were greater than 1 which indicated that contaminated vegetables were awfully detrimental to human health. Therefore, soil contamination as well as the heavy metal uptake into human body should be preven ted to avoid the health risk caused by heavy metal.

Key words: Heavy metal, Soil, Vegetables, pollution, atomic absorption spectrophotometer, Health risk.

1 Introduction

Vegetables are the important source for human diet for minerals, vitamins, fibers, as well as have beneficial anti-oxidative effects. However, intake of heavy metal contaminated vegetables may cause risk to the human health [1]. One of the most important aspects of food quality assurance is heavy metal contamination level of the food items [2]. Consumption of food tainted with heavy metals is a major food chain route for human exposure [3].The main sources of soil pollution with heavy metals are waste water irrigation, solid waste dumping, sludge uses, vehicular exhaust and industrial activities. In cemented metals uptakes often observed by the Crops which are cultivated on such contaminated soil [4]. About 95% of total tanning industries of Bangladesh were located in Hazaribagh which have now been shifted at savar in Dhaka. These tanneries were directly associated with the pollution of Buriganga river by discharging untreated toxic effluents that were contaminated with heavy metals [5]. The polluted water gets mixed with the surrounding cultivated Crops field on the river bank [6]. Therefore, heavy metals of effluents are penetrated into the soil, eventually trans-located into plants and human through eating up of these plants [7].Continuous use of wastewater for the irrigation of vegetables has positive consequent in the accumulation of heavy metals in soils and their transfer to the different Crops under cultivation, that exceeds the maximum permissible levels [8]. These heavy metals are continuously accumulated in different vital organs in the human body like kidney, bones, liver which causes severe diseases [9].

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Roots and foliage of the plants are responsible to uptake heavy metals [10]. Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals [11]. Concentration of heavy metals in the edible portion of each Crops varied significantly according to the type of Crops. The most toxic elements for man are Cadmium and Lead [12]. The accumulation of heavy metals in human body has adverse effects especially when consuming above the recommended limits from plants. Each metal has specific signs of their harmfulness, however, the followings common signs have been reported that are related to gastrointestinal (GI) disorders, diarrhea, stomatitis, tremor, hemoglobinuria causing a rust-red color to stool, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia and respiratory [13]. The effects of heavy metal can be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic in nature. Moreover, the accumulation of heavy metal- contaminated foodstuff can badly lessen some essential nutrients in the body that are responsible for diminishing immunological defenses such as intrauterine growth retardation, , impaired psycho-social facilities, disabilities associated with malnutrition and upper gastrointestinal cancer rates [14, 15]. The objectives of this study were to find out the levels of heavy metals in soil and vegetables grown on that and their effects on human health due to intake of vegetables.

2 Materials and methods

2.1. Sampling

In this analysis, samples were collected from the agricultural crop field beside the Buriganga River located Washpur, Keraniganj, Dhaka, which is about 1.5 km away from Rayer Bazar where untreated tannery effluent was discharged directly. These agricultural crop fields were immerged under water during rainy season consequently got enough time of contamination with polluted water of this river. Six varities of vegetables (Amaranthusgangeticus L, Spanaciaoleracea L, Corchoruscapsularies L, Lagenariasiceraria L, Brassica campestris L, impomoeaaquatica L) and their growing soils were collected in poly bag. After cleaning, the vegetable samples were separated into two parts root and edible (leaves and stems) and then dried using oven at 85^0C for 2 days. The dried samples were preserved for analysis.

2.2. Sample preparation

Soil and vegetable samples were digested according to the method of Berrow and Stein 1983 and the method of www.cem.com, Mathews NC28106. Then digested samples were kept at room temperature for metal analysis by Atomic Absorption Spectroscopy. HNO_3 (con.) and HCl(Aqua-regia) was used for the digestion of plant (root and stem-leaf).After digestion, the solution was filtered and preserved for metal analysis.

