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Heavy metal accumulation and health risk assessment in wastewater-irrigated urban vegetable farming sites of Addis Ababa, Ethiopia

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Abstract

Background: Wastewater irrigation for vegetable production is a highly prevalent practice in Addis Ababa and a number of articles have been published on wastewater-irrigated soils and vegetables contaminated with heavy metals. However, to the best of our knowledge, an insight into assessment of human health risks associated with the consumption of vegetable crops grown on wastewater-irrigated soils is non-existent in the city. Long-term effect of wastewater irrigation on the build-up of heavy metals in soils and selected vegetable crops in Addis Ababa urban vegetable farming sites (10) was evaluated. By calculating estimated daily intakes (EDIs) and target hazard quotients (THQs) of metals, health risk associated with the consumption of the analyzed vegetables was also evaluated.

Results: The heavy metal concentrations in irrigation water and soils did not exceed the recommended maximum limits (RMLs). Moreover, Cd, Co, Cr, Cu, Ni and Zn concentrations in all analyzed vegetables were lower than the RML standards. In contrast, Pb concentrations were 1.4–3.9 times higher. Results of two way ANOVA test showed that variation in metals concentrations were significant ($p < 0.001$) across farming site, vegetable type and site x vegetable interaction. The EDI and THQ values showed that there would be no potential health risk to local inhabitants due to intake of individual metal if one or more of the analyzed vegetables are consumed. Furthermore, total target hazard quotients (TTHQs) for the combined metals due to all analyzed vegetables were lower than 1, suggesting no potential health risk even to highly exposed local inhabitants.

Conclusions: There is a great respite that toxic metals like Pb and Cd have not posed potential health risk even after long term (more than 50 years) use of this water for irrigation. However, intermittent monitoring of the metals from irrigation water, in soil and crops may be required to follow/prevent their build-up in the food chain.

Keywords: Vegetable farming, Wastewater irrigation, Heavy metal, Health risk, Target hazard quotient, Addis Ababa

Background

Wastewater (untreated, partially treated or diluted) has been widely used for agriculture in most urban and peri-urban cities of developing countries (Scott et al. 2004). Market proximity, high opportunities for income generation, reliable and free irrigation water supply, and minimum artificial fertilizer requirement are the often cited benefits of irrigation within cities (Drechsel et al. 2006; Qadir et al. 2010). However, long-term application of partially treated or untreated wastewater could result in accumulation of heavy metals in the soil (Elgallal et al. 2016). Effluents from household and industries, drainage water, atmospheric deposition, and traffic-related emissions transported with storm water into the sewage and/or irrigation system carry number of pollutants and enrich the urban waste water with heavy metals (Saha et al. 2015; Zia et al. 2016; Woldetsadik et al. 2017). The consumption of food crops grown in wastewater-irrigated areas is one of the principal factor contributing human exposure to

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pathogens. In addition, the cultivation of crops for human consumption on wastewater-irrigated soil can potentially lead to the uptake and accumulation of trace metals in the edible plant parts resulting potential risk to human (Rattan et al. 2005; Xue et al. 2012; Ahmad et al. 2016; Zia et al. 2016). Heavy metals are very harmful because of their non-biodggrdable nature, long half-lives and their high bioaccumulation potential (Duruibe et al. 2007; Shah et al. 2012). Several researchers reported that serious health problems may develop as a result of excessive accumulation of heavy metals and even essential trace elements such as Cu and Zn in human body (Oliver 1997; Jarup 2003; Kabata-Pendias and Mukherjee 2007; Luo et al. 2011; Khan et al. 2015).

The increase of 'wastewater irrigation' is however in most cases not farmers' choice (Raschid-Sally and Jayakody 2008). In Africa, the number of people without access to adequate water and sanitation facilities has risen swiftly in recent decades as the continent's rapid urbanization outpaced its capacity to provide the essential water and sanitation services. In Addis Ababa, large volumes of untreated water are released to water bodies which farmers use for irrigation (Weldesilassie et al. 2011a, 2011b). According to Nuttal N. Fast pace of African urbanization affecting water supplies and sanitation. United Nations Environment Program and March 21 (2011)), not only liquid waste provides a challenge, but also solid waste dumped along Addis Ababa main river, near bridges and shores of small tributaries where it is washed into the river. Despite all potential risks, irrigated farming of high value crops is livelihood to many urban residents since it provides employment and income (Weldesilassie et al. 2009). About, 60% of the city's vegetable consumption, particularly leafy vegetables, is supplied by urban farmers who irrigate their crops using polluted river water (Nuttal N. Fast pace of African urbanization affecting water supplies and sanitation. United Nations Environment Program and March 21 2011).

Wastewater irrigation for vegetable production is a highly prevalent practice in the city and a number of articles have been published on wastewater-irrigated soils and vegetables contaminated with heavy metals starting from the 90′s (Itanna 1998, 2002; Alemayehu 2006; Weldegebriel et al. 2012; Aschale et al. 2015; Mekonnen et al. 2015). However, to the best of our knowledge, an insight into assessment of human health risks associated with the consumption of vegetable crops grown on wastewater-irrigated soils is non-existent. It has, for instance, been concluded from the data of heavy metal concentrations in vegetable crops on human health risk without analyzing the pattern for dietary intakes of these metals (Weldegebriel et al. 2012; Aschale et al. 2015). However, information about dietary intake of metals is equally important for assessing their potential risk to human health. Within this context our study tried to quantify the concentrations of heavy metals in irrigation water, soils and selected vegetables on a representative range of Addis Ababa's urban vegetable farming sites and estimate daily intake and target hazard quotient (THQ) of heavy metals through consumption of these vegetables.

Methods

Study area

This study was conducted in Addis Ababa, Ethiopia, where urban farmers have been practicing vegetable production at various urban farming sites along the Akaki River ('Tinishu' and 'Teleku' Akaki Rivers). The practice has been started in late 1940s. There are two form vegetable production: producers' cooperatives and individual bases. Currently, more than 800 ha of land are irrigated for vegetable production using water from the Akaki River (Weldesilassie and Nigussie 2011). The areas covered are ten prominent vegetable farming sites, locally known as Sore Amba, Lekunda, Peacock-Urael, Peacock-Bole, Kera, Mekanissa, Lafto, Hana-Mariam, Akaki 08, Akaki (Fig. 1) located at five sub-city administrative areas: Kolfe Keraniyo, Chirkos, Bole, Nefas Silk Lafto and Akaki Kaliti, which lies in 038° 41′ E to 038° 47′ E and 08° 52′ N to 9° 02′ N (Woldetsadik et al. 2017). The streams in consideration are highlighted with blue color.

With the exception of Akaki 08 and Akaki farming sites, at all other sites the manual construction of traditional weirs using sand bags and coarse stones is the most common method to block the water flow till it can enter a system of irrigation channels which follow gravity to support farms further downstream. In these farming sites, vegetable crops, mainly leafy vegetable such as lettuce, Ethiopian Kale and swiss chard, are grown using furrow irrigation method, by manually opening and closing furrows constructed within the farms. In addition to furrow irrigation technique, flood irrigation, by which fields are flooded in a controlled manner by manually opening and closing of a bund, is also used at Sore Amba, Lekunda, Peacock- Urael, and Peacock-Bole farming sites. At Akaki 08 and Akaki farming sites, the vast majorities of farmers use diesel motor pumps to extract water directly from the river and transport to farm using connected plastic pipes. Some farmers at Lafto farming sites also follow similar water extraction methods (Woldetsadik et al. 2017). Lettuce, swiss chard and Ethiopian kale were selected for this study since they are the major vegetable crops grown in the study sites.

