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SEASONAL VARIATION OF HEAVY METAL CONCENTRATIONS IN WATER AND PLANT SAMPLES AROUND TEJGAON INDUSTRIAL AREA OF BANGLADESH

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ABSTRACT

The Tejgaon industrial area is located within the Dhaka City Corporation and is about 5 km north of the city centre. Heavy metal concentration at different sampling points varied in different seasons and the maximum amount was observed in the dry season (January). Total Fe, Pb, Cd, Mn, Ni, Zn, Cu and Cr concentrations in water samples during dry season ranged from 0.11 - 2.78, 0.733 - 2.171, 0.05 - 0.1, 0.019 - 0.34, 0.02 - 0.17, 0.01 - 0.348, 0.10 - 0.846, and 0.02 - 0.09 mg/l respectively. The present study revealed that the pollution level was very much alarming and increasing slowly day by day. According to WHO guidelines, during both wet and dry seasons 100% water samples were found in the group of "in excess of tolerable level" for Pb (0.01 mg/l). 63, 42, 79, 58 and 95% water samples were found in the group of ‘in excess of tolerable level’ during dry season for Cu, Ni, Cd, Cr and Mn. Only 26% of the plant samples had Ni (< 20 mg/kg) in the normal range and 74% (≥ 20 - 30 mg/kg) plant samples were found in the group of "in excess of tolerable level" during dry season which was 63% (≥ 20 - 30 mg/kg) during wet season. Cadmium and Pb in plant samples found in the group of "in excess of tolerable level" was 26, 79% (> 10 mg kg), and 33, 59% (> 20 mg/kg) during wet and dry season, respectively. Plant samples accumulated more and tolerated higher amounts of Cr during dry season. Average concentration of Fe, Mn and Zn at different locations and plant species were 220.81, 279.33 and 239.81 mg/kg and 212.0, 313.43 and 159.19 mg/kg during wet and dry seasons, respectively. Kalmi, water hyacinth, grass (in wet season) and Boro rice, Cabbage (in dry season) accumulated the maximum concentration of Fe and Mn. In the rainy season the pollution was lower because of heavy rainfall and flushed out through the canal into the adjoining vast flood zone.

Key words: Tejgaon area, Water, Plant, Seasonal variation, Industrial area, Heavy metals

INTRODUCTION

Heavy metal contamination in water/plant is an increasing world-wide environmental concern (Ahmed *et al.* 2005). Water and plant have been used much as a recipient of toxic and solid waste from domestic, industrial and agricultural run off. Water-borne chemical pollution entering rivers and streams cause tremendous amounts of destruction. Water pollution by heavy metals due to human activities is causing serious ecological problems in many regions of the world. Metals which are discharged into natural waters at increased concentrations in sewage, industrial effluents or from mining operations can have severe toxicological effects on humans and aquatic ecosystems.

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In densely populated and industrialized countries, disposal of waste materials containing heavy metals presents an ever increasing problem. Injudicious applications to soil give rise to accumulation of heavy metals in the top soil, adversely affecting plant and crop quality. One of the major concerns is heavy metal enrichment in edible parts of metal-tolerant crops, creating a hazard to animal and human health.

There are many chemical industries in and around Tejgaon area, namely tannery, paper and pulps, textiles, carbides, pharmaceuticals, pesticides, distilleries etc. which discharge heavy metals like cadmium, lead, chromium, mercury, zinc, arsenic and in a few cases copper and manganese with their effluents and wastes. At present the underground water is not safe for drinking purpose because of heavy metal contamination. The need for the present project emerged from the results of the previous works (Chamon *et al*. 2005, Alam 2006). These investigations showed that industrial effluents and wastes lead to significant pollution of soils, water and plants around Dhaka city. Heavy metals like As, Cr, Cd, Pb, Hg, Cu, Zn, and nickel (Ni) are toxic for plants and humans. These metals, even in trace amounts, interfere with or inactivate enzymes of living cells (Rahman 1992), therefore their discharge into the environment must be minimized and carefully controlled.

Cadmium and Pb, which have no known beneficial effects, may become toxic to plants and animals if their concentrations exceed certain values (Adriano 1996). Nickel, Cu, and Zn are three micronutrients essential for plant nutrition. Nickel is an essential component of the enzyme urease, but when Ni concentrations in vegetative tissues of plants exceed 50 mg/kg dry weight (DW), plants may suffer from excess Ni and exhibit toxicity symptoms (Adriano 1996). Once absorbed, Cu apparently accumulates in roots, even in cases where roots have been damaged by toxicity (Adriano 1996). Zinc phytotoxicity is reported relatively often, especially for acid and heavily sludged soils (Kabata-Pendias *et al.* 1993). The physiology and biochemistry of the toxic effects of Zn in plants are likely to be similar to those reported for other heavy metals; however, Zn is not considered to be highly phytotoxic (Kabata-Pendias *et al*. 1993).

Dicotyledonous crop plants tend to absorb more metals than monocotyledonous crops (Kabata-Pendias *et al*. 1993). Monocots, which include most of the cereal crops, are known excluders of metal cations (Baker 1991). Metals are known to be poorly transported to grain tissues (Baker 1991, Sauerbeck 1982). Thus cereal crops such as wheat, barley, oat, rye and corn may be considered as excluders (Sauerbeck 1982).

The plant uptake of chemical species in soil solution is also dependent on a number of plant factors. The characteristics and behaviour of an individual plant species or variety are important in determining the amounts of heavy metals that are taken up from soils. There are a few reports of differing rates of absorption of Zn^{2+} and Mn^{2+} between species and varieties (Loneragan 1975). The proportions retained vary with the metal and plant species (Chamon *et al.* 2005). The differing responses of species and varieties to environmental changes will also contribute to differences in uptake of heavy metals from soils.

Available data on the impact of industrial pollution in Bangladesh especially on soils and crops and the mobility in the human food chain are quite limited. Therefore, the agrobased Bangladesh needs careful investigations. The aims of this work are: (1) monitoring seasonal variations of trace elements in the plant and water bodies around Tejgaon area following Balu river, (2) finding the environmental impact of industrial effluents on plant and water bodies, (3) providing the base line data on surface water quality to policy makers to manage and protect water bodies from water pollution for maintaining environmental ecological balance.

MATERIAL AND METHODS

The main focus of the study is Tejgaon industrial area which is located within the Dhaka City Corporation and about 5 km north of the city centre. The study area consisted of two distinct areas (Fig. 1). One was the lagoon bordering Tejaon industrial area. This area received the drainage residue of the industrial area, Gulshan model town, Niketan Housing Society, Begunbari and other adjoining residential and slum areas including numerous classified/ unclassified industries. The other consisted of the canal which received the inflow from the lagoon and drained into Balu river.

The effluents from many diverse industries in Tejgaon industrial area flow into a lagoon where the residue settles into a thick muck. It overflows through a sluice gate at Rampura into a channel which flows east for about 10 km to Balu river which in turn flows into Sitalakhya river (Fig. 1). The whole area is really a flood drainage zone. The common agricultural crop is rice with substantial amount of various vegetables like chilli, capsicum, carrot, cauliflower, cabbage, coriander, water gourd, and tomato. There are abundance of water hyacinth and natural grasses inside the embankment, which are used as fodder for domestic animals.

Water and plant samples were collected from the study area at two dates, September, 2006 (wet season) and January, 2007 (dry season). The sampling sites were georeferenced with GPS (Geographical Positioning System) and marked on the map (Fig. 1) and are given in Table 1. During wet season, due to influx of rain and flood water from surrounding areas, water samples were collected from 29 and plant from 27 sampling points but as water receded in the dry season, both (water and plant) samples were collected from19 sampling points.

Water samples (500 ml) were collected from each site in deionized polyethylene bottles fitted with liquid-tight stopper from source water. The water samples were immediately acidified with 4 ml of concentrated hydrochloric acid per liter and analyzed within 7 days of collection.

