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Assessment of Heavy Metals in Lettuce Grown in Soils Irrigated with Different Water Sources in the Accra Metropolis

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Abstract: This study was carried out to assess the levels of different heavy metals like Iron, Manganese, Copper, Zinc, Cadmium and Lead in three different irrigation water sources, irrigated soils and irrigated lettuce. The result indicates positive and significant correlation of heavy metals concentrations between the irrigation water, irrigated soils and irrigated lettuce. The range of various heavy metals in drained water irrigated lettuce was 162.00-190.00, 60.25-78.25, 6.03-8.80 and 23.88-52.00 mg/kg in Fe, Mn, Cu and Zn, respectively. Generally, mean heavy metal concentrations of the water, soil and lettuce from two vegetable growing sites were within the FAO/WHO recommended maximum concentrations for crop production. Although the levels of heavy metals in the irrigation water, irrigated soils and irrigated lettuce were below the recommended limits, regular monitoring of these metal levels from these sources is essential to prevent excessive heavy metal build-up in vegetables in general.

Keywords: Accra metropolis, heavy metals, lettuce, wastewater

INTRODUCTION

A mixture of municipal and domestic wastewater is used for vegetable production in some parts of Accra. Many countries including some developed countries reuse wastewater in agriculture. These water sources contain trace metals which in certain concentrations can be toxic to consumers of produce cultivated using wastewater. Living organisms require trace amounts of some heavy metals including copper, iron, manganese and zinc. Copper and zinc are micronutrients necessary for proper plant development. In appropriate amounts, they are essential for plants, but their excessive quantities may cause some disturbances in development of plants and result in their depressed quality.

Studies have shown that continuous use of wastewater containing heavy metals for crop production tends to accumulate these heavy metals in the soil and it becomes bioavailable to crops with time (Toze, 2004). This implies that although some of the heavy metals may be taken up by the crops, greater percentage is deposited in the soil. According to Angelova *et al*. (2004) heavy metal concentrations in the leaves and seeds of fibre crops grown in heavily polluted soil were lower than concentrations present in the soil. The concentration of toxic chemicals vary from place to place and usually depends on the number and type of industries that discharge their effluent into the wastewater and the degree to which they treat their waste prior to discharge (WHO, 2006).

Vegetables can absorb metals from soil as well as from deposits on parts of vegetables exposed to air from polluted environments (Haiyan and Stuanes, 2003).

High heavy metal concentration of agriculture soils as a result of irrigation with wastewater has serious implications on human health. Some of these heavy metals are neurotoxic and carcinogenic and continuous intake as a results of consumption of contaminated vegetables, will affect the central nervous system, the endocrine system and kidneys of people exposed to these toxicants (Obiri *et al*., 2010; Amonoo-Neizer and Amekor, 1994). Numerous studies link the presence of heavy metals such as Pb and Cd to incidence of cognitive impairments especially in children (Koger *et al*., 2005; Weiss, 2000; Porterfield, 2000; Myers and Davidson, 2000)

This study seeks to assess concentrations of heavy metals in irrigation water, irrigated soils and lettuce produced in the Accra Metropolis. Results from the study will give better understanding of the effect of contaminated water and soil on the production of lettuce for human consumption. It will also go a long way to safeguard the health of consumers of vegetable in the Accra metropolis.

METHODOLOGY

Study area: The study was carried out in Accra, the capital city of Ghana which lies within the coastal-savanna zone. Accra has a population of about 3.9 million

