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Transfer of heavy metals to leafy vegetables in Gazipur textile area

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Abstract

Heavy metal pollution of soils is a major concern today because contamination of food chain considered as one of the major environmental pathways of human exposure leading to potential health risk.A pot experiment was carried out to investigate the transfer of Zn, Cu, Ni, Fe, Cd, Cr, Pb and Mn from non-contaminated and contaminated soils to jute leaves vegetable plant and to evaluate their associated health risk in the local population.The mean concentration of the heavy metals in jute leaves vegetable plants followed a decreasing order of Fe>Zn>Mn>Cu>Cr>Pb>Cd>Ni. Among the all heavy metals the highest transfer factor (TF) values was found for Cu (77.50-34.95) and the lowest TF value was observed for Ni(0-0.001) in jute leaves vegetables plant. The daily intake of metals (DIM) for a person through ingestion of jute leaves were in order of Fe>Mn>Zn>Cu>Cr>Pb>Ni>Cd. The values of health risk index (HRI) for the heavy metals were less than 1, therefore, no significant health risk is anticipated for the local consumers through ingestion of jute leaves.

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Introduction

Heavy metals are conventionally defined as elements with metallic properties and an atomic number >20. The most common heavy metal contaminants are Cd, Cr, Cu, Hg, Pb, and Zn. Metals are natural components in soil (Lasat, 2000). Some of these metals are micronutrients necessary for plant growth, such as Zn, Cu, Mn, Ni, and Co, while others have unknown biological function, such as Cd, Pb, and Hg (Gaur and Adholeya, 2004). Uptake of heavy metals by plants from soils at high concentrations may result in a great health risk taking into consideration food-chain implications. Utilization of food crops contaminated with heavy metals is a major food chain route for human exposure. The food plants whose examination system is based on exhaustive and continuous cultivation have great capacity of extracting elements from soils. The cultivation of such plants in contaminated soil represents a potential risk since the vegetal tissues can accumulate heavy metals (Jordao *et al.,* 2006). Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Sobha *et al.,* 2007). Chronic level ingestion of toxic metals has undesirable impacts on humans and the associated harmful impacts become perceptible only after several years of exposure (Khan *et al.,* 2008). In Bangladesh, textile industrial wastes and effluents are being discharged at random without treatments directly to soil, canals, and rivers. They contain heavy metals like Cu, Zn, Pb, Cr, Cd, As, Hg, Mn, and Fe. Some of them are toxic to plants and some others to both plants and animals.

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They pollute our soils and natural water systems as well as ground water endangering human health, aquatic lives, and crop production (Begum *et al.,* 2011). 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 plants depends upon plant species, soil properties and the efficiency of different plants in absorbing metals, which is evaluated by either plant uptake or soil-to plant transfer factors of the metals (Rattan *et al*., 2005). It is necessary to obtain a better understanding about heavy metals accumulation in vegetables and agricultural soils. Consequently, the present study was aimed to evaluate the concentration of different heavy metals in post-harvest non-contaminated and contaminated soils of Gazipur and jute leaves vegetables grown on those soils.

Material and methods

Study site description

Gazipur district is located between 23°53' and 24°21' north latitudes and between 90°09' and 92°39' east longitudes (website 1). It is a district under Dhaka division of Bangladesh where most of the textile industries are located.The total area of Gazipur district is 1806.36 Sq Km. The total population of Gazipur district is 34,03,912, population density is 1884/Sq Km and annual growth rate is 5.21%. Major rivers of Gazipur are Lablong, Brahmaputra, Paruli, Turag, Suti, Goali, Banar, Balu, Chelai, Bangshi, Shitalakha etc. Annual average temperature of this district is maximum 36°C and minimum 12.7°C. Annual rainfall is 2376 mm. Potato, Paddy, Jute, Oilseed, sugarcane, cotton, bamboo, jack fruit, Papaya etc. are grown here (website 2).

Sampling and pre-treatment

Soil samples were collected at the depth from 0-15 cm plough layer from textile industrial area of the selected district. Contaminated and non-contaminated soil samples were collected from the site. The collected soil samples were air dried, ground and screened to pass through a 2.0 mm sieve and then mixed thoroughly to make it a composite sample. Dry roots, grasses and other vegetative residual parts were removed from the soil. In a plastic container one kg of each composite sample was taken for chemical analysis.

