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Accumulation of Heavy Metals in Soil and their Transfer to Leafy Vegetables in the Region of Dhaka Aricha Highway, Savar, Bangladesh

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Abstract: Accumulation of heavy metals in environmental matrices is a potential risk to living system due to their uptake by plants and subsequent introduction into the food chain. A study was conducted to investigate the heavy metals concentration in soils and leafy vegetables samples along the Dhaka Aricha Road to assess their potential ecological risk. Heavy metals concentration was analyzed by Atomic Absorption Spectroscopy. Concentrations of all the tested heavy metals except Cd in soil samples were below the permissible level. The mean concentration of Cd was found 3.99±1.85 mg kg^{-1}. Concentrations of all the tested heavy metals except Cd and Cr in vegetables samples were lower than recommended level. Mean concentration of Cd and Cr were found 1.00 ± 0.68 mg kg^{-1} and 2.32±0.84 mg kg^{-1}, respectively. Based on the Potential Ecological Risk Index, Cd posed very high risk to the local ecosystem due to its higher Risk Factor, >320 and based on Transfer Factor of Pb and Cd were found higher accumulator among the tested metals. The results of present study revealed that the bioconcentration of heavy metals along the Dhaka Aricha Road posed high risk to the ecosystem. Considering the Transfer Factor of Cd and Pb it can be suggested that plants and leafy vegetables grow in the soil near Dhaka Aricha Road should not be used as food or feed.

Key words: Heavy metals, leafy vegetables, AAS, transfer factor, ecological risk factor

INTRODUCTION

Environmental contaminants are widely distributed in air, water, soils and sediment and among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bio-accumulate in ecosystems (Censi *et al.,* 2006). Road side agricultural soil contamination with heavy metals may results from vehicular emission and elevated heavy metals uptake by crops affects food quality and safety (Ho and Tai, 1988). Very limited information is available in Bangladesh on the level of heavy metal accumulation in roadside soil and vegetable crops due to highway traffic that could be a new threat for agriculture of this county.

Vegetables are an important part of human's diet and sources of important nutrients like protein, vitamins, minerals, fiber etc. (Arai, 2002). Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. Through food chain toxic pollutants can enter human body (Qadir *et al.*, 1999). Leafy vegetables grown in heavy metals contaminated soils accumulate higher amounts of metals compare to those grown in uncontaminated soils (Al Jassir *et al.*, 2005).

Heavy metal accumulation in plants depends upon plant species, soil properties, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to plant transfer factors of the metals (Rattan *et al.*, 2005). The uptake of heavy metals in vegetables is likely to be higher and accumulation of these toxic metals in human body created growing concern in the recent days. Very limited informations regarding the accumulation of heavy metals in vegetables of industrially polluted areas of Bangladesh are available. But such information is vital for the production of quality vegetables as well as healthy food stuffs. Therefore, the aim of the present study was to determine the concentrations of heavy metals in soil vegetables samples along the Dhaka Aricha road, Savar, to assess the potential ecological risk posed by heavy metals and Transfer Factor of heavy metals in the soil-vegetables system.

MATERIALS AND METHODS

Reference standard for heavy metals: Reference standard heavy metals Cadmium, Copper, lead, Chromium,

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Manganese, Iron and Zinc were obtained from Kanto Chemical Co. Inc. Hydrochloric acid and Nitric acid were obtained from Merck.

Description of the study area: The area selected for the study was along the Dhaka Aricha Road and near the Savar area about 17 km north from Dhaka centre and runs northward. The site was selected for this study because it links capital Dhaka city Dhaka and it has a comparatively high traffic density. The study site is also exposed to different degrees of industrial pollution especially textile dying industries. Table 1 shows the sampling location with coordinate values and the map of the study area is shown in the Fig. 1.

Collection of soil sample: Soil samples (1 kg each) were collected from along the Dhaka Aricha Road. Polyethylene bags were used for collecting the soil sample. The samples were transferred to the laboratory as early as possible. The samples were properly labeled and preserve at -20°C to preclude the risk of hydrolysis and oxidation.

