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Heavy Metals Accumulation in Vegetables Irrigated with Different Water Sources and Their Human Daily Intake in Nevsehir

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ABSTARCT

In the present study, impact of different irrigation sources on metals (Cd, Pb, Zn, Cr, Cu, Ni and Fe) uptake by Tomato (*Solanum lycopersicum*), Onion (*Allium cepa* L.), Pepper (*Capsicum annuum* L.) and Beans (*Phaseolus vulgaris* L.) grown in Nevsehir Province were determined using ICP-OES (Inductively Coupled Plasma Optical Emission Spectroscopy). Heavy metal concentrations in vegetables irrigated by wastewater and river water were significantly (P< 0.05) higher than tube well water and exceeded the permissible limits of WHO/FAO. Among the edible parts of vegetables, maximum accumulation of Fe and Cr occurred in onion; Zn and Pb accumulation were determined in tomato followed by Ni in beans, while Cd and Cu were high in pepper. Also BioConcentration Factor (BCF) and Daily Intake Metal (DIM) values were calculated and it was determined that DIM values were free of risk, as the dietary intake limits of Cu, Fe, Zn, and Mn in adults can range from 1.2 to 3.0, 10.0 to 50.0, 5.0 to 22.0, and 2.0 to 20.0 mg, respectively. As a result, wastewater and river water are not appropriate for agriculture, especially when the river water is used for irrigation, because the significant metal contamination in soils causes several health problems.

Keywords: Beans, Bioconcentration factor, Health risks, Onion, Pepper, Tomato.

INTRODUCTION

Vegetables occupy a very significant place in the human diet. Many essential elements, which are necessary for normal growth and development of humans, are provided by vegetables. In addition, many green vegetables are protective against colon cancer and different toxic substances during digestion, and they reduce the risk of developing many health problems (Chopra and Pathak, 2015). Because of the fact that vegetables contain essential and non-essential minerals together, it is needed to pay much attention to food safety and nutrient quality values (Gupta *et al*., 2008).

Lack of adequate amounts of irrigation water and numerous difficulties in achieving access to suitable water has led farmers to use non-conventional water sources for irrigation. Industrial and domestic wastewater is widely used for irrigation in many countries, with the purpose of reusing the water, the ease of access, and -most importantly- inadequate amounts of tube well water. In addition, irrigation with wastewater provides an economical way for handling the problem of disposing of the wastewater (Arora *et al*., 2008). Using wastewater for irrigation might be useful for providing a suitable environment for plants and enriching the soil conditions because it contains organic wastes (Liu *et al*., 2005). However, besides these beneficial nutrients, chemicals and biological wastes that are highly hazardous to the environment are

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present in wastewater. Continuous usage of wastewater in agricultural activities causes not only a significant increase in the amount of heavy metals in soils but also degrades the quality of the soil and brings up huge risks for food safety (Al-busaidi *et al*., 2015). Heavy metals may accumulate in various locations in the human body, and it is extremely dangerous for human health. Because of the fact that they are non-degradable and permanent in nature, they cause extremely serious health problems even at very low concentrations (Duman and Kar, 2012). Additionally, a number of serious health problems may develop as a result of excessive uptake of dietary heavy metals. Furthermore, the consumption of heavy metals contaminated food can seriously deplete some essential nutrients in the body, causing a deficiency in immunological defense system, intrauterine growth retardation, impaired psycho-social behaviors, disabilities associated with malnutrition, and a high prevalence of upper gastrointestinal cancer (Orisakwe *et al*., 2012).

Some of the vegetables such as lettuce, spinach, radish, and carrot, can easily take up heavy metals, e.g., Cu, Cd, Pb, Zn, and Mn, in their tissue. The uptake of these metals by the plant is generally increased when they are grown on contaminated soils (Yang *et al*., 2011). Accumulated heavy metals are intaken in the human body via the food chain. Thus, the food safety is an important issue that attracts worldwide attention. Depending on the world population growth, demand for the food and the importance of the issue of food safety has been increased. Scientists have focused on investigating the potential risks of contaminated foods with chemicals such as heavy metals, pesticides, and agricultural chemicals. Generally, crops take up many essential nutrients and trace elements in a short period of time, therefore, the safety of vegetables has been a matter of concern for human health and has been attracting more attention (Farooq *et al*., 2009; Islam *et al*., 2015; Liu *et al*., 2005).

