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INFLUENCE OF WASTE WATER IRRIGATION ON HEAVY METAL ACCUMULATION IN SOIL & PLANT

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ABSTRACT

Concentrations of heavy metals in soils of the investigated areas are high; especially Cd is above the worldwide natural background concentration of surface soils. To study the effects of Chittagong city waste water irrigation on the heavy metal contamination of soils and their uptake by plants, soil and plant samples were collected from sixteen wastewater irrigated sites belonging four locations namely Syedpara, Hazipara, Jungalpara and Nazirpara and from another four sites belonging the location namely Chalidatoli selected as control location. Mean total Cd, Pb, Zn, Cu, Mn and Fe content in 0-15 cm depth of the study area ranged between 0.08 to 2.39, 13.96 to 50.29, 14.73 to 21.12, 27.07 to 59.13, 116.25 to 326.63 and 1523 to 2798 mg kg^{-1}, respectively. The metals content in 15-30 cm depth was in the ranges 0.01 to 1.98, 8.96 to 33.29, 51.44 to 267.31, 18.63 to 43.79, 68.89 to 271.74 and 1126 to 2054 mg kg^{-1}, respectively. Total and 0.1 N HCl extractable Cd, Pb, Zn, Cu, Mn and Fe contents of soils were significantly higher in wastewater irrigated location than those in the control location. Total Cd, Pb, Zn and Cu contents of surface soil in waste water irrigated locations were above the normal ranges of these metals for soils. Concentration of Cd, Pb, Zn, Cu, Mn and Fe in different plants (plant parts of rice, radish and aurum) varied from 0.02 to 16.65, 0.08 to 35.55, 0.84 to 102.75, 0.86 to.32.67, 0.95 to 185.50 and 3.23 to 485.23 mg kg^{-1}, respectively. Bioaccumulation coefficient of Cd, Pb, Zn, Cu, Mn and Fe in plants ranged from 0.20 to 13.91, 0.008 -0.72, 0.006 -1.60, 0.03-0.64, 0.01 - 0.73 and 0.002 -0.18, respectively. An establishment of soil quality standards for heavy metals to predict human induced soil pollution in Bangladesh is needed.

KEY WORDS: Wastewater, Soil, Plant, Heavy metal.

INTRODUCTION

Application of wastewater to cropland is an attractive option for disposal because it can improve physical properties and nutrient contents of soils (Pomares et al., 1984). Wastewater irrigation provides water, N, P and organic matter to the soils (Siebe, 1998), but there is a concern about the accumulation of potentially toxic elements such as Cd, Pb, Cu, Zn, Fe and Mn from both domestic and industrial sources (Kiziloglu et al., 2007). In many areas of developing countries, untreated waste water flows through channels into rivers where it is diverted to small plots of grain and vegetables crops. Chittagong city is the second largest city and the main industrial zone of Bangladesh with an area of 209.66 square kilometers and a population of about 3.202 millions (ASB, 2006). A large open canal (Noakhali khal) constructed to drain waste water including domestic and industrial sewage and sanitary waste from the central city of Chittagong passed through the areas of Syedpara, Hazipara, Jungalpara, and Nazirpara towards the Karnafuli River. A number of small open and closed canals receiving waste water from many sources of the city such as domestic waste water, industrial waste water, waste water from service activities and waste water from textile factories and handicraft foundations discharged their waste water into the large canal that finally joins the Karnafuli River. While the open large canal passing through the agricultural areas of Syedpara, Hazipara, Jungalpara, and Nazirpara that flows untreated waste water, it has been used by farmers for a long time (about 50 years) for irrigation of grain and vegetable crops especially of rice and arum where the canal is the main irrigation water source for soils of the area. Besides, some parts of the agricultural area, overflowing of waste water during heavy rainfall occurs and remains under waste water in the rainy season for a few months of the year. In recent years, one potential problem that has been recognized in connection with the disposal of sewage waste water to agricultural land is the accumulation of heavy metals in the soil and their uptake by plants (Kiziloglu, 2007).

