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ASSESSING HEAVY METAL ACCUMULATION IN SOILS OF TEA GROWING AREAS AND THEIR TRANSFER TO TEA LEAVES IN BANGLADESH

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ABSTRACT

An investigation was conducted at Bilashchhara and Shatgaon Tea Estates of Sreemangal under Moulvibazar district in Bangladesh to assessing the heavy metal accumulation in soils and their transfer to tea leaves. Thirteen composite soil and leaf samples were gathered from different elevations of the gardens where soil samples were from 0 to 25 cm depth and leaf samples were from three levels (upper, middle and lower leaves). Tea leaves were collected from the corresponding sites of the soils. The study showed that the heavy metal contents in soils of both the gardens were almost similar. Fertilized soils contained more heavy metals than the control soils. Chromium (Cr) and Cadmium (Cd) were not detectable in soils. The concentrations of Cu, Zn, Fe, Cr, and Ni in tea leaves were below the phytotoxic levels. Lead (Pb) and Cd were not found in leaves irrespective of the gardens.

Keywords: Assessment, heavy metals, tea plants, tea growing soils, phyto-toxic levels.

INTRODUCTION

Tea is regarded as the most popular temperate drink for nearly two-third of the world population daily (Nasir and Shamsuddoha, 2011). Tea has a great nutritional value. It contains antioxidants, flavonoids, amino acids, caffeine, polysaccharides, vitamins C, E and K (Eden, 1965; Yang *et al.*, 2004). Tea plant is grown in more than 45 countries spread over all the continents within the latitudinal range of 45°N to 34°S except North America. It grows best in tropical and subtropical areas having adequate rainfall, good drainage and acid soils (Barua, 2008). Tea is prepared from the dried leaves of *Camellia sinensis*. The first commercial tea plantation was introduced in the eastern part of Bengal in 1857 at Malnicherra in Sylhet (Eden, 1965; Nasir and Shamsuddoha, 2011). Currently, the country has 163 tea estates and 116 tea factories with a total grand area of 11, 3890.8 ha. Total production of tea is 57.62 m kg (BTRI, 2012).

Tea has become an integral part of our life. Recently, heavy metals such as Cu, Fe, Zn, Cd, Cr, Pd and Ni have been found in tea samples in Iran, India, Pakistan, China, Kenya, Saudi Arabia and Nigeria (Ebadi *et al.*, 2005; Chen *et al.*, 2009; Chen *et al*., 2010). Excessive levels of these metals can damage the organisms. Cadmium (Cd) and Chromium (Cr) are dangerous to health and environment while Zinc (Zn) and Lead (Pb) may cause corrosion (Ahmed *et al.*, 2012). Copper (Cu) and Nickel (Ni) have potential toxicity to plants and animals (Kabata-Pendias and Pendias, 2001; Barua, 2008). Over consumption of Cu from food and beverages can cause diseases, such as non-Indian childhood cirrhosis (Zietz *et al.*, 2003) and Wilson's disease (Verissimo *et al.*, 2005). Iron (Fe) may induce toxicity in plants although it is an essential micronutrient for them (Pais and Jones, 1997). Heavy metals have great significance due to their tendency to accumulate in the vital human organs over a prolonged period of time (Yousufzai *et al.*, 2001). So their presence in tea has become a worldwide concern. The factors affecting the metal contents in tea leaves subsequently influence the metal concentrations in the infusion.

As tea soils are aged, heavy metals may release from soil minerals. Continuous application of fertilizers and other agrochemicals may also cause heavy metal accumulation (Lal and Mathur, 1988; Ebadi *et al.*, 2005). Besides, as tea grows in acid soils, there is a possibility of their increased availability (Black, 1968; Adriano, 1986). Research information regarding heavy metals in tea growing areas of Bangladesh is not available. The present investigation was, thus undertaken to assess the presence of heavy metals, Cu, Zn, Pb, Cd, Cr, Ni and Fe in some tea growing soils and tea plants in Bangladesh. These heavy metals were selected because they are well-established as being toxic for living systems and their effects in humans have been widely documented. It is expected that these research findings will give an idea about the levels of heavy metal contents in tea leaves

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Table 1. Sampling area with elevations (BTRI, 2012).