Plant samples were collected fresh from the field in required amounts, wrapped in polyethylene bags and transported to laboratory and preserved at +4°C for processing on the next day. All plant samples were air dried and placed in oven for drying at 70°C and then ground to powder to pass through a 2 mm sieve for chemical analysis.

One gm of finely ground plant sample was weighed into a 100 ml Kjeldahl flask and digested with 10 ml conc. HNO_3 and 2 ml conc. $HClO_4$.

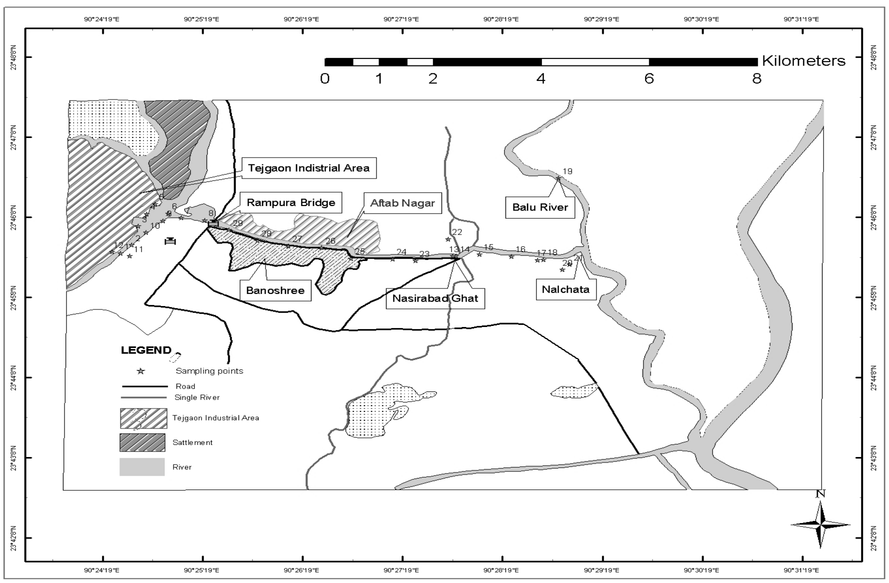

Fig. 1. Location of sampling sites during dry and wet season.

pH: The pH of water was measured using a glass electrode pH meter.

EC.: Electrical conductivity of water was measured using an EC meter.

TDS: Total dissolved solids of water were measured using a portable TDS meter.

TSS: Total soluble salts in water measured gravimetrically by evaporating 20 ml of water sample at 110°C and expressing it in mg/kg.

DO, *BOD_5,* and *COD:* Dissolved oxygen, Biological oxygen demand and Chemical oxygen demand in water was measured by Winkler method (Hach 1997).

Free CO_2: Free carbon dioxide in water was determined by titrimetric method (Hach 1997).

NH_4^+ and NO_3^-N: Ammonium- and nitrate-nitrogen in water was measured by microkjeldahl distillation method (Sparks *et al.* 2001).

The digested water and plant samples were analyzed for heavy metals, e.g., Cd, Cr, Cu, Mn, Ni, Pb, and Zn by atomic absorption spectrophotometer (AAS) at the Centre for Advanced Research in Physical, Chemical, Biological and Pharmaceutical Sciences, Dhaka University.

The results of experiments reported were statistically evaluated by the DMRT. Different letters were used to signify the statistically different results at the 5% level of significance.

RESULTS AND DISCUSSION

Table 2 summarizes the maximum, minimum and arithmetic mean of the 10 measured variables in the water samples around Tejgaon industrial area for wet and dry seasons. The physical water quality parameters like pH, EC, TDS, TSS, DO, BOD, COD, free CO_2 etc. at different locations for wet and dry season from this research work are already reported and comparison of these quality parameters were made with the parametrical DMRT (Sparks *et al.* 2001). From the wet and dry season sampling water data (Table 3) following inferences could be made. TSS and TDS values were much above the maximum standards of water quality (Elahi *et al.* 2008, CPCB 1995). BOD and COD values were much higher and DO values were much lower than the minimum standards of water quality (Elahi *et al.* 2008, CPCB 1995). The general water quality of the whole study area was extremely poor. Foul smell was so intense that some of the workers had to abandon the sampling protocol. Heavy metal (Fe, Cd, Cr, Mn, Cu, Zn, Ni and Pb) concentrations varied in water and plant samples in wet and dry season (Fig. 2 A-H) (Fig. 3 A-E). Here the heavy metal concentrations at different locations around Tejgaon industrial area are presented and discussed.

During wet season Zn concentration in water samples at different locations at Tejgaon area ranged from < 0.02 - 0.08 and 0 - 0.348 mg/l during wet and dry seasons (Fig. 2A). The USPH and WHO standards of Zn for drinking water is 5000 µg/l. Our observed values were within these limits. The toxic concentration level of Zn for general crops is 150 - 200 ppm (Sauerbeck 1982). Except the plant samples collected from the location Nos. 8, 10, 11 and 17, all other plant samples showed Zn concentration at toxic concentration level during wet season. Tomato, cabbage, coriander, carrot and grass samples showed Zn concentration at toxic concentration level during dry season (Fig. 3 A and B).

The concentration of iron in water samples was found remarkably higher in some locations at the study area. The maximum and minimum concentrations of Fe were 2.78 and 0.11 mg/l during dry season and 0.17 and 0.01 mg/l during wet season, respectively (Fig. 2 B). Concentration of Fe in most of the locations exceeded the permissible level of iron in water samples which is set at 0.30 mg/l during dry season (CPCB 1995). Iron concentration in plant samples at different locations during wet and dry season ranged from 40.21 - 431 and 112 - 286 mg/kg, respectively. The sufficiency range of Fe in crops is normally between 50 - 250 ppm (Tisdale and Nelson 1985). Grass, Bean leaf, water hyacinth at different locations showed values higher than the sufficiency levels during wet season. On the other hand kalmi, tomato, boro rice and grass samples showed higher concentration of Fe during dry season (Fig. 3 A and B).

Table 1. Description and location of sample collection during wet season (September, 2006) and dry season (January, 2007).

Wet season (September, 2006)						Dry season (January, 2007)					
Location No.	Location name	Longitude, north	Latitude, east	Sample type		Location No.	Location name	Longitude north	Latitude, east	Samples type	
1	Begun bari. Lal Tanki	23^{0}45.7	90^{0}24.5	Water	Water	1	Rampura bridge	23^{0}46.2	90^{0}25.0	Water	Grass
2	Boubazar	23^{0}45.8	90^{0}24.6	”	Bean leaf 1	2	Ullan	23^{0}46.2	90^{0}24.9	”	Grass
3	G S G	23^{0}46.0	90^{0}24.7	”	Grass 1	3	Niketon R. area	23^{0}46.2	90^{0}24.8	”	Grass
4	Back side of Arong	23^{0}46.2	90^{0}24.8	”	Grass 2	4	Arong	23^{0}46.0	90^{0}24.7	”	Grass
5	Iron bridge	23^{0}46.3	90^{0}24.9	”	Grass 3	5	Boubazar	23^{0}45.8	90^{0}24.6	”	Carrot
6	Flood plain	23^{0}46.2	90^{0}25.0	”	Grass 4	6	Begun Bari	23^{0}45.7	90^{0}24.6	”	Coriander
7	Ullan	23^{0}46.1	90^{0}24.9	”	Bean leaf 2	7	Rampura bridge	23^{0}45.7	90^{0}26.7	”	Cabbage
8	Rampura bridge	23^{0}46.1	90^{0}25.4	”	Water hyacinth 1	8	Banashree ghat	23^{0}45.6	90^{0}27.5	”	Boro rice
9	Mahanagar Project	23^{0}45.9	90^{0}24.8	”	Kalmi 1	9	Meradia	23^{0}45.7	90^{0}28.8	”	Tomato
10	Madhubag	23^{0}45.6	90^{0}24.6	”	Water hyacinth 2	10	Balu river	23^{0}45.8	90^{0}29.0	”	Boro rice
11	Ha-Meem Garments	23^{0}45.7	90^{0}24.4	”	–	11	Nalchata	23^{0}45.6	90^{0}29.0	”	Capsicum
12	Nasirabad 1	23^{0}45.7	90^{0}27.8	”	Water hyacinth 3	12	Nalchata	23^{0}45.5	90^{0}28.8	”	Cauliflower
13.	Nasirabad ghat 2	23^{0}45.7	90^{0}27.8	”	Bean leaf 3	13	Guronagar	23^{0}45.6	90^{0}28.8	”	Tomato
14	Nasirabad 3	23^{0}45.7	90^{0}27.9	”	Kalmi 2	14	Guronagar	23^{0}45.6	90^{0}28.8	”	Kalmi
15	Nasirabad 4	23^{0}45.7	90^{0}28.1	”	–	15	Guronagar	23^{0}45.6	90^{0}28.8	”	Kalmi
16	Guronagar bottala 1	23^{0}45.7	90^{0}28.4	”	Kalmi 3	16	Nasirabad	23^{0}45.7	90^{0}28.5	”	Kalmi
17	Guronagar 2	23^{0}45.6	90^{0}28.7	”	–	17	Nasirabad	23^{0}45.7	90^{0}27.9	”	Tomato
18	Balu river	23^{0}45.6	90^{0}28.7	”	Water hyacinth 4	18	Nasirabad	23^{0}45.6	90^{0}27.9	”	Bean leaf
19	Nalchata ghat 1	23^{0}46.6	90^{0}28.9	”	Kalmi 4	19	Nasirabad ghat	23^{0}45.7	90^{0}27.8	water	Kalmi