Although a few study have been conducted on heavy metal contamination of soil and plants in industrial sites around Dhaka city (Chamon et al., 2005; Kashem and Singh 1999, Ullah et al., 1999), soils irrigated with city waste water especially in Chittagong has not yet been studied. So the objectives of the present study are: (1) to assess the extent of heavy metal contamination (Cd, Pb, Zn, Cu, Mn etc) in waste water irrigated soils in Chittagong, (2) to investigate the uptake of heavy metals in crop plants in order to establish advice regarding consumption of rice and vegetables grown in soils contaminated by heavy metals, (3) to know the availability of heavy metals to plants and their accumulation in the food chain and (4) to observe the bioaccumulation coefficient of heavy metals from soil to crops. The study was carried out from November 2010 to December 2011.

Materials and Methods

The study area (22^0–$23^/$ N and 91^0–$53^/$ E) was situated at the northern part of the Chittagong City Corporation Area (Fig. 1). For soil and plant sampling, sixteen wastewater irrigated sites were selected belonging four locations namely Syedpara, Hazipara, Jungalpara and Nazirpara (4 sites in each location) along the canal at regular intervals which covered fully the distribution of irrigation water sampling points while another four sites for sampling belonging the location namely Chalidatoli was selected as control location, 1 km away from canal and that was neither irrigated nor overflowed by wastewater.

Soil samples were collected from two depths of 0-15 and 15-30 cm in each site. Plant samples of each species (rice, aurum, and radish) were collected from the corresponding sites in the respective growing seasons. Soil samples were air dried and ground to pass through a 2 mm sieve for determining the following physical and chemical properties (i) Particle size distribution and textural classes, (ii) pH (iii) Organic matter (iv) Cation exchange capacity (v) Total contents of Cd, Pb, Zn, Cu, Mn and Fe (vi)

0.1 M HCl extractable Cd, Pb, Zn, Cu, Mn and Fe. Collected plant samples were cleaned with tap water and then with distilled water. The samples were air dried in a dust free room and then dried at 65^0 for 72 hours and ground in a stainless steel mill to pass through a 0.5 mm sieve.

Particle size distribution (percentage of sand, silt and clay) was determined by hydrometer method (Day, 1965). Soil textural classes were determined by using Soil Textural Triangle of Marshal. Soil pH was measured by a glass electrode pH meter using soil –water suspension at the ratio of 1:2.5. The potassium dichromate wet-oxidation method of Jackson (1973) was used for the determination of organic carbon followed by multiplying the values with 1.724 to calculate the organic matter contents. The cation exchange capacity was determined by saturation with 1N NH_4OAc at pH 7.0 (Jackson, 1973). Total nitrogen was determined by micro - Kjeldahl method as described by Jackson (1973). The soil samples were digested with aqua regia (Jackson, 1973) on a sand bath for the determination of total Cd, Pb, Zn, Cu, Mn and Fe. In order to determine the mobility of heavy metals in the soils, the extractable amounts of the metals were determined after extraction with 0.1 M HCl (Sabienë and Brazauskienë, 2004). All the heavy metals (total and extractable) were measured by atomic absorption spectrophotometer (Varian spectra AA-220).

To determine the plant contents of heavy metals (Cd,Pb, Zn, Cu, Mn and Fe) wet oxidation of plant samples were made with tri acid mixture (HNO_3, $HClO_3$ and H_2SO_4 at the ratio of 5:1:2). After wet oxidation, all the elements were measured by using the procedure as described for soil analysis.

The one way analysis of variance (ANOVA) was done followed by DMRT to evaluate differences in soil properties and heavy metal contents among the locations and depths. Pearson's correlation coefficient was also estimated to test the relationship among various soil properties, between metal contents in soils and soil properties and between metal contents in soils and plants. The statistical software Excel (Excel Inc., 2003) and SPSS version 12 (SPSS Inc., 2003) were used in the analysis.

RESULTS AND DISCUSSIONS

General Soil Properties

Soil textural class varied from sandy clay loam to clay loam in the study area. The overall range of sand, silt and clay was from 37 to55 %, 14 to 33% and 20 to 36% respectively in the study area (Data not shown). Soil pH, organic matter, cation exchange capacity(CEC) and total N content of soils in the study area varied from 4.50 to 6.03, 1.40 to 3.09%, 5.94 to 9.41 cmol kg^{-1} and 0.08 to 0.13 % in 0 -15 cm depth of soil respectively. In 15-30 cm depth of soil, these values were from 4.68 to 6.05, 1.00 to 1.90 %, 4.14 to 7.73 cmol kg^{-1}, and 0.06 to 0.11 % respectively. Soil pH in Chalidatoli (Control) location was significantly higher from that of the wastewater irrigated locations in both 0-15 cm and 15-30 cm depths. Lower pH values in wastewater irrigated locations may be due to acidic effluents coming from industrial operations.. Total nitrogen, organic matter and cation exchange capacity in the surface soil of control location were significantly lower from those of the wastewater irrigated locations except total N in Jungalpara. The surface soil contained higher amounts of organic matter, CEC and total N in each location.