Sample number	Sampling area	Elevation (m)
	Bilashchhara Tea State	
1	Control High Flat (CHF)	38
2	Fertilized High Flat (FHF)	38
3	Control Tillah Top (CTT)	36
4	Fertilized Tillah Top (FTT)	36
5	Control Tillah Slope (CTS)	34
6	Fertilized Tillah Slope (FTS)	33
7	Control Tillah Base (CTB)	32
8	Fertilized Tillah Base (FTB)	32
	Shatgaon Tea State	
9	Control High Flat (CHF)	16
10	Fertilized High Flat (FHF)	18
11	Fertilized Tillah Top (FTT)	35
12	Fertilized Tillah Slope (FTS)	32
13	Fertilized Tillah Base (FTB)	29

and soils of Bangladesh.

MATERIALS AND METHODS

The study areas were located at Bilashchhara and Shatgaon Tea Estates of Srimangal under Moulvibazar district and were selected on the consideration that they are the highest tea growing areas of Bangladesh (BTRI, 2012). Belashcharra Tea Estate (BTE) is about 5 kilometers and Shatgaon Tea Estate (STE) is about 11.27 kilometers from Bangladesh Tea Research Institute (BTRI, 2012). The samples of soil and leaf were collected from high flat and tillah areas of BTE and STE at different elevations (Table 1). These include fertilized and non-fertilized (control group) areas maintained by garden management for monitoring soil fertility. The Soil samples were gathered from 0 to 25 cm depth. The leaves were Upper leaves, Middle leaves, and lower leaves.

The prepared soil and leaf samples were digested with nitric-perchloric acid as described by Piper (1966) for determination of total Cu, Zn, Cd, Cr, Pb, and Ni. The elements were determined by Atomic Absorption Spectrophotometer. Total iron of soil and leaf samples in the nitric- perchloric acid digest was measured colorimetrically using Spectrophotometer as described by Olsen and Ellis (1982).

RESULTS AND DISCUSSION

The concentrations of total heavy metals (Cu, Fe, Zn, Cd, Cr, Pb, Ni) in soil (0-25 cm) and leaf samples from Bilashchhara and Shatgaon Tea Estates are presented in Table 2 and Table 3, respectively.

The analytical results presented in Table 2 shows that the Cu, Fe, Pb and Ni contents of the soils of both gardens were almost in the similar range. Only Zn concentrations were considerably higher in Bilashchhara Tea Estate. Copper (Cu) contents ranged from 6.00 to 16.50 mg/kg. These values are lower than the values (17.3-34.8 mg/kg) obtained for soil Cu in the tea garden of Bay mine wasteland in China (Hua *et al.*, 2012). Values obtained for Zn concentrations in the present study ranged from 2.92 to 41.00 mg/kg. These findings are supported by the findings of Nath (2013) who found Zn in the range of 21.43 to 45.38 mg/kg in some tea soils of Assam. The findings are also corroborated with Hua *et al.* (2012). Lead (Pb) contents varied from 2.00 to 10.00 mg/kg. The findings disagree with Hua *et al.* (2012) who noted higher Pb than these values of the present study. In BTE and STE, Nickel (Ni) contents ranged from 3.80 to 15.87 mg/kg and total Fe contents varied from 0.54 to 2.67%. The analytical results of Fe are several times higher than the values obtained by Nath (2013) who found Fe ranged from 0.01 to 0.03% in some tea growing soils of Assam. Chromium (Cr) and Cd were not found in soils of the present study areas. These results disagree with the findings of Hua *et al.* (2012) who detected Cd in some tea growing soils of Guilin (Iran) and China.

