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Assessment of heavy metals in vegetables irrigated with Awash River in selected farms around Adama town, Ethiopia

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A study was conducted at Melka Hida and Wonji Gefersa farms where Awash River was used for cultivation of vegetable crops to assess heavy metal contamination of vegetables. To what extent these vegetables are contaminated is not known. Three leafy vegetable samples, namely, cabbage (*Brassica oleracea Linn*.), lettuce (*Lactuca sativa*) and spinach (*Spinacea oleracea*) from Melka Hida and Wonji Gefersa farms were examined for heavy metal (Cd, Cr and Pb) contamination using atomic absorption spectroscopy. The results indicate that the heavy metals in vegetables of Melka Hida farm were higher than those of the vegetables in Wonji Gefersa farm. In all the samples analyzed, the concentration of Pb and Cd was more than the maximum limit and their levels varied from 0.31 to 0.65 and 0.21 to 0.40 mg/kg, respectively. However, the level of chromium was generally within the normal range in cabbage (0.85 and 0.29 mg/kg) and spinach (1.30 and 1.06 mg/kg) from Melka Hida and Wonji Gefersa farms, respectively, except in lettuce from Melka Hida farm, 2.4 mg/kg. The high levels of these heavy metals place the consumers of these vegetables grown within the study area at health risk with time unless an urgent step is taken by relevant agencies to address this issue.

Key words: Awash River, contamination, trace elements, vegetables.

INTRODUCTION

Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals and trace elements (Abdola and Chmtelnicka, 1990). In recent years, their consumption is increasing gradually, particularly among the urban community. This is due to increased awareness on the food value of vegetables, as a result of exposure to other cultures and acquiring proper education (Thompson and Kelly, 2003). However, they contain both essential and toxic elements over a wide range of concentrations.

Rapid and unorganized industrialization and urbani-zation have contributed to the elevated levels of heavy

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metals in the urban environment in developing countries (Wong et al., 2003). As urban populations in developing countries increase, and residents seek better living standards, larger amounts of freshwater are diverted to domestic, commercial and industrial sectors, which generate greater volumes of wastewater (Asano et al., 2007; Qadir et al., 2007a). There is, however, a lack of investment capacity worldwide for construction and operation of adequate treatment facilities which threatens the quality of surface waters, soils and groundwater to which wastewater is discharged.

In addition to this, excessive application of nitrogen and other inorganic fertilizers and organic manures to these vegetables can accumulate high levels of nitrate and other anions as well as heavy metals. Heavy metals, such as cadmium, copper, lead, chromium and mercury, are important environmental pollutants, particularly in areas under irrigated with wastewater. Several studies have revealed that contamination of vegetables with heavy metals and pesticides poses a threat on consumers (D'Mello, 2003; Sharma et al., 2006; Zandstra and De Kryger, 2007).

International Water Management Institute (IWMI) (2006) suggests that at least 3.5 million ha of land is irrigated globally with untreated, partly treated, diluted, or treated wastewater. Wastewater often contains a variety of pollutants: salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds and active residues of personal care products. Moreover, the excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination but also may lead to elevated heavy metal uptake by vegetables, and thus affect food quality and safety (Muchuweti et al., 2006).

According to Bahemuka and Mubofu (1999) and Ikeda et al. (2000), humans are exposed to the risks through the consumption of vegetables contaminated with heavy metals. Most consumers are not aware of the source of the produce and the use of polluted irrigation water.

Adama and Wonji Gefersa towns are found in Adama *Woreda* of East Showa Zone, Oromia Region, with a population of 260,600 and 23,510, respectively (CSAE, 2005). Awash River is the only important river in Adama *Woreda* used for irrigating around 1132 ha of land. Among the major rivers of Ethiopia, Awash River, which flows from central highlands through Ethiopia's major industrial and agro-industrial belt, taking in a whole burden of all types of raw effluent stands as one of Ethiopia's river streams in urban areas of developed rivers (Tesfamariam, 1989). Most of the existing industries and major towns with in the upper watershed have no treatment plants for discharge of their wastes and are seriously polluting the water course (MWEE, 2010).

