Heavy Metal Accumulation in Selected Plants Irrigated with Sittaung River Water in Taungoo Area

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Abstract

Taungoo is located at the west bank of Sittaung River, Bago Region. It is situated on northern part of central alluvial plane of Sittaung River basins. There are small scale farmlands along the Sittaung River bank in Taungoo area. In this study, six soil samples from farmlands along the Sittaung River bank in Taungoo area were collected together with four selected plants *viz.*, bean (*Phaseolus vulgaris*), brinjal (*Solanummelongena*), spinach (*Spinaciaoleracea*) and asparagus (*Asparagus officinalis*) for some heavy metals (Zinc, Copper, Manganese, Cadmium, Chromium and Lead) investigation by using atomic absorption spectrophotometer. Some heavy metals (cadmium, chromium, lead, copper, manganese and zinc) concentrations in soils from irrigated farmlands were determined and it was found that chromium was not detected in soil samples. The concentrations of heavy metals were below the respective maximum recommended limits. Among heavy metals determined, manganese content was the highest (158.15 ppm) followed by zinc (35.42 ppm), copper (21.30 ppm), cadmium (0.054 ppm) and lead (0.005ppm). Among the plants, manganese uptake was highest in asparagus (57.27 ppm) followed by spinach (44.43 ppm), bean (42.05 ppm) and brinjal (28.40 ppm). High zinc contents in plants inhibit the cadmium uptake. Lead mobility from soil to plants was low in this study. Though heavy metals were absorbed, their concentration were below WHO/FAO recommended limits. Vegetables cultivated with irrigated Sittaung River water may be considered safe for consumption.

Keywords: Sittaung River, irrigated farmlands, heavy metals, asparagus, manganese

Introduction

Heavy metals are ubiquitous either naturally or anthropogenically. These are present in soils as natural component or as a result of human activities. Metal – rich mine tailing , metal smelting electroplating, gas exhaust, energy and fuel production, intensive agriculture and sludge damping are widespread human activities which contaminate soils and aqueous stream with large quantities of toxic metals. Heavy metal pollution of aqueous stream, soil and sediments is a major environmental problem globally. Metal accumulating plants are directly or indirectly responsible for much of the dietary uptake of toxic heavy metals by humans and other animals (Kabata- Pendias and Pendias, 1989). While some heavy metals are essential, excessive accumulation in living organisms is toxic. All heavy metals have high concentration have strong toxic effects and regarded as environmental pollutants (Chehregani *et al.*, 2005). The aim of this work was to measure the concentration of some heavy metals in soil and the trans-location in bean, brinjal, spinach and asparagus.

Materials and Methods

Sample Collection

Collection of Soil Samples from Some Selected Farmlands and Some Plants Grown on Farmlands

Locations of soil samples from six selected irrigated farmlands along the Sittaung River bank are shown in Table 1 and Figure1. Exact coordinate of sampling locations were recorded using a Global Positioning System (GPS) device. Photographs of sampling sites of six soil samples and four kinds of crops from the farmlands are shown in Figures 2 and 3 respectively. Selected crops *viz.*, bean (*Phaseolus vulgaris*),brinjal (*Solanummelongena*), spinach (*Spinacia oleracea*) and asparagus (*Asparagus officinalis*) were collected for determination of some

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heavy metals after irrigation periods (pre-monsoon periods during May) in the years 2013, 2014 and 2015.Six soil samples from irrigated farmlands were collected in Zig-Zag pattern using a spade. Sampling depth was 15-20cm (Jones, 1988).