(Contd.)

(Contd.)

20	Nalchata 2	$23^0 45.5$	$90^0 28.9$	Water	Kalmi 5
21	Balu river	$23^0 45.55$	$90^0 29.0$	”	Kalmi 6
22	Dasher Kandi	$23^0 45.9$	$90^0 27.8$	”	Water hyacinth 5
23	Trimohini 1	$23^0 45.6$	$90^0 27.5$	”	Water hyacinth 6
24	Trimohini 2	$23^0 45.6$	$90^0 27.2$	”	Water hyacinth 7
25	Aongargora Meradia	$23^0 46.6$	$90^0 26.8$	”	Water hyacinth 8
26	Meradia	$23^0 45.7$	$90^0 26.5$	”	Kalmi 7
27	Aftab nagar	$23^0 45.8$	$90^0 26.2$	”	Water hyacinth 9
28	Banashere	$23^0 45.8$	$90^0 25.9$	”	Water hyacinth 10
29	Rampura bridge	$23^0 46.0$	$90^0 25.6$	”	Water hyacinth 11

It is seen in the Fig. 2 that the higher concentration of Mn in water was found in the dry season at all locations except at location no 6 and the maximum value was 0.328 mg/l at the source point. The minimum level of Mn in water was found during wet season at the locations from 1 to 16 but at all the other locations Mn concentration was found higher which exceeded the maximum permissible USPH/WHO standard of Mn for drinking water purposes (0.05 mg/l, Fig. 2 C). High concentration of Mn in the water samples might be due to discharge from the small electroplating industries in the catchments of the canal.

Table 2. The minimum, maximum and arithmetic mean concentration of water quality parameters for wet and dry season at Tejgaon area.

Parameters	Wet season			Dry season		
	Min.	Max.	Mean	Min.	Max.	Mean
pH	6.0	7.9	7.1	6.8	7.5	7.1
EC µS/cm	463.0	2060.0	852.7	584	1721	835.9
TDS (ppm)	80	980	303.1	360	980	483.3
TSS ”	400	2800	1379	10	250	68.9
DO ”	0.0	0.1	0.1	0.1	0.3	0.2
BOD ”	1	46	17	0.05	0.7	0.5
COD ”	10.8	939.6	130.5	10.6	172.5	104
Free CO_2 ”	8.8	132	40.5	11.4	127.6	60.6
NH_4-N	1.26	11.3	4.3	7.0	50.4	37.8
NO_3-N	0.01	33.4	6.7	19.6	1022	198.3

Normal concentrations of Mn in plants are typically from 20 to 500 ppm (Tisdale and Nelson 1985). Plants are injured by excessive amounts of Mn. The average concentration of Mn during wet and dry season were 279.33 and 313.43 mg/kg which were in the normal range (Fig. 3 A and B). Water hyacinth at location 8 (564 mg/kg) and Kalmi (439.6 mg/kg) showed the highest concentration of Mn during wet and dry season, respectively.

The concentration of Pb in water sample ranges from 0.04 to 1.469 and 0.73 to 2.17 mg/l during wet and dry season, respectively. The lowest concentration was found only at location 20 (end/meeting point of the canal with Balu river which is too far from the source point) (Fig. 1) during wet season but the level of Pb was much higher than the permissible levels of WHO and USPH standard at all other locations during both wet and dry season. The highest concentration was at the source point and decreasing with distance (Figs. 1, 2 D).

Plant samples accumulated more and tolerated higher amounts of heavy metals was reported before (Chamon *et al*. 2005). Average total concentration of Pb in plant samples were 19.65 and 19.83 mg/kg, respectively, during wet and dry season, at Tejgaon industrial area which were in the range of plants general toxic concentration level

(Sauerbeck 1982). During 2nd sampling Pb concentration in plant samples were higher than 1st sampling data (Fig. 3 C). Pb concentration was above the toxic concentration limit in grass and waterhyacinth in some sampling point's e.g. in the point 7, 8, 9, 16, 17, 18, 25, 26 and 27 but low in other plant samples during wet season. During the 2nd sampling Pb concentrations in all plant samples, except a few, were above the toxic concentration limit (Fig. 3 C).

Cadmium concentrations in the dry season water samples were above the DOE (1992)/WHO (2004) drinking water standards (Fig. 2 E). The mean value was 0.068 mg/l with the range from 0.05 to 0.10 mg/l during dry season in water samples.

Average concentrations of Cd in plant samples were 6.18 and 14.91 mg/kg during wet and dry season respectively, at Tejgaon industrial area (Fig. 3 D and E). Cd concentration at many sampling points (e.g. point, 13, 22 - 27, 30 - 42, 45 and 46) were above the plants general toxic concentration level (> 10 mg/kg) (Sauerbeck 1982). During 2nd sampling Cd concentration in plant samples were higher than 1st sampling data (Fig. 3 D and E). Cd content was above the toxic concentration level in waterhyacinth and kalmi during wet season at some locations but other plant samples showed elevated concentration of Cd (Fig. 3 D). During the 2nd sampling Cd concentrations in all plant samples, except a few, were above critical limit (Fig. 3 E).

Cd concentrations in the Gulshan-Baridhara lake water ranged from 0.068 - 0.091 and 0.016 - 0.019 mg/l during summer and monsoon, respectively, as reported by Mohuya *et al.* (2010). Tejgaon industrial area soil also contained elevated level of Cd (2.6 mg/kg) as reported by Chamon *et al.* (2005). In case of water samples, cadmium concentration in the wet season were found in the normal group in all water samples but in the dry season 79% water samples (> 0.05 mg/l) were found in the group of "in excess of tolerable level" (Table 4).

Heavy metal concentration in plant samples was high at the study area. Water hyacinth, kalmi and some grass accumulated significantly higher concentration of Ni at the sampling point from 16 - 27 during wet season (1st sampling). Average concentration of Ni during wet and dry season samples were 21.64 and 26.31 mg/kg, respectively at Tejgaon industrial area which were above the plants general toxic concentration level (Sauerbeck 1982). Metal contaminations of soils, sediments, water bodies and plants have also been reported earlier (Chamon *et al.* 2005). Concentration of of Ni at locations 6 to 10 and 16 to 27 (except 22 No. point) were found to be above the toxic level during wet season plant samples. During dry season samples (2nd sampling) Ni concentration in plant samples were higher than 1st sampling data (Fig. 3 C). Mean concentration of Ni in dry season plant samples was 26.31 mg/kg. The concentration of this metal in rabi plants was above the toxic concentration levels (Sauerbeck 1982).