The present study showed that in most cases heavy metals

Table 2. Total heavy metal concentrations of the soil samples from the study areas.

Sample number and sampling area (*)	Belashchhara Tea Estate (BTE)								Shatgaon Tea Estate (STE)				
	1 CHF	2 FHF	3 CTT	4 FTT	5 CTS	6 FTS	7 CTB	8 FTB	9 CHF	10 FHF	11 FTT	12 FTS	13 FTB
Copper (Cu) (mg/kg)	9.45	6.00	13.89	13.96	10.46	13.50	9.75	13.42	9.00	10.55	16.50	9.05	8.45
Zinc (Zn) (mg/kg)	29.06	25.31	35.56	41.00	22.74	39.78	12.00	22.45	3.82	3.22	14.35	6.38	2.92
Iron (Fe) (%)	1.34	1.32	2.46	2.67	1.86	2.37	1.20	1.96	0.54	0.75	2.03	1.48	0.96
Lead (Pb) (mg/kg)	10.00	9.50	4.69	5.12	4.31	5.33	3.98	4.62	2.00	3.00	4.00	3.75	2.50
Nickel (Ni) (mg/kg)	10.35	8.25	6.52	13.24	11.70	15.87	9.23	10.56	4.05	3.80	ND	11.20	6.65

*Table1. Notes: Chromium (Cr) and Cadmium (Cd) were not detectable in any soil sample

Table 3. Total heavy metal contents of the leaf samples from the study areas.

Sample number and sampling area	Leaf	Belashsara Tea Estate								Shatgaon Tea Estate				
		1 CHF	2 FHF	3 CTT	4 FTT	5 CTS	6 FTS	7 CTB	8 FTB	9 CHF	10 FHF	11 FTT	12 FTS	13 FTB
Copper (Cu) (mg/kg)	Up	8.85	9.20	7.74	12.50	7.27	11.19	6.73	11.19	8.85	10.85	11.50	11.25	11.25
	Mid	9.50	3.75	6.66	13.00	5.23	7.15	5.29	8.46	13.30	17.40	16.35	6.23	7.65
	Low	6.85	8.10	6.21	7.45	5.22	10.75	5.87	10.42	5.70	6.50	7.60	5.03	5.25
Zinc (Zn) (mg/kg)	Up	16.50	17.00	11.78	19.52	19.12	23.50	23.34	22.15	10.50	19.00	19.50	26.75	23.00
	Mid	8.50	5.00	9.90	10.23	15.72	8.75	12.69	15.32	19.50	10.00	9.00	6.50	9.50
	Low	8.00	10.50	9.10	8.54	11.33	9.25	10.00	17.54	6.00	8.50	7.50	5.75	6.00
Iron (Fe) (%)	Up	1.34	1.32	2.46	2.67	1.86	2.37	1.20	1.96	0.10	0.05	0.03	0.04	0.01
	Mid	1.25	1.17	2.10	2.23	1.71	1.25	1.11	1.23	0.09	0.03	0.02	0.01	0.02
	Low	1.23	1.17	2.05	1.10	1.62	1.00	0.94	1.10	0.09	0.08	0.01	0.02	0.02
Chromium(Cr) (mg/kg)	Up	ND	ND	1.26	ND	1.03	ND	ND	ND	ND	2.52	11.87	ND	ND
	Mid	3.40	ND	ND	1.11	ND	ND	ND	ND	0.65	5.60	5.15	2.10	0.45
	Low	1.47	14.55	3.10	2.42	12.50	11.21	5.26	12.24	ND	0.20	1.23	ND	1.25
Nickel (Ni) (mg/kg)	Up	2.95	ND	2.12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mid	ND	ND	ND	2.02	ND	ND	2.10	ND	10.95	ND	2.55	ND	ND
	Low	ND	ND	1.02	2.25	ND	ND	ND	2.00	ND	ND	ND	ND	ND

Notes: Up-Upper leaf, Mid- Middle leaf and low- lower leaf.
Lead (Pb) and Cadmium (Cd) were not detectable in any leaf sample.

were more in the soils of fertilized sections than in the control areas (Table 2). So fertilizer may be a potential source of heavy metals in tea growing soils of BTE and STE. In some cases, opposite trend was found where control soils contained more heavy metals. This might be due to inherent characteristics of the soils. The metal concentrations were relatively higher in tillah areas than flat areas. Except Ni, the concentrations of four other metals decreased gradually from tillah top to tillah base.