Table 1 Sampling Position of Soil Samples

No	Sampling site	Position	
		Longitude	Latitude
1	S_1Near Myogyiharbour	96°28' 1.79" E	18°55' 10.99" N
2	S_2East part of Do Thaung	96°27' 53.07" E	18°55' 20.81" N
3	S_3Middle part of Do Thaung	96°27' 44.21" E	18°55' 32.41" N
4	S_4West part of Do Thaung	96°27' 36.89" E	18°55' 42.51" N
5	S_5Edge of ThaPhanpin	96°27' 36.22" E	18°55' 0.01" N
6	S_6East part of ThaPhanpin	96°26' 2.59" E	18°55' 12.65" N

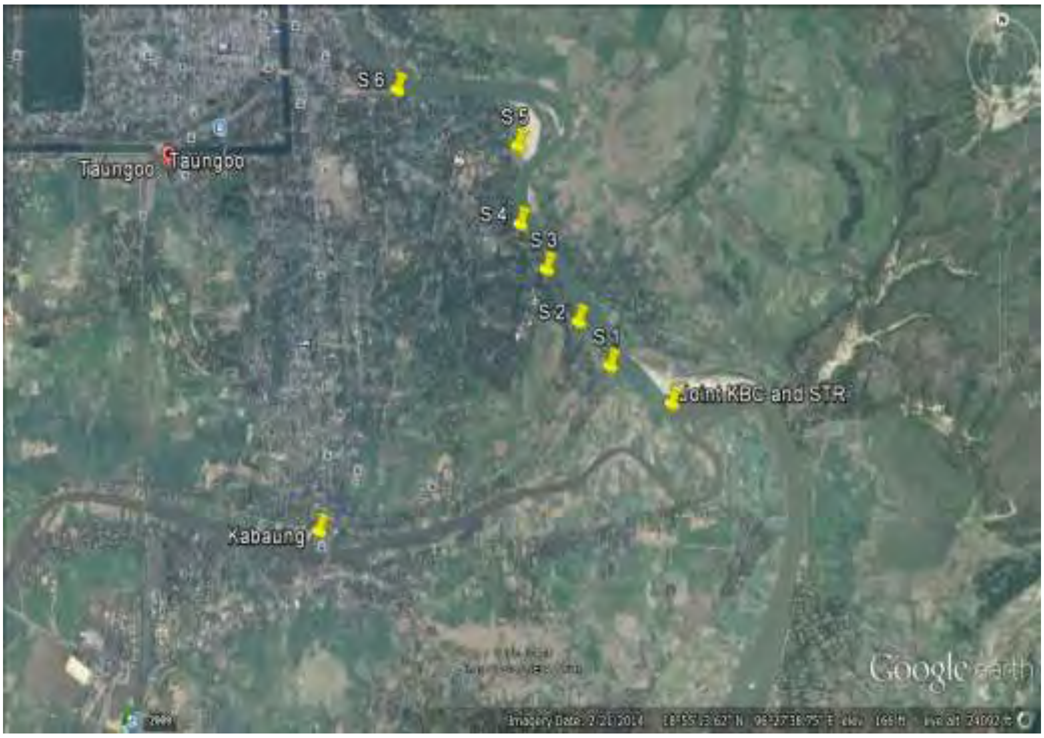

Figure 1 Google earth map of soil sampling locations

(a) Near Myogyi harbour (S_1) **(b) East part of Do Thaung village (S_2)**

(c) Middle part of Do Thaung (S_3)

(d) West part of Do Thaung(S_4)

(e) Edge of Tha Phanpin (S_5)

(f) East part of Tha Phanpin (S_6)

Figure 2 Soil sampling sites from farmlands

(a) Bean farm

(b) Spinach farm

(c) Brinjal farm

(d) Asparagus farm

Figure 3 Plant sampling sites from farmlands in Taungoo area

Preparations of Soil and Plants Samples

Apart from moisture content determination of soil, each of the soil sample, brought to the laboratory was spread out on aluminum tray and removed unnecessary things like stones, pieces of root and leave. The collected soil samples were thoroughly mixed on clean piece of thick paper and the bulk reduced by quartering technique so that about 500g of composite samples were retained individually. Each of the samples was kept in polyethene bag with suitable description and identification marks. Samples were mixed during drying to expose fresh surfaces. After air-drying, soil samples were crushed gently in mortar and pestle, sieved through a 2 mm sieve.

The fresh plant samples were washed with deionized water. The extra moisture was wiped out in order to remove discrepancies arising due to varying moisture contents of the wet samples. They were air dried.