Concentrations of Ni at different locations of the study area during wet season were below the maximum permissible limit value of water except location no 21 (< 0.1 mg/l). In the dry season at location Nos. 2, 3, 7, 10, 12, 14, and 16 Ni concentrations exceeded the standard values for drinking water (DOE 1992) (> 0.1 mg/l). The highest Ni concentration was observed at location No. 2 (0.17 mg/l) and the lowest at location no 19 (0.02 mg/l) during dry season for water samples.

Ni content was above the critical limit in cabbage, kalmi, boro-rice, tomato but low in bean leaf and some grass samples during dry season (Fig. 3 D). Ni content was low in grass samples but above critical limit in other samples. During dry season (2nd sampling) Ni concentrations in all plant samples, except a few, were above toxic concentration limit (Fig. 3 C and D). Tejgaon area soil contained high Ni concentration i.e. 93.12 and 223.89 mg Ni/kg during wet and dry season, respectively, as reported also by Chamon *et al.* (2005).

Chromium concentrations in the water samples at Tejgaon industrial area varied considerably and ranged from 0.002 - 0.092 and 0.02 - 0.1 mg/l in the wet and dry season, respectively. Concentration of Cr in the river Karnaphuli was 0.060 mg/l and in the river Halda it was 0.01 mg/l as reported by Bashar *et al.* (2007). Mohuya *et al.* (2010) found the concentration of Cr ranged from 0.048 - 0.225 mg/l in the lake of Gulshan-Baridhara during summer and 0.005 - 0.035 mg/l in the monsoon. During wet season, the maximum concentration of Cr in water sample at Tejgaon area was found at location Nos 9 (0.09 mg/l) and the lowest value were at location Nos. 15, 16 and 17 (0.002 mg/l) (Fig. 2 F). In the dry season, at location Nos. 1, 4 and 11-19 Cr concentration exceeded all standards for water (CPCB 1995, DOE 1992, WHO 2004) (Fig. 2 F) at Tejgaon area.

Average concentration of Cr in plant samples were 2.07 and 2.17 mg/kg during wet and dry season, respectively at Tejgaon industrial area which were above the plants general toxic concentration level (Sauerbeck 1982). Kalmi and waterhyacinth accumulated the highest concentration during wet season but rabi crops e.g. bean leaf, tomato, boro rice, cabbage, coriander, carrot and grass samples showed Cr concentration above the plants general toxic concentration level (Sauerbeck 1982) during dry season (Fig. 4 A and B). Only capsicum, tomato and kalmi at some locations showed lower values (Fig. 4 B) during dry season.

In the month of January (dry season) the maximum concentration of copper in water sample was found 0.532 mg/l (mean value) which was 0.349 mg/l during September (wet season) (Fig. 2 G). The maximum permissible concentration of copper for aquatic life and fish is 500 μg/l. The recommended maximum concentration of Cu for drinking water supply with respect to USPH and WHO standard is 1000 and 1500 μg/l, respectively. The observed values were below the permissible level for drinking purposes. In case of water samples, 100% (0 - 1.0 mgCu/l) water samples were found in the group of normal level during both seasons (Fig. 2 G) for drinking water purposes. Chowdhry *et al.* (2007) reported the concentrations of Cu in the three rivers Buriganga, Turag and Shitalakhya and the values ranged from 0.00 - 0.01, 0.03 - 0.07 and 0.00 - 0.05 mg/l, respectively. Compared to these values, Cu concentrations at Tejgaon area showed increasing concentrations. Lethal Cu concentration for fish and aquatic invertebrates ranged from 0.02 - 3.0 mg/l (Lopez and Lee 1977). But for aquatic life and fish, 14 and 63% water samples from this Tejgaon industrial area were above the " in excess of tolerable level" (Group 3, Table 4). In this respect high Cu concentration in the canal is also a threat to its fish community and aquatic invertebrates. Every year lots of dead fishes are found in the canal. Similar results were also reported by Mohuya *et al*. (2010) which were 0.101 - 6.135 and 0.002 - 0.018 mg Cu/l in the Gulshan-Baridhara lake water during dry and wet season, respectively.

Toxic concentration level of Cu in plant is 15 - 20 mg/kg (Sauerbeck 1982). Mean concentration of Cu in plant samples were 23.88 and 33.16 mg/kg during wet and dry season, respectively (Fig. 4 C and D). During 2nd sampling (dry season) Cu concentration in plant samples were higher than 1st sampling data (wet season). Cu concentration was above the toxic concentration limit in grass but low in other plant samples. Cu content was low in rice samples but above critical limit in other samples. During the 2nd sampling Cu concentrations in all plant samples, except a few, were above toxic concentration limit.

Table 3. Trace elements of some drinking water standards (DOE 1992, Zakarul *et al.* 2008).

Parameters	WHO standard	EPA standard	Bangladesh standard	USPHS standard for domestic water supply	WHO Standard	DOE Standard
			(μg/l)		(mg/l)	
Lead	50	15	50	50	0.01	0.05
Cadmium	10	5	5	10	0.003	0.005
Iron (mg/l)	0.3	0.3	0.3	<0.30	0.3	-
Zinc	-	5000	5000	5000	3.0	5.0
Copper	1500	1300	1000	1000	2.0	1.0
Chromium	50	10	50	50	0.05	0.05
Manganese	50	50	100	100	0.05	-
Nickel	-	100	100	100	0.02	0.1

Tejgaon industrial area soil was polluted with Ni, Pb and Cd as reported by Chamon *et al*. (2005) (Ni-40.1, Pb-136 and Cd- 2.6 mg/kg). In Dhanmondi lake, Pb concentrations varied from 0.151 - 0.210 during the dry period and from 0.030 - 0.120 during the wet period as reported by Ali *et al.* (1998). In summer, Pb concentrations in Gulshan-Baridhara lake ranged between 0.023 and 0.067 mg/ and 0.052 - 0.151 mg/l during monsoon as reported by Mohuya *et al.* (2010).

The extent of contamination for water due to heavy metal deposition at Tejgaon industrial sites are presented in Table 4. The total heavy metal content of the water samples showed wide range of values from background to a level considered to reflect severe contamination especially lead. The extent of contamination (in %) was identified by using information of background levels of total trace metal in water (DOE 1992) for Bangladesh.

In case of water samples, 82.76 and 42.11% (0 - <0.05 mg/l) Cr samples were found in the group of normal level, but in the group of in excess of tolerable level was 17.24 and 57.89% (≥ 0.05 mg/l) during wet season and dry season, respectively (WHO 2004) (Table 4).

89.47% Fe (≥ 0.3 mg/l), 94.73% Mn (≥ 0.05 mg/l), 100% Pb (> 0.01 mg/l), 63% Cu (> 0.5 mg/l), 79% Cd (> 0.05 mg/l), 42.11 % Ni (> .01 mg/l) and 57.89% Cr (≥ 0.05 mg/l) samples were found in the group of "in excess of tolerable level" during dry season, respectively (WHO 2004) (Table 4). During wet season the extent of contamination was lower compared to the dry season values for the above metals except Pb. During both wet and dry seasons, 100% Pb (> 0.01 mg/l) samples were found in the "group 3" (Table 4).

The extent of contamination due to heavy metal deposition in Tejgaon industrial sites is presented in Table 5. The total metal concentration of the plant samples showed wide range of values from background to a level considered to reflect severe contamination. The extent of contamination (in %) was identified by using information of background levels (Sauerbeck 1982) of total trace metal concentration in plant samples.