Collection of vegetables sample: Fresh leafy vegetables (Red Spinach) samples were randomly collected from the sides along the Dhaka Aricha road. Vegetables samples were stored in polyethylene bags in the field, the samples were transferred to the laboratory as early as possible. Samples were directly oven dried at temperature of 75°C for 24 h and then finally crushed and sieved at room temperature conditions. The sieved samples were stored in airtight sealed plastic bottles until required for analysis.

Soil sample preparation and digestion procedure: Soil samples were oven dried at 95°C for 48 h and ground into fine powder using pestle and mortar. Further 15 g of fine powder sediment sample was taken in a conical flask to which 15 mL of 1M HNO_3 were added. Then 30 mL of distilled water was added to the mixture and the solution kept 24 h. After 24 h distilled water was added to the solution and making the solution 150 g by weight and the sample was centrifuged and filtered by Whatman No. 41 filter paper. Filtrates were then analyzed by AAS.

Vegetable sample preparation and digestion procedure: Samples were digested with Nitric acid for heavy metal determination as described by Allen *et al.* (1986). Once collected, samples were first washed with normal tap water. All washed samples were carefully air dried, cut into small pieces and drying in the oven at 60°C for 24 h until samples became fully dry. This was followed by grinding and homogenization of the dried samples into fine powder using an electric grinder. The powdered samples are then stored in closed containers in absence of humidity. Vegetables samples (1.00±0.001 g) were placed into crucible, to which 10 mL of acid 65% high purity HNO_3 was added. The mixture was then digested at 60°C till the solution became semi dried. Again 10 mL of con HNO_3 and 4 mL of H_2O_2 was added and again kept on hot plate for 1 h. After getting semi dried than cooled and filtered with the help of what men filter paper. Volume of the residues was made up to 50 mL with 2 M HNO_3. Finally, the solution was analyzed.

Determination of heavy metal concentrations of soil and vegetables samples: Atomic Absorption Spectroscopy (AAS) (Model: AA-6401F, Shimadzu, Made in Australia), was used for the determination of heavy metals. To provide element specific wavelengths, a light beam from a lamp whose cathode is made of the element

Table 1: Sampling location description with GPS readings of soil and vegetables along the Dhaka Aricha Road, Savar

Sample ID	GPS readings	Description
S_BS_1 and S_BV_1	Lat-23.3969N Long-91.7429E	Sample was collected from near Bank town along the Dhaka Aricha road
S_BS_2 and S_B V_2	Lat-23.4012N Long-91.9234E	Sample was collected from agriculture land near Bank town along the Dhaka Aricha road
S_BS_3 and S_B V_3	Lat-23.4136N Long-91.8625E	Sample was collected from agriculture land near Bank town 200 m away from the Dhaka Aricha road
S_BS_4 and S_B V_4	Lat-23.4345N Long-91.8124E	Sample was collected from agriculture land near Bank town 200 m away from the Dhaka Aricha road
S_BS_5 and S_B V_5	Lat-23.4359N Long-91.7829E	Sample was collected from agriculture land near Phulbari a the Dhaka Aricha road
S_BS_6 and S_B V_6	Lat-23.4586N Long-91.7516E	Sample was collected from agriculture land near Tetuljhora a the Dhaka Aricha road
S_BS_7 and S_B V_7	Lat-22.4726N Long-91.2563E	Sample was collected from agriculture land near Tetuljhora a the Dhaka Aricha road
S_BS_8 and S_B V_8	Lat-23.4965N Long-91.7325E	Sample was collected from agriculture land near Tetuljhora a the Dhaka Aricha road
S_BS_9 and S_B V_9	Lat-23.5126N Long-91.7429E	Sample was collected from agriculture land near Tetuljhora along the Dhaka Aricha road
S_BS_{910} and S_B V_{10}	Lat-23.5326N Long-91.772E	Sample was collected from agriculture land near Tetuljhora along the Dhaka Aricha road