Sample collection and preparation

At all farming sites, irrigation water was collected at a point where farmers fetch/collect, or where it enters the

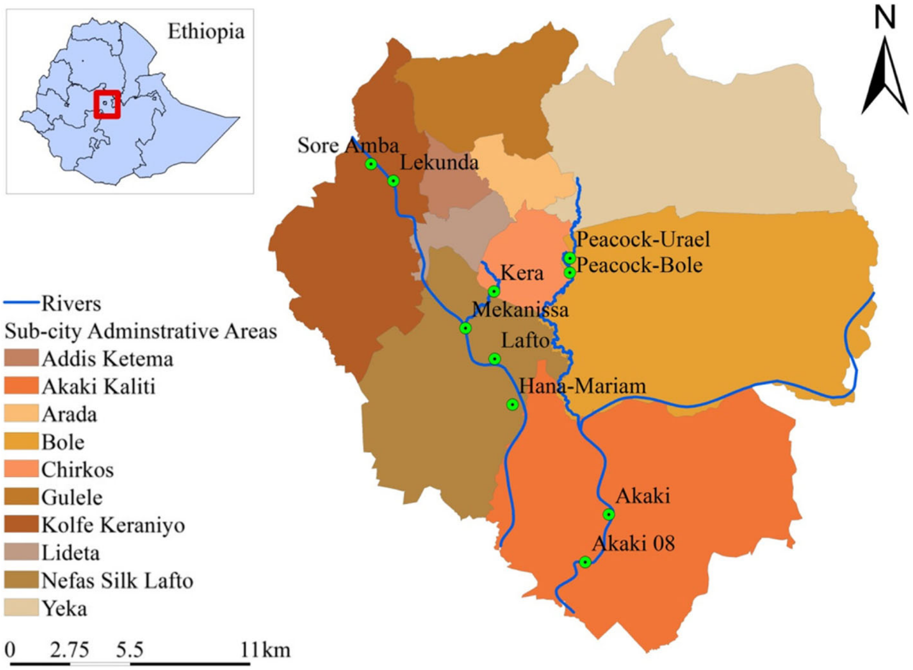

Fig. 1 Map of the sampling sites

farm via canals. From each site, quadruplicate composite samples from 4 different fetching points/inlets to farm were collected in 500 ml plastic bottles, pre-treated with 5 ml of concentrated HNO_3 to prevent microbial degradation of heavy metals, and transported in an icebox to laboratory where they were stored at 4 °C until analysis. So a total of 40 irrigation water samples were collected.

At each farming site, 4 different farmers vegetable farms were selected based on the type of vegetables they grow. From each vegetable farm, 15 surface subsamples (0–20 cm) (3 plots per farm * 5 subsamples from each plot) were collected and made into a single composite sample. So a total of 4 composite soil samples were made per farming site and packed into polyethylene bags and then transported to the laboratory for preparation. The samples were air-dried, passed through a 2 mm sieve and then put into zipped lock polyethylene bags and stored at ambient temperature before further analysis.

Standing vegetable samples (*Lactuca sativa var. crispa*, *Brassica carinata A. Br.* and *Beta Vulgaris var. cicla*) were also collected from the same vegetable farms where soils were collected. The same sampling technique was followed except only 6 subsamples (for each vegetable type) were used to prepare the composite samples in case of vegetables. A total 120 composite samples (10 farming sites * 3 vegetables * 4 composite samples) were collected, packed into polyethylene bags and transported to the laboratory. Vegetable samples were properly washed with deionized water to remove all visible soil particles. After removing the extra water from the surface of vegetables, the samples were then cut into pieces with a knife. All the samples were then oven-dried at 80 °C for 48 hours. Dried samples were powdered using a pestle and mortar.

Analyses

Fifty ml of water sample was digested with HNO_3 (10 ml) (APHA 2005). After cooling, the digested sample was filtered and the digest was maintained to 50 ml with distilled water. The digest was analyzed for heavy metals with Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS, Thermo Scientific, USA).

Soil particle size distribution was determined by hydrometer method (Gee and Bauder 1986). Soil pH (McLean 1982) was determined from a suspension of 1: 2.5 of soil: water ratio. The cation exchange capacity was determined by leaching method with ammonium acetate solution (1 M NH_4OAc). The organic carbon was determined by dichromate oxidation method and subsequent titration with ferrous ammonium sulphate (Walkley and Black 1934). Soil organic matter (OM) was calculated by multiplying soil organic carbon by 1.724 assuming that average C concentration of organic matter is 58%. For heavy metal analysis of soil, 0.25 g of samples were placed into 50 ml vessels, followed by addition of 10 ml concentrated HNO_3. The mixtures were left to cold digest in a fume cupboard over night and then heated in 1.6 KW microwave oven for 30 min. After cooling to room temperature, 10 ml of double distilled water was added into the vessel and filtered via a 0.45 μm cellulose nitrate filter paper. Finally, the filtrate was subjected to the total element analysis using ICP-OES (Ciros CCD, SPECTRO Analytical Instruments GmbH, Kleve, Germany).

Nitric acid and H_2O_2 has been used to digest the vegetable samples, 1 g of ground vegetable sample was digested with 5 ml of nitric acid and 3 ml of hydrogen peroxide. The extract was filtered, insolubles were removed and finally the volume was made up to 50 ml with distilled water. The concentration of heavy metals (Pb, Cd, Cu and Co) in the filtrate was determined using Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS, Thermo Scientific, USA).

Data analysis

Estimated daily intake (EDI) of heavy metals

The estimated daily intake (EDI) of heavy metals was determined based on both the metal levels in crops and the amount of consumption of the respective food crop. The EDI of metals was evaluated according to the average concentrations of each metal in each food crops and the respective daily consumption rate (Zhuang et al. 2009). The EDI of the metals for adults was determined by the following equation:

$$\mathrm{EDI} = C_{\mathrm{metal}} \mathrm{x}\ W_{\mathrm{food}}/B_{\mathrm{w}}$$

Where C_{metal} is the concentration of heavy metals in vegetable crops; W_{food} represents the daily average consumption of crops in the 5 sub-city administrative areas and B_w is the body weight. A short survey was undertaken to assess vegetable intake patterns of adults and understand how green salads are commonly washed at home. This short survey was carried out in 5 sub-city administrative areas (Kolfe Keraniyo, Chirkos, Bole, Nefas Silk Lafto and Akaki Kaliti). Questionnaire interview were administered to gather information on daily intake pattern of selected leafy vegetables and common washing methods used before serving salad (Woldetsadik et al. 2017). A total of 200 adults were involved in the survey. The minimum and maximum age and body weight record in the questionnaire survey for adults were 18–73 years and 42–84 kg, respectively. Based on the results, the average daily vegetables intakes for adults ranged from 11.9 to 16.3, 27.4 to 36.7 and 22.3 to 37.2 g day^{-1} for *Lactuca sativa var. crispa*, *Brassica carinata A. Br.*and *Beta Vulgaris var. cicla*, respectively. The conversion factor to convert fresh green vegetable weights to dry weights was 0.085 (Zhuang et al. 2009). The metal intakes were compared with the tolerable daily intakes of metals recommended by WHO (1993).