Using wastewater and river water for irrigation in agricultural activities is widespread in Nevsehir Province. Kizilirmak River, which passes through residential areas, is exposed to very heavy amounts of domestic and industrial pollutants (Duman and Kar, 2012). Therefore, the water quality of the river water has fallen by a significant amount and there is the danger of exposure to heavy metal contamination.

In this study, we aimed to compare heavy metal concentrations in plants gathered from farmlands irrigated with different water sources (tube well water, river water, wastewater). Also, the BioConcentration Factor (BCF) of metals in the studied vegetables and Daily Intake of Metals (DIM) values were calculated for children and adults.

MATERIALS AND METHODS

Study Area

A total of 70 samples of four different vegetables (*Solanum lycopersicum*, *Allium cepa*, *Capsicum annuum* and *Phaseolus vulgaris*) were collected from 3 different locations, where they were commonly consumed and produced. These locations were: Kavak farmland; using Tube-well Water (TW) for irrigation, Avanos farmland; using River Water (RW) for irrigation, and Sulusaray farmland; using WasteWater (WW) for irrigation purposes (Figure 1).

Sample Preparation

The samples were collected from fields during the months of August and September. Vegetables were handpicked using vinyl gloves and carefully packed into polyethylene bags. All the collected vegetable samples were thoroughly washed with double distilled water to get rid of airborne pollutants. The samples were then cut to separate the roots, stems, leaves and

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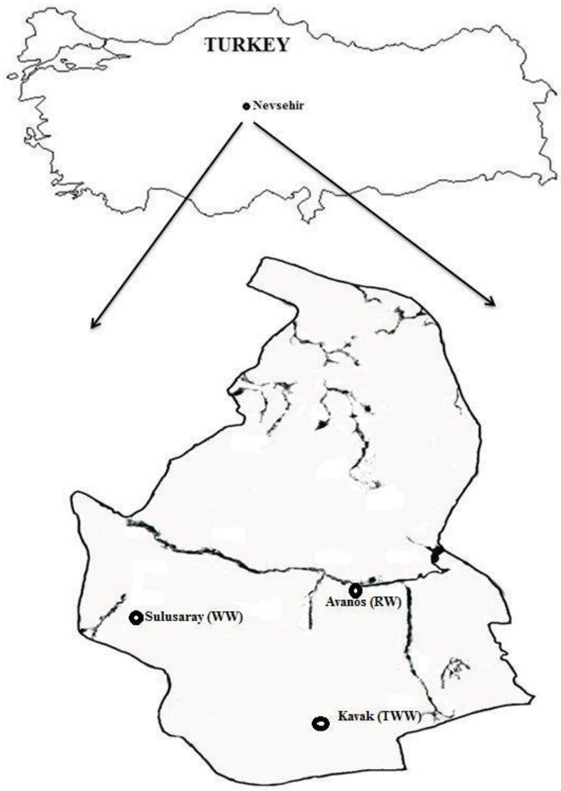

Figure 1. Sampling map, Kavak farmland Tube well Water irrigation (TW), Sulusaray farmland Waste Water irrigation (WW) and Avanos farmland River Water irrigation (RW).

fruits. All the samples were then oven-dried in a hot air oven at 70–80°C for 24 hours, to remove all of the moisture. To ensure the uniform distribution of metals in the sample, all materials were milled in a micro-hammer cutter and sieved through a 1.5-mm sieve and kept in clean polyethylene bottles.

In addition, a total of 20 soil samples were collected from the sites, where the vegetables were taken. Soil specimens were taken at each station from depth of about 10 and 15 cm from the periphery of the plant root. Soil samples were collected with a stainless steel crab, air-dried and passed through a 2-mm sieve. After homogenization, soil samples were placed in clear paper bags and stored for analysis (Dilek and Aksoy, 2005).

The irrigation water samples were collected directly from the irrigation pools in the water basins. Irrigated water was taken from the irrigated basin. Samples in the amount of 1 L were taken at different times from the canals after the treatment plant, especially near the field entrance and were evaluated compared to tap water and pure water. Four water samples from each station were taken and placed in the glass bottles of 1 L. Then, the water samples were filtered (45 lm Whatman no.1 filter paper) in the lab; and 9 mL of the water was kept in a falcon tube and was stored in a refrigerator until the analysis, after the addition of 1 mL HNO_3 (APHA., 1998)

Digestion and Metal Determination

Plant and soil samples were digested with 10 mL of pure HNO_3 using a CEM Mars 5 (CEM Corporation Mathews, NC, USA) microwave digestion system. The digestion conditions were as follows; the maximum power was 1,200W, the power was at 100%, the ramp was set for 20 minutes, the pressure was 180 psi, the temperature was