In addition, the Modjo River, which is highly polluted by discharging effluent from Modjo tannery industry and waste disposed from the town, is the main tributary of Awash River. Besides this, the expansion of new industries and disposal of industrial wastes to the Awash River is of great concern to the nation (Girma, 2001). Furthermore, food and beverage factories tend to discharge heavy organic pollutants and dyes from textile factories are also released into the same river. The level of toxic heavy metals in vegetables grown on irrigated Awash River is not known in the study area. Therefore, the study was designed to assess the levels of some toxic heavy metals contaminants on selected vegetables irrigated with Awash River in Melka Hida and Wonji Gefersa farms around Adama town.

MATERIALS AND METHODS

Description of the study area

This study was conducted at two wastewater irrigated vegetable growing farms, that is, Melka Hida and Wonji Gefersa that are found in Adama *Woreda*. Melka Hida is found in Adama Town Administrative Zone, Oromia Region, which is 99 km away from Addis Ababa and is located at latitude of 8° 33′ 0″ north and longitude 39° 16′ 12″ east. It has an elevation of 1620 m above sea level.

Wonji Gefersa is a town that is found in Adama *Woreda* of East Showa Zone, Oromia Region, nearby Adama Town, which is 107 km away from Addis Ababa and located at a latitude of 8° 26' 59'' north and longitude of 39° 16' 48'' east. It has an elevation of 1588 m above sea level and its temperature and annual rain fall is 23°C and 500-800 mm, respectively (Environmental Protection Authority, 2005). Awash River is the only important river in Adama *Woreda* used for irrigating around 1132 ha of land, which originates from the highlands of Dandi *Woreda* located west of Addis Ababa, Ethiopia, and flows along the rift valley into the Afar region, where it eventually terminates in a salty lake, Lake Abbe, found on the border with Djibout.

Study design

A cross sectional survey was conducted to assess the level of heavy metal contamination on the main leafy vegetables [lettuce (*Lactuca sativa*), cabbage (*Brassica oleracea Linn*.), and spinach (*Spinacea oleracea*)] that were grown in Melka Hida and Wonji Gefersa vegetable farms irrigated with Awash River. The samples were regularly collected in three week intervals during January 2013 - March 2013. The vegetable samples were analyzed for heavy metals, cadmium (Cd), lead (Pb), and chromium (Cr) concentrations using atomic absorption spectroscopy (AAS).

Sample collection

A total of 72 samples comprising three types of fresh vegetables (cabbage, lettuce, spinach,) were collected from Melka Hida and Wonji Gefersa vegetable farms using a random sampling technique method. Recently, matured leaves of lettuce, cabbage, and spinach were sampled at early maturity according to methods used by Fisseha (1998). All samples were collected aseptically in a sterilized

Table 1. Mean concentration of three purposively selected heavy metals in vegetables cultivated at Melka Hida and Wonji Gefersa farms in terms of mg/kg dry weight (Mean±SE).

Parameter	No. of examined sample	Site	Vegetable type				
			Cabbage	Lettuce	Spinach	Mean	Maximum limit
Pb	12	MH	$0.31{\pm}0.3^b$	$0.65{\pm}0.3^a$	$0.33{\pm}0.3^b$	$0.43{\pm}0.2^a$	0.3*
	12	WG	$0.30{\pm}.03^b$	0.40 ± 0.3^a	$0.31{\pm}0.3^b$	$0.34{\pm}0.2^b$	
		Mean	$0.31{\pm}0.2^b$	$0.53{\pm}0.2^a$	$0.32{\pm}0.2^b$		
Cr	12	MH	$0.85{\pm}0.4^b$	$2.4{\pm}0.4^a$	$2.1{\pm}0.4^a$	$1.78{\pm}0.2^a$	2.3**
	12	WG	$0.29{\pm}0.4^b$	$1.33{\pm}0.4^a$	$1.06{\pm}0.4^a$	$0.89{\pm}0.2^b$	
		Mean	$0.57{\pm}0.3^b$	$1.86{\pm}0.3^a$	$1.58{\pm}0.3^a$		
Cd	12	MH	$0.23{\pm}0.3^b$	$0.40{\pm}0.3^a$	$0.3{\pm}0.3^b$	0.31±0.2	0.2*
	12	WG	$0.20{\pm}0.3^b$	$0.32{\pm}0.3^a$	$0.22{\pm}0.3^b$	0.25±0.2	
		Mean	$0.22{\pm}0.2^b$	$0.36{\pm}0.2^a$	$0.26{\pm}0.2^b$		

$^{a\text{-}b}$ Means with different superscript letters along the row for the same parameter in the same site do significantly differ (P<0.05). Pb = Lead, Cr = Chromium, Cd = Cadmium. **Source: Weigert (1991) *Source: FAO/WHO (2001).

universal container and plastic bags and transported to Dilla University for laboratory processing.