2.3. Data analysis

Transfer Factor

An effective process for measuring the uptake of heavy metals from soil to plants is Transfer factor which depends on dry weight. Transfer factor means the ratio of heavy metal concentration in vegetable (dry weight) and the soil (dry weight) [15, 16]. The transfer factor (TF) of metal was determined by the following equation:- Where, $C_{edible\ part}$, C_{root} and C_{soil} represent the heavy metal concentrations in extracts of edible part and root of vegetables and soils respectively. Estimated daily intake of heavy metals from vegetables The estimated daily exposure of heavy metals (EDEM) through vegetables was totally dependent on metal concentrations in vegetables, body weight, and daily vegetable consumption [17] EDIM was calculated with the help of following formula:

$$\mathrm{EDIM} = \frac{DIM}{B_w} \qquad (3)$$

DIM = Daily intake of metals = daily vegetable consumption × mean metal concentration in vegetable and B_W = Body weight.

Where, for adult daily vegetable consumption rate was an average of 166.08 g (BBS, 2010) and the average body weight for adult 60 kg.

Health risk index

The health risk index (HRI) for the human health through the consumption of polluted vegetables was assessed largely depends on the food chain and the reference oral dose (RfD) for each heavy metal. The HRI <1 means the exposed inhabitants is considered to be safe.

3 Result and discussion

3.1. Determination of heavy metal concentration of soil and vegetables

The experimental results of heavy metal concentration in inspected soil and vegetable samples collected from agricultural land which immerged under water approximately 6 months during rainy season were delineated on table 1 and table 2 respectively. The mean concentrations of heavy metals (Cd-6.72, Cr-511.67, Cu-47.94, Ni- 53.37, Fe-30408.94, Pb-38.86 and Zn-280.69 in mg.kg-1) obtained in this analysis for soil sample shown in table 1 were higher than the world limit. But in case of control sample, the values of metal concentration were less than that of inspected soil and mostly approximate to the world limit. So, it is obvious that the influence of the pollution of Buriganga River water is the main reason for the higher concentration of heavy metals in soil samples. Vegetables are vital parts of human diet which can be taken both cooked and raw condition. In this investigation, the values of Cd, Cr, Cu, Ni, Fe , Pb and Zn concentrations recorded as 1.33, 135.83, 2.33, 2.97, 1605.2, 9.74 and 116.25 in mg.kg-1 respectively in vegetable samples (edible parts) were depicted on table 2 which were higher than the standards set by WHO & FAO, 2011. The obtained values of heavy metals varied greatly depending on the plant species in this analysis. In case of control sample, the analysis values were not as high as inspected vegetable samples. Copper had the higher concentration in Spinach with a range of 12.0 to 18.3 in mg/kg followed by Red amaranth with a range of 9.86 to 14.1 mg/kg [18]. Lead, Nickel and Zinc were higher in concentration in Bottle gourd but Water spinach contained higher amount of Chromium. Again, Cadmium had higher in Jute leaf. Although Zn and Cu are essential elements, their higher concentration in plants are of great threat due to

Table 1: concentration of heavy metals in soil (mg.kg^{-1})

Soil	Cd	Cr	Cu	Ni	Fe	Pb	Zn
Sample-1	5.6	491	37.21	36.6	18469.09	26.71	331.89
Sample-2	9.1	455	54.21	57.41	31637.24	52.42	269.12
Sample-3	8.5	561	46.32	55.97	32411.37	38.38	299.55
Sample-4	8.2	501	44.53	48.07	29855.76	36.24	210.96
Sample-5	4.7	525	47.93	57.92	31726.55	35.14	294.81
Sample-6	4.2	537	57.45	65.46	38353.65	44.25	277.2
Minimum	4.2	455	37.21	36.6	18469.09	26.71	210.96
Maximum	9.1	561	57.45	65.46	38353.65	52.42	299.5
Mean	6.72	511.67	47.94	53.57	30408.94	38.86	280.69
Control Sample	2.9	100	11.07	14.52	948.63	17.60	18.22
World limit	0.35	70	30	50	1000	35	197.26