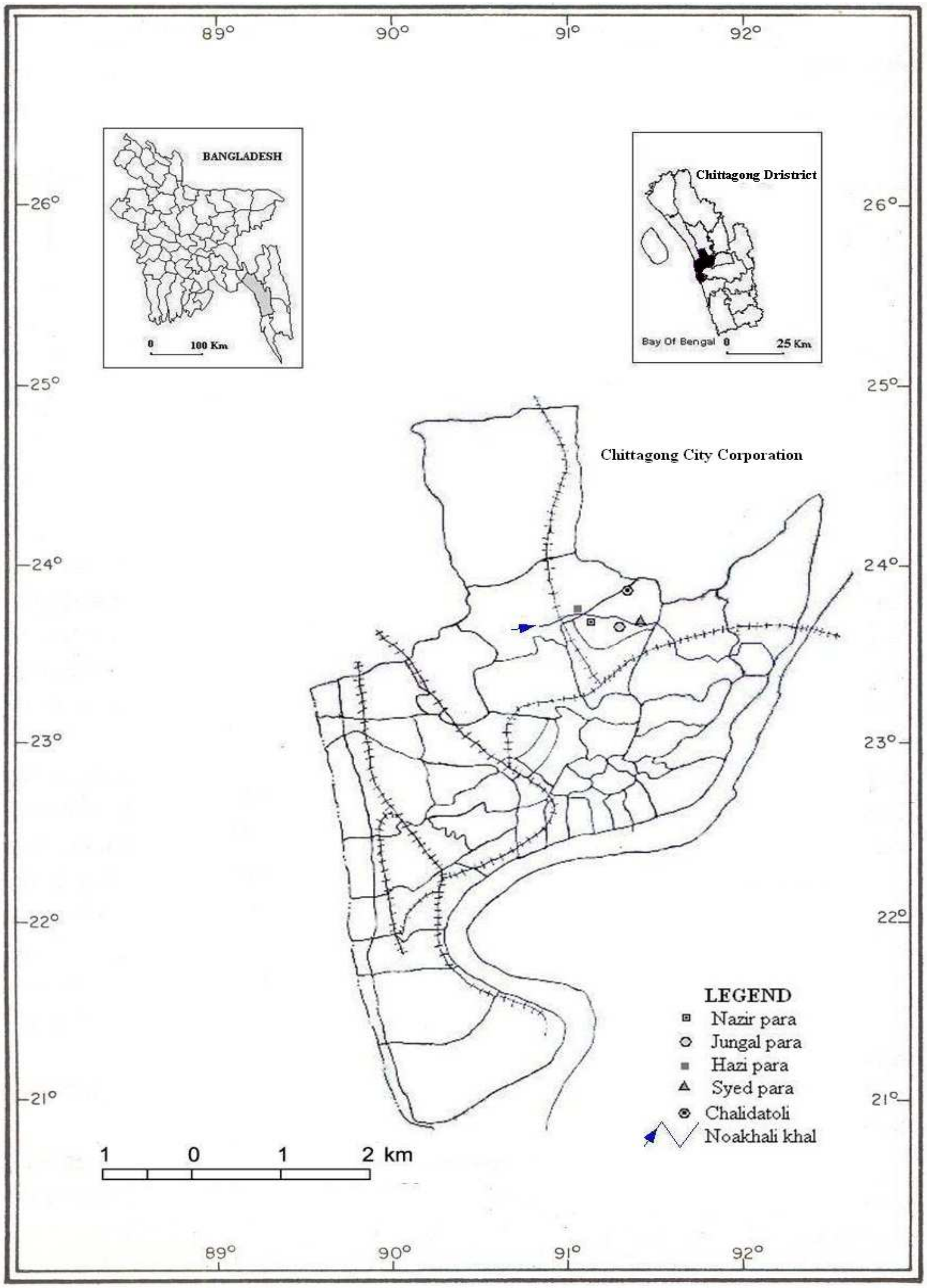

Figure 1: Location of the Study area (Bangladesh, Chittagong District, Chittagong City Corporation)