Determination of heavy metals in leafy vegetables

Vegetable samples were washed with distilled water to eliminate suspended particles. The leafy stalks were removed from all samples and these were sliced and dried on a sheet of paper to eliminate excess moisture; and then carefully dried in oven at 70°C for 24 h. 2 g of the plant material were weighed and ground in a pestle and mortar followed by wet digestion with HNO_3 and H_2O_2 in Tappi (1989) test method, as cited in Subhashini (2013) in the ratio of 3:1. The samples were digested on a hot plate at a temperature of 93°C for 4 h. Heating was done such that it did not boil and until it dried up completely to give a whitish brown dry mass. It was then cooled and the precipitate/digest mixture was extracted in acid water mixture (HCl: distilled water, ratio 3:1) and filtered through Whatman filter paper No. 42. Following this, the volume of the filtrate was made up to 50 ml. Finally, the filtrate was analysed for heavy metal content using atomic absorption spectroscopy (GBC 932AA).

Data analysis

In this study, all statistical analyses were computed using SAS software version 9.1 for heavy metal analysis. The recorded data were subjected to analysis of variance (ANOVA) to assess the effect of vegetable type and site of production on the concentrations of heavy metal contaminant in the vegetables tested. As the level of heavy metal contamination might vary with sample collection site and vegetable type, ANOVA was used to test the existence of significant difference between means. In all statistical analyses, confidence level was held at 95% and P<0.05 was considered as significant.

RESULTS AND DISCUSSION

Heavy metal contamination of vegetables

The concentrations of heavy metals in leafy vegetables (lettuce, spinach and cabbage) from both study sites are shown below in Table 1. Average concentration of Pb in lettuce was 0.65 and 0.4 mg/kg; spinach 0.33 and 0.31 mg/kg; cabbage 0.31 and 0.30 mg/kg dry weight each at Melka Hida and Wonji Gefersa, respectively. Lettuce showed a highly significant difference (p<0.01) in Pb concentration among the other vegetables and between the sites. However, all the Pb concentrations on the samples analyzed exceeded the permissible limit of 0.3 mg /kg dry weight (FAO/WHO, 2001), except cabbage at Wonji Gefersa farm. Meanwhile the cadmium (Cd) concentration in the leafy vegetables (spinach, lettuce and cabbage) analyzed mean were 0.3, 0.4, 0.23 and 0.22, 0.32, 0.20 mg/kg dry weight at Melka Hida and Wonji Gefersa sites, respectively. The concentrations of Cd in leaf vegetables had highly significant difference (P <0.01) between vegetable types, and there was significant difference (p<0.05) between sites. This might be because the plantation of industries there directly discharges their effluents into Awash River where the water is used in Melka Hida farm.

However, the concentrations of Cd in almost all samples exceed the tolerable limit of 0.2 mg/kg dry weight (FAO/WHO, 2001), except cabbage at Wonji Gefersa site. However, chromium accumulation in the analyzed leafy vegetables was within normal range of the permissible levels, except lettuce at Melka Hida farm, which is 2.40 mg/kg dry weight. There were highly significant differences (P <0.01) between vegetable types and between sites.

Lead

Elevated lead levels are toxic to plants and humans.