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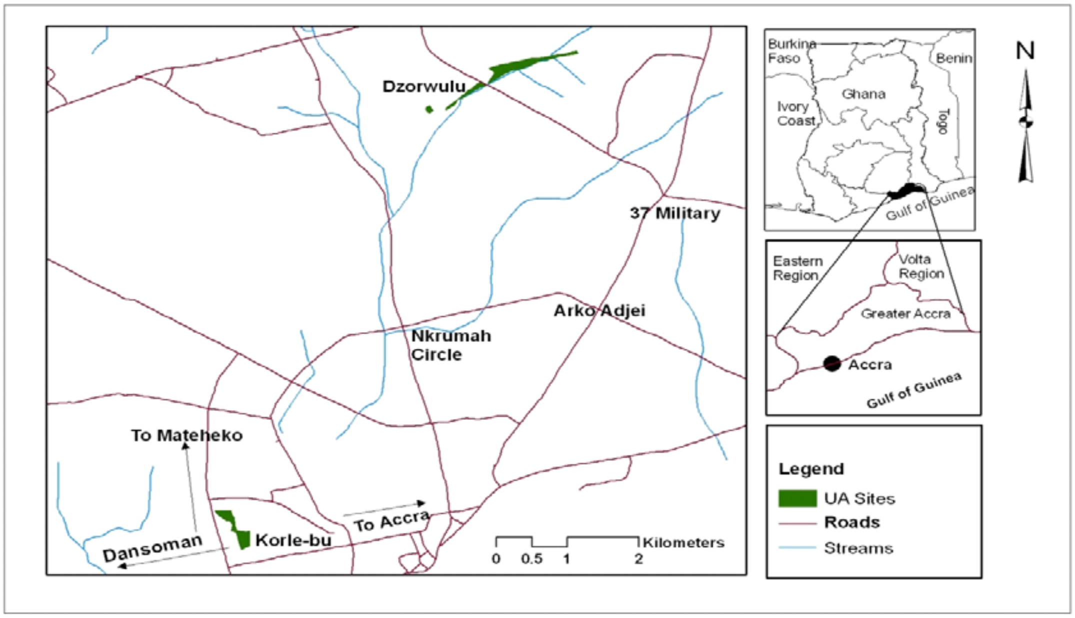

Fig. 1: Map of sampling sites

(www.ghana.gov gh/index.php). It covers an area of about 230 to 240 km^2 (Obuobie *et al*., 2006). The rainfall pattern of Accra is bimodal, with the major season falling between the months of March and June and a minor rainy season around October. The mean annual rainfall is about 730 mm. Mean temperatures vary from 24ºC in August to 27ºC in March and also has a least average monthly humidity of 60% and the highest not exceeding 75% (Obuobie *et al*., 2006; Dickson and Benneh, 1995). The vegetation of Accra consists of dense shrubs without grass in the west and grass with isolated patches of shrub and occasional trees in the east. Baobab and neem trees are also quite common in Accra (Dickson and Benneh, 1995).

Sampling techniques:

Description of sampling sites: Two main vegetable growing sites were selected in the Accra metropolis for the study namely; Dzorwulu and Korle-Bu. (Fig. 1)

Dzorwulu is one of the major vegetable growing suburbs in the Accra metropolis. The farming site has a total land area of about 12 ha (Amoah, 2008). The sources of water for irrigation are tap water which in most cases are filled and stored in unprotected dugouts using water hose, these dugouts are small ponds about 6 m in diameter and 1.5 m deep where farmers store irrigation water before use. The other source is water from the stream (Onyasia stream) which is a tributary of the Odaw River. This stream is polluted with wastewater generated from neighboring settlements. Korle-Bu is another major vegetable growing suburb in Accra with a total farming land of about 10 ha (Obuobie *et al.*, 2006). The main source of irrigation water is drain water from houses of hospital staff and surrounding communities, channeled into dugouts.

Sampling of water, soil and lettuce: Water samples were collected in 250 mL plastic bottles from the irrigation water sources. All water samples for heavy metal analysis were acidified (pH<2) by adding 1 mL conc. HNO_3.

Six soil samples each were randomly taken from the different irrigated soils at a depth of 10 cm with sterile spatulas and 60 mm diameter soil auger.

Six lettuce heads were randomly collected from the farm for each of the different irrigation water sites. All samples were sent to the laboratory for analysis.

Digestion of samples for the analysis of Fe, Mn, Cu, Zn, Pb and Cd:

Water samples: One hundred mL of acidified water sample was mixed with 5 mL each of conc. HNO_3 and conc. H_2SO_4. The mixture was heated until the mixture was reduced to about 20 mL on a hot plate. The digested samples were cooled to room temperature, filtered through a 0.45 μm Whatman filter paper and the final volume adjusted to 100 mL with double distilled water and stored for analysis of heavy metals (APHA, AWWA, WEF, 1998).