Cadmium in plant samples were found in the group of in excess of tolerable level was 26% (> 10 mg/kg) during rainy season. But in the dry season 79% (> 10 mg/kg Cd) plant samples were found in the group of in excess of tolerable level (Table 5). Plants take up Pb from solution without any hindrance. 33 and 59% (> 20 mg/kg Pb) of plant samples were found in the group of in excess of tolerable level during wet and dry season, respectively (Table 5). Cu concentration in plant samples were found in the group of in excess of tolerable level was 52 and 74% (> 20 mg/kg) respectively, during wet and dry season (Table 5). Concentration of total Ni in plant samples, during 2nd sampling i.e. in dry season were found above the natural background level with few exceptions. Only 26% of Ni (< 20 mg/kg) plant samples were in the normal range and 74% (≥ 20 - 30 mg/kg) samples were found in the group of in excess of tolerable level during wet season.

Chromium concentration in plant samples was found in the group of ‘below toxic level’ (< 1 mg/kg) was 18.52 and 10.53% and in the group of ‘within toxic level concentration’ was 37.03 and 31.58% (1 - 2 mg/kg) during wet season and dry season, respectively. Cr concentrations were found ‘in excess of toxic level concentration’ was 44.44 and 57.89% (> 2 mg/kg) respectively, during wet season and dry season (Table 5).

DISCUSSION

The pH dependence of the solution concentration of the trace element showed that the mobility and availability of the metals were high at strongly to extremely acid soil reaction (Chowdhury *et al*. 2007). The discharge of various types of waste materials from industries into the water bodies raise the concentration of metals. High content of Cd in the water samples might be due to discharge from the electroplating industries in the catchments of the canal and also from the surface drain pipe or septic tank pipe connected to the canal/study area.

High amount of Cr in the water samples might be due to discharge from the adjoining industries like tannery/leather, chemical manufacturing, textile etc. and also due to large amounts of particulate matter in the canal, which retained Cr as adsorbed ion. Acute toxicity of Cr to invertebrates is highly variable upon species (Brummer *et al*. 1983, Moore and Ramamoorthy 1984) and the concentration may create toxic effect on aquatic organisms. Pilling up of various types of garbage, household materials, cans, etc. near the study area increased Cu concentration of the studied samples (Mohuya *et al*. 2010).

During 1st sampling period, wet season had dilution of water due to influx of rain water and flood water from surrounding areas. Fresh water diluted and washed away much of the pollutants. But it was not enough to completely wash pollutants away. As water receded, the pollution load increased in the dry season than that the rainy season.

Expeditions to collect samples were extremely difficult due to the foul smell and unknown nature of gases emitting out of the water body. The soil (Chamon *et al*. 2009), water and air were unfit of any kind of human habitation. But a vast number of populations were living and working in the area disregarding the existing severe health hazards. Results show that the soil (DOE 1992, Ullah *et al.* 1999), water and plant (Alam 2006, Ullah *et al.* 1999) were of extremely low quality in the rainy season. Their quality deteriorated several fold in the dry season. In the rainy season the pollution was lowest because of heavy rainfall; most of the suspended materials, which were not complexed and precipitated with soil, organic matter and other compounds, were flushed out through the canal into the adjoining vast flood zone. As the rainy season receded the soils and water were enriched with the pollution load.

Plants take up heavy metals from solution without any hindrance. During the rainy season most plants were grass and water hyacinth with a few other plants. Most of the grasses and water hyacinth find their way into the food chain in the form of cattle feed. During the dry season rice, grass and many other types of ‘rabi’ crops, e.g., tomato, capsicum, cabbage, cauliflower, etc. were growing in the contaminated soils irrigated with these polluted water. Pb concentrations were very high and above critical level in all crops in both seasons.

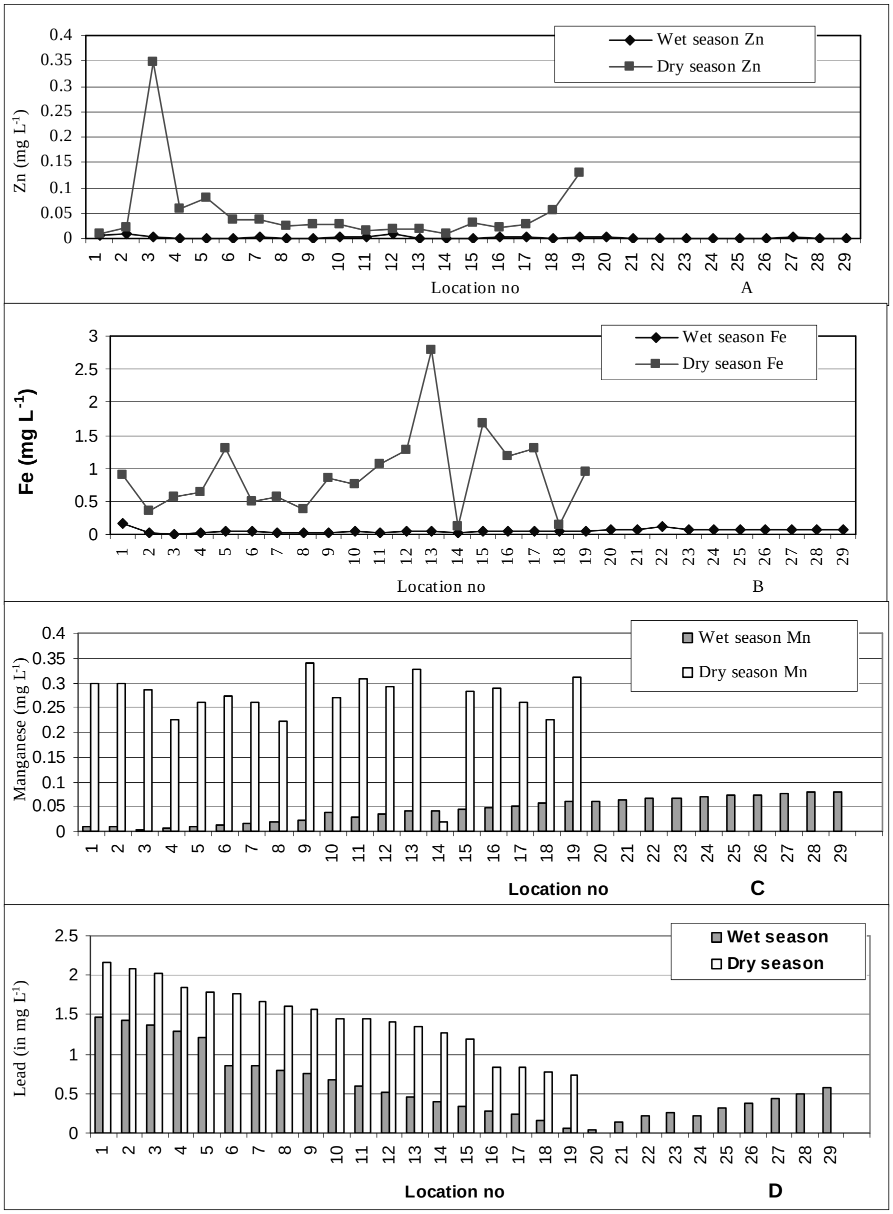

Fig. 2(A-D). Seasonal variation in heavy metal concentration in water samples at different locations around Tejgaon area: Zn (A), Fe (B), Mn (C), Pb (D).