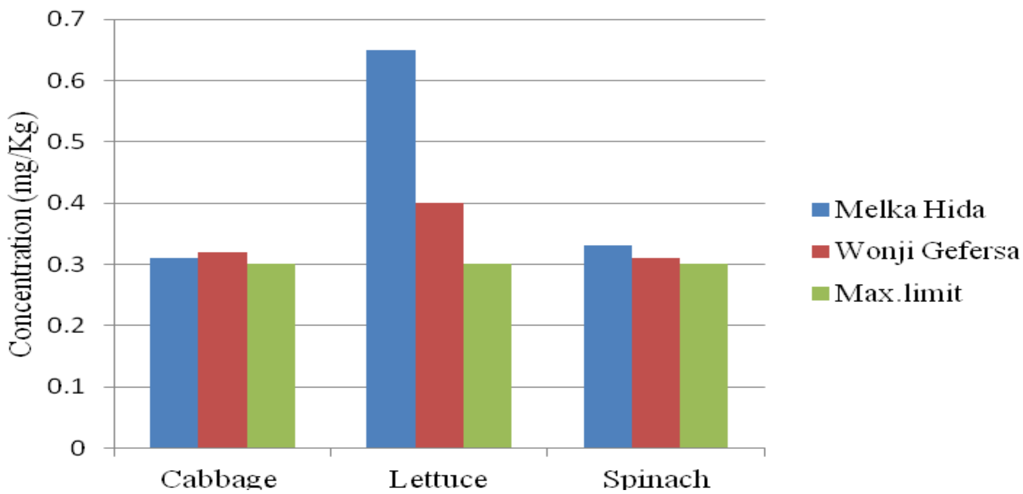

Figure 1. Lead concentration levels in vegetables of Melka Hida and Wonji Gefersa farms.

Even though many plants accumulate large amounts of lead without visible changes in their appearance or yield, this may cause a series of metabolic changes in plant such as slow growth, delayed flowering and reduction in quality. In addition, this can bring Pb into the human food chain, thereby becoming a major concern for health (Concon, 1988). Like most heavy metals, Pb can bioaccumulate overtime and exist in the body for long periods.

Thus, it is necessary to detect such metals even at very low concentrations. Heavy metal contamination of vegetables may occur due to irrigation with contaminated water (Sinha et al., 2006) and emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during production, transport and marketing (Maleki and Zarasvand, 2008; Sharma et al., 2008a and 2008b) the addition of fertilizers and metal based pesticides on vegetable farm. A similar study that is conducted by Singh and Kumar (2006) and Kumar et al. (2009), reported that lead concentrations of lettuce ranged from 2.3-5.30 mg /kg sample by which super passed the maximum permissible level of Pb set by (FAO/WHO, 2001).

In respective of these results, Farooq et al. (2008) stated that Pb concentration was above toxicity level in leafy vegetables grown in vicinity of an industrial area of Faisalabad, Pakistan. In this study, the concentration of Pb levels in cabbage is least among the other vegetables (Figure 1).

This finding is similar to that of Fisseha (1998) who commented that cabbage was generally the least accumulator of heavy metals as compared to other vegetables. In the current study, the high level of Pb in all vegetables suggests that the water used for irrigation was not good for irrigation of crops in general and leafy vegetables in particular.

Chromium

Exposure to chromium may occur through breathing air, drinking water, or eating food containing chromium or even through skin contact. Exposure to elevated levels chromium leads to skin irritation, ulceration, damage to circulatory and nerve tissue which lead to health problems (Bubb and Lester, 1994). In this study, the chromium content of samples analyzed ranged from 0.29 to 2.40 mg/kg of dry weight. This shows that chromium metal levels are generally within normal range in all vegetable samples from both farms, except lettuce in Melka Hida farm. The chromium contents of lettuce at Melka Hida farm exceed maximum limit of metal concentration set by Weigert (1991) among all vegetables studied as shown in Figure 2.

In line with these results, Fisseha (1998) reported that lettuce had generally the highest concentrations of Cr, Cd, Co, Fe and Mn at Peacock (Addis Ababa) vegetable farm. Similarly, Farooq et al. (2008) reported that Pb and Cd were above toxicity level in leafy vegetables grown in vicinity of an industrial area of Faisalabad, Pakistan whereas other heavy metal (Cr) were within the permitted limits.

Cadmium

Cadmium is a non-essential element in foods and natural waters. It accumulates principally in the kidneys and liver (Divrikli et al., 2006). Various sources of environmental contamination have been implicated for their presence in