Soil samples: The soil was air dried, grounded and homogenized. This was then sieved off using 0.4 μm mesh size to remove debris such as leaves and large stones. (0.2 g) of the sieved soil sample was weighed into Teflon tubes and of 2 mL concentration Nitric acid (HNO_3) added to the soil in the Teflon tube. The tube was closed and placed in stainless bombs. The stainless bomb was then placed on a hot plate and heated at 150ºC for 7 h. The bomb was opened after it had been allowed to cool to room temperature and the pressure had been released. The digested sample was then transferred into a polypropylene graduated tube and the Teflon was rinsed three times with deionised water. The rinsing water was also added to the polypropylene tube. This solution was diluted to the 25 mL mark of the tube with deionised water and mixed thoroughly. The particles were allowed to settle overnight and samples stored for analysis.

Lettuce samples: The lettuce leaves were oven dried for 2 days at a temperature of 80ºC after which it was grounded and homogenized and finally sieved to remove all debris. An amount of 0.2 g of the sieved lettuce sample was weighed into Teflon tubes. A volume of 2 mL concentration of Nitric acid (HNO_3) was added to the lettuce in the Teflon tube. The tube was closed and placed in stainless bombs. The stainless bomb was then placed on a hot plate and heated at 110ºC for 1 h and then 150ºC for 3 h. The bomb was opened after it had been allowed to cool to room temperature and the pressure had been released. The digested sample was then transferred into a polypropylene graduated tube and the teflon was rinsed three times with deionised water. The rinsing water was also added to the polypropylene tube. This solution was diluted to the 25 mL mark of the tube with deionised water and mixed thoroughly. The particles were allowed to settle overnight and sample stored for analysis.

Analyses of Fe, Mn, Cu, Zn, Pb and Cd: The concentrations of Fe, Mn, Cu, Zn, Pb and Cd were determined using flame AAS (Atomic Absorption Spectrophotometer) Unicam 699 after double distilled water has been used to zero the instrument, the concentrations of Fe, Mn, Cu, Zn, Pb and Cd in the blank were also measured and then followed by the determination of the concentrations of Fe, Mn, Cu, Zn, Pb and Cd in the digested samples. In the determination a sample solution was aspirated into a flame and atomized. A light beam was directed through the flame, into a monochromator and onto a detector that measures the amount of light absorbed by the atomized element in the flame (APHA-AWWA-WEF, 2001).

Quality control: Reproducibility and recovery studies were conducted. The percentage of Fe, Mn, Cu, Zn, Pb and Cd recovered in the recovery studies ranges from 98-100% for Fe, Mn, Cu, Zn, Pb and Cd respectively. Similar results were obtained for the reproducibility studies. The percentage of Fe, Mn, Cu, Zn, Pb and Cd, recovered in the reproducibility studies ranges from 97.3 to 99.6% (standard error ± 0.005 to 0.590). The standard error was less than 1,

Table 1: Levels of physical parameters in the irrigation water

Water source	Values	pH	Electrical conductivity (μS/cm)
Tapwater	Range	6.79-7.28	236-265
	Mean	7.00	248
Stream	Range	7.08-7.68	1267-1354
	Mean	7.28	1307
Drain	Range	7.14-7.83	1296-1893
	Mean	7.46	1629

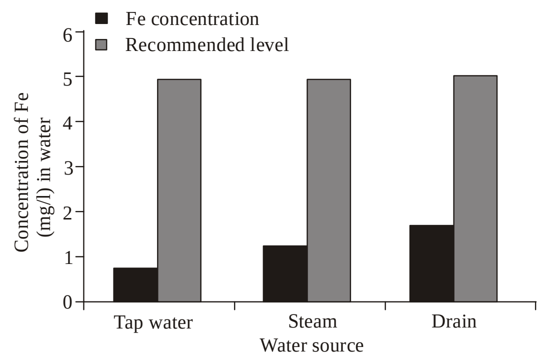

Fig. 2: Iron concentration in irrigation water

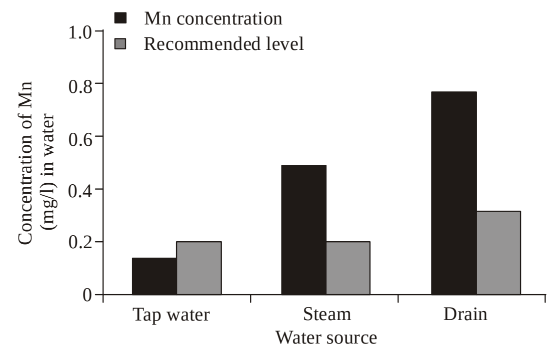

Fig. 3: Manganese concentration in irrigation water

RESULTS AND DISCUSSION

Concentration of physical parameters and heavy metals in irrigation water: The pH, EC levels of the irrigation water samples collected from the vegetable growing sites are given in (Table 1).