Determination of Some Heavy Metals Contents in Soil Samples and Selected Plants

The soil sample (1 g) was digested by the addition of 5 mL of concentrated nitric acid and heated for 1 hour and cooled to room temperature. Then, the volume of the solution was made up to 50 mL in a volumetric flask. After that, it was filtered with filter paper and filtrate was analyzed for above metals. The concentrations of (Cd, Cr, Pb, Cu, Mn and Zn) were determined by using their specific hollow cathode lamps of atomic absorption spectrophotometer (Analyst- 300/FIAS-400 spectrophometer, Perkin –Elmer, U.S.A).

Dried plants leaves (1 g) were added in volumetric flask and digested with concentrated nitric acid (5 mL) and heated for 30 minutes. After that it was cooled to room temperature and the volume being made up to 50 mL with distilled water. Then, it was filtered with filter paper and filtrate was analyzed for above metals. The content of (Cd, Cr, Pb, Cu, Mnand Zn) were determined by using their specific hollow cathode lamps of atomic absorption spectrophotometer.

Results and Discussion

Heavy metal contents in irrigated soil

The results of heavy metal concentration of soil samples in the irrigated farm lands in pre -monsoon periods of 2013, 2014 and 2015 are presented in Tables 2, 3 and 4 respectively. Cadmium concentration were found to be in the range of 0.001 to 0.054 ppm with the mean value of 0.017±0.012 ppm. However, the values were lower than the permissible limit of 3 ppm (FAO/WHO, 1994). Furthermore, chromium was not detected in all soil samples during study period. Lead concentrations were in the range of 0.001 to 0.005 ppm with 0.002±0.001 ppm which were far below the maximum permissible limit of 100 ppm (FAO/WHO, 1994). Moreover, copper, manganese and zinc concentrations were found to be 11.50 to 21.30 ppm, with mean value of 16.33±2.70 ppm; 111.85 to 158.15 ppm with the mean value of 127.56±13.45 ppm and 10.21 to 35.42 ppm (mean value 16.66± 6.45 ppm) respectively, during the study period. Among the concentrations of heavy metals in soil used for irrigation, manganese was found to be highest followed by zinc, copper, cadmium and lead. Manganese concentrations of soil from farmlands had appreciable amount due to gravel beds overlie local bed rock granite and gneiss in alluvial parts of Sittaung River basin. Gravel beds contain considerable numbers of clay bands and are partly weathered (TunKo, 2005). However, copper, manganese and zinc concentrations were less than permissible limits of 100 ppm, 2000 ppm, and 300 ppm, respectively (FAO/WHO,1994). According to critical values of available micronutrients set by Halvin *et al*., (1999), the amount of copper, manganese and zinc may not be deficient for crop production. In this study, zinc, lead and copper contents of soil were strongly and positively correlated with bulk density (r = 0.937, 0.664 and 0.551, for zinc, lead and copper respectively). Manganese and cadmium contents of soil were found to have weak positive correlation with bulk density (r = 0.466 and 0.302 for manganese and cadmium respectively).

Table 2 Some Heavy Metal Contents of Soil Samples from Farmlands along Sittaung River Bank in Pre-monsoon Period in 2013

Sample	Element (ppm)					
	Cd	Cr	Pb	Cu	Mn	Zn
S_1	0.001	ND	0.002	14.36	120.76	21.86
S_2	0.001	ND	0.001	11.84	114.70	11.24
S_3	0.002	ND	0.001	13.43	112.14	18.47
S_4	0.001	ND	0.003	17.32	116.37	15.45
S_5	0.001	ND	0.002	16.56	111.97	12.18
S_6	0.001	ND	0.001	20.75	111.85	11.17
MRL (FAO/WHO,1994)	3	50	100	100	2000	300

MRL = Maximum Recommended Limit

ND = Not detected

Table 3 Some Heavy Metal Contents of Soil Samples from Farmlands along Sittaung River Bank in Pre-monsoon Period in 2014