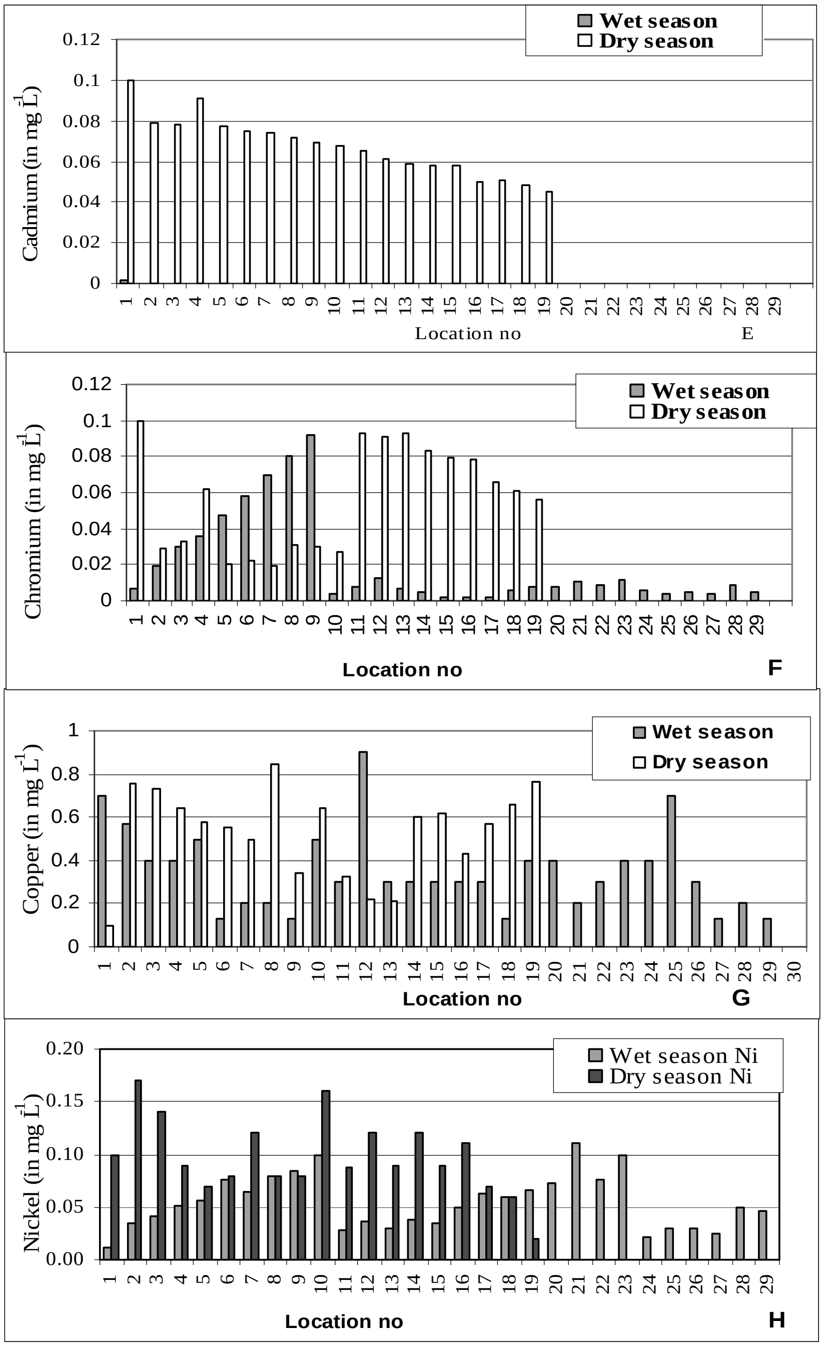

Fig. 2 (E-H). Seasonal variation in heavy metal concentration in water samples at different locations around Tejgaon area: Cd (E), Cr (F), Cu (G), Ni (H).

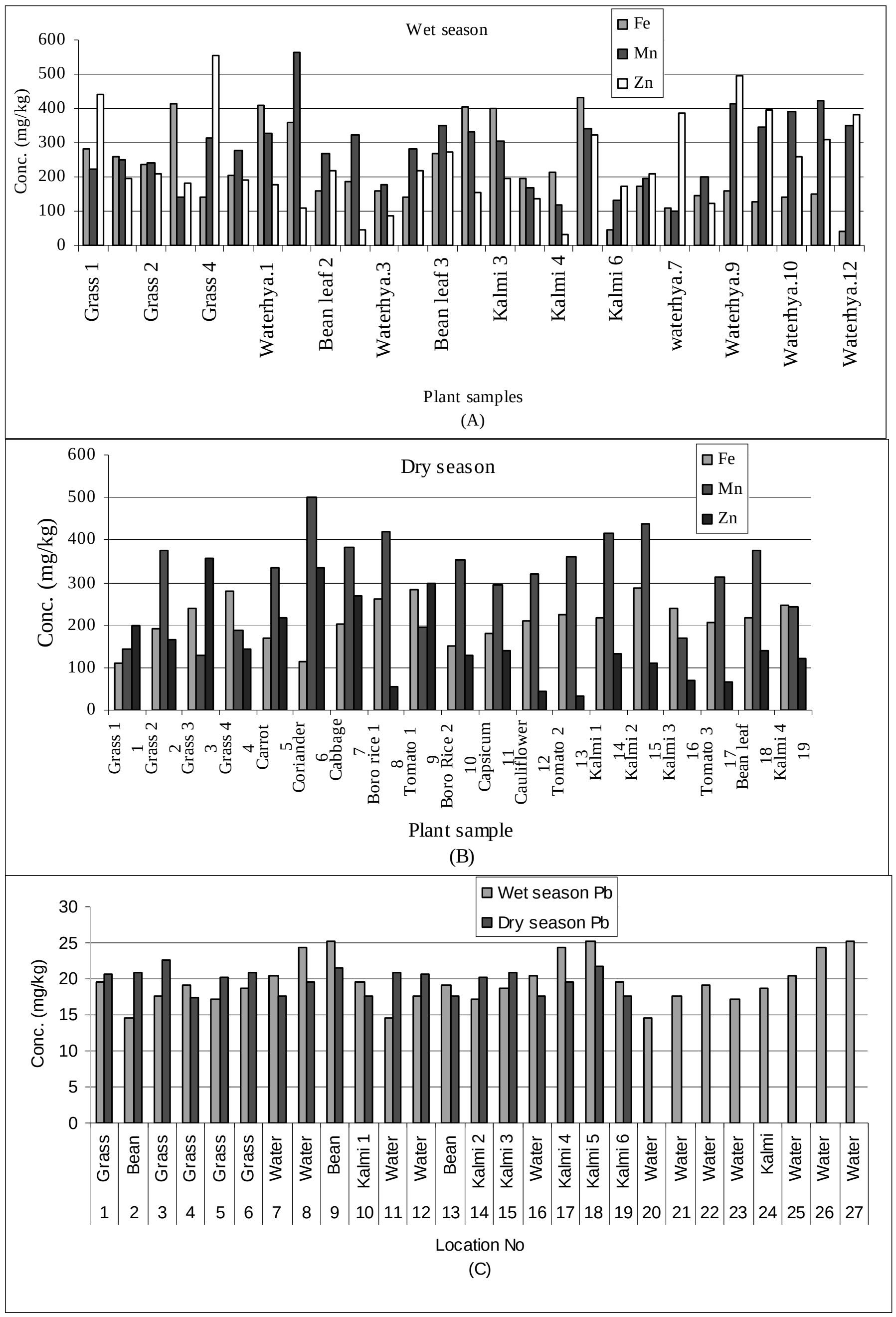

Fig. 3 (A-C). Seasonal variation in heavy metal concentration in plant samples at different locations around Tejgaon area: Fe, Mn & Zn (A) and (B), Pb (C).