There was significant difference in the mean values of the Electrical Conductivity (EC) between the various water sources. However, the mean values of pH and (EC) in the different irrigation water were within the recommended level used for irrigating agriculture crops of (6.5-8.4) pH and ≥3000 μS/cm for EC (Ayers and Westcot, 1985). These values indicate that in terms of salinity, all the three water sources are suitable for irrigation.

The heavy metals concentration in the different irrigation water were in the trend of Fe>Mn>Cu >Zn. Figure 2 with the exception of Tapwater source the Mn concentrations in the stream and drain water source were slightly above the recommended level of 0.2 mg/L (Fig.3)

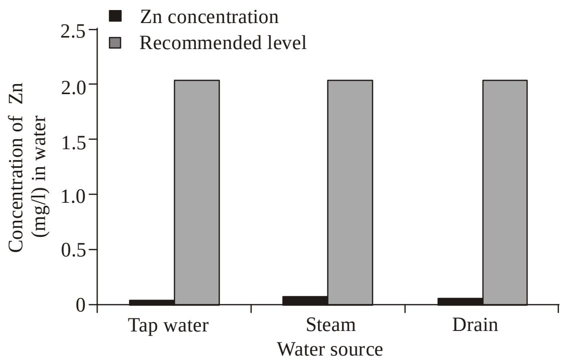

Fig. 4: Zinc concentration in irrigation water

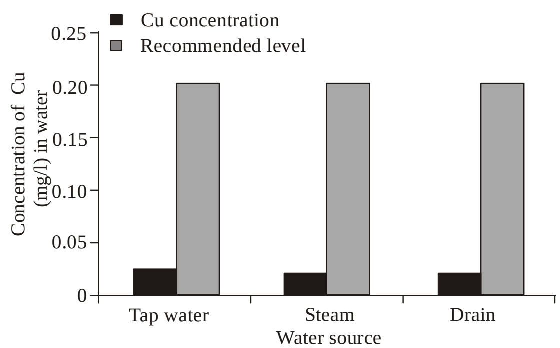

Fig. 5: Copper concentration in irrigation water

Concentrations of Copper and Zinc in all the water sources were far below the recommended levels (Fig. 4 and 5), respectively. There was significant difference in the Manganese (Mn) concentration between Tapwater source and Stream ($p = 0.003$), Tapwater and Drain ($p = 0.001$) and Stream and Drain source ($p = 0.014$). The relatively higher concentration of Mn in the Drain source could be attributed to the influence from domestic effluents. A similar trend was observed by Cornish *et al*. (1999). According to the findings by Ghesquiere (1999), no health risk has been associated with food containing high manganese concentrations. However, high concentration of manganese can be toxic to some plants (Pescod, 1992).

In the study, concentrations of Lead and Cadmium were found to be below detection levels (0.005 and 0.002 mg/L respectively).

Concentration of physical parameters and heavy metals in irrigated soils: The pH of soils irrigated with tapwater, stream and drain water ranged from 7.28 to 8.08, 7.38 to 7.78 and 7.38 to 7.75, respectively (Table 2). These difference were however not significant ($p>0.05$).

The EC ranged from 481 to 848, 616 to 923 and 744 to 931 μS/cm in soils irrigated with tapwater, stream and drain water, respectively, (Table 2). Statistical analysis showed no significant difference ($p>0.05$) in EC of soils irrigated with water from different sources.

Table 2: Physical parameter in the three irrigated soils

Water source	Values	pH	Electrical conductivity (μS/cm)
Tapwater	Range	7.39-8.08	481-848
	Mean	7.71	637.4
Stream	Range	7.38-7.78	616-923
	Mean	7.598	725
Drain	Range	7.38-7.75	744-931
	Mean	7.58	813