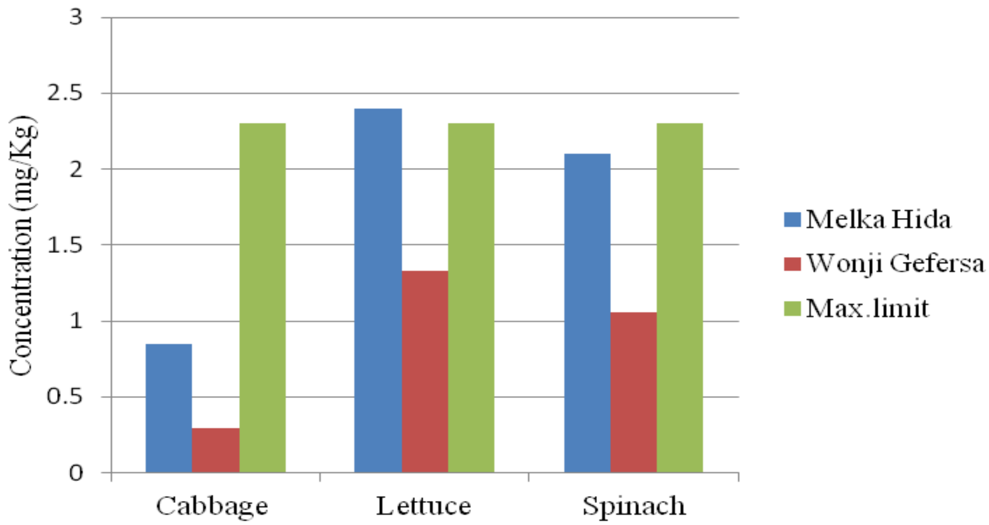

Figure 2. Chromium concentration levels of vegetables in Melka Hida and Wonji Gefersa farms.

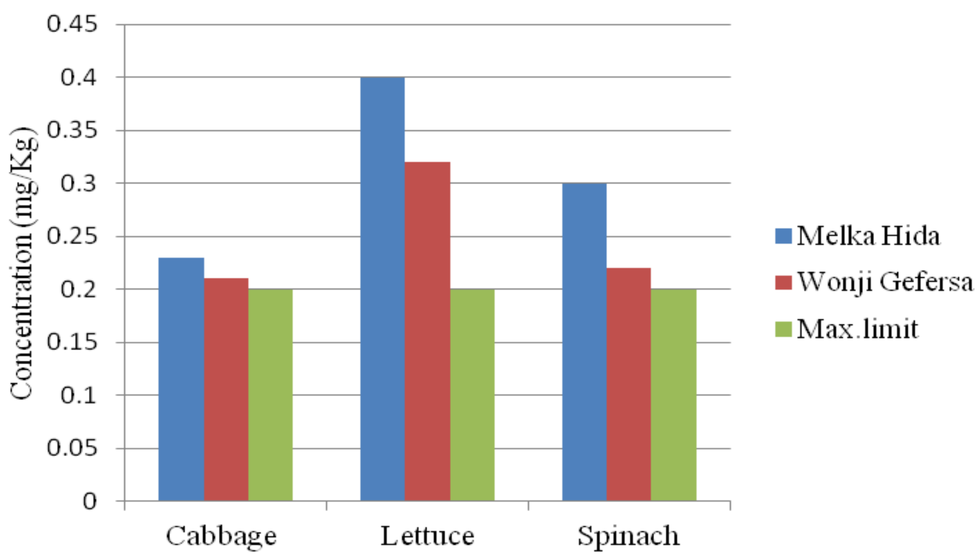

Figure 3. Cadmium concentration levels of vegetables in Melka Hida and Wonji Gefersa farms.

foods. Cadmium is the most toxic heavy metal because its bioaccumulates has a long half-life of about 30 years and may cause health disorders even at low doses (Lenntech, 2006). Toxic effects of Cd on plants include chlorosis, growth inhibition, reduction in water and nutrient uptake and crop protein synthesis (Dass et al., 1997). Cadmium is easily absorbed and translocated to shoots of food crops and may lead to chronic Cd toxicity in human (Mumba et al., 2008). However, it can also cause damage to the skeletal system and kidneys and induce cancer in humans (He et al., 2005). The level of cadmium in this study ranges from 0.20 to 0.40 **(**Figure 3**)** which exceeded the recommended limit set by FAO/WHO (2001), 0.20 mg /kg dry weight. In strong connection with this finding, an earlier study by Rahlenbeck et al. (1999) reported that metal contents of vegetables from Addis Ababa market showed that lettuce contained the highest Cd accumulation and cabbage contained the least.