Target hazard quotient (THQ)

The health risks to local inhabitants associated with the intake of Cd, Cu, Ni, Co, Pb, Zn and Cr through the consumptions of wastewater-irrigated vegetables (*Lactuca sativa var. crispa*, *Brassica carinata A. Br.* and *Beta Vulgaris var. cicla*) were based on Target Hazard Quotients (THQs). The THQ is a ratio of determined dose of a pollutant to a reference dose level. If the ratio is less than 1, the exposed population is unlikely to experience obvious adverse effects. Non-carcinogenic health risks for humans associated with the consumption of these vegetables were assessed by calculating THQ. The method to estimate THQ was provided in USEPA Region III Risk-Based Concentration Table (USEPA. Integrated Risk Information System-database. Philadelphia PA, Washington 2007) and in Chien et al. (2002) and Zhuang et al. (2009):

$$\mathrm{THQ} = C_n \mathrm{x}\ I\ \mathrm{x}10^{-3} \mathrm{x}\ \mathrm{Efr}\ \mathrm{x}\ \mathrm{ED}/\mathrm{RfD}\ \mathrm{x}\ B_w \mathrm{x}\ \mathrm{AT}$$

where C_n represents the mean metal concentration in a specific vegetable on fresh weight basis (mg kg^{-1}); I is ingestion rate (g person^{-1} d^{-1}); EFr is exposure frequency (365 days year^{-1}); ED is exposure duration (70 years); RfD is the oral reference dose (mg kg^{-1} d^{-1});BW is the average body mass, adult (65 kg); AT is averaging time for noncarcinogens (365 days $\mathrm{year}^{-1}\times$ number of exposure years).

Statistical analysis

Data of heavy metal concentrations in vegetables were checked for homogeneity of variance and normality. The data of heavy metal concentrations in all analyzed vegetables across the various farming sites were subjected to two-way analysis of variance (ANOVA) to assess the significance of differences in heavy metal concentrations by site, vegetable type and their interaction. Pearson correlation analyses were also carried out to assess the relationships of soil and vegetable metal concentrations. All statistical analyses were computed with SPSS software version 16.

Results and discussion

Heavy metals in irrigation water

Mean concentrations of selected heavy metals in irrigation water samples collected from various urban farming sites of Addis Ababa are given in Table 1. Across the ten sampling sites, the metals concentrations were far below the recommended maximum limit for irrigation water set by FAO (Ayers and Westcot 1985). The mean concentrations of Cd, Co, Cr, Cu, Ni, Pb and Zn were 3.54–58.8, 2.11–13.6, 2.26–6.74, 2.78–29.3, 3.71–33.5, 105–938 and 17.8–48.8 times below the recommended maximum limit. As compared to the concentrations reported in the present study, Aschale et al. (2015)) reported lower mean ranges of Cd (0.04–0.06 μg L^{-1}), Co (2.1–2.7 μg L^{-1}), Cu (3.3–6.6), Ni (3.9–6.5 μg L^{-1}), Pb (1.4–5.1 μg L^{-1}) and Zn (10.9–22.5 μg L^{-1}) but higher mean range of Cr (2.4–255 μg L^{-1}) in irrigation water samples of the same vegetable farming sites. Similarly,

Table 1 Mean heavy metal concentration of irrigation water of Addis Ababa vegetable farming sites

Site	Total concentration (μg L^{-1})						
	Cd	Co	Cr	Cu	Ni	Pb	Zn
Sora Amba	0.43(0.05)	3.68(0.72)	17.7(2.27)	6.83(1.08)	11.5(2.08)	5.33(0.96)	40.9(6.35)
Lekunda	0.80(0.07)	14.6(1.55)	29.3(3.41)	38.6(3.62)	16.2(2.25)	21.8(2.28)	58.5(5.09)
Peacock-Urael	0.37(0.06)	7.28(0.92)	8.53(1.08)	30.7(3.42)	24.4(2.56)	6.82(0.58)	49.7(4.79)
Peacock-Bole	0.17(0.05)	5.48(0.94)	3.09(0.51)	8.04(1.31)	5.97(0.86)	13.8(3.06)	54.0(5.78)
Kera	2.82(0.62)	16.3(2.37)	44.2(6.38)	71.5(6.73)	29.6(3.55)	47.7(4.98)	88.4(12.9)
Mekanissa	0.81(0.05)	8.73(1.35)	19.8(2.75)	27.7(3.39)	53.9(5.50)	9.48(1.93)	112(16.4)
Lafto	1.48(0.26)	21.6(3.64)	14.2(1.15)	78.3(8.32)	36.5(3.68)	36.9(2.75)	56.9(5.12)
Hana-Mariam	1.05(0.25)	23.7(3.00)	35.1(4.92)	17.7(2.73)	9.48(1.90)	19.4(2.02)	69.6(2.45)
Akaki08	0.57(0.04)	3.38(0.64)	24.4(3.09)	49.2(6.22)	16.2(2.67)	18.6(2.32)	62.8(6.13)
Akaki	0.33(0.04)	5.57(0.47)	14.8(2.69)	36.1(4.10)	8.44(1.76)	16.8(2.00)	44.8(4.03)
RML (μg L^{-1})	10	50	100	200	200	5000	2000

Figures in parentheses represent standard deviation
RML Recommended Maximum Limit for irrigation water by FAO (Ayers and Westcot 1985)

Alemayehu (2006) reported lower levels of Cd, Co, Cr, Cu, Ni and Zn in Akaki river/irrigation water. As a consequence of very few localized industrial activities and the dilution of wastewater with stream water, low levels of metals in irrigation water samples were recorded. Furthermore, wastewater discharged into the river and irrigation canals are more of domestic origins. Related study in Accra has shown similar phenomena. Unlike the usual trends of observing low levels of metals in irrigation water of Addis Ababa's urban vegetable farming sites (Itanna 1998; Alemayehu 2006; Aschale et al. 2015), Weldegebriel et al. (2012) have reported Cd, Co, Cu, Ni and Zn concentrations as high as 33 μg L^{-1}, 626 μg L^{-1}, 370 μg L^{-1}, 216 μg L^{-1} and 618 μg L^{-1}, respectively. Despite the low levels of metals in diluted wastewater, continuous use of this water for irrigation could contribute the accumulation of metals into the soil.