Each earthen pot was filled up by 7 Kg of air dried soil. Experiments were executed with four treatments; T_1 =non-contaminated soil + 0% RDF(Recommended dose of fertilizer) (Control), T_2=non-contaminated soil + 100% RDF, T_3=contaminated soil + 0% RDF, T_4= contaminated soil + 100% RDF. Each treatment has three replications. The jute leaves vegetable (BJRI deshi pat shak-1) was used as test crop. Tapwater was used for irrigation of all treatments. No infection of insecticides and pesticides were observed during jute leaves growth. The crop was allowed to grow for 45 days. After harvest soil samples were collected and the separated plant parts were kept in an oven for 72 hours at 85^0 C and after constant weight, plant samples were taken out of the oven and their dry weight were taken. The dried plant samples were powdered using an electronic grinder and stored in labeled paper bags for acid extraction and heavy metal analysis.

Digestion

0.250 g of sample were accurately weighed and placed in a 250 ml Pyrex erlenmeyer flask. First, the pre-digestion step was done at room temperature for 24 h with 10 ml of a (3:1) mixture of 12 M HCl and 17 M HNO_3. Then, the suspension was digested on hotplate at 130^0C for 15 min. The obtained suspension was cooled until room temperature, filtered through an ashless Whatman 41 filter and, finally, diluted to 25 ml with 0.17 M HNO_3. The extraction was based on the ISO 11466 (1995) method.

Heavy metal analysis

Flame atomic absorption spectrophotometer was used for the analysis of the heavy metals Fe, Zn, Mn, Cu, Co, Ni, Cd, Crand Pb (Wodaje and Abebaw 2017). Final concentrations of the metals in the soil samples were calculated using the following formula (Uwah *et al.,* 2012):

$$\text{Concentration (mg/kg)} = \frac{\text{Concentration (mg/L)} \times V}{W}$$

where, V = final volume of solution, and W= initial weight of sample measured.

Determination of transfer factor (TF)

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 = Cplant / Csoil

where, Cplant = metal concentration in plant tissue, mg/kg fresh weight and

Csoil = metal concentration in soil, mg/kg dry weight.

Daily intake of metals

The average daily intake of metals (DIM) was calculated according to the following formula as used by Khan *et al.* (2008, 2010) and Jan *et al.* (2010):

$$DIM = \frac{Cm \times Cf \times IRveg}{Bw}$$

Where Cm, Cf, IRveg and Bw represent the metal concentrations in vegetable (mg/kg), conversion factor (0.085) for conversion of fresh to dry weight vegetable (Jan *et al.,* 2010), ingestion rate of vegetable, and average body weight, respectively. The average daily consumption of vegetables suggested by WHO guidelines in human diet is 300 to 350 g per person (WHO, 1989). The mean of 325 g/person/day was used in calculating the average daily ingestion values in this paper. An average weight of person was considered to be 60 kg (WHO/FAO, 2013).

Health risk Index

$$HRI = \frac{DIM}{R_fD}$$

To estimate the chronic health risk, health risk index (HRI) for each metal through contaminated food-crop consumption was determined using the following formula (Khan *et al.,* 2008; Jan *et al.,* 2010).

Here, HRI, DIM, and R_fD, represent the human health risk index, daily intake of metal, and reference dose of metal, respectively.

R_fD is an approximation of daily tolerable exposure to which a person is expected to have without any significant risk of harmful effects during a lifespan. R_fD for Pb, Zn, Cu, Cd, Cr and Ni is 0.004, 0.3, 0.04, 0.0005, 0.003 and 0.02 mg/kg/day, respectively (WHO/FAO, 2013). R_fD for Mn and Fe is 0.14 and 0.7 mg/kg/day, respectively (USEPA IRIS, 2011). The exposed population is considered to experience no significant risk when HRI < 1 (Khan *et al.,* 2008; Muhammad *et al*., 2011).