Similarly, Bhatia and Choudhri (1991) reported the concentrations of Cd in edible vegetables ranged from 0.05 to 0.9 mg/kg dry weight and leafy plants such as lettuce, spinach and cabbage contains relatively higher Cd than grain or fruit plant such as apple, due to their higher transpiration. In addition, investigation done by Awashthi (2000) showed that the concentrations of Cd in spinach (4 mg/kg) and radish (2.5 mg/kg) were above the recommended level. In the present study, the accumulation of elevated concentration of Cd in lettuce and spinach might be attributed to the use of contaminated water and industrial effluents for their cultivation. The other possible reason for accumulation is that Cd is relatively easily taken by food crops and especially by leafy vegetables.

Comparing the two contaminated sites, lettuce and spinach accumulated more Pb and Cd at both sites (Melka Hida and Wonji Gefersa); while the cabbage and lettuce accumulated (Pb and Cr) more at Melka Hida farm, respectively. This shows that Melka Hida farm is, hence, more contaminated than Wonji Gefersa farm. This might be due to the fact that more industrial effluents from various industrial sources enter Awash River near the point where water is used for irrigation.

Conclusions

The study reveals that there was heavy metals contamination of fresh leafy vegetables grown in Melka Hida and Wonji Gefersa vegetable farms. In this study, lettuce exhibits higher Cr, Pb and Cd concentrations than other vegetables, whereas elevated Cd level was also exhibited by spinach. However, cabbage was found to be the least accumulator of heavy metals. Generally, the results of the present study revealed heavy metal contamination of vegetables in varying magnitude among vegetables in the study area. Hence, it poses an important public health risk. So monitoring heavy metals in plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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REFERENCES

Abdola M, Chmtelnicka J (1990). New aspects on the distribution and metabolism of essential trace elements after dietary exposure to toxic metals. Biol. Trace Element Res. 23:25-53.

Asano T, Burton F, Leverenz H, Tsuchihashi R, and Tchobanoglous G (2007). Water reuse: issues, technologies, and applications. McGraw-Hill. pp. 345-350.

Awashthi SK (2000). Prevention of Food Adulteration, Act no. 37 of 1954. Central and State rules as amended for 1999. Ashoka Law House, New Delhi.

Bahemuka TE, Mubofu EB (1999). Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi Rivers in Dar es Salaam, Tanzania. Food Chemistry 66:63-66.

Bhatia I, Choudhri GN (1991). Impact of automobile effusion on plant and soil. Int. J. Ecol. Environ. Sci. 17:121-127.

Bubb JM, Lester JN (1994). Anthropogenic heavy metals inputs to low land river system, a case study, the river store. U.K, water, air and soil pollute. 78: 279-297.

Concon JM (1988). Food Toxicology: Contaminants and Additives, New York, Marcel Dekker. pp:1371

CSAE (Central Statistical Agency of Ethiopia), 2005. Census preliminary pdf-file.

D'Mello J PF (2003). Food safety: Contaminants and Toxins. CABI Publishing, Wallingford, Oxon, UK,Cambridge, MA. p. 480.

Dass P, Samantaray S, Rout GR (1997). Studies on cadmium toxicity in plants: A review. Environmental Pollution. 98:29-36.

Divrikli U, Horzum N, Soylak M, Elci L (2006). Trace heavy metal contents of some spices and herbal plants from western Anatolia, Turkey. Int. J. Food Sci. Technol. 41: 712-716

FAO/WHO (2001). Food additives and contaminants, Joint *codex alimentarius* commission, FAO/WHO. Food standards program, ALINORM 01/12A.

Farooq M, Farooq A, and Umer R (2008). Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area. Pak. J. Bot. 40 (5):2099-2106

Fisseha I (1998). Metal concentrations of some vegetables irrigated with industrial liquid waste at Akaki, Ethiopia. Ethiop. J. Sci. 21(1):133-144.

Girma T (2001). Land degradation: A challenge to Ethiopia. Environmental Management 27:815-824.

He Z, Jiangchuan L, Haiyan Z, Ma M (2005). Different effects of calcium and lanthanum on the expression of phytochelatin synthase gene and cadmium absorption in *lactuca sativa*. Plant Science, 168:309-318.

Ikeda M, Zhang ZW, Shimbo S, Watanabe T, Nakatsuka H, Moon CS, Matsuda- Inoguchi, N and Higashikawa K (2000). Urban population exposure to lead and cadmium in east and south-east Asia. Science of the Total Environment 249:373-384.