Heavy metals in soils

The physico-chemical parameters determined for wastewater irrigated soils in urban vegetable farming sites of Addis Ababa are listed in Table 2. Across the vegetable farming sites, the mean values of soil pH varied from 5.99 to 7.16. The mean organic matter content was highest at Sore Amba (4.6%) followed by Lekunda (4.1%), Mekanissa (3.8%) and lowest in soils from Akaki (2.6%). The CEC value was highest in soils of Akaki 08 (54.5). As compared to other vegetable farming sites, the lowest CEC value (34.9) was exhibited from soils of Peacock-Urael. The CEC results concurred the findings of Weldegebriel et al. (2012). The mean clay content ranged between 34.8 and 60.2%, with the highest and lowest at Sore Amba and Peacock-Urael sites, respectively. The mean Cd, Co, Cr, Cu, Ni, Pb and Zn concentrations in soils from the sampling areas ranged 0.95–3.61, 28.6–58.6, 55.9–140, 24.2–51.6, 31.5–61.7, 22.1–107 and 119–203, respectively. With the exception of Mean Cr(140 mg kg^{-1}) at Lekunda, Ni(61.7 mg kg^{-1}) at Kera, Cd (3.61 mg kg^{-1}), Pb (107 mg kg^{-1}) and Zn(203 mg kg^{-1}) at Lafto, the mean concentrations of the metals in soils of the studied sites were below the threshold levels for agricultural soils. For sewage-irrigated site (Lafto), greater levels of metals were observed than those sites having no specific application of sewage. But even the upper limits of the metal concentrations (Co, Cr, Cu and Ni) were below the maximum threshold levels. The mean levels of Cd, Co, Cu, Ni, Pb and Zn recorded during the present study were comparable or slightly higher than those reported in previous studies (Itanna 1998, 2002; Weldegebriel et al. 2012; Aschale et al. 2015). In the studied sites, the soils had been irrigated by wastewater for more than 60 years, which showed higher or comparable levels of metals compared to wastewater-irrigated agricultural soils in other African (Mapanda et al. 2005; Lente et al. 2012) and Asian cities (Ahmad et al. 2016; Xue et al. 2012). Conversely, others reported high levels of heavy metals in soils under wastewater cropping system, e.g. in Kolkata city, India (Saha et al. 2015) and Beijing city, China (Liu et al. 2005). High metal levels were also obtained in soils irrigated with wastewater in Harare, Zimbabwe (Muchuweti et al. 2006). However, periodic monitoring of mobile fractions of metals, together with physico-chemical properties of soils and agricultural practices, is required to prevent excessive uptake by vegetable crops.

Heavy metals in vegetables

Concentrations of heavy metals in edible parts of the analyzed vegetables are summarized in Table 3. Mean Cd concentrations were highest in vegetables harvested from Kera and Lafto farming sites, with levels ranging

Table 2 Physicochemical characteristics of soils irrigated with wastewater in urban vegetable farming sites

Total concentration (mg kg^{-1})								pH (H_2O)	OM(%)	CEC(cmol$_{(+)}$kg^{-1})	Particle size		
Site	Cd	Co	Cr	Cu	Ni	Pb	Zn				Sand	Silt	Clay
Sora Amba	0.95(0.17)	28.6(2.14)	94.0(14.5)	24.2(1.57)	31.5(2.62)	22.1(1.87)	119(14.2)	6.51	4.6	42.9	11.8	28	60.2
Lekunda	2.72(0.20)	43.7(2.37)	140(10.3)	30.7(4.91)	60.3(4.10)	36.7(4.40)	150(12.1)	6.59	4.14	39.7	17.2	34.3	48.5
Peacock-Urael	2.58(0.21)	38.8(2.43)	67.4(3.42)	27.4(2.89)	46.2(2.50)	27.8(2.87)	157(6.41)	6.8	3.3	34.9	15	50.2	34.8
Peacock-Bole	1.55(0.10)	37.1(1.83)	55.9(6.52)	28.5(2.35)	46.0(3.99)	25.8(3.60)	120(9.69)	7.16	2.92	39.6	23.8	27	49.2
Kera	2.95(0.42)	58.6(3.74)	76.3(6.74)	49.9(6.20)	61.7(9.15)	81.1(10.9)	160(8.35)	6.11	3.22	43.9	16.7	43.3	40
Mekanissa	2.27(0.31)	38.6(3.58)	61.6(7.32)	43.3(4.41)	48.7(4.75)	29.6(3.59)	145(26.4)	6.57	3.79	39.5	25	31.2	43.8
Lafto	3.61(0.38)	44.9(3.15)	78.0(10.4)	51.6(8.26)	49.1(6.21)	107(10.7)	203(19.5)	5.99	3.62	44.7	16.8	42.5	40.7
Hana-Mariam	1.37(0.20)	28.8(3.27)	56.3(2.52)	38.3(4.92)	39.9(4.85)	33.1(1.88)	130(16.6)	6.63	3.06	40.3	23.2	25	51.8
Akaki08	1.99(0.24)	40.5(3.75)	66.2(5.26)	32.3(4.53)	43.8(5.97)	42.1(1.67)	156(10.2)	7.1	2.88	54.5	15.5	27.3	57.2
Akaki	1.19(0.27)	43.4(2.38)	69.1(8.51)	27.9(1.59)	46.6(3.27)	35.9(5.22)	154(28.1)	6.93	2.6	49.1	17.7	28.5	53.8
RML [a](mg kg^{-1})	3	50	100	100	50	100	300						

Figures in parentheses represent standard deviation

[a] Source: Ewers 1991

Table 3 Metal concentrations in vegetables grown in wastewater-irrigated urban farming sites