Results and discussion

Heavy metal concentration in soils

Total soil heavy metal concentration is commonly used to indicate the degree of soil contamination (Karaka, 2004). Loading and accumulation of heavy metals in the soil depend on different factors such as the chemical form of elements, pH, organic matter content, texture and cation exchange capacity (CEC) of the soil (Logan and Chaney, 1983). Heavy metal content in non-contaminated and contaminated soils of Gazipur are shown in Table I. In contaminated soil heavy metals concentration were higher than non-contaminated soil. Concentration of Zn, Cu, Ni, Fe, Cd, Cr, Pb and Mn were 1.9 and 19.38, 0.22 and 0.82, 25.84, and 30.00, 50.12 and 118.70, 0.054 and 0.133, 32.42 and 37.72, 10.21 and 27.02, 6.05 and 13.02 mg/kg in non-contaminated and contaminated soils of Gazipur, respectively. The heavy metal contents decreased in order of Fe>Cr>Ni>Pb>Mn>Zn>Cu>Cd in non-contaminatedsoil, andFe>Cr>Ni>Pb>Zn>Mn>Cu>Cd in contaminated soil.

Table I. Content of heavy metal in non-contaminated and contaminated soils of Gazipur

Parameters (mg/kg)	Non -Contaminated Soil of Gazipur	Contaminated Soil of Gazipur
Zinc (Zn)	1.9	19.38
Copper (Cu)	0.22	0.82
Nickel (Ni)	25.84	30.00
Iron (Fe)	50.12	118.70
Cadmium (Cd)	0.054	0.133
Chromium (Cr)	32.42	37.72
Lead (Pb)	10.21	27.02
Manganese (Mn)	6.05	13.02

Zakir *et al.* (2015) found that the mean concentrations of Cu, Zn, Pb, Cd and Cr in Gazipur soil samples were 36.19, 176.67, 27.95, 0.41 and 29.21 mg/kg, respectively. Islam *et al.* (2011) reported that at Gazipur district the dumping of waste resulted in a marked increase in the concentration of heavy metals in soils, and the measured metals varied in the order of Fe>Zn>Pb>Cu>Cd. The mean concentrations of the selected heavy metals in the surface soil of the dumped site were 0.40, 1.42, 0.46, 350.38 and 0.03 mg/kg for Cu, Zn, Pb, Fe and Cd, respectively, while the mean concentrations of the heavy metals in the subsurface soil were 0.39, 1.36, 0.47, 313.3 and 0.03 mg/kgfor Cu, Zn, Pb, Fe and Cd, respectively.

Heavy metal concentration in leafy vegetable

Values obtained for Zn concentration in jute leaves plants indicated that in contaminated soil Zn accumulation was higher than non-contaminated soil (Table II). Highest value of Zn (65.70 mg/kg) was found with T_3, where in contaminated soil no fertilizer was applied. Lowest accumulation of Zn (40.70 mg/kg) was observed in control

Table II. Heavy metal concentration in jute leaves vegetable plant

Treatment	Heavy metal concentration (mg/kg)							
	Zn	Cu	Ni	Fe	Cd	Cr	Pb	Mn
T_1	43.70	15.35	ND	1080.09	0.007	1.11	0.100	57.50
T_2	46.70	17.05	0.030	1184.09	0.006	1.70	0.050	61.20
T_3	65.70	30.46	ND	991.17	0.011	0.038	0.060	50.10
T_4	60.70	28.66	0.030	976.03	0.010	0.045	0.047	51.90

Table III. Transfer factor of heavy metal from soil to jute leaves vegetables

Treatment	Transfer Factor (TF)							
	Zn	Cu	Ni	Fe	Cd	Cr	Pb	Mn
T_1	23.00	69.77	0	21.55	0.129	0.034	0.0097	9.50
T_2	24.58	77.50	0.001	23.63	0.111	0.052	0.0048	10.12
T_3	3.39	37.15	0	8.35	0.097	0.001	0.0022	3.85
T_4	3.13	34.95	0.001	8.22	0.088	0.001	0.0017	3.99