IWMI (2006). Recycling realities: Managing health risks to make wastewater an asset, IWMI, issue 17 papers prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29August 1, 2007.

Kumar A, Sharma IK, Sharma A, Varshneg S and Verma PS (2009). Heavy metal contamination of vegetable foodstuffs in Jaipur (India). Electro. J. Environ. Agric. food chem. 8(2):96-101

Lenntech (2006). Water treatment and air purification: http://www.lenntech.com/heavy-metals.htm; accessed on January 23, 2006

Maleki A, Zarasvand MA (2008). Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, Iran. Southeast Asian J. Trop. Med. Public health 39:335-340

Muchuweti M, Birkett JW, Chinyanga E, Zvauya R, Scrimshaw MD and Lester JN (2006). Heavy metal content of vegetables irrigated with mixture of wastewater and ewage sludge in Zimbabwe: implications for human health. Agriculture. Ecosystem and Environment 112:41-48.

Mumba PP, Chibambo BQ Kadewa W (2008). A comparison of the levels of heavy metals in cabbages irrigated with reservoir and tap water. Int. J. Environ. Resour. 2(1): 61-64.

MWEE (2010). Water quality management. Addis Ababa, Ethiopia. Qadir M, Wichelns D, Raschid-Sally L, Minhas PS, Drechsel P, Bahri A, McCornick P (2007a). Agricultural use of marginal quality water opportunities and challenges. Comprehensive assessment of water. Management in Agriculture. Mc Grow Hill, New York. 3:567-70.

Rahlenbeck SI, Burberg A and Zimmermann RD (1999). Lead and cadmium in Ethiopian vegetables. Bulletin of Environmental Contamination and Toxicology. 62:30

Sharma RK, Agrawal M and Marshall FM (2006). Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. Bulletin of Environmental Contamination and Toxicology. 77:311-318.

Sharma RK, Agrawal M and Marshall FM (2008a). Heavy metals (Cu, Cd, Zn and Pb) contamination of vegetables in Urban India: a case Study in Varanasi. Environmental Pollution.154:254-263.

Sharma RK, Agrawal M and Marshall FM (2008b). Atmospheric depositions of heavy metals (Cd, Pb, Zn, and Cu) in Varanasi city, India. Environmental Monitoring and Assessment. 142 (1-3):269-278.

Singh S, Kumar M (2006). Heavy metal load of soil, water and vegetables in peri-urban Delhi. Environmental Monitoring and Assessment. 120:71-79.

Sinha S, Gupta AK, Bhatt K, Pandey K, Rai UN and Singh KP (2006). Distribution of metals in the edible plants grown at Jajmau, Kanpur (India) Receiving Treated Tannery Wastewater: Relation with physiochemical properties of the soil. Environmental Monitoring and Assessment.115:1-22.

Subhashini V, Swamy AVVS, Hema Krishna R (2013). Pot Experiment: To study the uptake of zinc by different plant species in artificially contaminated soil. 1(2):27-33.

Tesfamariam T (1989). Water pollution and natural resources degradation. A challenge to Ethiopia Beyen D (ed) , First Natural Resources Conservation Conference,7-8 February ,1989, IAR, Addis Ababa.

Thompson HC, Kelly WC (2003). *Vegetable Crops.* 5th Edn. New Delhi: McGraw Hill Publishing Company Ltd; 199067. Türkdogan MK, Kilicel F, Kara K, Tuncer I, Uygan I. Heavy metals in soil, vegetables and fruit in the endemic upper gastrointestinal cancer region of Turkey. Environ Toxicol Pharmacol., 13(3):175-179.

Weigert P (1991). Metal loads of food of vegetable origin including mushroooms. In: Merian E, ed. Metals and their compounds in the environment: occurrence, analysis and biological relevance. pp. 458-68.

Wong CSC, Li XD, ZhangG, Qi SH and Peng XZ (2003). Atmospheric depositions of heavy metals in the Pearl River Delta, China. *Atmospheric Environment* vol. 37 issue 6 February, pp. 767-776

Zandstra BH, De Kryger TA (2007). Arsenic and lead residues in carrots from foliar applications of monosodium methanearosonate (MSMA): A comparison between mineral and organic soils, or from soil residues. Food Additives Contaminants. 24:34-42.