Site	Vegetable	Mean concentration (mg kg^{-1})						
		Cd	Co	Cr	Cu	Ni	Pb	Zn
Sora Amba	*Lactuca sativa var. crispa*	0.54(0.06)	0.42(0.08)	5.28(0.50)	23.9(0.69)	3.49(0.40)	10.5(0.88)	57.7(8.91)
	Brassica carinata A. Br.	0.34(0.03)	0.32(0.03)	4.47(0.71)	12.0(1.26)	3.13(0.50)	7.16(1.03)	80.2(16.6)
	Beta Vulgaris var. cicla	0.39(0.05)	0.54(0.08)	2.85(0.33)	17.0(1.16)	5.94(0.36)	8.63(0.74)	84.8(9.21)
Lekunda	*Lactuca sativa var. crispa*	0.73(0.11)	0.70(0.07)	6.29(0.63)	34.3(1.54)	5.44(0.59)	10.7(0.82)	87.1(10.7)
	Brassica carinata A. Br.	0.45(0.11)	0.51(0.10)	3.11(0.54)	16.0(1.82)	2.87(0.49)	6.52(0.68)	76.8(5.32)
	Beta Vulgaris var. cicla	0.62(0.08)	0.91(0.06)	3.81(0.30)	38.9(1.42)	4.92(0.37)	12.6(1.50)	105(8.26)
Peacock-Urael	*Lactuca sativa var. crispa*	0.56(0.11)	0.48(0.12)	2.38(0.18)	13.7(1.02)	3.28(0.46)	8.88(0.95)	63.4(5.22)
	Brassica carinata A. Br.	0.53(0.20)	0.65(0.12)	1.56(0.14)	14.5(1.24)	2.78(0.42)	6.12(0.83)	89.6(10.2)
	Beta Vulgaris var. cicla	0.76(0.11)	0.76(0.04)	2.36(0.22)	24.3(1.06)	5.24(0.52)	9.79(0.83)	87.0(8.70)
Peacock-Bole	*Lactuca sativa var. crispa*	0.40(0.10)	0.53(0.07)	3.08(0.10)	23.2(1.03)	5.21(0.55)	12.9(0.61)	56.9(3.90)
	Brassica carinata A. Br.	0.35(0.04)	0.52(0.12)	1.17(0.20)	21.4(1.24)	3.01(0.53)	7.90(0.88)	66.3(6.12)
	Beta Vulgaris var. cicla	0.31(0.01)	0.59(0.05)	3.43(0.36)	23.6(1.74)	4.54(0.39)	13.2(0.96)	82.5(7.70)
Kera	*Lactuca sativa var. crispa*	1.59(0.13)	0.81(0.06)	8.01(0.60)	36.2(1.67)	2.78(0.31)	12.7(0.87)	94.4(11.6)
	Brassica carinata A. Br.	0.87(0.12)	0.78(0.07)	4.06(0.68)	21.5(1.54)	2.34(0.42)	8.57(0.63)	105(9.80)
	Beta Vulgaris var. cicla	1.09(0.11)	1.23(0.16)	5.53(0.79)	25.1(1.83)	4.12(0.29)	15.9(0.90)	129(10.2)
Mekanissa	*Lactuca sativa var. crispa*	0.78(0.08)	1.45(0.08)	5.07(0.67)	31.0(8.32)	7.86(0.58)	9.22(1.57)	67.7(4.93)
	Brassica carinata A. Br.	0.71(0.13)	0.63(0.08)	6.32(0.68)	15.5(1.44)	4.00(0.34)	6.74(1.20)	91.3(9.22)
	Beta Vulgaris var. cicla	0.86(0.07)	1.86(0.17)	6.21(0.55)	31.3(3.73)	6.67(0.55)	8.79(1.31)	78.9(11.5)
Lafto	*Lactuca sativa var. crispa*	1.79(0.12)	1.30(0.15)	6.95(0.32)	35.0(1.30)	4.30(0.56)	8.46(1.47)	82.5(10.9)
	Brassica carinata A. Br.	1.17(0.06)	0.71(0.10)	6.57(0.42)	27.8(2.58)	5.19(0.71)	9.50(1.57)	109(11.9)
	Beta Vulgaris var. cicla	1.65(0.09)	1.61(0.07)	7.62(0.48)	37.1(4.08)	7.99(0.84)	13.8(1.37)	117(9.42)
Hana-Mariam	*Lactuca sativa var. crispa*	0.49(0.15)	0.91(0.05)	5.40(0.80)	20.9(1.18)	7.08(0.41)	9.14(1.56)	72.2(7.84)
	Brassica carinata A. Br.	0.44(0.09)	0.78(0.07)	2.09(0.38)	17.4(1.09)	3.78(0.32)	4.14(0.50)	85.5(9.95)
	Beta Vulgaris var. cicla	0.68(0.12)	1.83(0.16)	4.58(0.35)	30.3(1.14)	10.3(0.66)	7.19(1.66)	77.7(11.7)
Akaki08	*Lactuca sativa var. crispa*	0.80(0.17)	0.78(0.08)	2.88(0.28)	24.7(1.36)	5.30(0.39)	9.23(0.65)	67.6(5.01)
	Brassica carinata A. Br.	0.39(0.08)	0.70(0.10)	5.13(0.80)	22.9(1.50)	3.14(0.21)	4.95(0.78)	84.1(6.82)
	Beta Vulgaris var. cicla	0.58(0.09)	1.47(0.10)	3.93(0.39)	44.3(4.44)	6.40(0.47)	8.61(1.80)	98.9(5.81)
Akaki	*Lactuca sativa var. crispa*	1.05(0.14)	0.94(0.12)	5.39(0.62)	19.6(1.83)	4.42(0.92)	6.92(1.18)	79.8(8.87)
	Brassica carinata A. Br.	0.72(0.09)	0.73(0.11)	3.92(0.58)	13.3(1.00)	3.29(0.33)	4.84(0.53)	92.6(9.34)
	Beta Vulgaris var. cicla	0.71(0.11)	1.18(0.14)	3.89(0.15)	34.2(4.23)	5.98(0.68)	11.8(1.04)	87.5(9.46)
RML (mg kg^{-1} dry weight)		2.35[a]	50[b]	27.1[c]	235[d]	800[d]	3.53[a]	588[d]

RML; 0.085 was taken as conversion factor, to convert fresh green vegetable weight to dry weight (Qureshi et al. 2016)

Sources: [a](FAO/WHO-codex alimentarius commission 2001; EC 2006)

[b](Pendias and Pendias 1992)

[c](Weigert 1991)

[d](Mapanda et al. (2007) based on UK and FAO/WHO standards)

Figures in parentheses represent standard deviation

from 0.87 mg kg^{-1} (*Brassica carinata A. Br.*) to 1.79 mg kg^{-1} (*Lactuca sativa var. crispa*) dry weights. But even the highest concentrations did not exceed the RML standard. The high accumulation of Cd in vegetables at the two sites may be attributed to the acidic nature of the soils (Table 2), resulting in greater Cd availability (Kachenko and Singh 2006). This was further supported by the significant correlations ($p = 0.696$–0.748) of vegetable Cd concentrations with soil Cd. Higher Cd levels which surpassed the recommended maximum limit were reported by Weldegebriel et al. (2012) in vegetables harvested from Kera and Goffa urban vegetable farming sites. Conversely, lower levels of Cd in vegetables at various vegetable farming sites of Addis Ababa were reported by Aschale et al. (2015) and Mekonnen et al. (2015). Cadmium levels exceeding the

RMLs were reported by Mapanda et al. (2007) and Gupta et al. (2010). Similar high level was also found in Radish (Bigdeli and Seilsepour 2008). Results of two way ANOVA test showed that variation in Cd concentrations were significant across farming site, vegetable type and site x vegetable interaction (Table 4). Among the analyzed vegetables, Cd accumulation was significantly high ($p < 0.05$) in *Lactuca sativa var. crispa*. As a result, we emphasize the differences in physiology of metal uptake, exclusion, accumulation, as well as foliage deposition and retention (Zurera et al. 1987; Cui et al. 2004; Zia et al. 2016).

The results obtained in the present study showed that the concentrations of Co in the vegetables were between 0.32 and 1.86 mg kg^{-1} DW (Table 3), the lowest concentration was found in *Brassica carinata A. Br.* and highest in *Beta Vulgaris var. cicla.* The concentrations were substantially lower than its RML. Yet, there were significant differences in Co concentrations in the analyzed vegetable ($p < 0.05$). Among the metals under the consideration of the present study, Co showed minimum in all vegetables next to Cd. Weldegebriel et al. (2012), Aschale et al. (2015) and Mekonnen et al. (2015) have also found lowest concentrations of Co as compared to Cr, Cu, Mn, Ni, Pb and Zn. In the analyzed vegetables, concentrations of Cr were substantially lower than the RML standard. Mean Cr concentrations among vegetable crops was in the order of *Lactuca sativa var. crispa* > *Beta Vulgaris var. cicla* > *Brassica carinata A. Br.*. The observed mean (overall) Cr concentrations were 5.1, 3.84 and 4.42 mg kg^{-1} in *Lactuca sativa var. crispa*, *Brassica carinata A. Br.*, *Beta Vulgaris var. cicla*, respectively. Similar low levels were also obtained in previous studies (Itanna 1998; Liu et al. 2005; Aschale et al. 2015; Mekonnen et al. 2015; Zia et al. 2016;). The two way ANOVA test revealed significant differences by farming site, vegetable type and their interaction (Table 4).