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210°C and the holding time was 10 minutes. After digestion, solutions were evaporated until becoming nearly dry in a beaker. The volume of each sample was adjusted to 10 mL using 0.1M HNO_3 (Osma *et al*., 2012)

Determinations of Cu, Zn, Fe, Cr, Cd, Pb and Ni in the plant, soil and water samples were performed by inductively coupled plasma optical emission spectroscopy (Varian-Liberty II, ICP-OES). Reagent blanks were also prepared to determine any potential contamination during the digestion and analytical procedure. Peach leaves (NIST, SRM- 1547) were used as the reference material for all of the performed analytical procedures. Recoveries of heavy metals from NIST, SRM-1547 and certified values of heavy metals of NIST, SRM 1547 analyses were determined by ICP-OES (Table 1). Detection limits of Cd^{2+}, Cr^{3+}, Cu^{2+}, Fe^{3+}, Ni^{2+}, Pb^{2+}, and Zn^{2+} were 0.3×10^{-3}, 0.3×10^{-3}, 0.5×10^{-3}, 0.2×10^{-3}, 0.8×10^{-3}, 2×10^{-3}, and 0.2×10^{-3} µg g^{-1}, respectively. All treatments were performed in triplicate. All chemicals used in this study were analytical reagent grade chemicals (Merck, Darmstadt, Germany) (Ozturk *et al*., 2010).

BioConcentration Factor (BCF)

Bioconcentration factor is the ratio of metal concentration in plant tissue (root, stem etc.) to the concentration of metals in soil (µg g^{-1}) (Rahmani and Stenberg 1999).

BCF(Edible)= $C_{\text{Edible part}}/C_{\text{Soil}}$

Daily Intake of Metals (DIM)

The Daily Intake of Metals (DIM) was calculated using the following equation:

DIM= (M×K×I)/W

Where, *M* is the concentration of heavy metals in plants (µg g^{-1}); *K* is the conversion factor; *I* is the daily Intake of vegetables, and *W* is the average body Weight. Fresh weight of vegetables was converted to dry weight by using the conversion factor 0.085, as described previously (Rattan *et al*., 2005). The average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively. All the data are presented in terms of means and standard errors of triplicates.

Statistical Analysis

One-way analysis (ANOVA) was done with all the data to confirm the variability of data and validity of results, and Duncan's Multiple-Range Test (DMRT) was performed to determine the significant difference between treatments. Statistical Package for the Social Sciences (SPSS) statistical program was used for statistical analysis.

RESULTS AND DISCUSSION

Heavy Metal Concentration in Water and Soil

Heavy metal concentrations detected in tube well water, river water, and wastewater were compared with the permissible limits announced by national and international organizations, as given in Table 2. According to the table, the metal concentrations determined in waters -except for Zn in wastewater- are under permissible limits. In general, both river and wastewater are dangerous in terms of heavy metal; however, we can claim that the river water has a more adverse effect than wastewater, regarding the heavy metal uptake. In a study conducted in Pakistan, the results were similar to our findings (Amin *et al*., 2013).

Table 3 gives the FAO threshold values for soil trace elements for crop production. The heavy metal concentrations in the treated tube well water, river water, and wastewater irrigated soils in the Nevsehir may be compared with these threshold values (Table 4). The first observation to make from a comparison of the soils of the

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Table 1. Results for trace elements in standard reference materials (($\mu g\ l^{-1}$).

NIST 1547	^{63}Cu	^{64}Zn	^{57}Fe	^{52}Cr	^{114}Cd	^{208}Pb	^{60}Ni
Mean (n= 5)	3.75	16.5	213	0.90	0.025	0.75	0.85
St. dev. n= 5)	0.05	0.04	1	0.05	0.005	0.05	0.05
Certified value	3.70±0.40	17.0±0.50	215±15	0.95±0.50	0.020±0.008	0.80±0.05	0.85±0.05

Table 2. The heavy metal concentration in the studied irrigation waters and comparison with guidelines ($\mu g\ l^{-1}$).[a]

		Cr	Ni	Cu	Zn	Cd	Pb
	TSE [a]	0.05	0.2	0.02	2	0.005	0.01
	WHO [b]	0.05	-	0.02	2	0.01	0.05
	EPA [c]	0.05	-	-	1.3	0.01	0.05
This study	TWW [d]	0.0050	0.0137	0.031	0.0073	0.0007	0.0140
	RW [e]	0.0060	0.0190	0.034	0.0080	0.003	0.0240
	WW [f]	0.0070	0.0210	0.041	0.0187	0.0030	0.0300

[a] Turkish Standardization, [b] World Health Organization, [c] European Protection Agency, [d] Tube-Well Water; [e] River Water; [f] Waste Water; Institute;.