	Cd	Cr	Cu	Ni	Fe	Pb	Zn	Cd	Cr	Cu	Ni	Fe	Pb	Zn
Red amaranth	1.2	201	6.25	5.45	2669.1	14	146.1	1.1	87	5.64	2.15	1904.1	10.85	111.1
Mustard green	1.33	317	2.45	4.20	1436.34	13.25	126.26	1.29	198	1.35	2.82	1404.5	6.85	92.10
Jute leaf	3.65	247	2.34	1.35	2362.56	15.6	142.11	2.63	103	1.45	1.08	1144.1	11.6	128
Water spinach	1.15	322	1.35	1.54	1979.1	11.4	101.22	1.13	221	0.75	0.85	1794.7	8.6	83.1
Bottle gourd	1.2o	228	1.45	7.86	1660.50	18.35	151.90	1.08	143	1.05	3.55	1569.1	11	105.1
Spinach	0.78	188	2.35	1.27	1629.1	7.35	174.6	0.64	63	2.25	1	589.1	6.4	64.1
minimum	0.78	188	1.35	1	1144.1	7.35	83.1	0.64	63	0.75	0.85	589.1	6.4	64.10
Maximum	3.65	322	6.25	7.86	2362.56	18.35	174.6	2.63	221	5.64	5.45	1979.1	14	151.9
Mean	1.55	250.5	2.4	2.50	1752.05	12.8	121.36	1.33	135.83	2.33	2.97	1605.2	9.74	116.2
Control sample	0.13	5.45	1.13	0.73	131.03	2.1	9.7	0.11	2.4	0.97	0.51	56.02	1.35	4.78
Limit (FAO & WHO, 2011)	0.2	2.3	40	66.9	425	0.3	20	0.2	2.3	40	66.9	425	0.3	20

Table 3: Standard and obtained mean concentration of heavy metals in soil, root and edible parts (mg.kg-1)

	Soil		**Root**		**Edible parts**	
Metal	Standard value	Obtained value	Standard value	Obtained value	Standard value	Obtained value
Cd	0.35	6.72	0.2	1.55	0.2	1.33
Cr	70	511.67	2.3	250.5	2.3	135.83
Cu	30	47.94	40	2.4	40	2.33
Ni	50	53.57	66.9	2.50	66.9	2.97
Fe	1000	30408.94	425	1752.05	425	1605.2
Pb	35	38.86	0.3	12.8	0.3	9.74
Zn	197.29	280.69	20	121.36	20	116.25