Mean concentrations of Cu in vegetables across the 10 vegetable farming sites were varied and all below the RML standard (Table 3). At Lekunda, the concentrations ranged from 16.0 (*Brassica carinata A. Br.*) to 38.9 (*Beta Vulgaris var. cicla*) mg kg^{-1}, in Kera farming site they ranged from 21.5 (*Brassica carinata A. Br.*) to 36.2 (*Lactuca sativa var. crispa*) mg kg^{-1} and in Akaki 08 they ranged from 22.9 (*Brassica carinata A. Br.*) to 44.3 (*Beta Vulgaris var. cicla*) mg kg^{-1} dry weights. An earlier study by Weldegebriel et al. (2012) in vegetable farming site around Goffa showed concentration of Cu in *Lactuca sativa* that were twice that of those sampled in the present study. Lower concentrations of Cu in various vegetables were also reported in selected vegetable farming sites in Addis Ababa and its outskirts (Aschale et al. 2015; Mekonnen et al. 2015). Studies in other African cities have shown varied results but all substantially below the RML standard. In Harare, Muchuweti et al. (2006) showed elevated levels of Cu in various crops while Lente et al. (2012) in Accra and Mapanda et al. (2007) in Harare showed lower concentrations. Similarly, concentrations of Ni were substantially lower than the RML standard. When the concentrations of Ni in *Lactuca sativa* grown at wastewater -irrigated sites of Addis Ababa, Ethiopia (Aschale et al. 2015) were compared with the values recorded in the present study, the values of the previous study were 2–4 fold lower. Similar lower results were obtained in Accra (Lente et al. 2012) and Varanasi, India (Ghosh et al. 2012).

Table 4 Results of two way ANOVA test for heavy metal levels in vegetables harvested from wastewater-irrigated urban vegetable farming sites

Heavy metals	Farming site	Vegetables	Site x vegetable
Cd	138.56***	67.17***	7.75***
Co	107.86***	330.23***	21.32***
Cr	100.90***	56.60***	19.73***
Cu	54.79***	250.25***	20.44***
Ni	66.08***	313.59***	17.60***
Pb	32.05***	168.79***	7.67***
Zn	22.61***	59.37***	3.36***

***Level of significance: $p < 0.001$

Despite the relatively low analyzed Pb concentrations in water and soil, marked differences were observed for Pb accumulation in the leaves of the analyzed vegetables, which exceeded 1.4–3.9 times the RML standard of the respective crops. This confirms the Pb levels of vegetables analyzed previously in Addis Ababa's urban vegetable farming sites (Weldegebriel et al. 2012) and with results reported from other African cities (Muchuweti et al. 2006; Odai et al. 2008; Lente et al. 2012). According to Hamilton et al. (2005), plant roots can adsorb Pb but may not translocate it to shoots, a possibility is that like in Ghana, high Pb levels on wastewater as well as control sites (groundwater irrigated urban farms) are attributable more to vehicular exhaust fumes (Affum et al. 2008) than to irrigation water. In fact, high soil pH, clay and organic matter content are not supporting Pb uptake via roots. On the other hand, Kylander et al. (2003) analyzed in Accra a Pb distribution following traffic density as also shown in other studies (Baye and Hymete 2010; Osma et al. 2013; Teju et al. 2012). Since lead is not biodegradable, and highly immobile, once soil has become contaminated, it remains a long-term source of dust exposure, although lead-free gasoline dominates today's market. This finding showed that the washing of leaves before analysis requires more attention, and has to go beyond the removal of visible dust particles.

Zinc accumulation varied in the vegetables across the 10 farming sites, from 57.7 for *Lactuca sativa var. crispa* and 129 mg kg^{-1} for *Beta Vulgaris var. cicla*. The values were 4.55–10.2 times lower than the RML standard. Zinc concentrations in Kera farming site were consistently higher than vegetables sampled over all other farming sites, ranging from 94.4 (*Lactuca sativa var. crispa*) and 129 (*Beta Vulgaris var. cicla*) mg kg^{-1} dry weights. In general, the level of metal accumulation in *Beta Vulgaris var. cicla* was higher than the other vegetables. Briefly, *Beta Vulgaris var. cicla* accumulated significantly ($p < 0.05$) higher levels of Co, Cu, Ni, Pb and Zn, while *Lactuca sativa var. crispa* exhibited significantly ($p < 0.05$) higher levels of Cd and Cr.

Daily intake of metals and target hazard quotient

The estimated daily intakes (EDIs) of metals for adults in wastewater -irrigated vegetable farming sites at 5 sub-city administrative areas via the consumption of leafy vegetable are presented in Table 5. The provisional tolerable daily intakes (PTDIs) for Cd, Cr, Cu, Ni, Pb and Zn are 0.06 mg, 0.2 mg, 3 mg, 0.3 mg, 0.214 mg and 60 mg, respectively (National Research Council 1989). For each individual metal measured in the present study, none of the EDIs exceeded its corresponding PTDIs, nor did approach the doses. The highest EDI of Cd (0.122 μg d^{-1}) through the consumption of the analyzed vegetables was from Nefas Silk Lafto sub-city administrative area. The EDIs of Cd for Selected sub-city administrative areas in Addis Ababa (0.046–0.122 μg d^{-1}) were substantially lower than the values reported for other countries: Tanzania (21.6 μg d^{-1}) (Bahemuka and Mubofu 1999), China (59 μg d^{-1}) (Zhuang et al. 2009), Pakistan (5.29 μg d^{-1}) (Mahmood and Malik 2014) and India (32 μg d^{-1}) (Chopra and Pathak 2015). This discrepancy could be partly attributed to others (Bahemuka and Mubofu 1999; Zhuang et al. 2009; Mahmood and Malik 2014; Chopra and Pathak 2015) analyzing more vegetable types than we did in the present study. The present study showed that the contribution of these vegetables to the daily intake of Cd was less than 0.3% of its corresponding PTDI. It is, however, worth considering the contribution other food groups to Cd or other metals dietary intakes.

The total EDIs of Co ranged from 0.052 to 0.116 μg d^{-1}, much lower than the values estimated in other countries: Ghana 5.3 μg d^{-1} (Lente et al. 2012) and Pakistan 541 μg d^{-1} (Mahmood and Malik 2014). In the present study, the vegetable that contributed the greatest quantity of Co to the intake was *Beta Vulgaris var. cicla*. In Accra, cabbage grown on wastewater-irrigated site contributed 3.14 μg to the daily intake (Lente et al. 2012).