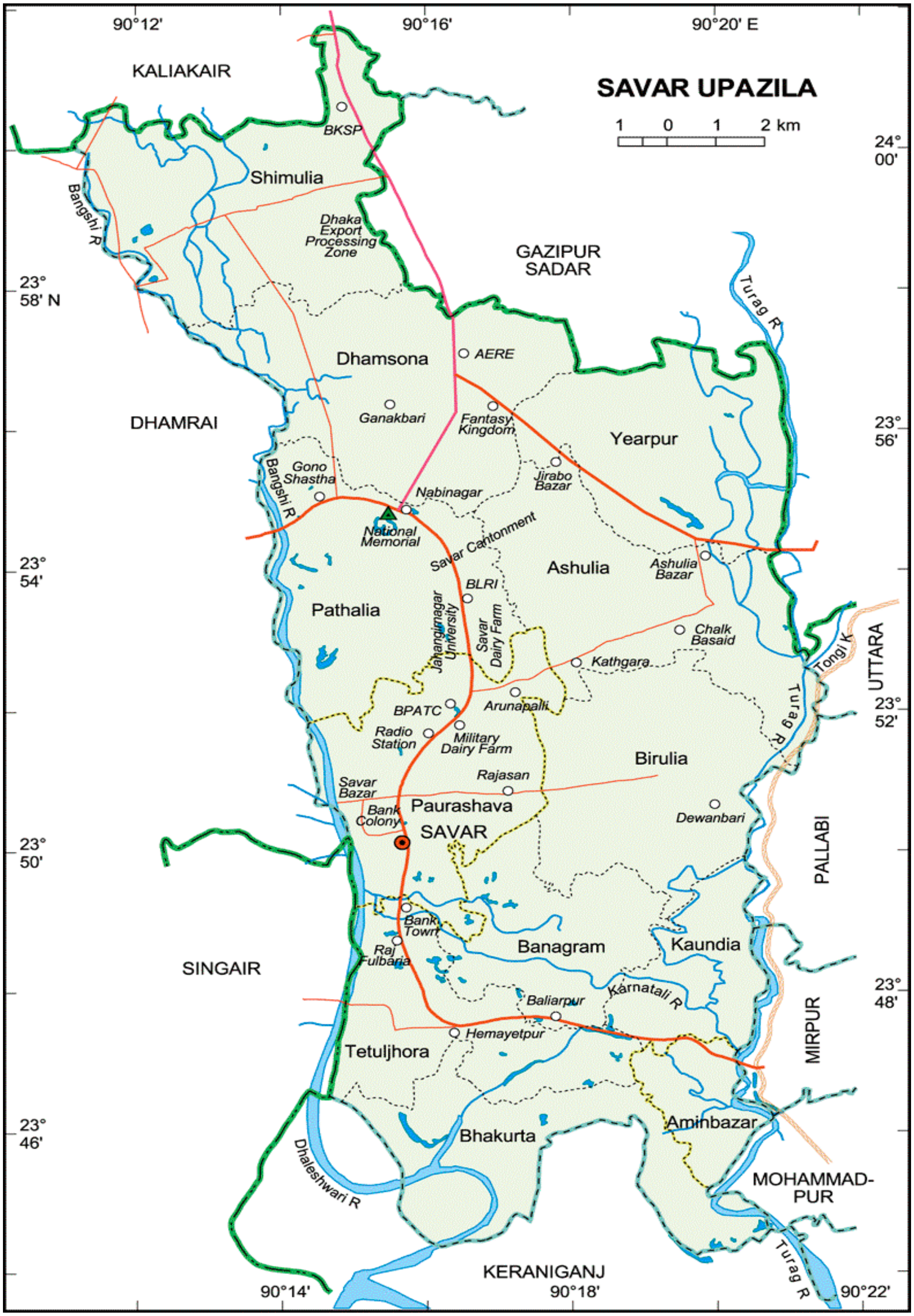

Fig. 1: Map of the study locations Savar Upazila, Dhaka, Bangladesh

being determined is passed through the flame. A device such as photon multiplier can detect the amount of reduction of the light intensity due to absorption by the analyte and this can be directly related to the amount of the element in the sample.