Table IV. Daily intake of heavy metals (DIM) through consumption of jute leaves

Treat.	Zn	Cu	Ni	Fe	Cd	Cr	Pb	Mn
T 1	0.020102	0.007061	0	0.496841	3.22E-06	0.000511	0.000046	0.02645
T 2	0.021482	0.007843	1.38E-05	0.544681	2.76E-06	0.000782	0.000023	0.028152
T_3	0.030222	0.014012	0	0.455938	5.06E-06	1.75E-05	2.76E-05	0.023046
T_4	0.027922	0.013184	1.38E-05	0.448974	4.6E-06	2.07E-05	2.16E-05	0.023874

Table V. Health risk index (HRI) for heavy metals caused by consumption of jute leaves

Treat.	Zn	Cu	Ni	Fe	Cd	Cr	Pb	Mn
T_1	0.067	0.177	0	0.710	0.006	0.170	0.012	0.189
T_2	0.072	0.196	0.0007	0.778	0.006	0.261	0.006	0.201
T_3	0.101	0.350	0	0.651	0.010	0.006	0.007	0.165
T_4	0.093	0.330	0.0007	0.641	0.009	0.010	0.005	0.171

(T_1). For Zn accumulation, the treatment may be arranged in order of T_3>T_4>T_2>T_1.Similarly, highest concentration of Cu in jute leaves vegetable plant observed with T_3, which was 30.46 mg/kg. In control (T_1) lowest Cu accumulation was found,which was 15.35 mg/kg. For Cu accumulation, the treatment may be arranged in order of T_3>T_4>T_2>T_1. Nickel was not found with T_1 and T_3. And in both T_2 and T_4 concentration of Ni was 0.030 mg/kg.

The highest level of Fe (1184.09 mg/kg) was found with T_2, where 100% fertilizer was applied in non-contaminated soil. The lowest level of Fe(976.03) was observed in T_4, where in contaminated soil 100% fertilizer was applied. The treatment may be arranged as T_2>T_1>T_3>T_4 for Fe accumulation in jute leaves vegetable plant. Thehighestand lowest concentration of Cd 0.011 and 0.006 mg/kg in jute leaves vegetable plant were found in T_3 and T_2, respectively. Cr concentration in T_2 (1.70 mg/kg) and T_3 (0.038mg/kg) were highest and lowest values, respectively. Pb concentration was found highest with T_1, which was 0.100 mg/kg in jute leaves plant. Lowest value of Pb (0.047 mg/kg) was observed with T_4. Manganese accumulation was found maximum (61.20 mg/kg) in T_2 and minimum (50.10 mg/kg) in T_3. For Cd, Cr, Pb and Mn accumulation the treatment may be arranged in order of T_3>T_4>T_1>T_2, T_2>T_1>T_4>T_3, T_1>T_3>T_2>T_4 and T_2>T_1>T_4>T_3, respectively. The findings are in consent with the following research workers:

Lübben (1993) showed large differences in the transfer of Cd, Zn, Ni, Cu, Pb and Cr from soil to plant. Natasa *et al.* (2015) found that the vegetables grown on contaminated soils accumulate high concentrations of heavy metals in their edible parts. The green vegetables particularly the leafy vegetables uptake higher amounts of heavy metals from the soil ecosystem. They also suggested to use adequate NPK fertilizers to minimize plant uptake of Pb. Filipovię *et al.* (2012) showed accumulation and distribution of heavy metals in the plant depend on the plant species, the levels of the metals in the soil and air, the element species and bioavailability, pH, cation exchange capacity, climacteric condition, vegetation period and multiple other factors. Jolly *et al.* (2013) reported that the concentration of heavy metals in soil depended mainly on the characteristics of the soil sample and the distance from the source of contamination. Uptake and accumulation of heavy metals by shoots and roots varied with heavy metal type and plant species. Jassir *et al*. (2005) reported that leafy vegetables grown in heavy metals contaminated soils accumulate higher amounts of metals compare to those grown in uncontaminated soils.