Table 3. Recommended maximum levels of trace elements for crop production (FAO, 1985).

Element	Recommended maximum concentration (mg L^{-1})	Remarks
Cd	0.01	Toxic to beans beets and turnips at concentrations as low as 0.1 mg L^{-1} in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Cu	0.20	Toxic to a number of plants at 0.1 to 1.0 mg L^{-1} in nutrient solutions.
Fe	5.	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Ni	0.2	Toxic to a number of plants at 0.5 to 1.0 mg L^{-1}; reduced toxicity at neutral or alkaline pH.
Pb	5.0	Can inhibit plant cell growth at very high concentrations.
Zn	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH> 6.0 and in fine textured or organic soils

Table 4. Heavy metal concentrations in the studied soils.[a]

	Cu	Zn	Fe	Cr	Cd	Pb	Ni
TWS [a]	0.212	0.9510	92.1947	0.0527	0.0010	0.1617	0.2077
RWS [b]	0.750	4.7427	129.8720	0.2420	0.0177	0.5817	0.2780
WWS [c]	0.306	1.1750	129.8757	0.0720	0.0017	0.1930	1.0930

[a] Tube-well Water irrigated Soil, [b] River Water irrigated Soil, [c] Waste Water irrigated Soil.

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irrigated tube well water is that the soils appear to naturally have values under the permissible limits, except for Fe. Dikinya and Areola (2010) aimed to analyze and compare heavy metal concentration in secondary wastewater irrigated soils being cultivated with different crops such as olive, maize, spinach and tomato in the Glen Valley near Gaborone City, Botswana. They found that the crop cultivation under wastewater irrigation had actually lowered the trace element content of the soils. Contrary to this study, we have found that irrigation with river water and wastewater accelerated the metal concentration.

The second major observation that might be made is that, based on FAO (1985), the river water and wastewater irrigated soils in Nevsehir have higher values than the recommended levels of trace elements for crop production. Especially Kizilirmak River water irrigated soils have shown very intensive metal accumulation. Duman and Kar (2012) determined that the heavy metal concentration in Yamula Dam Lake sediment settled on Kizilirmak and claimed that Kizilirmak River water carried heavy metal because of passing through many settlements and industrial areas. Additionally, in a study conducted in Iran Golestan Province, the authors concluded that heavy metal contamination causes serious effects on the environment quality in the studied area (Ghorbani *et al*., 2015).

Heavy Metal Accumulation in Vegetables

The metal content of soils changes when irrigated with heavy metal contaminated water due to intensively metal load; and heavy metal is accumulated in green vegetables. Heavy metal concentrations in the studied plant samples taken from freshwater, river water, and wastewater irrigated areas are given in Tables 5 and 6. Metal concentrations are based on the dry weights of the studied plants. Heavy metal concentrations in river water irrigated vegetables are significantly higher than with tube well water vegetables ($P< 0.05$). In general both river and waste water are dangerous in terms of heavy metal, but we can claim that the river water has more adverse effect than wastewater according to heavy metal uptake. In a study conducted in Pakistan, results were similar to our findings (Amin *et al*., 2013).

The concentrations of Fe in vegetables varied between 0.9270-23.4253, 1.1693–51.6210 and 0.7417-13.9013 µg g^{-1} for tube well water, river water, and wastewater, respectively (Table 5). Metal concentrations of the samples irrigated with river water showed significant differences in the metal concentrations from the other irrigated areas ($P< 0.05$). The highest accumulation of Fe was in the stems of the tomatoes, while roots of onions and peppers accumulated high levels and the leaves of beans were major sinks for Fe. Iron, which is used in the synthesis of chlorophyll in all green plants, was detected in high concentrations. (Ravet *et al*., 2009) Fe toxicity occurs when they accumulate an amount of Fe greater than 300 (µg g^{-1}), at less than 5.0 soil pH value. Amin *et al*. (2013) determined high Fe concentration in the plants they analyzed; and they emphasized the importance of its role in chlorophyll syntheses and abundance in the earth crust. This study supports these findings.