Calculation of metal content of sample: Metal content of samples was calculated as follows:

$$\text{Metal content} = \frac{\text{Conc. of matal determined by AAS}}{10 \times \text{sample weight}} \text{ppm}$$

Analysis of potential ecological risk index: The Potential Ecological Risk Index (RI) was assessed according to Hakanson (1980) as the degree of heavy metal pollution in soil and according to the toxicity of metals and the response of the environment. RI could evaluate ecological risk caused by toxic metals comprehensively. The calculating methods of RI are listed below:

$$F_i = \frac{C_n^i}{C_O^i}$$

$$E_T^i = T_r^i \times F_i$$

$$RI = \sum_{i=1}^{n} = Ei$$

where, Fi is the single metal pollution index; C_n^i is the concentration of metal in the samples; C_0^i is the reference value for the metal; E_r^i is the monomial potential ecological risk factor; T_r^i is the metal toxic response factor according to Hakanson (1980). The values for each element are in the order Zn = 1<Cr = 2<Cu = Ni = Pb = 5<As = 10<Cd = 30. RI is the potential ecological risk caused by the overall contamination. There are four categories of RI and five categories of E_r^i as shown in Table 2.

Determination of Transfer Factor (TF): The transfer coefficient was calculated by dividing the concentration. The transfer coefficient was calculated by dividing the concentration of heavy metals in vegetables by the total heavy metal concentration in the soil (Kachenko and Singh, 2006).

$$TF = \frac{C_{plant}}{C_{soil}}$$

Table 2: Indices and grades of potential ecological risk of toxic metals contamination

E_r^i value	Grades of ecological risk of metals	RI value	Grades of the environment
E_r^i<40	Low risk	RI<110	Low risk
40≤E_r^i<80	Moderate risk	110≤RI<200	Moderate
80≤E_r^i<160	Considerable risk	200≤RI<400	Considerable risk
160≤E_r^i<320	High risk	400≤RI	Very high risk
320≤E_r^i	Very high risk		

where, C_{plant} = metal concentration in plant tissue, mg kg^{-1} fresh weight and C_{soil} = metal concentration in soil, mg kg^{-1} dry weight.

Statistical analysis: Statistical software Spss 16.0 was applied to determine the mean concentrations and standard deviation of heavy metals. Statistical significance was tested at 95% confidence level. Variations were considered significant at p<0.05. Following formula was used to calculate the mean of the concentration of metals:

$$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} xi$$

where, $\bar{x}$ is mean of concentration of pesticides, X_i is observed pesticide concentration in different samples.

Following formula was used to calculate the standard deviation of the concentration of pesticides:

$$\sigma = \sqrt{\frac{1}{N}{}_{i=0}^{n}(xi - \bar{x})}$$

where, σ is Standard deviation of the data, N is Sample size.

The 95% certainty is expressed in 95% confidence level. Normal distribution was performed to assess 95% confidence level due to sample size was below 30. To determine the confidence level by normal distribution, following formula was used:

$$z = \frac{\bar{x} - \mu o}{\frac{\sigma}{\sqrt{n}}}$$

where, $\bar{x}$ = Sample mean, μ_0 = Mean of particular pesticide, ó = Standard deviation of corresponded pesticide, n = Sample Size.

RESULTS AND DISCUSSION

Analysis of soil sample along the Dhaka Aricha Road near Savar: Heavy metal concentrations in soil samples collected from along the sides of Dhaka Aricha Road near the Savar are presented in Table 3. Metal concentrations ranges were: Pb: 1.68-18.75; Cr: 4.55-33.46; Cd: 1.01-7.83 Cu: 03.05-23.26 and Zn: 5.01-32.65 mg kg^{-1} Dw.