Transfer factor of heavy metal

The ability of a metal species to migrate from the soil into plant roots is referred to as transfer factor (TF). Transfer factor of heavy metal from soil to jute leaves vegetables are presented in Table III. Among the treatmentsthe highest transfer factor of Zn, Cu, Ni, Fe, Cr and Mn were 24.58, 77.50, 0.001, 23.63, 0.052 and 10.12, respectively found with T_2, where 100% fertilizer was applied in non-contaminated soil. The lowest transfer factor of Zn,Cu, Fe, Cd, Cr, and Pb were 3.13, 34.95, 8.22, 0.088, 0.001, 0.0017, respectively observed with T_4, where 100% fertilizer was applied in contaminated soil. On the other hand,the highest transfer factor of Cd (0.129) and Pb (0.0097) were found with T_1 (control). Among the all heavy metals the highest TF values were found for Cu (77.50-34.95) in jute leaves vegetables. The TF value for toxic element Zn (24.58 -3.13), Fe (23.63-8.22) and Mn (10.12-3.85) werealso quite high compared to Cd (0.129 - 0.088), Cr (0.052 - 0.001). Lowest TF value in jute leaves vegetable plant were observed for Ni(0-0.001). The sequence of transfer factor of heavy metals values was Cu>Zn>Fe>Mn>Cd>Cr>Pb>Ni. These results have similarity with the following research workers:

Natasa *et al.* (2015) found that the TF values differed significantly between locations and between plant species. TF decreased when the plants were grown in the higher soil heavy metal contamination. Saglam (2013) found that if the value of the translocation factor is higher for plants, more elements would be accumulated by them. Zhuang *et al.* (2009) reported the leafy vegetables are found to show a higher transfer factor.

Daily intake of metals (DIM) through consumption of jute leaves and health risk

Several human exposure pathways including food-chain, dermal-contact, and inhalation are possible routes, but oral intake is considered to be the primary pathway for exposure via the food chain (Garg *et al.,* 2014). The daily intakes of eight metals (Zn, Cu, Ni, Fe, Cd, Cr, Pb and Mn) were estimated according to the mean concentration of each metal in jute leaves vegetable. The DIM of studied metals from the consumption of jute leaves vegetable are shown in Table IV. DIM values for all selected metals through ingestion of jute leaves were below 1. The overall sequence of DIM for individual metals in a person through ingestion of cultivated jute leaves vegetable were in order of Fe> Mn > Zn > Cu > Cr > Pb > Ni > Cd.

The values of HRI calculated for the selected heavy metals through consumption of jute leaves for a person are shown in Table V. Health risk indexes considering for all the heavy metals in jute leaves were lower than 1, which suggests that consumers may not experience potential health hazard due to intake of it. Due to jute leaves ingestion in all treatments the HRI trend were in decreasing order of Fe>Cu>Mn>Cr>Zn>Pb>Cd>Ni. The maximum HRI (0.778) was calculated for a person through Fe consumption in T_2, while the minimum (zero) was observed through Ni consumption in T_1 and T_3. The findings are in consent with the following research workers:

Muhammad *et al.* (2011) found that all of the calculated HRI values were less than one, which indicates that no significant health risk is anticipated for consumption of these tested vegetables.

Heavy metals accumulation in the post-harvest soils

After cultivation of jute leaves vegetable plant in all treatments heavy metals accumulation in the post-harvest soils decreased (Fig.1 to 8). In this experiment jute leaves vegetable plants were acted as for phytoremediation processes of heavy metals from the soils.Phytoremediation is the use of plants to clean up a contamination from soils, sediments, and water. This technology is environment friendly and potentially cost effective (Cho-Ruk *et al.,* 2006).

In both non-contaminated and contaminated post-harvest soils Zn concentrationsignificantly ($P \leq 0.05$) decreased as compared with initial values (Fig. 1). Maximum Zn concentration reduction were found with T_1 (0.66 mg/kg) and T_3 (17.55 mg/kg) in non-contaminated and contaminated soil, respectively. Fertilizers were not applied in both of these treatments.