Among all heavy metals, zinc, with the role of regulating the immune system functions, is the most important one in the human diet and is the least toxic heavy metal. Moreover, the lack of zinc metal in the diet has more devastating effects than having excessive zinc in the diet. The allowable range for zinc in the human diet was determined as 15 mg d^{-1} for men, and 12 mg d^{-1} for women, however, a very high concentration of Zn in vegetables can lead to vomiting, cramps and kidney disorders (Alexander *et al*., 2006). Zn concentration in ranged between 0.1193 and 4.084 µg g^{-1} (Table 5). While fresh water irrigated plants' zinc concentration showed compatibility with international standards, wastewater and

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river water irrigated vegetables' Zn concentration was quite high (FAO/WHO, 1993).

In studied vegetables, copper concentration ranged between 0.0747 and 0.5143 µg g^{-1} (Table 5). In this study, we noted that the average copper concentration detected was lower than the average copper concentrations detected in other studies in the literature. Gupta *et al*. (2010) determined high Cu concentration in vegetables, and they claimed that it was the result of having taken samples from locations nearby the heavy duty vehicles carrying sand from the river. On the contrary; we can explain the low Cu concentration in studied vegetables with the fact that there were no heavy duty vehicles or industrial activity around the sampling area.

Pb concentration in the studied vegetables varied between 0.0177 and 0.1063 µg g^{-1} (Table 6). Several Pb concentrations were higher than the safe limits announced by WHO (0.3 µg g^{-1}) (FAO/WHO, 1993). The upstream area of the river passes through Sivas and Kayseri provinces which are developed industrial areas with high population density. Because of these high industrial and habitation areas, wastes discharged into the upstream are transported by the river and carried to Nevsehir. Kumar *et al.* (2007) claimed that; the high level of lead in wastewater irrigated vegetables could be attributed to acid-lead batteries, urban and industrial wastes discharged into the irrigation system. Our findings support this study; where highest Pb concentration was determined in tomato and onion roots that were irrigated with river water. Several pathological conditions such as nervous and immune systems disorders, anemia and reduced Haemoglobin synthesis, cardiovascular diseases, and bone metabolism, renal and reproductive dysfunction are associated with Pb intoxication in children and adults (Al-busaidi *et al*. 2015)

In this study, chromium was the metal least accumulated by plants, compared to other metals (Table 6). Cr concentration did not exceed the limits determined by WHO (0.1 µg g^{-1}). This explains that there is no significant risk in terms of the chromium concentration in studied vegetables. These results are consistent with previous studies, which reported that Cr is least accumulated in cabbage (Ferri *et al*., 2012).

Ni is a poisonous heavy metal. The concentration of Ni ranged between 0.0037 and 5.3583 µg g^{-1} (Table 6). Ni concentration in vegetables sampled from wastewater and river water irrigated areas was significantly higher than international guidelines (Ni= 0.2 µg g^{-1}) (WHO/EU, 1990). The primary sources for Ni are ultramafic rocks and the soil derived from these rocks. However, it is also used extensively as the catalyst in different industrial and chemical processes (Khan *et al*., 2015). Also, in Nevsehir, it is extensively used as a catalyst in different industrial and chemical processes, so, supporting these findings, Ni concentration was especially high in river water irrigated vegetables.

The range of cadmium for tube well, river, and wastewater irrigated vegetables was 0.0007 to 0.0190 µg g^{-1} (Table 6). Our Cd findings for wastewater and tube well-irrigated vegetables did not show higher levels than the safe limit set by WHO (0.01 µg g^{-1}), but leaf samples of tomato and pepper irrigated with river water exceeded the limits (WHO/EU, 1990). Demirezen and Aksoy (2005) reported Cd content (0.24-0.97 µg g^{-1}) in various vegetables and suggested that its consumption was inappropriate for human health. In general, with this study, we can claim that Cd accumulation in the studied vegetables does not pose a threat for human consumption.

The sequence of the amounts of heavy metals in vegetable samples was in the order of Fe> Zn> Cu> Ni> Pb> Cr> Cd. The heavy metal accumulation probability of vegetable is related to irrigation frequency of river water and wastewater, physical structure and chemical composition of soil, and the capacity of metal accumulation.