Table 5 Estimated Dietary Intake (EDI) for individual heavy metals caused by the consumption of different vegetables grown on wastewater-irrigated soils at 5 sub-city administrative areas

Administrative areas	Vegetable	Cd	Co	Cr	Cu	Ni	Pb	Zn
Kolfe Keraniyo	*Lactuca sativa var. crispa*	1.44E-05	1.27E-05	1.31E-04	6.59E-04	1.01E-04	2.40E-04	1.64E-03
	Brassica carinata A. Br.	1.56E-05	1.65E-05	1.49E-04	5.50E-04	1.18E-04	2.69E-04	3.08E-03
	Beta Vulgaris var. cicla	1.59E-05	2.28E-05	1.05E-04	8.79E-04	1.71E-04	3.34E-04	2.98E-03
	Total	4.59E-05	5.20E-05	3.85E-04	2.09E-03	3.89E-04	8.43E-04	7.71E-03
Chirkos	*Lactuca sativa var. crispa*	2.84E-05	1.44E-05	1.43E-04	6.46E-04	4.96E-05	2.27E-04	1.68E-03
	Brassica carinata A. Br.	4.26E-05	3.85E-05	2.00E-04	1.06E-03	1.15E-04	4.22E-04	5.19E-03
	Beta Vulgaris var. cicla	4.57E-05	5.15E-05	2.32E-04	1.05E-03	1.72E-04	6.70E-04	5.40E-03
	Total	1.17E-04	1.04E-04	5.74E-04	2.76E-03	3.37E-04	1.32E-03	1.23E-02
Bole	*Lactuca sativa var. crispa*	1.14E-05	1.20E-05	6.48E-05	4.38E-04	1.01E-04	2.58E-04	1.43E-03
	Brassica carinata A. Br.	1.98E-05	2.62E-05	6.13E-05	8.05E-04	1.30E-04	3.15E-04	3.50E-03
	Beta Vulgaris var. cicla	2.34E-05	2.96E-05	1.26E-04	1.04E-03	2.14E-04	5.01E-04	3.70E-03
	Total	5.47E-05	6.77E-05	2.52E-04	2.29E-03	4.44E-04	1.07E-03	8.63E-03
Nefas Silk Lafto	*Lactuca sativa var. crispa*	2.12E-05	2.54E-05	1.21E-04	6.02E-04	1.33E-04	1.86E-04	1.54E-03
	Brassica carinata A. Br.	4.24E-05	3.88E-05	2.75E-04	1.11E-03	2.38E-04	3.73E-04	5.24E-03
	Beta Vulgaris var. cicla	5.81E-05	9.65E-05	3.35E-04	1.80E-03	4.55E-04	5.42E-04	4.99E-03
	Total	1.22E-04	1.61E-04	7.31E-04	3.51E-03	8.26E-04	1.10E-03	1.18E-02
Akaki Kaliti	*Lactuca sativa var. crispa*	1.94E-05	1.80E-05	8.68E-05	4.65E-04	1.02E-04	1.69E-04	1.55E-03
	Brassica carinata A. Br.	2.96E-05	3.82E-05	2.40E-04	9.62E-04	1.71E-04	2.60E-04	4.69E-03
	Beta Vulgaris var. cicla	2.93E-05	5.96E-05	1.76E-04	1.77E-03	2.79E-04	4.59E-04	4.20E-03
	Total	7.82E-05	1.16E-04	5.03E-04	3.20E-03	5.52E-04	8.88E-04	1.04E-02

The total EDIs of Cr, Cu and Ni ranged from 0.252–0.731, 2.09–3.51, and 0.337–0.826 μg d^{-1}, respectively. Similarly, the findings of the present study concerning EDIs of these metals show that the values are substantially lower than their corresponding PTDIs and are free of potential risk. Conversely, other estimates made from other countries have shown that the daily intakes for Cr, Cu and Ni were higher than their corresponding PTDIs (Maleki and Zarasvand 2008; Gupta et al. 2012). Although the concentrations of Pb in all analyzed vegetables were far above the RML standard, the total EDIs (0.094–1.32 μg d^{-1}) were substantially lower than the PTDI standard. The highest total EDI of Pb (1.32 μg d^{-1} at Chirkos) was found to contribute 0.6% to the PTDI. Higher dietary exposure estimate for Pb through the consumption of vegetables grown on wastewater-irrigated fields were reported by Singh et al. (2010) and Mahmood and Malik (2014). Thus, in the context of the present study, intake of these contaminated (Pb) vegetables is unlikely to induce health risks arising from Pb.

Based on the consumption of selected vegetables grown on polluted river water-irrigated vegetable farming sites, the total EDIs of Zn (7.71–11.8 μg d^{-1}) were relatively high as compared to the other metals. But these EDI values contributed less than 0.02% to the corresponding PTDI standard. Yet, it can be clearly observed that our estimates for Zn are far lower than those reported from other countries (Khan et al. 2008; Lente et al. 2012; Mahmood and Malik 2014). Overall, a large daily consumption of these vegetables is unlikely to pose detrimental health risks to the consumer associated with individual metal intake. However, it is worth considering other food crops which may contribute to metal exposure and further studies are required to completely understand the risk involved.

The health risk associated with the consumption of selected leafy vegetables grown on wastewater -irrigated vegetable farming sites was evaluated using Target Hazard Quotient (THQ). The THQ has been recognized as a useful parameter for the evaluation of risk associated with the consumption of contaminated (metals) food crops (Zheng et al. 2007; Zhuang et al. 2009). Target Hazard Quotient value of less than 1 indicates a relative absence of health risk associated with the consumption of metal contaminated food crops (USEPA 2007). The THQ values ranged from 0.042–0.108, 0.005–0.014, 0.0002–0.0004, 0.048–0.078, 0.015–0.037, 0.194–0.298 and 0.026–0.037 for Cd, Co, Cr, Cu, Ni, Pb and Zn, respectively (Table 6). From the above data, it is apparent that the consumption of the examined vegetables do not expose local inhabitants to a potential health risk from dietary Cd, Co, Cr, Cu, Ni, Pb and Zn. The results obtained in the present study did not concur with THQ values recorded by Zheng et al. (2007), Zhuang et al. (2009) and Hu et al. (2014). Among the metals THQ values, the greatest values were obtained for Pb for the consumption of wastewater-irrigated vegetables at 5 sub-city administrative areas and were in the order: Chirkos (0.298) > Nefas Silk Lafto (0.244) > Bole (0.243) > Akaki Kaliti (0.197) > Kolfe Keraniyo (0.194).

The total metal THQ (sum of individual metal THQ for the analyzed vegetables) is shown in Fig. 2. The TTHQs of the metals ranged from 0.33 to 0.53. Comparing sub-city administrative areas, the TTHQs of the metals decrease in the order of Chirkos > Nefas Silk Lafto > Akaki Kaliti > Bole > Kolfe Keraniyo. The present result indicate that Pb and Cd were the major component contributing to the TTHQs, in agreement with separate assessments for areas near Huludao Zinc plant in Huludao, China (Zheng et al. 2007) and in the vicinity of Dabaoshan mine in Shaoguan city, China (Zhuang et al. 2009). In the studied sites, the consumption of all analyzed vegetables resulted in TTHQ values of less than 1, compared to the high TTHQ values obtained from emerging economies (Abbasi et al. 2013; Qureshi et al. 2016). Compared with our previous study (Woldetsadik et al. 2017) which focused on microbial hazards of wastewater irrigation, it is clear that heavy metals pose relatively no risk to local inhabitants through the consumption of leafy vegetables grown on wastewater- irrigated vegetable farming sites. However, it is worth considering the effects that may result from the interaction of the metals.