The study sites are situated along the very busy Dhaka Aricha Road so the vehicular emission could be the probable source of Pb contamination in the soil. The mean concentration of Pb (7.31±5.04) mg kg^{-1} in the soil of along the Dhaka Aricha Road was lower than the mean concentration of Pb 49.71 mg kg^{-1} in soil of industrial area

Dhaka as described by Jasim and Abdul (2010). The present findings were also lower compared to the concentration range (54-59) mg kg^{-1} in the soil of Gazipur as reported by Habib *et al.* (2009). Concentration of Cr was recorded 21.51 mg kg^{-1} in the soil of Ado Ekiti, Southwestern Nigeria (Aruleba and Ajayi, 2012), 54.88 mg kg^{-1} in urban soil of Hongkong (Li *et al.*, 2001) and 159.3 mg kg^{-1} in urban soils and roadside dust of China (Shi *et al.*, 2008). The investigation found lower concentration of Cu compared to that in the soil of Gazipur (55-65) mg kg^{-1} in as reported by Habib *et al.* (2009). Concentration of Cd was recorded 0.02 mg kg^{-1} in the road soil of Botswana (Mmolawa *et al.*, 2011), concentration of Cd 2.8 mg kg^{-1} in the soil of Ado Ekiti (Southwestern Nigeria) (Aruleba and Ajayi, 2012), 2.73 mg kg^{-1} urban soil of Hongkong (Demirezen and Aksoy, 2006) and 1.23 mg kg^{-1} urban soils and roadside dust in Shanghai (Shi *et al.*, 2008).

The concentrations of metal found in soil along the Dhaka Aricha road were moderately to heavily polluted for Pb, Cr and Cu according to soil quality guidelines for heavy metal in soil (Pekey, 2006). On the other hand, Mn and Zn in all soil samples belong to unpolluted.

Assessment of potential ecological risk for soil along the Dhaka Aricha Road: The potential ecological Risk Index (RI) was originally introduced by Hakanson (1980) to assess the degree of heavy metal pollution in soil, according to the toxicity of metals and the response of the environment. The potential ecological risk assessment results of heavy metals in soil adjacent to Dhaka Aricha highway are summarized in Table 4. It was found that the average monomial risk factors E^i_r of heavy metals in soil were ranked in the following order Zn<Cr<Cu<Pb<Cd. The average monomial ecological risk for all selected metals except Cd were found below the 40 that indicate all metals except Cd posed low risk to the surrounding ecosystem. In order to quantify the overall potential ecological risk of observed metals in the soil sample along the Dhaka Aricha road, RI was calculated as the sum of all the five risk factors. The RI values for the sampling site ranged from 154.73-1180.

Analysis of vegetables sample along the Dhaka Aricha Road for heavy metals: Heavy metal concentrations in leafy vegetables (Red Spinach) grown in along the Dhaka Aricha Road and their statistical analysis are presented in Table 5. Concentrations of heavy metal ranges were: Pb: 0.695-3.155; Cr: 1.173-3.83; Cd: 0.180-2.305; Cu: 0.2568-3.5294 mg kg^{-1}; Zn: 1.452- 8.298 and order of heavy metals concentration in the vegetables samples were: Zn>Cr>Cu>Pb>Cd.

Table 3: Heavy metal concentration of soil sample along the Dhaka Aricha Road

	Concentration (mg kg^{-1})				
Sample ID	Pb	Cr	Cd	Cu	Zn
S_BS_1	7.32050	9.44100	3.29720	11.02650	5.01650
S_BS_3	18.75360	4.54940	7.83100	5.63290	13.56930
S_BS_2	4.12500	6.43210	4.71400	23.25980	8.26540
S_BS_4	2.10260	11.32720	5.14720	8.23659	6.35880
S_BS_5	1.68250	13.58640	4.00560	6.98750	11.36500
S_BS_6	9.75390	16.26590	2.87210	16.52940	7.63250
S_BS_7	6.89570	28.27160	1.01650	4.06320	12.05630
S_BS_8	4.96350	33.45560	3.71400	3.05200	15.07260
S_BS_9	11.64420	25.36590	4.96580	9.05200	18.06560
S_BS_{10}	5.90710	11.92540	2.36980	11.36520	32.65360
Min.	1.68000	4.55000	1.01000	3.05000	5.01000
Max.	18.75000	33.46000	7.83000	23.26000	32.65000
Mean	7.31490	16.06200	3.99230	9.92050	13.00460
Std	5.08035	9.73531	1.85296	6.11905	8.02313

