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Heavy Metal Concentration in Soil and Swiss Chard Grown in the Vicinity of Addis Ababa, Ethiopia

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Abstract: Urban and Peri-urban lands are often used for production of vegetables for better market accessibility and higher prices. But most of these lands are contaminated with heavy metals through industrial effluents, sewage and sludge, and vehicular emissions. Vegetables grown in such lands, therefore, are likely to be contaminated with heavy metals and unsafe for consumption. The objective of this study was to determine the concentration of heavy metals in soils, as well as on the leafy vegetable (Swiss chard) grown in the vicinity of industrial areas. The study was conducted from October 2014 to June 2015. Soil and vegetable samples were collected from three vegetable growing farms (Bulbul, Kebena and Akaki) in the vicinity of Addis Ababa to monitor their heavy metal loads. The analysis was carried out at JIJA laboratory using atomic absorption spectrophotometer (AAS) following the standard laboratory procedures. The final result of the study showed that soil samples collected from Bulbul, Kebena and Akaki sites in two different soil depths showed a significant ($p < 0.05$) variation in the level of heavy metal loads. Swiss chard samples showed Cr and Zn levels higher than FAO/WHO limits. The level of Cd, Pb and Cu however, were at their safe limits.

Key words: Heavy metals · Soil · Swiss chard · Addis Ababa · Ethiopia

INTRODUCTION

Urban and peri-urban horticulture (UPH) includes all horticultural crops grown for human consumption and ornamental use within and in the immediate surroundings of cities [1]. The products of UPH include a large variety of vegetables, cereals, flowers, ornamental trees, aromatic vegetables and mushrooms [1]. The main function of urban and pre-urban agriculture is supplying fresh food, but emerging functions that are becoming more essential are income generation, job opportunity, living environment (open space greening), and food security [2]. It also contributes to strengthening social sustainability and increasing ecological sustainability by transforming wastes, conserving natural resources, preventing soil erosion, and reducing pollution [1].

It is estimated that about 800 million people worldwide are engaged in urban agriculture. Globally, urban agriculture produces 15% of all food consumed in urban areas [2]. Increases in urban agriculture have also been recorded in African cities such as Bissau (Guinea Bissau), Dakar (Senegal), Kumasi (Ghana), Lome (Togo), Nairobi (Kenya and Dare-Salamm (Tanzania) [3].

A major challenge for urban agriculture, and especially for horticulture, is to supply safe products in this often polluted environment. In urban areas, the main pollutants of horticultural crops are heavy metals, pesticide residues, and biological contaminants. The pollutants are generated from extensive use of fertilizers, pesticides, mining processes, industrialization, vehicular exhausts etc. Such pollution presents a risk not only to the consumers, but also to the producers who come in contact with contaminated materials [4]. To face the growing demand for irrigation water, non-conventional resources are often used. Important sources of heavy metals in wastewater are urban and industrial effluents and deterioration of sewerage pipelines. Irrigation with wastewater is known to contribute significantly to the heavy metal content of soils [5].

Throughout the world, there is a long tradition of farming intensively within and at the edge of cities [6]. However, most of these peri-urban lands (lands in the periphery of city) are contaminated with pollutants including heavy metals such as Cu, Zn, Pb, Cd, Ni, and Hg. These metals are contributed mainly through industrial effluents, sewage and sludge, vehicular

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emission, diesel generators and application of pesticides in agriculture. This loading of heavy metals often leads to degradation of soil health and contamination of food chain mainly through the vegetables grown on such soils [7, 8]. When grown on contaminated soils toxic metals are accumulated in vegetables resulting in reduction of yields due to the inhibition of metabolic processes [9]. Heavy metals are cytotoxic, mutagenic and carcinogenic in nature and are posing serious threat to the urban population, which rely on vegetable and foliage crops grown in peri-urban lands [10, 11]. Since food chain contamination is one of the major routes for entry of metals into the animal system, monitoring the bio-available pools of metals in contaminated soils has generated a lot of interest [12].

The consumption of plants produced in contaminated areas, as well as ingestion or inhalation of contaminated particles is two principal factors contributing to human exposure to metals. Potential health risks to humans and animals from consumption of crops can be due to heavy metal uptake from contaminated soils via plant roots as well as direct deposition of contaminants from the atmosphere onto plant surfaces [13].

In Ethiopia urban and per-urban horticulture have become very popular and expanding rapidly. Major vegetables such as Irish potato, Swiss chard, carrot, cabbage, lettuce, Ethiopian kale and beet root are grown in the vicinity of industrial areas. They are often grown on the embankments along the major rivers though the rivers are contaminated with various pollutants, among which are heavy metals [14]. One of the most serious problems of urban farming in Addis Ababa is the use of highly polluted river water to irrigate the vegetable farms as well as to wash vegetables product. The rivers that cross the city are the only water source for urban vegetable producers [15]. Thus, vegetables that are grown at the contaminated sites might contain high concentration of heavy metals. Very limited and out dated information is available about the concentration of heavy metals in the soil, the rivers and vegetables products that are grown in the vicinity of industrial areas. Therefore, the aim of this study was to determine the concentration of heavy metals in soils, as well as on the leafy vegetable (Swiss chard) grown in the vicinity of industrial areas.