It has been noticed from Table 3 that the concentrations of Cu, Zn, Fe, Cr and Ni in tea leaf samples of both gardens were almost similar. Copper (Cu) varied from 3.75 to 17.40 mg/kg. The findings validate the findings of Jin *et al.* (2008). They found an average Cu concentration of 13.26 mg/kg in some tea leaves in China. The concentrations of Zn in the present study areas varied from 5.00 to 26.75 mg/kg. These results confer the results of Nath (2013). He found that Zn concentrations ranged from 24.82 to 58.26 mg/kg in some tea leaves of Assam. Total Fe contents varied from 0.01 to 2.67%. These findings are related to the findings of Nath (2013) who found Fe ranged from 0.02 to 0.05% in some tea leaves from Assam. Nickel (Ni) was detected in few leaf samples of both Bilahsara and Shatgaon Tea Estates and it ranged from 1.02 to 10.95 mg/kg. Chromium (Cr) was not detectable in soil samples but found in leaf samples in the range of 0.20 to 14.55 mg/kg. It may be a result of airborne deposition, sprinkler irrigation and foliar application of pesticides (Pais and Jones, 1997; BTRI, 2012). These estimated values of Cr are much higher than the values found by Chen *et al.* (2009). Lead and Cd were not detectable in leaf samples of the present study areas. Chen *et al.* (2009) and Chen *et al.* (2010) however found Pb and Cd in different tea leaf samples in different ranges. Lead can be readily absorbed by plant roots but little is translocated to the tops (Pais and Jones, 1997).

In most cases fertilized upper leaf samples contained more heavy metals than control samples (Table 3). In the case of Cr and Ni, concentrations were higher in middle and lower leaves which indicate their non-mobility inside the plants. The heavy metal contents did not vary considerably between flat and tillah areas. From tillah top to tillah base, most of the leaf samples showed slight decreases in Cu and Fe concentrations, whereas Zn concentrations increased. Lower leaf samples of BTE tillah slope and tillah base contained more Cr than tillah top samples. In STE, the concentrations of Cr in tillah top leaf samples were higher than tillah slope and tillah base samples. Nickel contents were higher in tillah top leaf samples of both BTE and STE. The calculated values (data not shown) indicated that the soil Cu, Zn and Fe did not correlate with leaf Cu, Zn and Fe of the study areas. Experimental data for Pb, Cd, Cr and Ni concentrations were not available for statistical analysis (correlation).

The phytotoxic levels of Cu, Zn, Fe, Cr and Ni in plant foliage start from 20 mg/kg, 500 mg/kg, 300 mg/kg, 20 mg/kg and 50 mg/kg, respectively (Chaney, 1983; Pais and Jones, 1997). The presence of Zn, Fe, Cr and Ni in the two study areas was well below the phytotoxic levels. Copper concentrations were close to the phytotoxic level. Liming, the addition of phosphate fertilizers and the addition of organic matter may help to reduce the plant availability of Cu (Pais and Jones, 1997).

CONCLUSION

The concentrations of most heavy metals are not a threat to the quality of tea in BTE and STE. However, a comprehensive research covering a large number of tea estates in Bangladesh is required to generalize our findings and to understand the science of heavy metal accumulation in soils and their bioaccumulation in tea plants. The present research findings may be a useful tool for the future research and planning for tea in Bangladesh.

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