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Table 5. Comparison of accumulation of Fe, Zn, and Cu in different parts of tomato, onion, pepper, and beans irrigated with different water sources (µg g^{-1}).[a]

	Plant	Parts	TW	RW	WW
Fe	Tomato	Root	16.8890(f)	35.2767(h)	5.0913(c)
		Stem	2.3657(b)	50.1930(i)	2.6130(b)
		Leave	23.4253(g)	15.7073(f)	8.1480(d)
		Edible part	1.0383(ab)	1.8273(ab)	1.6053(ab)
	Onion	Root	2.2530(b)	2.3803(b)	11.8090(e)
		Leave	8.5827(d)	7.7800(d)	3.6710(b)
		Edible part	4.3687(c)	1.2177(ab)	0.7417(a)
	Pepper	Root	22.1260(g)	30.2383(h)	11.8090(e)
		Stem	1.3740(ab)	1.2093(ab)	0.7957(a)
		Leave	5.3583(c)	9.1300(d)	4.4027(c)
		Edible part	3.3467(b)	1.7060(ab)	0.8837(a)
	Beans	Root	3.7563(b)	19.8460(g)	4.4117(c)
		Stem	1.7980(ab)	8.8650(d)	2.0163(b)
		Leave	8.4243(d)	51.6210(i)	13.9013(e)
		Edible part	0.9270(a)	1.1693(ab)	0.9477(a)
Zn	Tomato	Root	0.7130(b)	1.2603(bc)	0.4273(ab)
		Stem	0.5973(b)	1.9827(c)	0.3543(ab)
		Leave	0.3677(ab)	0.7257(b)	0.4977(ab)
		Edible part	0.5877(b)	0.4997(ab)	0.5440(b)
	Onion	Root	0.9293(bc)	4.0840(d)	1.6030(c)
		Leave	0.1163(a)	0.2080(ab)	0.1193(a)
		Edible part	0.5793(b)	0.6570(b)	0.7487(b)
	Pepper	Root	0.6147(b)	1.7273(c)	0.7480(b)
		Stem	0.4867(ab)	0.2783(ab)	0.5667(b)
		Leave	0.8160(b)	0.7700(b)	0.8970(b)
		Edible part	0.5377(b)	0.4607(ab)	0.4680(ab)
	Beans	Root	0.3567(ab)	0.4273(ab)	0.6130(b)
		Stem	0.3650(ab)	0.5070(b)	0.6757(b)
		Leave	0.2370(ab)	0.5460(b)	0.5873(b)
		Edible part	0.2843(ab)	0.6603(b)	0.5770(b)
Cu	Tomato	Root	0.2687(c)	0.3150(c)	0.1900(b)
		Stem	0.0747(a)	0.2307(c)	0.1183(b)
		Leave	0.1520(b)	0.4280(d)	0.1677(b)
		Edible part	0.1970(b)	0.1513(b)	0.2583(c)
	Onion	Root	0.1563(b)	0.1933(b)	0.1563(b)
		Leave	0.1153(b)	0.0837(a)	0.1120(b)
		Edible part	0.1693(b)	0.1447(b)	0.1723(b)
	Pepper	Root	0.2393(c)	0.5143(e)	0.2540(c)
		Stem	0.0823(a)	0.1903(b)	0.1823(b)
		Leave	0.0733(a)	0.3697(d)	0.1483(b)
		Edible part	0.1047(b)	0.2700(c)	0.2330(c)
	Beans	Root	0.1193(b)	0.1377(b)	0.1273(b)
		Stem	0.0850(a)	0.2260(c)	0.1173(b)
		Leave	0.0917(a)	0.2197(c)	0.1633(b)
		Edible part	0.0853(a)	0.2330(c)	0.1660(b)

[a] For a given metal, mean concentrations followed by the same letter are not significantly different ($P< 0.05$).

Table 6. Comparison of accumulation of Lead (Pb); Chromium (Cr); Nickel (Ni), and Cadmium (Cd) in different parts of Tomato; Onion; Pepper, and Beans irrigated with different water sources (µg g^{-1}).[a]