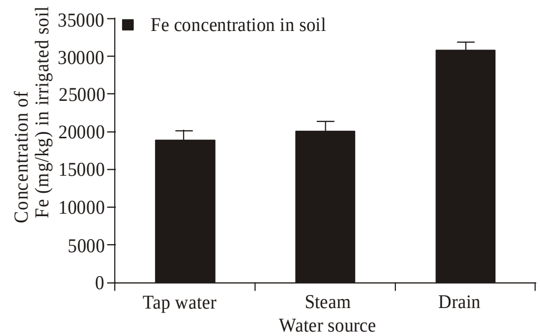

Fig. 6: Iron concentrations in soil from the three irrigation water sources

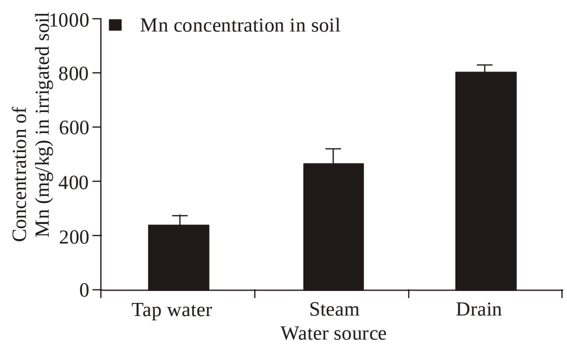

Fig. 7: Manganese concentrations in soil from the three irrigation water source

With respect to the irrigated soils, all the three irrigated soils were contaminated with Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn), The mean concentrations of heavy metal in the soils irrigated with the different water sources were highest in Fe, followed by Mn, Zn and Cu. Generally, the concentrations of heavy metals in the soil irrigated with drain sources was higher than concentrations found in the soil irrigated with tapwater and stream (Fig. 6, 7, 8 and 9). Among the irrigated soils, the mean concentration of Zn was recorded minimum (44.33 mg/kg) in soil irrigated with tapwater and maximum (85.56 mg/kg) in soil irrigated with drain water. The difference between these soils was significant ($p = 0.001$). However, the concentrations of the various heavy metals in the three water sources were below the recommended maximum concentration of crop requirement. These concentrations are 50000, 2000, 100 and 300 mg/kg for Iron, Manganese, Copper and Zinc, respectively (Ewers, 1991; Pendias and Pendias,1992).

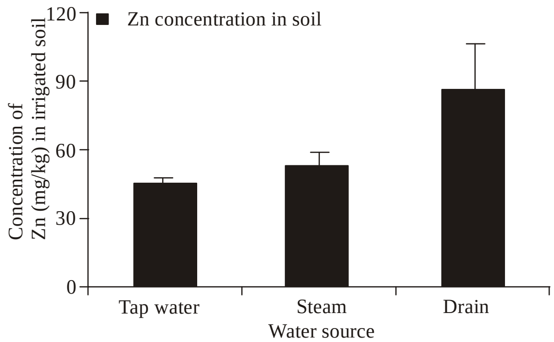

Fig. 8: Zinc concentrations in soil from three irrigation water sources

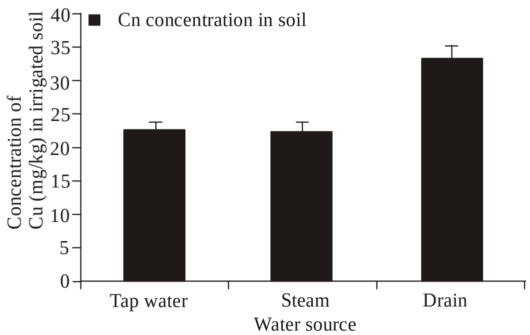

Fig. 9: Copper concentrations in soils from three irrigation water sources

Concentration of physical parameters and heavy metals in irrigated lettuce: The mean concentrations of heavy metal in the lettuce from the different irrigation sources were higher in Fe followed by Mn, Zn and Cu (Table 3). The highest Fe concentration (170.44 mg/kg) was detected in lettuce irrigated with drain water source. There was significant difference in the manganese concentrations between lettuces irrigated with tapwater and drain water source (p = 0.005) as well as lettuce irrigated with stream and drain water source (p = 0.002). Similarly there was significant difference in the zinc concentrations between lettuce irrigated with tapwater and stream water source (p = 0.015), as well as lettuce irrigated from tapwater and drain source (p = 0.043). Although there was difference in the various heavy metal concentrations in lettuce irrigated with different water sources, the concentrations were below the recommended maximum concentration of crop. The difference of the metal concentrations in the lettuce irrigated with different water sources depends on the physical and chemical nature of the soil and absorption capacity of each metal by the vegetable. This is usually altered by various factors like the environmental and human interference (Zurera *et al*., 1989).