Table 4: Heavy Metal potential ecological risk Indexes in the soil sample along the Dhaka Aricha Road

	Ecological index risk for single metal E_r^i					
Sample ID	Pb	Cr	Cd	Cu	Zn	RI
S_BS_1	1.83	0.40	494.58	1.72	0.08	498.61
S_BS_2	4.68	0.19	1174.65	0.88	0.22	1180.00
S_BS_3	1.03	0.27	707.10	3.63	0.13	712.17
S_BS_4	0.52	0.48	772.08	1.28	0.10	774.48
S_BS_5	0.42	0.59	600.84	1.09	0.18	603.12
S_BS_6	2.43	0.69	430.81	2.58	0.12	436.65
S_BS_7	1.72	1.20	150.97	0.63	0.20	154.73
S_BS_8	1.24	1.42	557.10	0.47	0.25	560.49
S_BS_9	2.91	1.07	744.87	1.41	0.30	750.57
S_BS_{10}	1.48	0.50	355.47	1.77	0.54	359.77
Mean	1.89	0.68	598.84	1.55	0.21	

Table 5: Heavy metal concentrations in vegetables sample along the Dhaka Aricha Road

	Concentration (mg kg^{-1})				
Sample ID	Pb	Cr	Cd	Cu	Zn
S_BV_1	1.900	1.807	0.605	2.001	1.452
S_BV_2	1.100	1.171	1.030	2.568	3.032
S_BV_3	0.710	1.697	0.180	1.121	8.298
S_BV_4	1.887	2.321	0.605	3.019	6.754
S_BV_5	2.142	3.254	1.030	0.259	4.184
S_BV_6	2.861	1.465	1.880	3.522	2.893
S_BV_7	3.154	1.850	1.115	2.166	4.006
S_BV_8	3.013	2.878	0.463	0.256	2.925
S_BV_9	0.692	2.630	2.305	2.052	5.125
S_BV_{10}	1.955	3.835	0.321	3.375	6.326
Max.	3.152	3.835	2.305	3.522	8.298
Min.	0.692	1.171	0.180	0.259	1.452
Mean	1.940	2.320	1.000	2.009	4.560
Std	0.900	0.840	0.680	1.174	2.110

In the analyzed samples lead levels ranged from 0.693-3.155 mg kg^{-1}. The mean concentration of Pb of was recorded (1.94±0.90 mg kg^{-1}). Similar levels (1.44 mg kg^{-1}) were also reported by Habib *et al.* (2009) in spinach sample of industrial area of Bangladesh. Fytianos *et al.* (2001) examined a high concentration of Pb in spinach grown in industrial and rural areas of Greece. Al Jassir *et al.* (2005) studied green leafy vegetables from

Saudi Arabia and noted the highest concentrations of Pb in the coriander 0.171 mg kg^{-1} and purslane (0.226 mg kg^{-1}).

The mean level of Cr in vegetables in the present study were significantly lower than concentrations reported in Titagarh, West Bengal, India (34.83-96.30 mg kg^{-1}) (Gupta *et al.,* 2008) and also less than those of reported by Sharma *et al.* (2007) in Varanasi, India (5.37-27.83 mg kg^{-1}). Habib *et al.* (2009) reported that Cd concentrations 1.40 mg kg^{-1} in spinach sample of industrial area of Bangladesh which are almost similar to the results of the present result. The present study revealed that the mean Cd level (1.00±0.683) mg kg^{-1} measured in vegetables collected from along the Dhaka Aricha high way near Savar area was lower than the vegetables from Titagarh, West Bengal, India (10.37-17.79 mg kg^{-1}) (Gupta *et al.,* 2008). Demirezen and Aksoy (2006) analyzed various vegetables from Turkey and reported the Cd content range 0.24 to 0.97 mg kg^{-1}.