Heavy Metal Concentrations in Soil

Total Cd, Pb, Zn, Cu, Mn and Fe in the study area ranged from 0.08 to 2.39, 13.96 to 50.29, 83.55 to 350.03, 27.07 to 59.13, 16.25 to 326.63 and 1523 to 2798 mg kg^{-1} in the surface soil (0-15 cm depth) and 0.01 to 1.98, 8.96 to 33.29, 51.44 to 267.31, 18.63 to 43.79, 68.89 to 271.74 and 1126 to 2054 mg kg^{-1} in subsurface soil (15-30 cm depth) respectively (Table. 1). In the surface soil (0-15 cm depth) of the study area, 0.1 N HCl extractable Cd, Pb, Zn, Cu, Mn and Fe were in the range from 0.04 to 1.22, 7.11 to 41.84, 12.25 to 91.84, 7.90 to 16.20, 31.94 to 129.91 and 417 to 1238 mg kg^{-1} respectively and in the subsurface soil (15-30 cm depth) the corresponding values were in the range from 0.003 to 1.02, 4.62 to 27.70, 7.48 to 70.15, 5.42 to 12.01, 18.78 to 107.69 and 311 to 883 mg kg^{-1} respectively.

All the wastewater irrigated locations contained significantly higher amounts of total heavy metals than the control (Chalidatoli) location in both surface and subsurface soil. Mean 0.1 N HCl extractable heavy metals in wastewater irrigated locations were also significantly higher than those in the control (Chalidatoli) location in both the depths. Among the wastewater irrigated locations, the highest total Cd and Zn in both 0-15 cm and 15-30 cm depths were found at Jungalpara and the lowest total Cd and Zn in both the depths were found at Nazirpara and Hazipara respectively. There was no significant difference in Fe content among the wastewater irrigated locations. The high content of these metals especially in the surface layer of the wastewater irrigated locations indicates their contamination via the city wastewater received by these soils over about 50 years. This might be due to liquid wastes, flocculated sludge and other solids with excessive heavy metals coming from anthropogenic activities in Chittagong city. This is in conformity with Lü (1998) and Zhou et al. (1992) who reported that heavy metal pollution problems in agricultural soils of Shanghai, China were mainly caused by sewage irrigation and improper industrial waste disposal. Among all sources of pollutants, irrigation with untreated sewage water plays a vital role in increasing soil heavy metals (Wang and Li, 1999). Total Cd concentration in surface soils (0-15 cm) of waste water irrigated locations was many folds higher than the worldwide mean Cd concentration of 0.53 mg kg^{-1} in surface soils (Kabata -Pendias, 2001). The total Pb concentration of surface soils (0-15cm) of all the locations was also found above the normal range for soils (5-10 mg kg^{-1}) quoted by Ashwathanarayana (1999). Concentration of total Zn and Cu were found above the natural background levels (68 mg kg^{-1} for Zn and 27 mg kg^{-1} for Cu) of Bangladesh soils in all the locations (Domingo and Kyuma, 1983).

Heavy Metal Concentration in Plants

Cadmium concentration varied from 0.02 to 16.32 mg kg^{-1} in rice, 0.28 to 16.65 mg kg^{-1} in aurum and 0.13 to 3.80 mg kg^{-1} in radish (Table 2). Lead concentration ranged from 0.08 to 35.55, 0.28 to 15.32 and 0.45 to 2.25 mg kg^{-1} in rice, aurum and radish respectively. Zinc concentration in rice, aurum and radish varied from 0.84 to 102.75, 66.50 to 448.25 and 16.49 to 74.38 mg kg^{-1}, respectively. Copper concentration ranged from 0.86 to 32.67, 3.15 to 26.65 and 3.55 to 12.48 mg kg^{-1} in rice, aurum and radish respectively (Tab. 4). Manganese concentration in rice, aurum and radish was in the range of 0.95 - 49.85, 28.52 - 175.46 and 46.55- 185.50 mg kg^{-1}, respectively. Iron concentration varied from 3.23

to 485.23, 54.75 to 106.25 and 66.59 to 149.52 mg kg^{-1} in rice, aurum and radish respectively. All of the heavy metals (Cd, Pb, Zn. Cu, Mn and Fe) concentration in rice, aurum and radish was significantly higher in wastewater irrigated locations from that in the control location (Chalidatoli).