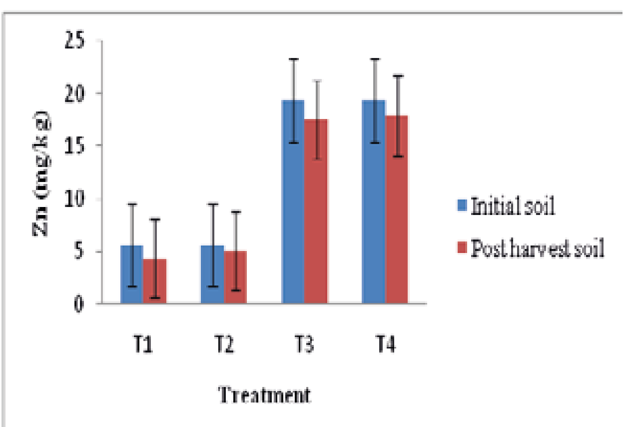

Fig. 1. Concentration of Zn in post-harvest soils of Gazipur

Cu accumulation in post-harvest soils decreased 9.09% (T_1) and 4.55% (T_2) in non-contaminated soil as compared with initial value (0.22 mg/kg). And in contaminated soil Cu concentration reduction in post soil was comparatively low, which were 6.1%(T_3) and 2.44%(T_4) as compared with initial value (0.82 mg/kg) (Fig.2).

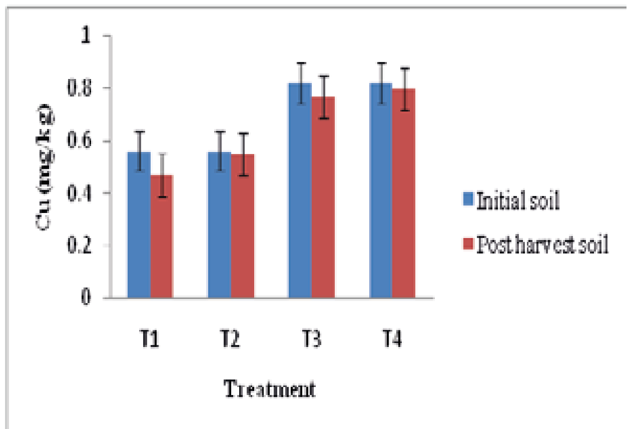

Fig. 2. Concentration of Cu in post-harvest soils of Gazipur

The treatments without fertilizer application in both non-contaminated and contaminated post-harvest soil Ni accumulation reduced more than fertilizer applied treatments (Fig. 3). Lowest concentration of Ni in post-harvest soils were observed in T_1 (20.33 mg/kg) and T_3 (29.1 mg/kg) in non-contaminated and contaminated soils, respectively, which were 21.32% and 3% less as compared with initial values.