Sample	Element (ppm)					
	Cd	Cr	Pb	Cu	Mn	Zn
S_1	0.001	ND	0.001	15.70	132.27	12.14
S_2	0.001	ND	0.004	15.27	129.17	15.40
S_3	0.002	ND	0.005	15.30	123.31	17.30
S_4	0.002	ND	0.002	17.26	118.22	10.21
S_5	0.001	ND	0.003	11.50	122.83	14.25
S_6	0.001	ND	0.002	14.70	148.75	11.10
MRL (FAO/WHO,1994)	3	50	100	100	2000	300

MRL = Maximum Recommended Limit

ND = Not detected

Table 4 Some Heavy Metal Contents of Soil Samples from Farmlands along Sittaung River Bank in Pre-monsoon Period in 2015

Sample	Element (ppm)					
	Cd	Cr	Pb	Cu	Mn	Zn
S_1	0.041	ND	0.002	21.30	142.23	19.14
S_2	0.021	ND	0.002	18.23	139.14	35.42
S_3	0.032	ND	0.001	19.31	125.96	27.34
S_4	0.043	ND	0.003	18.36	138.26	12.21
S_5	0.054	ND	0.004	15.80	129.95	18.25
S_6	0.053	ND	0.003	17.10	158.15	16.81
MRL (FAO/WHO,1994)	3	50	100	100	2000	300

MRL = Maximum Recommended Limit

ND = Not detected

Heavy metal contents in selected plants samples

Heavy metal concentrations in selected plants from irrigated farmlands are shown in Table 5 and Figure 4, Table 6 and Figure 5, Table 7 and Figure 6 and Table 8 and Figure7 for beans, brinjal, spinach and asparagus respectively. Data presented were restricted to the leaves of the four selected plants. The concentrations on heavy metals in vegetables samples were in the descending order:

Bean manganese(42.05 ppm) > zinc (36.83ppm) > copper (14.75 ppm) >cadmium (0.03 ppm) > lead (0.001ppm), chromium(ND)

Brinjal zinc (28.77 ppm)> manganese (28.40 ppm) > copper (9.35 ppm) > cadmium (0.02ppm) > lead (0.01 ppm) > chromium(ND)

Spinach manganese (44.43 ppm) > zinc(35.02 ppm) > copper (6.47 ppm) > cadmium (0.23 ppm) > lead (0.01 ppm), chromium(ND)

Asparagus manganese (57.27 ppm) >zinc(19.50 ppm) > copper (9.41 ppm) > cadmium (0.13ppm) > lead (0.02 ppm) > chromium(ND)

It was noted that most selected plants samples contain highest amount of manganese and second highest being zinc. Manganese concentrations in soil samples from irrigated farmlands were found as 111.85 to 158.15 ppm. Higher manganese contents in plants may be due to high manganese in soil. The decreasing order of manganese absorption in plants was found to be asparagus > spinach> bean>brinjal. However, manganese in plants samples were far below the maximum recommended limit of 300 ppm (Tandon, 1999). Zinc concentration in plant samples were in the range of 16.95 to 36.83 ppm and cadmium concentrations were 0.01 to 0.23 ppm. The relatively low concentration of cadmium accumulated in plant samples may be due to the presence of zinc in these vegetables. The presence of zinc can inhibit cadmium absorption and thereby cause low cadmium accumulation in plants (Adriano, 1986). Zinc accumulation in plants were bean> spinach>brinjal>asparagus.

In this study, copper concentration in four selected plants were in the range of 2.95 to 14.75 ppm. The order of copper accumulation in various plants was found to be bean> asparagus >brinjal> spinach.