Table : 1. Heavy Metal Concentration In Soil (Mg Kg^{-1}) Of The Areas Under Study

Location	Total				0.1 N HCl Extractable			
	0-15 cm depth		15-30 cm depth		0-15 cm depth		15-30 cm depth	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Cd								
Syedpara (WI)	2.01 b	0.13	1.69 b	0.08	1.22 a	0.21	1.02 a	0.16
Hazipara (WI)	2.07 b	0.09	1.75 b	0.13	1.20 a	0.28	1.01 a	0.25
Jungalpara (WI)	2.39 a	0.13	1.98 a	0.07	1.03 a	0.14	0.85 a	0.11
Nazirpara (WI)	1.93 b	0.09	1.54 b	0.26	1.06 a	0.13	0.85 a	0.21
Chalidatoli (C)	0.08 c	0.02	0.01 c	0.00	0.04 b	0.01	0.003 b	0.005
Pb								
Syedpara (WI)	50.29 a	3.31	33.29 a	2.09	41.84 a	2.73	27.70 a	1.59
Hazipara (WI)	41.36 b	3.27	28.46 b	2.31	28.60 b	4.11	19.74 b	3.26
Jungalpara (WI)	40.91 b	3.43	29.49 ab	4.91	16.40 c	5.47	11.98 c	4.85
Nazirpara (WI)	42.57 b	2.99	31.38 ab	1.34	30.44 b	2.14	22.56 b	2.94
Chalidatoli (C)	13.96 c	2.57	8.96 c	1.19	7.11 d	3.07	4.62 d	2.16
Zn								
Syedpara (WI)	314.44 b	16.75	231.73 b	18.03	75.66 b	11.24	55.65 b	7.84
Hazipara (WI)	236.09 c	15.01	169.52 c	6.16	58.82 c	4.24	42.26 c	2.91
Jungalpara (WI)	350.03 a	14.73	267.31 a	11.89	91.84 a	10.37	70.15 a	8.15
Nazirpara (WI)	290.74 b	17.00	213.49 b	12.17	78.31 b	8.87	57.73 b	8.93
Chalidatoli (C)	83.55 d	21.12	51.44 d	15.72	12.25 d	2.00	7.48 d	1.36
Cu								
Syedpara (WI)	48.85 ab	14.45	27.25 b	5.87	13.53 a	2.81	7.58 cd	0.97
Hazipara (WI)	49.86 ab	6.35	39.03 a	3.35	14.58 a	3.36	11.37 ab	2.09
Jungalpara (WI)	59.13 a	5.14	43.79 a	6.19	16.20 a	2.74	12.01 a	2.57
Nazirpara (WI)	43.10 b	4.95	29.68 b	4.23	13.03 a	1.86	8.98 bc	1.52
Chalidatoli (C)	27.07 c	3.26	18.63 c	2.13	7.90 b	1.54	5.42 d	0.93

Mn								
Syedpara (WI)	278.84 a	22.48	230.64 b	11.43	129.91 a	3.77	107.69 a	5.53
Hazipara (WI)	228.07 b	31.19	183.22 c	12.62	85.64 c	13.87	68.72 b	7.13
Jungalpara (WI)	326.63 a	41.01	271.74 a	16.22	119.18 ab	19.22	99.25 a	12.30
Nazirpara (WI)	283.69 a	30.31	257.45 a	28.05	104.95 b	13.12	95.18 a	11.30
Chalidatoli (C)	116.25 c	22.68	68.89 d	15.28	31.94 d	6.51	18.78 c	3.26
Fe								
Syedpara (WI)	2798 a	128	2054 a	91	1050 b	110	770 b	66
Hazipara (WI)	2656 a	165	1894 a	131	1238 a	39	883 a	36
Jungalpara (WI)	2690 a	149	1990 a	103	998 b	123	737 b	83
Nazirpara (WI)	2705 a	126	1938 a	91	989 b	135	708 b	88
Chalidatoli (C)	1523 b	121	1126 b	92	417 c	22	311 c	44

WI=Wastewater irrigated, C= Control, Mean values in the column followed by the same letter(s) are not significantly different according to DMRT ($P \leq 0.05$)