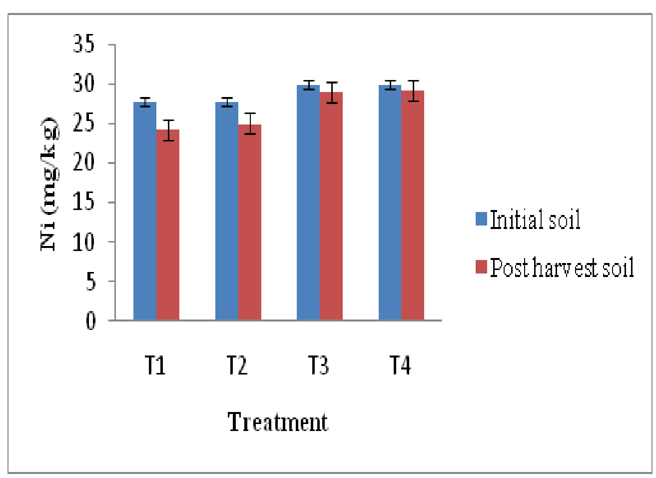

Fig. 3. Concentration of Ni in post-harvest soils of Gazipur

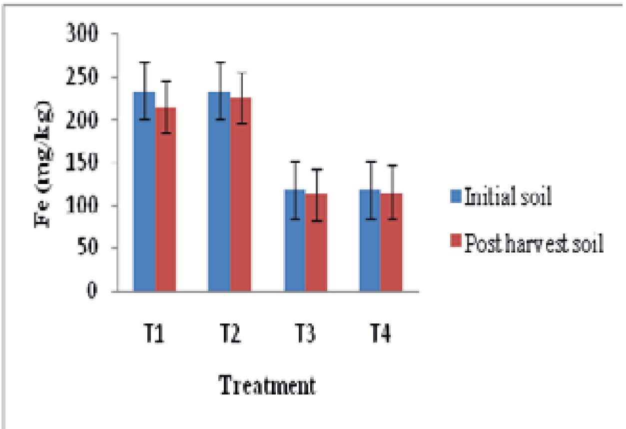

Fig. 4. Concentration of Fe in post-harvest soils of Gazipur

Due to no fertilizer application concentration of Fe in post-harvest soils reduced more than the treatments where 100% fertilizers wereused (Fig. 4). Minimum accumulation of Fe in non-contaminated post-harvest soil was 45.41 mg/kg and in contaminated soil it was 113.22 mg/kg. In post-harvest soil 9.4% and 4.62% Fe concentration decreased in T_1 and T_3,respectively for cultivation of jute leaves vegetables without fertilizer.

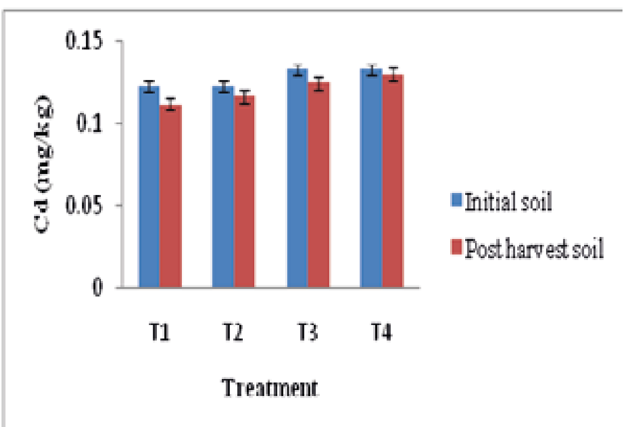

Fig. 5. Concentration of Cd in post-harvest soils of Gazipur

In all treatments Cd concentration in post-harvest soil significantly ($P\leq$ 0.05) decreased as compared with initial values (Fig.5). The lowest values of Cd in post-harvest non-contaminated and contaminated soils were found 0.048 mg/kg and 0.125 mg/kg, respectively. Maximum reduction of