	Plant	Parts	TW	RW	WW
	Tomato	Root	0.0293$^{(b)}$	0.1190$^{(e)}$	0.0243$^{(b)}$
		Stem	0.0153$^{(a)}$	0.0297$^{(b)}$	0.0367$^{(bc)}$
		Leave	0.0307$^{(bc)}$	0.0403$^{(c)}$	0.0330$^{(bc)}$
		Edible Part	0.0197$^{(a)}$	0.0310$^{(bc)}$	0.0247$^{(b)}$
	Onion	Root	0.0200$^{(b)}$	0.0193$^{(a)}$	0.0293$^{(b)}$
		Leave	0.0207$^{(b)}$	0.0257$^{(b)}$	0.0177$^{(a)}$
Pb		Edible Part	0.0187$^{(a)}$	0.0227$^{(b)}$	0.0213$^{(b)}$
	Pepper	Root	0.0403$^{(c)}$	0.1063$^{(e)}$	0.0403$^{(c)}$
		Stem	0.0147$^{(a)}$	0.0247$^{(b)}$	0.0233$^{(b)}$
		Leave	0.0787$^{(d)}$	0.0427$^{(c)}$	0.0210$^{(b)}$
		Edible Part	0.0150$^{(a)}$	0.0237$^{(b)}$	0.0263$^{(b)}$
	Beans	Root	0.0240$^{(b)}$	0.0780$^{(d)}$	0.0227$^{(b)}$
		Stem	0.0173$^{(a)}$	0.0330$^{(bc)}$	0.0257$^{(b)}$
		Leave	0.0407$^{(c)}$	0.0767$^{(d)}$	0.0253$^{(b)}$
		Edible Part	0.0227$^{(b)}$	0.0187$^{(a)}$	0.0243$^{(b)}$
	Tomato	Root	0.0167$^{(b)}$	0.0300$^{(c)}$	0.0030$^{(ab)}$
		Stem	0.0067$^{(ab)}$	0.0010$^{(a)}$	0.0060$^{(ab)}$
		Leave	0.0107$^{(b)}$	0.0100$^{(b)}$	0.0030$^{(ab)}$
		Edible Part	0.0040$^{(ab)}$	0.0040$^{(ab)}$	0.0043$^{(ab)}$
	Onion	Root	0.0023$^{(ab)}$	0.0001$^{(a)}$	0.0040$^{(ab)}$
Cr		Leave	0.0003$^{(a)}$	0.0001$^{(a)}$	0.0040$^{(ab)}$
		Edible Part	0.0017$^{(ab)}$	0.0040$^{(ab)}$	0.0067$^{(ab)}$
	Pepper	Root	0.0140$^{(b)}$	0.0353$^{(c)}$	0.0033$^{(ab)}$
		Stem	0.0040$^{(ab)}$	0.0037$^{(ab)}$	0.0047$^{(ab)}$
		Leave	0.0020$^{(ab)}$	0.0053$^{(ab)}$	0.0030$^{(ab)}$
		Edible Part	0.0010$^{(a)}$	0.0023$^{(ab)}$	0.0050$^{(ab)}$
	Beans	Root	0.3567$^{(d)}$	0.0163$^{(b)}$	0.0053$^{(ab)}$
		Stem	0.0070$^{(ab)}$	0.0040$^{(ab)}$	0.0050$^{(ab)}$
		Leave	0.0020$^{(ab)}$	0.0487$^{(c)}$	0.0043$^{(ab)}$
		Edible Part	0.0047$^{(ab)}$	0.0053$^{(ab)}$	0.0057$^{(ab)}$
	Tomato	Root	0.1130$^{(c)}$	0.1977$^{(d)}$	0.0390$^{(b)}$
		Stem	0.0123$^{(b)}$	0.0490$^{(b)}$	0.0213$^{(b)}$
		Leave	0.0660$^{(bc)}$	0.0827$^{(bc)}$	5.3583$^{(f)}$
		Edible Part	0.0253$^{(b)}$	0.0363$^{(b)}$	0.0493$^{(b)}$
	Onion	Root	0.0340$^{(b)}$	0.0620$^{(bc)}$	0.0680$^{(bc)}$
		Leave	0.0037$^{(a)}$	0.0340$^{(b)}$	0.0273$^{(b)}$
Ni		Edible Part	0.0390$^{(b)}$	0.0477$^{(b)}$	0.0200$^{(b)}$
	Pepper	Root	0.1090$^{(c)}$	0.3043$^{(e)}$	0.0547$^{(bc)}$
		Stem	0.0297$^{(b)}$	0.0637$^{(bc)}$	0.0227$^{(b)}$
		Leave	0.0293$^{(b)}$	0.0887$^{(bc)}$	0.0317$^{(b)}$
		Edible Part	0.0270$^{(b)}$	0.0767$^{(bc)}$	0.0270$^{(b)}$
	Beans	Root	0.0430$^{(b)}$	0.1080$^{(c)}$	0.0403$^{(b)}$
		Stem	0.0290$^{(b)}$	0.0590$^{(bc)}$	0.0367$^{(b)}$
		Leave	0.0350$^{(b)}$	0.2127$^{(d)}$	0.0583$^{(bc)}$
		Edible Part	0.0233$^{(b)}$	0.0943$^{(c)}$	0.0767$^{(bc)}$
	Tomato	Root	0.0023$^{(ab)}$	0.0090$^{(b)}$	0.0030$^{(ab)}$
		Stem	0.0003$^{(a)}$	0.0077$^{(b)}$	0.0013$^{(ab)}$
		Leave	0.0013$^{(ab)}$	0.0190$^{(c)}$	0.0060$^{(b)}$
		Edible Part	0.0017$^{(ab)}$	0.0013$^{(ab)}$	0.0010$^{(ab)}$
	Onion	Root	0.0013$^{(ab)}$	0.0013$^{(ab)}$	0.0013$^{(ab)}$
		Leave	0.0007$^{(a)}$	0.0037$^{(ab)}$	0.0250$^{(d)}$
Cd		Edible Part	0.0010$^{(ab)}$	0.0010$^{(ab)}$	0.0010$^{(ab)}$
	Pepper	Root	0.0013$^{(ab)}$	0.0287$^{(d)}$	0.0023$^{(ab)}$
		Stem	0.0040$^{(b)}$	0.0087$^{(b)}$	0.0007$^{(a)}$
		Leave	0.0040$^{(b)}$	0.0150$^{(c)}$	0.0023$^{(ab)}$
		Edible Part	0.0007$^{(a)}$	0.0040$^{(b)}$	0.0037$^{(b)}$
	Beans	Root	0.0240$^{(d)}$	0.0017$^{(ab)}$	0.0030$^{(ab)}$
		Stem	0.0020$^{(ab)}$	0.0030$^{(ab)}$	0.0030$^{(ab)}$
		Leave	0.0013$^{(ab)}$	0.0014$^{(ab)}$	0.0010$^{(ab)}$
		Edible Part	0.0030$^{(ab)}$	0.0030$^{(ab)}$	0.0037$^{(b)}$