Table 5 Some Heavy Metal Contents of Bean from Farmlands along Sittaung River Bank in Pre-monsoon Periods (based on 1 g of dried weight)

Heavy Metals	Contents (ppm) 2013	2014	2015	Remark
Cd	0.01	0.01	0.03	*<2
Cr	ND	ND	ND	*<23
Pb	ND	ND	0.001	**<3
Cu	8.61	10.21	14.75	7-30
Mn	21.26	28.50	42.05	50-300
Zn	22.42	30.51	36.83	20-200

(Cu, Mn, Zn) (Tandon, 1999), *FAO/WHO (1994)

** Weigert (1991) , ND = Not detected

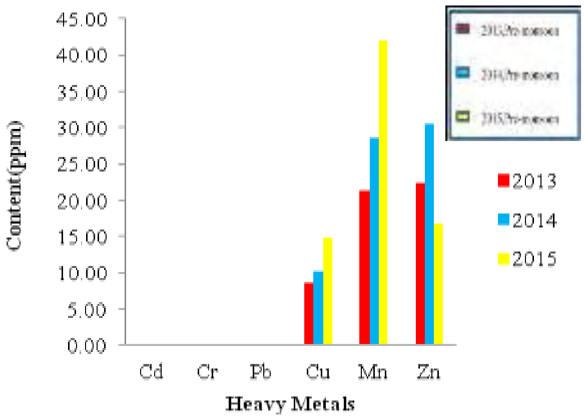

Figure 4 Some heavy metal contents of bean from farmlands along Sittaung river bank in pre-monsoon periods

Table 6 Some Heavy Metal Contents of Brinjal from Farmlands along Sittaung River Bank in Pre-monsoon Periods (based on 1 g of dried weight)

Heavy Metals	Contents (ppm)			Remark
	2013	2014	2015	
Cd	0.02	0.01	0.01	*<2
Cr	ND	ND	ND	*<23
Pb	0.01	0.01	0.01	**<3
Cu	7.54	9.35	9.33	8-60
Mn	23.95	28.40	27.72	40-250
Zn	18.37	20.37	28.77	20-250

(Cu, Mn, Zn) (Tandon, 1999)
*FAO/WHO (1994), ** Weigert (1991)
ND = Not detected

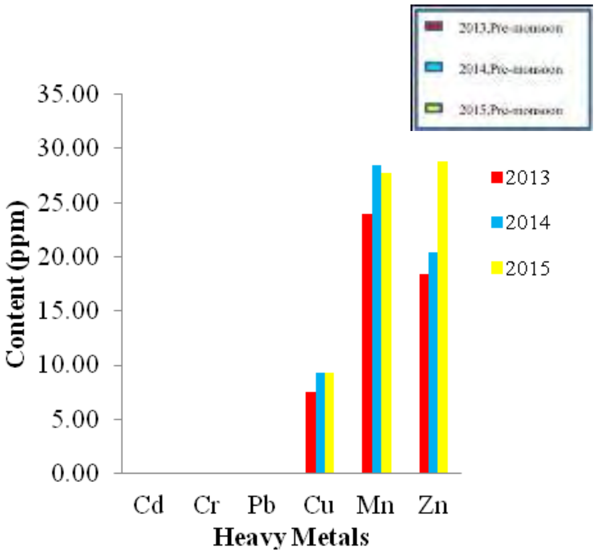

Figure 5 Some heavy metal contents of brinjal from farmlands along Sittaung river bank in pre-monsoon periods

Table 7 Some Heavy Metal Contents of Spinach from Farmlands along Sittaung River Bank in Pre-monsoon Periods (based on 1 g of dried weight)

Heavy Metals	Contents (ppm)			Remark
	2013	2014	2015	
Cd	0.17	0.23	0.21	*< 2
Cr	ND	ND	ND	*< 23
Pb	0.01	0.01	0.01	**< 3
Cu	3.12	6.47	6.47	5-25
Mn	11.85	44.31	44.43	30-250
Zn	19.13	22.56	35.02	25-100

(Cu, Mn, Zn) (Tandon, 1999)
*FAO/WHO (1994), ** Weigert (1991)
ND = Not detected

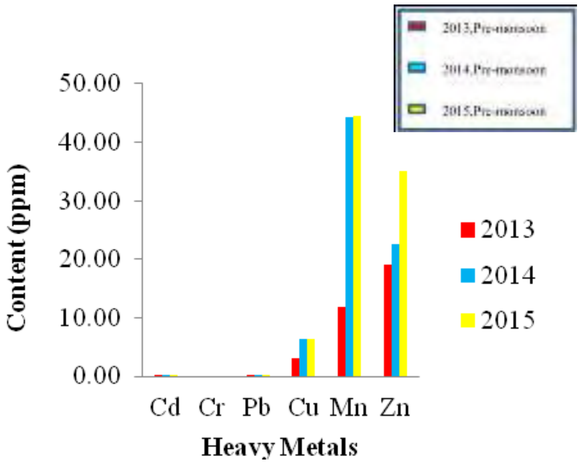

Figure 6 Some heavy metal contents of spinach from farmlands along Sittaung river bank in pre-monsoon periods