MATERIALS AND METHODS

Description of the Study Area: The study was conducted at three different farmlands in Addis Ababa. Addis Ababa lies at an altitude of 2,300 m.a.s. and located at 9°1'48?N38°44'24?E9.03°N 38.74°E coordinates. The city lies at the foot of Mount Entoto. From its lowest point, around Bole International Airport, at 2,326 meters above sea level in the southern periphery, the city rises to over 3,000 meters in the Entoto Mountains to the North. The city possesses a complex mix of highland climate zones, with temperature differences of up to 10°C, depending on elevation and prevailing wind patterns average temperature is 11-17°C in high area and 20°C in lowland area, rain fall is 1200mm. The samples were collected from three major farms (Akaki, Bulbul, and Kebena farm). The main water sources for the production of urban and per-urban vegetables in the Addis Ababa are Akaki, Bulbul, and Kebena rivers.

Soil Sample Processing and Analysis: A total of 18 composite soil samples were collected at the depths of 0-15 cm and 16-30 from three cultivated lands which were located to the vicinity of industrial areas. The samples were stored in plastic bag then air-dried, and crushed to pass a 2-mm mesh sieve. Heavy metal concentrations in the samples were determined at JIJA soil laboratory using atomic absorption spectrophotometer (AAS) following standard laboratory procedures. The guidelines for maximum levels of metals in soils were adopted from [16].

Plant Sample Preparation and Analysis: A total of 30 physiologically mature Swiss chard leaves were randomly sampled from three different cultivated lands which were located in the vicinity of industrial area Rivers (Akaki, Bulbul, and Kebena Rivers). From each river one farm was selected for sampling and ten physiologically matured Swiss chard leaves were randomly sampled (farms were selected based on their size and production volume). The samples were then brought in plastic bags to JIJA soil laboratory where they were cleaned with de-ionized water repeatedly. Then the samples were dried in an oven at 105°C for about 24hrs and it was ground using a Cross-beater Grinding mill. The samples were then analyzed for heavy metal concentration using atomic absorption spectrophotometer (AAS) following the standard laboratory procedures. Guidelines for maximum limit (ML) of metals in vegetables were adopted from [17].

Statistical Analysis: All the recorded quantitative data were subjected to analysis of variance (ANOVA) using GenStat 12th edition [18].

RESULTS AND DISCUSSION

Heavy Metal Concentration in Soil at Farms: Any metal derived from anthropogenic source is strongly influenced by their form, phase and oxidation state and hence bio-

Table 1: Heavy metal concentration in soil at Kebena, Bulbul, and Akaki rivers irrigated vegetables growing farms at Addis Ababa, Ethiopia.

	0-15 (cm)Soil depth				
	Heavy metals (mg/kg)				
Farms	Cd	Cr	Cu	Pb	Zn
Kebena	<0.01	178.1	99.2	56.7	25.93
Bulbul	<0.01	50.2	16.8	35.9	14.20
Akaki	<0.01	51.2	17.4	31.5	13.27
LSD	NS	32.25	6.84	8.09	1.066
CV (%)	0.0	15.3	6.8	8.6	2.6
	15-30(cm) Soil depth				
	Heavy metals (mg/kg)				
Farms	Cd	Cr	Cu	Pb	Zn
Kebena	<0.01	81.9	107.6	61.3	27.61
Bulbul	<0.01	46.9	13.3	33.2	13.55
Akaki	<0.01	40.5	17.9	32.5	13.40
LSD	NS	19.25	25.56	10.40	4.353
CV (%)	0.0	15.1	20.0	10.8	10.6

Table 2: Heavy metal concentrations in Swiss chard leaf at Kebena, Bulbul and Akaki farms at Addis Ababa, Ethiopia

	Heavy metals (mg/kg)				
Farms	Cd	Pb	Cr	Cu	Zn
Kebena	< 0.2	< 0.3	5.83	10.77	110.83
Bulbul	< 0.2	< 0.3	5.93	14.77	147.08
Akaki	< 0.2	< 0.3	5.80	10.07	74.17
Mean	0.2	0.3	5.85	11.87	110.69
Std error	±0.0	±0.0	± 0.039	±1.464	± 21.047

availability. Chemical soil tests are designed to extract a quantity of element from the soil solids that correlates statistically to the size of the ''available pool'' in the soil defined by the quantity of element taken up by the plants [19]. Chemical extraction techniques provide a well-established means of identifying and characterizing different fractions of heavy metals in the soil [20].