Table : 2 Heavy Metal Concentration (Mg Kg^{-1} Dry Weight) in Rice, Aurum And Radish of Areas Under Study

	Rice			Aurum		Radish	
Location	**Grain**	**Straw**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**
Cd							
Syedpara (WI)	1.02 a	3.20 ab	15.57 b	7.58 b	15.57 ab	2.59 b	3.47 b
Hazipara (WI)	0.96 a	3.18 ab	15.81 b	7.76 b	14.38 bc	2.41 c	3.31 bc
Jungalpara (WI)	0.85 a	3.35 a	16.32 a	8.63 a	16.65 a	2.76 a	3.80 a
Nazirpara (WI)	0.75 a	3.11 b	15.39 b	6.85 c	13.63 c	2.48 b	3.18 c
Chalidatoli (C)	0.02 b	0.11 c	1.14 c	0.28 d	1.34 d	0.13 d	0.19 d
Pb							
Syedpara (WI)	0.98 a	5.07 a	35.55 a	6.98 b	15.32 a	1.56 a	2.25 a
Hazipara (WI)	0.75 b	3.93 b	30.54 b	7.68 ab	12.56 b	1.24 b	1.74 c
Jungalpara (WI)	0.84 ab	4.45 b	29.46 b	8.70 a	14.23 a	0.63 c	1.23 d
Nazirpara (WI)	0.56 c	2.49 c	28.42 b	6.87 b	12.60 b	1.28 b	2.02 b
Chalidatoli (C)	0.08 d	0.35 d	5.37 c	0.28 c	7.26 c	0.45 d	0.98 e
Zn							

Syedpara (WI)	1.80 b	32.48 a	102.75 a	226.25 b	448.25 a	90.25 a	67.05 ab
Hazipara (WI)	1.60 b	28.83 b	94.50 a	200.50 c	338.50 b	67.31 b	55.82 b
Jungalpara (WI)	2.30 a	27.58 b	80.75 b	297.50 a	359.00 b	93.45 a	74.38 a
Nazirpara (WI)	1.73 b	24.68 c	72.50 b	184.50 c	233.75 c	85.39 a	62.97 ab
Chalidatoli (C)	0.84 c	9.45 d	45.00 c	66.50 d	125.75 d	16.49 c	13.92 c
Cu							
Syedpara (WI)	2.11 b	7.25 a	29.81 ab	5.82 b	24.29 b	5.79 a	12.48 a
Hazipara (WI)	1.87 b	6.36 b	27.29 bc	5.93 b	23.18 bc	5.55 a	12.23 a
Jungalpara (WI)	2.79 a	5.52 c	32.67 a	6.55 a	26.65 a	5.91 a	12.00 a
Nazirpara (WI)	1.27 c	5.69 c	24.18 c	4.52 c	21.58 c	5.21 b	10.62 b
Chalidatoli (C)	0.86 d	2.44 d	12.25 d	3.15 d	11.51 d	3.55 c	6.45 c
Mn							
Syedpara (WI)	2.53 b	5.25 a	49.85 a	91.38 b	167.59 a	132 .35 a	185.50 a
Hazipara (WI)	2.20 c	4.61 b	42.42 bc	89.83 b	145.15 b	108.75 b	164.25 bc
Jungalpara (WI)	2.94 a	4.31 bc	48.56 ab	128.18 a	175.46 a	121.20 a	173.43 ab
Nazirpara (WI)	2.71 ab	4.19 c	41.75 c	95.37 b	135.13 b	104.50 b	155.25 c
Chalidatoli (C)	0.95 d	1.49 d	26.68 d	28.52 c	41.25 c	46.55 c	75.50 d
Fe							
Syedpara (WI)	6.42 ab	278.55 a	485.23 a	114.25 b	94.50 b	97.55 a	149.52 a
Hazipara (WI)	6.63 a	255.70 a	474.25 a	134.55 a	106.25 a	86.33 bc	141.25 ab
Jungalpara (WI)	6.36 ab	268.25 a	450.55 b	112.25 b	98.00 b	82.72 c	135.60 b
Nazirpara (WI)	6.11 b	264.58 a	439.25 b	96.00 c	86.50 c	91.35 ab	142.75 ab
Chalidatoli (C)	3.23 c	169.72 b	265.66 c	54.75 d	47.15 d	66.59 d	90.58 c