Although Lead and Cadmium concentrations were determined in the water, soil and vegetables, there was no evidence of their presence in the samples since the levels were below detection limit of <0.625 and <0.25 respectively. This indicates that the site where the study was carried out was free of these heavy metals. This was not surprising since there are no industries (including battery production, metal production, metal smelting and cable coating industries) which are known to be major contributing factors for these metals in the environment (Bigdeli and Seilsepour, 2008).

In general, the mean concentrations of the heavy metals detected in the irrigation water, soils and lettuce are Fe>Mn>Zn>Cu. Besides, the heavy metal concentrations found in the irrigation water from the different sources were far lower than the concentrations in the irrigated lettuce. The concentrations for the heavy metals including Fe, Mn, Cu and Zn in the lettuce ranged from 148.25 to 192.50, 49.50 to 78.25, 6.03 to 9.23 and 23.88 to 58.50 mg/kg, respectively (Table 4). However, the highest concentrations of the metals were obtained in the different irrigated soils.

Correlations of heavy metals in water, soil and lettuce samples: The Pearson correlation analysis showed a positive relationship (r = 0.849) between the concentration of Cu in the tap irrigated water and its respective irrigated lettuce. Also, Fe concentration in stream irrigation water source showed positive correlation

Table 3: Concentrations of heavy metals on lettuce irrigated from different water sources

Irrigated lettuce	Heavy metals	Value: Range (mg/kg)	Value: Mean (mg/kg)	Recommended max. conc. of crops (mg/kg)
Lettuce irrigated with tapwater source	Fe	148.25-178.00	169.42 (±4.9)	425.50
	Mn	49.50-69.00	61.57 (±4.5)	500
	Cu	7.48-8.03	7.66 (±0.14)	73.3
	Zn	29.50-58.50	42.45 (±6.9)	100
Lettuce irrigated with stream source	Fe	157.00-192.50	168.21 (±9.9)	425.50
	Mn	54.75-76.00	60.45 (±5.1)500	
	Cu	7.05-9.23	8.09 (±0.65)73.3	
	Zn	29.00-48.50	36.66 (±5.4)100	
Lettuce irrigated with drain source	Fe	162.00-190.00	170.44 (±6.5)425.50	
	Mn	60.25-78.25	68.19 (±6.2)500	
	Cu	6.03-8.80	7.24 (±0.7)73.3	
	Zn	23.88-52.00	38.12 (±6.7)100	

Table 4: Mean concentration of heavy metals in irrigation water, soil and lettuce

		Heavy metals		
Heavy metals	Value	Water source (mg/L)	Irrigated soil (mg/kg)	Irrigated lettuce (mg/kg)
Fe	Range	0.113-2.870	17200-32400	148.25-192.50
	Mean	1.165	22964.29	169.28
Mn	Range	0.038-0.962	202-836	49.50-78.25
	Mean	0.442	522.07	63.06
Cu	Range	0.020-0.030	20.80-35.20	6.03-9.23
	Mean	0.021	26.13	8.80
Zn	Range	0.005-0.190	41.30-107.00	23.88-58.50
	Mean	0.033	61.83	52.00

($r = 0.697$) with the respective stream water irrigated lettuce. Similarly, a significant and strong positive relationship ($r = 0.911$) was observed between Cu in stream water irrigated soil and its corresponding irrigated lettuce. Furthermore, Pearson's correlation analysis to identify the relationship between the concentrations of Mn in drain irrigation water, soil and lettuce, significant positive correlation ($r = 0.884$) was detected between the soil and lettuce. Similarly, the Zn concentrations in the drain water source showed positive correlation ($r = 0.688$) between the irrigated soil and the lettuce.

CONCLUSION

Generally, there was no evidence of significant pollution with heavy metals (Fe, Mn, Cu, Zn, Pb and Cd) that might pose a threat to the irrigated lettuce as far as irrigation water was concerned in this study. The levels of heavy metals in the water sources were below FAO threshold for crops. All the metals analysed on the lettuce showed levels which were below the FAO/WHO recommended levels. Heavy metals of public health concern like lead (Pb) and cadmium (Cd) were below detectable limit. However, measures have to be taken in other not to heavily pollute the irrigation water and soils with heavy metals to protect the safety of vegetable consumers and the general environment.

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