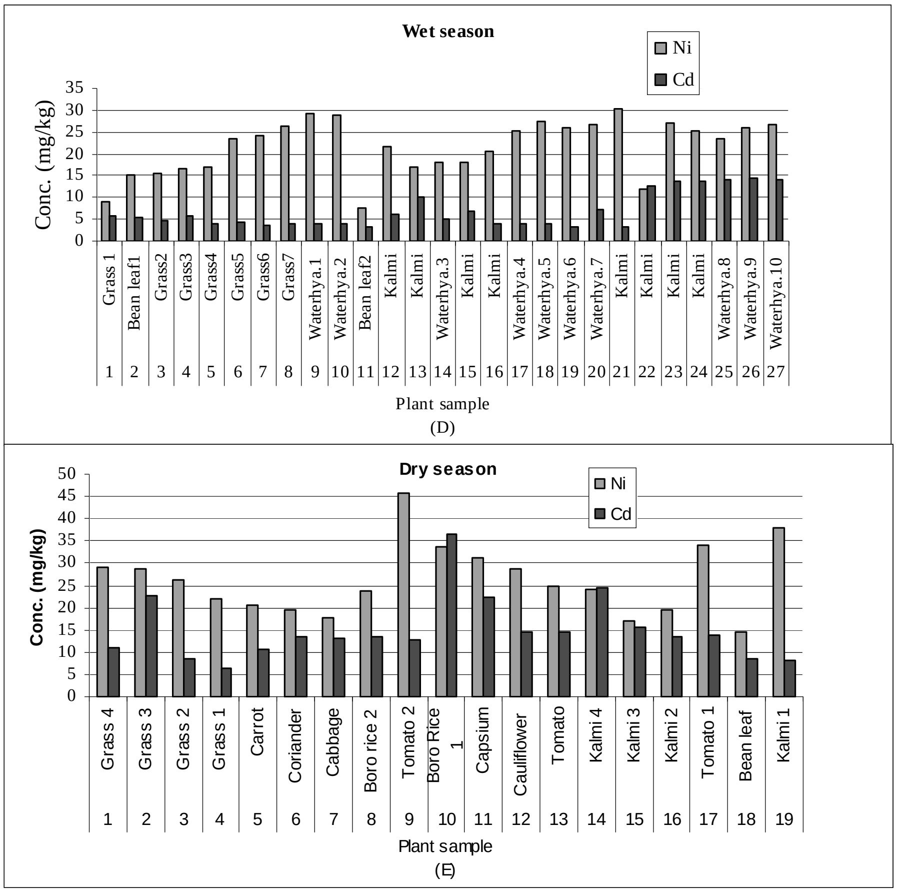

Fig. 3 (D-E). Seasonal variation in heavy metal concentration in plant samples at different locations around Tejgaon area: Ni & Cd (D) and (E).

One of the most alarming facts is that some sampling points under investigation were apparently far from the pollution source. Bumper crops were being produced in the vicinity of Balu river. Consumers have no idea that locally produced crops with attractive appearances have high pollution content of heavy metals like Pb, Cd, Cr and Ni.

From the results of the experiment it can be clearly stated that the concentrations of studied pollutants were higher during the dry season particularly in the month of January, when the rainfall was comparatively low. But during the monsoon the values were in general low and fall within various standard levels. This adjustment might have occurred because of rainfall and dilution. Only in the case of lead, concentration level was high during the wet season. It might be due to the high percentage of lead in Dhaka's air in recent time which mixed up with rain water during monsoon and finally reached to the water bodies through precipitation.

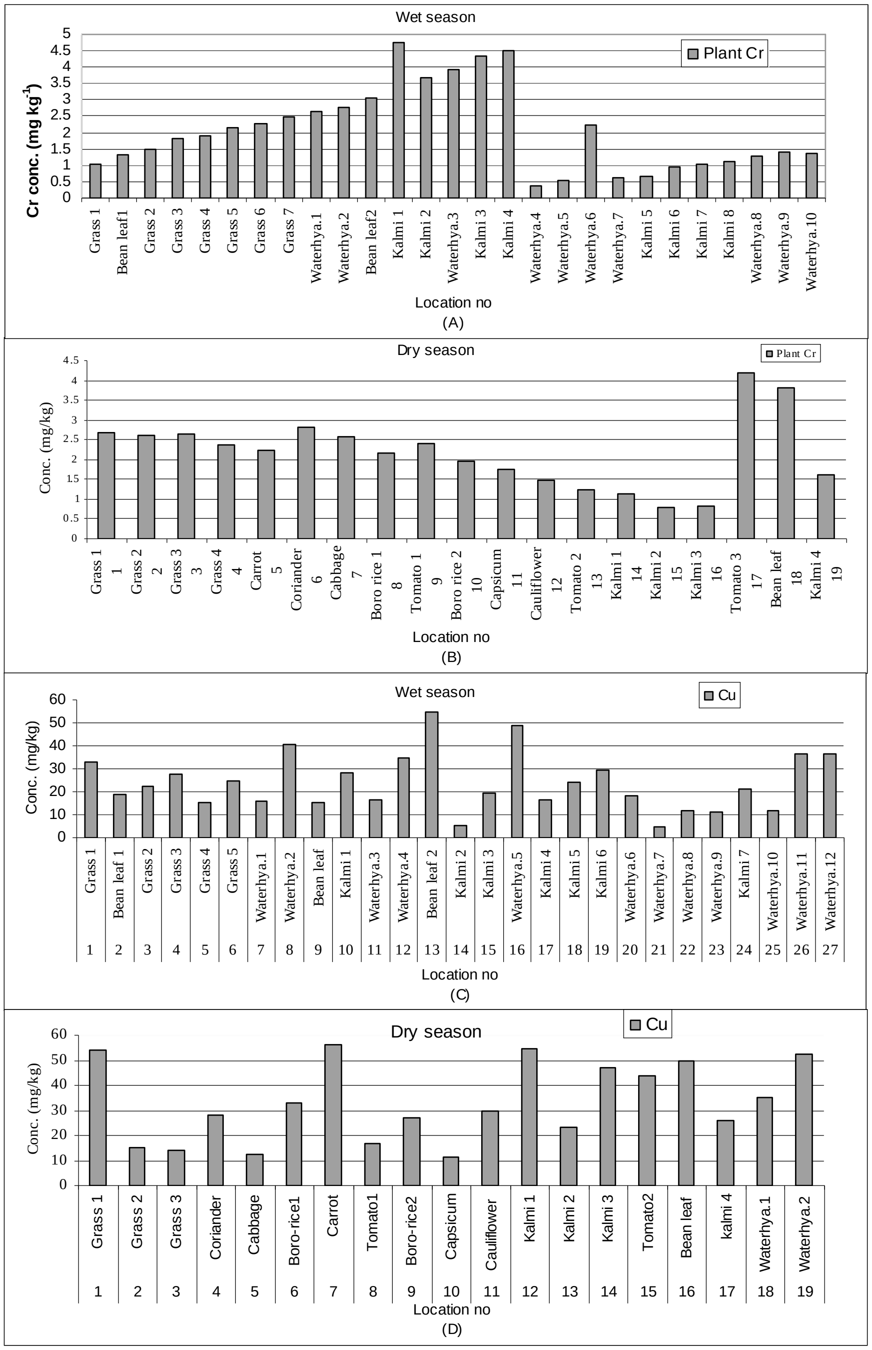

Fig. 4. Seasonal variation in heavy metal concentration in plant samples at different locations around Tejgaon area: Cr(A), (B) and Cu (C) and (D).

Discharge of Pb from the adjoining battery industries, and pesticides application to the farmer's field might be another reason. Lead concentrations exceeded the standards of drinking water at all locations. When the fishing-, industrial- and irrigation water standards were taken into concentration, Pb concentration exceeded the standard level (0.01 mg/).

The addition of pollutants leads to the shift in flora and fauna due to homeostatic factors operating in the aquatic systems. The diversity of organisms decreases due to presence of only a few tolerant forms in the polluted conditions.

Table 4. Extent of contamination according to total trace metal concentration in water (mg/l) during wet and dry seasons' sampling. Percentage of sampling locations in parentheses.