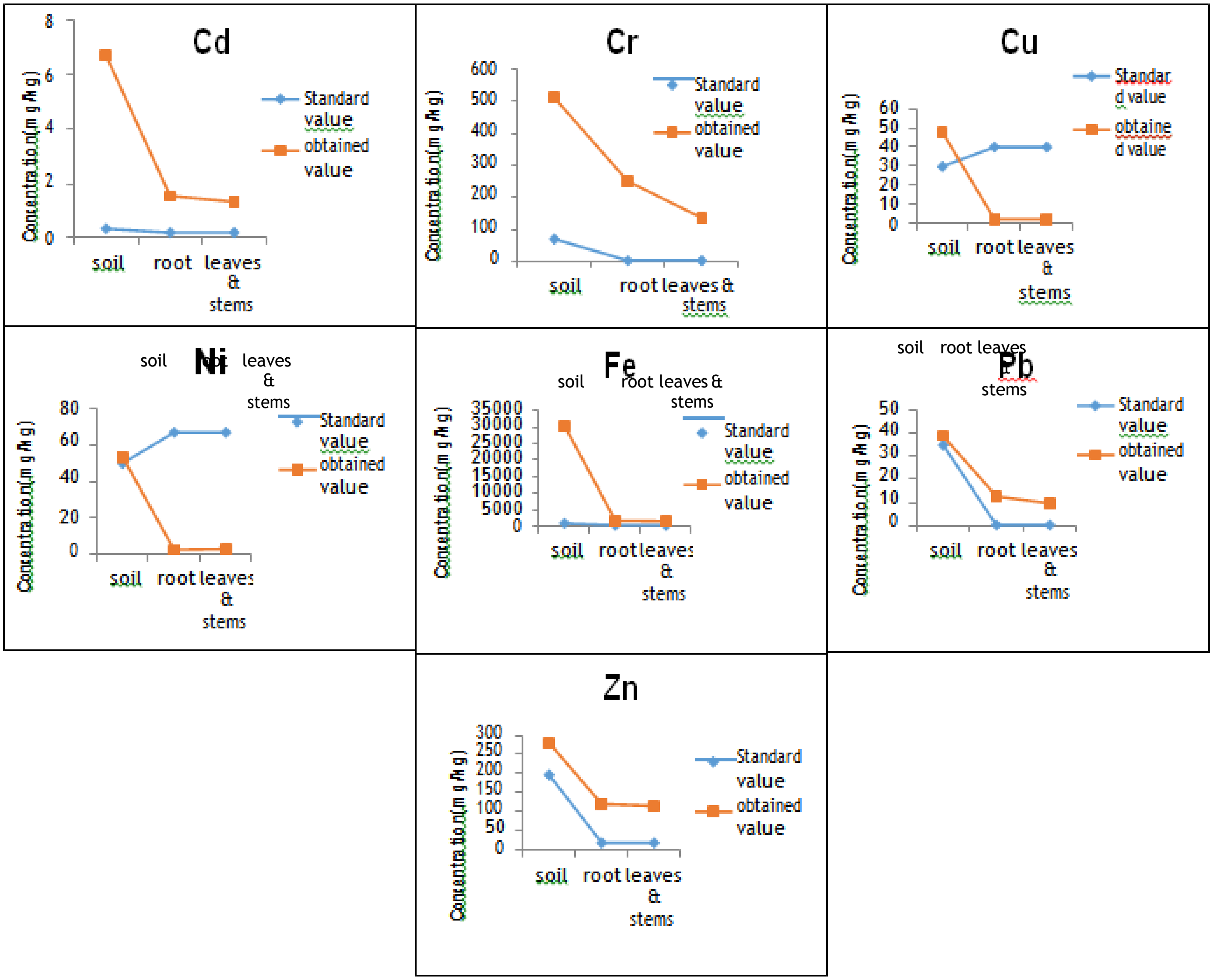

Figure 1: *Comparison of standard and obtained values of metals in soil, root and edible part of vegetables*

Their toxicity to humans and animals body[19]. Several research mentioned that vegetables cultivated in heavy metal polluted soils have higher concentrations of heavy metals than those cultivated in untainted soils [20]. The variations of the mean concentrations of each metal in soil, root and edible parts were shown in figure 1 compared with the standard value of World Limit (soil) and Permissible limit set by WHO & FAO, 2011(root & edible parts) according to the data of table 3. From the figure 1, the concentrations of Ni & Cu were shown the lower values than the standard value whereas the rest of these values showed the higher metal concentration than standard.

3.2 Translocation factors (TF)

The determination of the PCF (Plant Concentration Factor) as the soil-to-plant transfer factor is one of the key elements for human being of metal exposure through the food chain and in order to investigate the human HRI associated with waste water-irrigated soils [21].The mean values of Transfer factors between soil and root for heavy metals including Cd, Cr, Cu, Ni, Fe, Pb and Zn were obtained as 0.23, 0.50, 0.06, 0.07, 0.07, 0.36 and 0.50 respectively given in Table 4. Again heavy metal translocation factors between root and edible part of vegetables were 0.89, 0.52, 0.72, 0.61, 0.73, 0.71 and 0.71 respectively also shown in table 4. So the mean values of PCF in case of soil to root were in the following decreasing order Cr>Zn>Pb>Cd>Cu>Ni>Fe and on the other hand in case of root to edible part were as follows Cd>Fe>Cu>Pb>Zn>Ni>Cr respectively. The resulted values were shown that Cr up take of plant in root from soil was higher than that of others. But Cd uptake from root to edible part of vegetables was greater than other metals.