The concentration of Cu was recorded (0.25-3.52) mg kg^{-1} and mean concentration (2.00 ±1.174) mg kg^{-1}. Alam *et al.* (2003) reported that the mean Cu concentrations in leafy and non-leafy vegetables 15.5 and 8.51 mg kg^{-1}, respectively from Samata village, Jessor, which is also greater than present findings. The mean concentration of Cu (0.25-3.52) mg kg^{-1} in vegetables grown in along the Dhaka Aricha Road was lower than the concentration of Cu (22.19-76.50) mg kg^{-1} in the leafy vegetable specie from Turkey (Demirezen and Aksoy, 2006). The mean concentration of Zn in vegetables collected from along the Dhaka Aricha high way was substantially lower than the Zn concentrations (3.00-171.03) mg kg^{-1} in vegetables from Titagarh West Bengal, India (Gupta *et al.,* 2008), vegetables of Varanasi, India (59.61-79.46) mg kg^{-1} (Sharma *et al*., 2007).

Heavy metal transfer from soils to vegetables: Soil-to-plant transfer is one of the key components of human exposure to metals through food chain. Transfer Factor (TF) or Plant Concentration Factor (PCF) is a parameter used to describe the transfer of trace elements from soil to plant body. In the present study, the Transfer factor of different heavy metal from soil to vegetable are presented in Table 6.The TF or PCF value ranges were: Pb 0.058-0.89, Cr 0.06-0.32, Cd 0.03-1.1, Cu 0.03-0.53 and Zn 0.06-0.37 and the trend of TF for heavy metal in vegetable samples studied were in order: Pb>Cd>Zn>Cu>Cr.

The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of vegetable species, and is altered by innumerable environmental and human factors (Zurera *et al.,* 1987). The highest TF value was found 1.11 and 0.89 for Cd and Pb. These might be due to higher mobility of Cd with a natural occurrence in soil (Alam *et al.,* 2003) and the low retention of Cd in the soil than other toxic cations (Lokeshwari and Chandrappa, 2006). However, the higher concentrations of Pb, Cd and Zn along Dhaka Aricha Road near Savar area indicates that industrial activities, such as textile, paint, battery, milling and chemical industries contaminate or introduce heavy metals into the soil.

Table 6: Transfer factor of heavy metal from soils into vegetables samples

	Transfer factor				
Sample ID	Pb	Cr	Cd	Cu	Zn
S_BV_1	0.260	0.19	0.18	0.18	0.29
S_BV_2	0.060	0.25	0.13	0.45	0.22
S_BV_3	0.170	0.26	0.04	0.05	0.30
S_BV_4	0.890	0.26	0.12	0.36	0.06
S_BV_5	0.640	0.24	0.26	0.04	0.36
S_BV_6	0.290	0.09	0.65	0.21	0.38
S_BV_7	0.450	0.07	1.11	0.53	0.33
S_BV_8	0.770	0.08	0.12	0.08	0.19
S_BV_9	0.050	0.10	0.46	0.22	0.28
S_BV_{10}	0.330	0.32	0.13	0.29	0.19
Max	0.890	0.32	1.10	0.53	0.38
Min	0.058	0.06	0.04	0.04	0.06
Mean	0.430	0.18	0.32	0.24	0.26

CONCLUSION

Concentrations of all the heavy metals except Cd (mg kg^{-1} Dw) in the studied soil were below the permissible level. The mean concentration of Cd was found 3.99±1.85 mg kg^{-1}.

Concentrations of all the heavy metals except Cd and Cr in vegetables samples were lower than recommended levels. Mean concentrations of the Cr and Cd were found 2.32±0.84 and 1.00±0.68 mg kg^{-1}, respectively.

Cd poses very high risk to the local ecosystem according to Grades of ecological risk of metals (E_r^i) value, which was >E_r^i 320. The overall risks levels of heavy metals were in order of Cd>Pb>Cu>Cr>Zn.

According to the soil to plant Transfer Factor (TF) calculated for tested metals and leafy vegetables consumed by local residents, it can be concluded that Pb and Cd was high accumulator among the investigated metals. The trend of TF for heavy metal in vegetable samples studied was in order of: Pb>Cd>Zn>Cu>Cr.

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