Metals	Group 1	Group 2	Group 3
Pb (wet season) (n = 29)	0.00 - < 0.01 (0)	0.01 - ≤ 0.01(0)	> 0.01 (100)
Pb (dry ”) (n = 19)	0.00 - < 0.01 (0)	0.01 - ≤ 0.01(0)	> 0.01 (100)
Cu (wet ”) (n = 29)	0.00 - < 0.5 (79)	0.5 (7)	> 0.5 (14)
Cu (dry ”) (n = 19)	0.00 - < 0.5 (32)	0.5 (5)	> 0.5 (63)
Ni (wet ”) (n = 29)	0.00 - < 0.01 (0)	> 0.01 ≤ 0.1 (100)	> 0.1 (0)
Ni (Dry ”) (n = 19)	0.00 - < 0.01 (0)	> 0.01 ≤ 0.1 (58)	> 0.1 (42.11)
Cd (wet ”) (n = 29)	0.00 - < 0.05 (100)	0.05 (0)	> 0.05 (0)
Cd (dry ”) (n = 19)	0.00 - < 0.05 (0)	0.05 (21)	> 0.05 (79)
	Below tolerable level	In excess of tolerable level	
Cr (wet season) (n = 29)	0.00 - < 0.05 (82.76)	≥ 0.05 (17.24)	
Cr (dry ”) (n = 19)	0.00 - < 0.05 (42.11)	≥ 0.05 (57.89)	
Fe (wet ”) (n = 29)	0.00 - < 0.3 (100)	≥ 0.3(0)	
Fe (dry ”) (n = 19)	0.00 - < 0.3 (10.5)	≥ 0.3 (89.47)	
Mn (wet ”) (n = 29)	0.00 - < 0.05 (48.28)	≥ 0.05 (51.72)	
Mn (dry ”) (n = 19)	0.00 - < 0.05 (5.26)	≥ 0.05 (94.73)	
Zn (wet ”) (n = 29)	0 - 5.0 (100)	≥ 5.0 (0)	
Zn (dry ”) (n = 19)	0.00 - 5 (100)	≥ 5.0 (0)	

Group 1 = Background level, group 2 = Maximum tolerable level and group 3 = In excess of tolerable level. Background concentration for Pb = 0.00 - < 0.01 mg/l ppm of drinking water of Bangladesh (WHO 2004). Tolerable total concentrations is ≤ 0.01 ppm for Pb (WHO 2004).

Background concentration for Cu = 0.00 - < 0.5 mg L^{-1}ppm of inland surface water of Bangladesh (for fish and aquatic life) (DOE 1992). Tolerable total concentrations is ≤ 0.5 ppm for Cu for fish and aquatic life.

Background concentration for Ni = 0.00 - < 0.1 mg/l ppm of drinking water of Bangladesh (DOE 1992).

Background concentration for Cd = 0.00 - < 0.05 mg/l of inland surface water of Bangladesh (DOE 1992). Tolerable total concentration upto 0.05 mg/l for Cd (DOE 1992).

Tolerable total concentrations is 0.05, 0.3, 0.05 and 5.0 mg/l for Cr, Fe, Mn and Zn. respectively (WHO 2004).

Table 5. Extent of contamination in plants (mg/kg) during wet and dry seasons (Percentage of sampling locations in parentheses).

Trace elements	Group 1	Group 2	Group 3
Cd (wet season) (n = 27)	3 - < 5.0 (48)	5 - 10 (26)	> 10 (26)
Cd(dry ”) (n = 19)	3 - < 5.0 (0)	5 - 10 (21)	> 10 (79)
Pb (wet ”) (n = 27)	0 - < 10 (0)	> 10 - ≤ 20(67)	> 20 (33)
Pb (dry ”) (n = 19)	0 - < 10 (0)	> 10 - ≤ 20(41)	> 20 (59)
Cu (wet ”) (n = 27)	5 - < 15 (18.5)	15 - 20 (26)	> 20 (52)
Cu (dry ”) (n = 19)	5 - < 15 (16)	15 - 20 (11)	> 20 (74)
Ni (wet ”) (n = 27)	< 20 (37)	≤ 20 (0)	> 20 - 30(63)
Ni (Dry ”) (n = 19)	< 20 (26)	≤ 20 (0)	> 20 - 30(74)
	Below tolerable level		In excess of tolerable level
	Below toxic level	Within toxic conc. level	In excess of toxic conc. level
Cr (wet season) (n = 27)	< 1 (18.52)	1 - 2 (37.03)	> 2 (44.44)
Cr (dry ”) (n = 19)	< 1 (10.53)	1 - 2 (31.58)	> 2 (57.89)
Fe(wet ”) (n = 27)	0 - < 50 (7.41)	50 - 250 (59.26)	> 250 (33.33)
Fe (dry ”) (n = 19)	0 - < 50 (0)	50 - 250 (78.95)	> 250 (21.05)
Zn (wet ”) (n = 27)	0 - < 150 (22.22)	150 - 200(25.93)	> 200 (51.85)
Zn (dry ”) (n = 19)	0 - < 150 (63.16)	150 - 200(10.53)	> 200 (26.32)
	Below normal range	Within normal range	Above normal range
Mn (wet season) (n = 27)	-	20 - 500 (100)	-
Mn (dry ”) (n = 19)	-	20 - 500 (100)	-

Group 1 = Background level, group 2 = Maximum tolerable level and group 3 = In excess of tolerable level. Background concentration for Cd = 3 - < 5.0 (Sauerbeck 1982, Melsted 1973) mg/kg. Tolerable total concentrations are 5 - 10 mg/kg for Cd (Sauerbeck 1982). Background concentration for Pb = 0 - < 10 mg/kg (Sauerbeck 1982). Toxic concentrations is 10 - 20 mg/kg for Pb (Sauerbeck 1982). Background concentration for Cu = 5 - <15 mg/kg (Tisdale and Nelson 1985). Tolerable total concentrations is 15 - 20 ppm for Cu (Sauerbeck 1982). Background concentration for Ni = < 20 mg/kg (Sauerbeck 1982). Tolerable total concentrations are ≤ 20 ppm Ni and in excess of tolerable total concentrations is 20 - 30 ppm for Ni (Sauerbeck 1982). Toxic level concentrations is 1 - 2 mg/kg for Cr (Sauerbeck 1982). Sufficiency range for Fe is 50 - 250 mg/kg (Tisdale and Nelson 1985). Normal range for Mn is 20 - 500 and for Zn is 25 - 150 mg/kg (Tisdale and Nelson 1985). Toxic conc. level for Zn is 150 - 200 mg/kg (Sauerbeck 1982).

Table 6. Normal, sufficiency and toxic conc. level for heavy metals in plants and soil.

Plant (in general) (Tisdale and Nelson 1985)	Fe		Mn		Zn	
	mg/kg					
Sufficiency range	50 - 250		–		–	
Normal range	–		20 - 500		25 - 150	
Toxicity	–		–		> 400	
Plant (in general) (Sauerbeck 1982)	Cd	Cr	Cu	Ni	Pb	Co
Toxic conc. level (mg/kg)	5 - 10	1 - 2	15 - 20	20 - 30	10 - 20	10 - 20
Tolerable total conc. in soil (Kloke 1980) (mg/kg)	3.0	100	100	50	100	Zn 300 / Mn 1000

CONCLUSION

Within this research program, the study was carried out to evaluate the contamination and seasonal variation of toxic metals in the water and plant samples at different locations of Tejgaon industrial area. The specific aims of the research are to the determination of heavy metal toxicity indicators in different kinds of plants in different locations.

The study area consisted of two distinct areas. The industries at Tejgaon are discharging their wastes and effluents in the natural systems in most cases without any treatment and thereby cause environmental pollution especially due to heavy metals and organic toxins. The hazardous wastes and effluents are generally discharged in low-lying areas, along the road sides or in the vicinity of the industrial installations. Besides, fertilizers, pesticides and the contaminated water (for irrigation purposes) are being randomly used in agricultural lands by the farmers.

The investigations under this project showed that industrial effluents and wastes lead to significant pollution of water around Dhaka city. The important heavy metals discharged from industries in the study area are cadmium, lead, chromium, and in few cases iron and manganese. Trace metals as shown in the wet and dry season sampling considered above the maximum tolerable limit value (CPCB 1995). 100, 63, 42, 79, 58 and 95% water samples were in the group of in excess of tolerable level during dry season for Pb, Cu, Ni, Cd, Cr and Mn. Kalmi, water hyacinth, grass (in wet season) and Boro rice, cabbage (in dry season) accumulated the maximum concentration of Fe and Mn.

In the rainy season the pollution was lower because of heavy rainfall, were flushed out through the canal into the adjoining vast flood zone. As the rainy season receded the soils (Chamon *et al.* 2009, Ullah *et al*. 1999) and water were enriched with the pollution load.

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