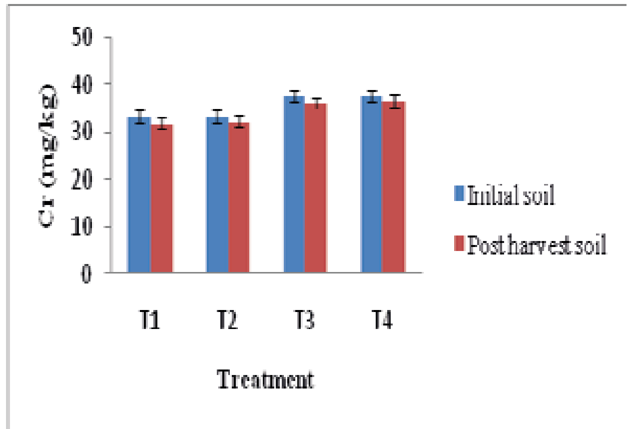

Fig. 6. Concentration of Cr in post-harvest soils of Gazipur

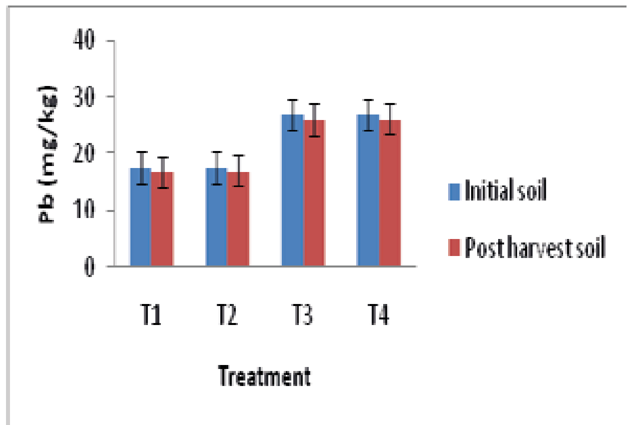

Fig. 7. Concentration of Pb in post-harvest soils of Gazipur

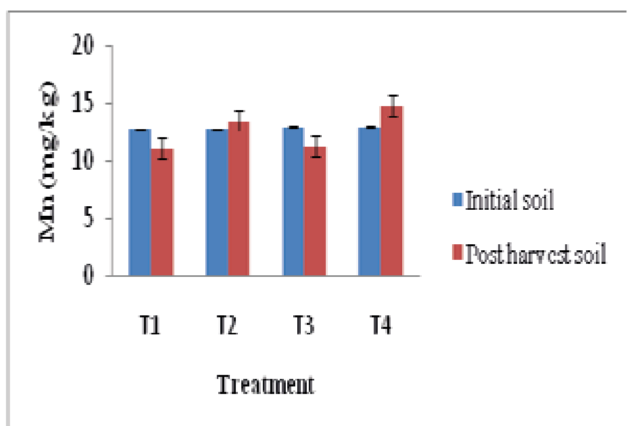

Fig. 8. Concentration of Mn in post-harvest soils of Gazipur

Cd in post-harvest soil were found in T_1 and T_3, respectively in non-contaminated and contaminated soil.

Minimum Cr concentration in post-harvest non-contaminated and contaminated soils were observed 29.2 mg/kg (T_1) and 36.24 mg/kg (T_3), respectively (Fig.6). These values were 9.93% and 3.92% less as compared with initial values of non-contaminated and contaminated soils, respectively.

Lead (Pb) concentration in post-harvest soils decreased more with T_1 and T_3 in non-contaminated and contaminated soil,respectively as compared with initial values. Lowest value of Pb in post-harvest soils were 10.02 mg/kg and 26.11mg/kg, which were 1.86% and 3.38% lower than initial values of non-contaminated and contaminated soil, respectively(Fig.7).

Application of 100% fertilizer significantly ($P \leq 0.05$) increased but no fertilizer used significantly ($P \leq 0.05$) decreased Mn accumulation in both post-harvest soils (Fig.8). In non-contaminated post-harvest soil Mn concentration 29.75% increased with T_2 but with T_1 21.16% decreased as compared with initial value (6.05 mg/kg). Similarly in contaminated post-harvest soil Mn accumulation 13.44% increased with T_4 but with T_3 13.59% decreased as compared with initial value (13.02 mg/kg).The results are consistent of the following scientists:

Wang and Greger (2006) reported that phytoextraction is considered as an environment friendly method to remove metals from contaminated soils in situ. This method can be used in much larger-scale for clean-up operations and has been applied for other heavy metals. Mwegoha (2008) found that phytoremediation can be a time-consuming process, and it may take at least several growing seasons to clean up a site. Bhatti *et al.* (2016) reported that use of NPK fertilizers and other agrochemicals further contaminate the soil with heavy metals. Various NPK fertilizers act as source of heavy metals such as Cd, As, Pb, Cr, Ni, Cu etc.

Conclusion

From the above findings, it could be concluded that the concentration of Fe was highest at the study area followed by Cr>Ni>Pb>Mn>Zn>Cu>Cd in non-contaminated soil, and Cr>Ni>Pb>Zn>Mn>Cu>Cd in contaminated soil. Jute leaves vegetables grown in heavy metals contaminated soils accumulate higher amounts of metals compare to those grown in non-contaminated soils, which were lower than maximum allowable limit of FAO/WHO (2001). The sequence of the transfer factor of heavy metals for jute leaves vegetable was Cu>Zn>Fe>Mn>Cd>Cr>Pb>Ni. The results of this study indicated that all the HRI values of selected heavy metals were found with the safe limits (HRI<1), with no significant health risk anticipated for the local consumers through ingestion of jute leaves grown in the study area.Cultivation of jute leaves vegetable also reduced the heavy metals concentration in post-harvest soils, which removed heavy metals from contaminated soils as phytoremediation. It is suggested that monitoring of heavy metals should be conducted regularly for all agricultural soils and food-crop to minimize the human health risks.

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