Soil samples collected from Bulbul, Kebena and Akaki sites in two different soil depth showed a significant ($p < 0.05$) variation in the level of heavy metal contents (Table 1). The soil collected from Kebena site had the highest level of Cr (178.1 mg/kg, 81.9mg/kg soil), Cu (99.2 mg/kg, 107.6 mg/kg soil), Pb (56.7 mg/kg, 61.3 mg/kg soil) and Zn (25.93 mg/kg, 27.61 mg/kg soil) from 0-15 and 15-30 cm soil depth compared to Bulbul and Akaki sites (Table 1). In addition to that Kebena site soil registered the highest levels of Cr (178.1 mg/kg soil) than Cd, Cu, Pb and Zn in the samples collected from the top soil depth (0-15 cm). However, this site had the highest levels of Cu (107.6 mg/kg soil) in the samples collected from the bottom soil depth (15-30 cm) (Table 1). The lowest level of Cd (<0.01 mg/kg soil) contamination was registered in Kebena; Bulbul and Akaki sites (Table 1). The Cr contents in all sites are highest than Cd, Cu, Pb and Zn (Table 1).

According to [21, 22] the differences in heavy metal level of soil was due to use of different quantity and quality of sewage and sludge, level and type of industrialization near the sampling sites, proximity of field from main road and highways, presence of thermal power plants, and use of different types of agrochemicals containing heavy metals. Moreover, they reported that availability of heavy metal is decided by the various physico-chemical properties of soil. Organic matter in soil may chelate these metals and reduce their availability. Cationic metals such as Zn^{2+}, Cu^{+1}, Cu^{+2}, Pb^{2+}, Cd^{2+} may exist as adsorbed ion on clay-humus complex. There are reports elsewhere stating long term sewage irrigation significantly increased the mobile metal fraction of all metals in general and Pb, Zn, and Cd in particular [23, 27, 28, 29].

Heavy Metal Concentrations in Swiss chard Leaf: According to [14], the Ethiopian metal tools factory is the major source of pollution of rivers which is used to irrigate part of vegetable farms. In addition to that the author reported that waste from garage, hospitals, gas station as well as households also discharged into these rivers. This had impact on concentration of heavy metals such as Cu, Zn, Pb, Cd and Cr were exceeding the maximum limits recommended by FAO/WHO in the vegetables produced by irrigating these contaminated rivers.

Elevated levels of heavy metals in the soil may lead to uptake by plant but there is no generally high relation between the concentration in soils and plants, because it depends on many different factors such as soil metal bio-availability, plant growth and metal distribution to plant parts [24].

Highest concentration of Cu and Zn were detected in Swiss chard leaf harvested from Bulbul, Kebena and Akaki sites than Cd, Pb and Cr (Table 2). Besides, the higher concentration of Cu and Zn were registered from Bulbul and Kebena sites compared to Akaki site. On the other hand Swiss chard leaf harvested from Kebena site showed higher Zn content than Bulbul and Akaki farms (Table 2). The lowest level of Cd (<0.2 mg/kg) and Pb (<0.3 mg/kg) contamination was registered in Kebena, Bulbul and Akaki sites (Table 2).

According to [25] report Cd, concentration in the plants ranged below 1 mg/kg and can consider as normal. Low contains and slightly alkaline pH (6.5-7.8) in the soil reduce the mobility and the uptake of Cd. This might be the reason why Cd content in Swiss chard leaf is less than 0.2 mg/kg. The higher Pb levels are possibly due to the circumstance that contamination with lead mainly takes place via transport through air of lead containing dust practices. However, Pb content in the Swiss chard is below 0.3mg/kg and can be classified as normal. According to [26] codex Alimentarius Commission report recommended maximum limit of Cr for many vegetables is 2.3 mg/kg. On the other hand Cr content in Swiss chard leaf was registered in the range of 5.80 to 5.93 mg/kg; these might have toxic effect and result in reduction of growth.

Cu is an essential nutrient for plants, but concentration of only 25 to 30 mg/kg (dry plant mater) is already toxic and result in inhibition of growth [25]. Cu contents in Swiss chard leaf the range 10-15 mg/kg and can be classified as normal. Swiss chard leaf has the highest Zn concentration compared to other heavy metals. This result in increase the level of contamination of this vegetable compared to above for heavy metals and this might reduce the growth and development of Swiss chard vegetable.

CONCLUSIONS

The soil and Swiss chard leaf samples collected from Kebena, Bulbul and Akaki farms around Addis Ababa area showed substantial level of contamination with heavy metal such as Cr, Cu, Pb and Zn. Most of the soil samples collected from Kebena site from 0-15 and 15-30 cm soil depth showed higher level of Cr, Cu, Pb and Zn lodes than Bulbul and Akaki sites. The lowest level of Cd was registered in Kebena, Bulbul and Akaki sites. Most of the Swiss chard leaf samples crossed the safe limits of Cr and Zn while Cd and Pb content were below the safe limit. Cu content in the Swiss leaf can be classified as normal.

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