WI=Wastewater irrigated, C= Control, Mean values in the column followed by the same letter(s) are not statistically different according to DMRT ($P \leq 0.05$)

The present experiment showed that the Cd concentrations in rice grain grown in waste water irrigated locations were 7.5 to 10.2 times higher respectively than the maximum safe-intake levels (0.1 mg kg^{-1}) in grains proposed by the FAO/WHO (1995), while the grain Cd concentration of rice in control location was 5 times lower to that level. Although Cd concentration in the rice grain was low relative to the other parts of the plants, it is a potential cause for concern.. The Pb concentrations in the grain of rice in the study area were all below the safety level of 10 mg kg^{-1} reported by Lin et al. (1993), but were all beyond the allowable limit of Germany (0.3 mg kg^{-1}) and maximum level (0.2 mg kg^{-1}) of Joint FAO/WHO Food Standards Programme (2002) except for control location. The highest concentration of Zinc Concentration in rice grain in all the locations of the study area were below its excessive level of Japan (21 mg kg^{-1}) in rice grain (Kabata –Pendias , 2001). However, Zn concentration in aurum and radish in the study area exceeded its reference value (0.7-8.0 mg kg^{-1}) of USA in vegetables (Kabata –Pendias , 2001). Copper Concentration in grain of rice was within the reference limit (0.3-4.0 mg kg^{-1}) of USA in cereals but its concentration in aurum and radish was beyond the reference limit (0.1-3.2 mg kg^{-1}) in vegetables (Kabata –Pendias, 2001). Manganese concentration in grain of rice in all the locations of the study area was below the worldwide background contents of Mn (15-80 mg kg^{-1}) in cereal grain (Kabata –Pendias, 2001).

Relationship Between Heavy Metals in Plants and Extractable Metals in Soils

Correlation coefficients between the concentration of heavy metals in the plants and 0.1N HCl extractable heavy metals in soils (0-15cm depth) of the areas under study are presented in Tab. 3. Cadmium concentration in plant parts of rice, aurum and radish correlated significantly with its content in soil extracted with 0.1N HCl. The correlation between the Pb contents in the plants with 0.1N HCl extractable Pb in soil were also highly significant ($p<0.01$). Zinc in the plants showed significant positive correlation with its content in soil extractable with 0.1N HCl. The contents of Cu in the plants were positively and significantly correlated with 0.1N HCl extractable Cu in soil. Similar results were found with Mn and Fe. Metals extracted with 0.1 M HCl are thought to represent the mobile fraction of metals and may reflect the bioavailability of metals (Kashem et al., 2007).

Table 3. Correlation Coefficient Between Heavy Metals in Plants and 0.1 N Hcl Extractable Heavy Metals in 0-15 Cm Depth of Soil.

Heavy metals	Rice			Aurum		Radish	
	Grain	Straw	Root	Shoot	Root	Shoot	Root
Cd	0.993**	0.936**	0.916**	0.907**	0.905**	0.927**	0.905**
Pb	0.689**	0.672**	0.782**	0.568**	0.711**	0.952**	0.954**
Zn	0.844**	0.819**	0.612**	0.897**	0.694**	0.940**	0.934**
Cu	0.537**	0.616**	0.677**	0.700**	0.767**	0.767**	0.735**
Mn	0.848**	0.859**	0.827**	0.832**	0.901**	0.871**	0.886**
Fe	0.915**	0.789**	0.895**	0.924**	0.926**	0.695**	0.832**

** represents significant at $p\leq 0.01$

CONCLUSIONS

The results of this study indicate anthropogenic inputs of heavy metals in agricultural soils associated with discharge of city wastewater near the area of investigation around Chittagong Municipality. The concentrations of heavy metals in soils in the investigated areas are high; especially Cd is above the worldwide natural background concentration of surface soils. Potential transfer of metals from soil to plants may be an especially important issue in areas where agricultural production has been pushed onto marginal lands. The distribution of heavy metals in various parts of crops implies that it would be a high risk to human health if paddy rice were grown in soils heavily polluted with Cd since a large proportion of this metal accumulated in the edible parts. The results of the present investigation highlight the need for establishing soil quality standards for heavy metals to predict human induced soil pollution. For further information about other areas of the Chittagong Municipality, the investigation should be expanded in the near future to enlarge and improve the basis for proposing agricultural soil quality standards at national levels.

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