Table 8 Some Heavy Metal Contents of Asparagus from Farmlands along Sittaung River Bank in Pre-monsoon Periods (based on 1 g of dried weight)

Heavy Metals	Contents (ppm) 2013	2014	2015	Remark
Cd	0.13	0.02	0.10	*<2
Cr	ND	ND	ND	*<23
Pb	0.01	0.02	0.01	**<3
Cu	2.95	9.41	4.73	5-25
Mn	52.23	41.30	57.27	25-200
Zn	16.95	18.52	19.50	20-100

(Cu, Mn, Zn) (Tandon, 1999)

*FAO/WHO (1994)

** Weigert (1991)

ND = Not detected

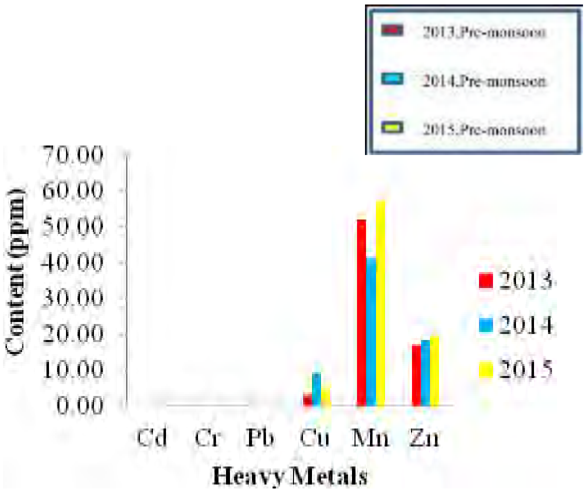

Figure 7 Some heavy metal contents of asparagus from farmlands along Sittaung river bank in pre-monsoon periods

The lead was detected in trace amount in all plants except bean in 2013 and 2014. Lead is difficult to be trans-located by plants. Lead is heavily adsorbed by particles of sediment and thus it is difficult to be trans-located. The limiting step for lead accumulation is long distance trans-location from roots to shoot (Smical *et al.*,2008).

The heavy metal accumulations were trans-location potential which varied from metal to metal and from plant to plant and did not follow any particular pattern. Genotypic effect, environmental effect and their interaction effects highly affect heavy metals uptake in crops genotypes (Zeng *et al* .,1992, Liu *et al* ., 2007).

Conclusion

Investigations of the acceptability of some heavy metals were conducted in soil sample from six small scale farmlands along the Sittaung River bank in pre-monsoon periods (May) 2013, 2014 and 2015. Heavy metals accumulation in four selected plants *viz.*, bean (*Phaseolus vulgaris*), brinjal (*Solanummelongena*), spinach (*Spinaciaoleracea*) and asparagus (*Asparagus officinalis*) were also studied. From the results of the study, the following conclusions were reached.

Results of heavy metals including three key heavy metals, chromium, cadmium and lead together with copper, manganese and zinc of irrigated soil samples showed the undetectable chromium. All heavy metals determined in soil samples in this study were below the permissible limit for crop cultivation. Like in the cases of irrigated soil, chromium was not detected in four selected plants. Mobility of manganese to plants was faster than other heavy metals in this study since highest amount of manganese was observed compared to others. Lead was the least mobility to plants compared to others. Among the plants, asparagus contained highest concentration of manganese followed by spinach, bean and brinjal. In sum, there was no obvious contamination of heavy metals in irrigated soils from farmlands and four selected plants cultivated in farmlands during the course of the study.

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