Conclusions

From this study, it was evident that the concentrations of metals in irrigation water and soil were lower than the RML standards. Wastewater dilution may be the important reason for lower levels of metals in irrigation water. Based on 1:100 dilution, the process is predicted to bring 3 mg kg^{-1}metal level down to just 0.03 mg kg^{-1}, as compared to only 2 log units reduction for pathogens, and still above thresholds, indicating metals discharged to streams will dissipate by dilution and incorporate into sediments. Hence, a more differentiated view is required as the readers might associate the term wastewater with raw effluent. Significant variations in metal concentrations between the analyzed vegetables reflect the difference in their uptake capabilities. With the exception of Pb, the concentrations of the other metals in all analyzed vegetables were far below the various international RML standards. From the health point of view, the EDI and THQ values showed that there would be no potential health risk to local inhabitants due to intake of individual metal if one or more of the analyzed vegetables are consumed. Furthermore, hazard quotients for the combined metals (TTHQ) due to all analyzed vegetables

Table 6 THQ for individual heavy metals through the consumption of different vegetables grown on wastewater-irrigated soils at 5 sub-city administrative areas

Administrative areas	Vegetable	Cd	Co	Cr	Cu	Ni	Pb	Zn
Kolfe Keraniyo	*Lactuca sativa var. crispa*	1.33E-02	1.17E-03	8.07E-05	1.52E-02	4.67E-03	5.54E-02	5.05E-03
	Brassica carinata A. Br.	1.43E-02	1.50E-03	9.05E-05	1.25E-02	5.37E-03	6.13E-02	9.38E-03
	Beta Vulgaris var. cicla	1.48E-02	2.12E-03	6.49E-05	2.04E-02	7.93E-03	7.76E-02	9.25E-03
	Total	4.23E-02	4.80E-03	2.36E-04	4.82E-02	1.80E-02	1.94E-01	2.37E-02
Chirkos	*Lactuca sativa var. crispa*	2.48E-02	1.26E-03	8.33E-05	1.41E-02	2.17E-03	4.95E-02	4.91E-03
	Brassica carinata A. Br.	3.86E-02	3.48E-03	1.21E-04	2.39E-02	5.23E-03	9.55E-02	1.57E-02
	Beta Vulgaris var. cicla	4.18E-02	4.72E-03	1.41E-04	2.41E-02	7.89E-03	1.53E-01	1.65E-02
	Total	1.05E-01	9.46E-03	3.45E-04	6.21E-02	1.53E-02	2.98E-01	3.71E-02
Bole	*Lactuca sativa var. crispa*	1.03E-02	1.08E-03	3.89E-05	9.86E-03	4.54E-03	5.82E-02	4.29E-03
	Brassica carinata A. Br.	1.82E-02	2.40E-03	3.75E-05	1.85E-02	5.96E-03	7.23E-02	1.07E-02
	Beta Vulgaris var. cicla	2.11E-02	2.67E-03	7.59E-05	2.35E-02	9.63E-03	1.13E-01	1.11E-02
	Total	4.96E-02	6.15E-03	1.52E-04	5.19E-02	2.01E-02	2.43E-01	2.61E-02
Nefas Silk Lafto	*Lactuca sativa var. crispa*	1.87E-02	2.23E-03	7.08E-05	1.32E-02	5.86E-03	4.09E-02	4.52E-03
	Brassica carinata A. Br.	3.72E-02	3.41E-03	1.61E-04	2.44E-02	1.04E-02	8.18E-02	1.53E-02
	Beta Vulgaris var. cicla	5.18E-02	8.60E-03	1.99E-04	4.00E-02	2.03E-02	1.21E-01	1.48E-02
	Total	1.08E-01	1.42E-02	4.31E-04	7.77E-02	3.65E-02	2.44E-01	3.47E-02
Akaki Kaliti	*Lactuca sativa var. crispa*	1.67E-02	1.55E-03	4.98E-05	1.00E-02	4.39E-03	3.65E-02	4.44E-03
	Brassica carinata A. Br.	2.63E-02	3.40E-03	1.43E-04	2.14E-02	7.60E-03	5.78E-02	1.39E-02
	Beta Vulgaris var. cicla	2.61E-02	5.32E-03	1.05E-04	3.95E-02	1.25E-02	1.02E-01	1.25E-02
	Total	6.91E-02	1.03E-02	2.97E-04	7.09E-02	2.44E-02	1.97E-01	3.09E-02

were lower than 1, which signifies no potential health risk even to highly exposed inhabitants. These results emphasize the need for further investigations of other crops from the study sites. Still, health risk exposure of children through the consumption of local vegetables should also be investigated due to their high sensitivity to metal exposure. There is a great respite that toxic metals like Pb and Cd have not pose potential health risk even after long term (more than 50 years) use of this water for irrigation. Our previous study indicated that faecal contamination level of lettuce irrigated with wastewater is above the threshold of safe consumption. Hence, it is imperative to focus on and off farm mitigation measures including proper vegetable washing that helps reduce potential pathogenic risks. However, intermittent monitoring of the metals from irrigation water, in soil and crops may be required to follow/prevent their build-up in the food chain.

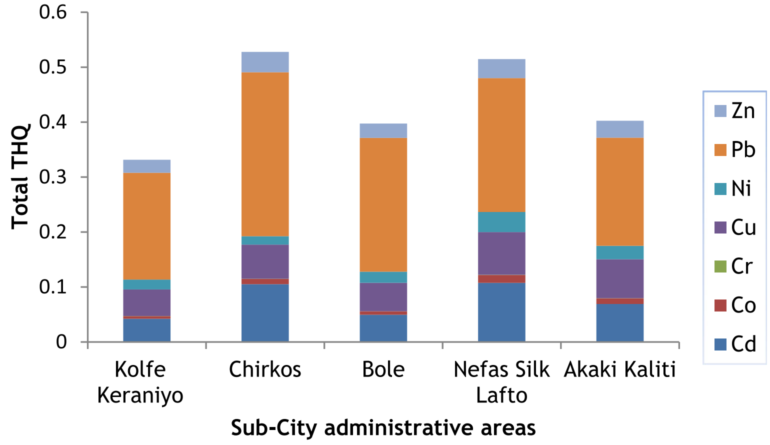

Fig. 2 Total THQ values for metals at 5 sub-city administrative areas

Abbreviations

CEC: Cation exchange capacity; EDI: Estimated daily intake; RML: Recommended maximum limit; OM: Organic matter; THQ: Target hazard quotient; TTHQ: Total target hazard quotient

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Availability of data and materials

The data sets on which the conclusions of the paper rely is presented in the main body of the manuscript.

Authors' contributions

DW, PD, BK, FI and HG conceived and designed the study. DW conducted the study. DW, PD, BK and FI contributed to the analysis and interpretation of data. DW drafted the manuscript. DW, PD, BK, FI and HG revised the draft manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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