3.3 Health Risk Index (HRI)

The below Table 5 was shown the daily intake of metals (mg/kg.bw) by an adult person including Cd, Cr, Cu, Ni, Fe, Pb, and Zn were in the following amount 0.0037, 0.376, 0.0064, 0.0082, 4.4431, 0.0269, 0.3217. Again Health Risk Index was also calculated in this study indicated that the HRI values of Cr, Cd, Fe, Pb and Zn were greater than 1 except Ni and Cu. The HRI of each metal through consumption of vegetables decreased in the order of Cr>Cd >Pb>Fe>Zn>Ni>Cu. HRI values obtained in the research indicated great risk to human health upon consumption of the food stuff [22]. However, If the whole intake of metals through dietary means (vegetables) is taken into account, the potential health risks from exposure to vegetables are consequently of some apprehension [23].

Table 4: Heavy metal transfer factor in roots and edible parts of vegetables (mg.L^{-1})

Plants	Soil to roots							Roots to edible parts(leaves & stems)						
	Cd	Cr	Cu	Ni	Fe	Pd	Zn	Cd	Cr	Cu	Ni	Fe	Pd	Zn
Red amaranth														
Mustard green	0.15	0.70	0.05	0.07	0.05	0.25	0.47	0.97	0.62	0.55	0.67	0.98	0.52	0.73
Jute leaf	0.43	0.44	0.05	0.02	0.07	0.41	0.47	0.72	0.42	0.62	0.80	0.48	0.74	0.90
Water spinach	0.14	0.64	0.03	0.03	0.07	0.31	0.48	0.98	0.69	0.56	0.55	0.91	0.75	0.82
Bottle gourd	0.26	0.43	0.03	0.14	0.05	0.52	0.52	0.90	0.63	0.72	0.45	0.94	0.60	0.69
Spinach	0.19	0.35	0.04	0.02	0.04	0.17	0.63	0.82	0.34	0.96	0.79	0.36	0.87	0.37
Control sample	0.04	0.05	0.10	0.05	0.13	0.12	0.53	0.84	0.44	0.85	0.70	0.43	0.64	0.49
Mean	0.23	0.50	0.06	0.07	0.07	0.36	0.50	0.89	0.52	0.72	0.61	0.73	0.71	0.71

Table 5: Estimation of daily intake of metal (mg/kg/bw) and Health Risk Index

Metal	Daily intake of metal(Adult)	Reference Dose(JECFA, 1993; USEPA, 2007)	Health risk Index
Cd	0.0037	0.0005	7.36>1
Cr	0.376	0.003	125.33>1
Cu	0.0064	0.04	0.16<1
Ni	0.0082	0.02	0.41<1
Fe	4.4431	0.7	6.35>1
Pb	0.0269	0.004	6.74>1
Zn	0.3217	0.3	1.07>1
Total		1.0675	147.42

Conclusion

This study showed that heavy metals were of great concern as the soil and vegetables polluted with them created a risk to the human and ecology. The contribution of heavy metals in soil was higher than world limit. The heavy metal concentrations in contaminated vegetables were beyond tolerable level to human body. The TF values confirmed that these heavy metals were directly entered into the human body through consuming such kind of vegetables as nutritive. Moreover, the HRI values of Cr, Cd, Fe, Pb and Zn were greater than 1 which revealed the high potentiality of health risk. Toxic heavy metals, the main source of tannery waste water, contaminated the soil and vegetables grown on that and they posed health risk to the human. So, it can be recommended that public awareness is a must so that the residents in the study area can reduce the consumption of vegetables.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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