[a] For a given metal, mean concentrations followed by the same letter are not significantly different (P< 0.05).

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Bioconcentration Factor

Bioconcentration factor was determined in the selected vegetables for the studied metals (Figure 2). The results are given in the form of figures. Kahn *et al*. (2015) determined that the tube well irrigated plant generally had the highest *BCF* value; and this finding is parallel with our findings. Nickel accumulation was significantly higher ($P< 0.05$) in peppers and beans when irrigated with river water. The highest *BCF* value for Cd was observed in beans when irrigated with tube well water, and also pepper irrigated with wastewater showed difference from the other vegetables. All *BCF* values of Pb in all plants and all types of irrigations were high (Figure 2). It was also observed that the *BCF* values for Pb in wastewater irrigated tomato were found to be significantly greater ($P< 0.05$). In the case of Cu, Cr, and Zn, the maximum *BCF* value was recorded in tomato, onion, and pepper, respectively, when irrigated with tube well water and wastewater; while the greatest *BCF* value for Fe was observed in onion and pepper irrigated with tube well water. The overall trend of *BCF* values for the metals in selected vegetables were Cd> Cu> Zn> Ni> Pb> Cr> Fe for tube well water; and Cu> Ni> Zn> Cd> Pb> Cr> Fe; and Cd> Cu> Zn> Pb> Ni> Cr> Fe for river water and wastewater, respectively (Figure 2).

Daily Intake Metals

Determination of the ways the pollutants reach the target organism and their duration of exposure are among the most important steps to overcome the health problems caused by pollutants. The food chain is the most important pathway for heavy metals in their exposure to the humans (Li *et al*., 2006). In this study, *DIM* values were calculated for adults and children (Figure 3). For the studied vegetables, Figure 3 clearly indicates that all heavy metals, except for Fe, had the highest daily intake amounts when wastewater and river water were used for irrigation.

Several studies emphasize that *DIM* values of vegetables irrigated with heavy metal contaminated waters are very high, and these findings are in agreement with the present study (Chopra and Pathak, 2015; Khan *et al*., 2015). However, according to the guidelines of WHO (WHO, 2002), the *DIM* for Cu, Zn, Fe, Pb and Ni is 0.01, 0.025, 0.05, 0.005, 0.002, respectively, thus, in this study, *DIM* values are risk-free .

Heavy metals are taken into the body in different ways such as dust inhalation, dermal contact, and ingestion of metal contaminated food. We emphasized only one way of heavy metal intake in this study. It is notable that, the pathway of heavy metal intake that this study has focused on can be combined with the other ways of intake, and cause very damaging effects on the human health.

CONCLUSIONS

In this study, four different green vegetables were studied, namely, tomato, onion, pepper and beans irrigated with different water resources (tube well water, river water, and wastewater), in Nevsehir Province. Accumulation of seven different heavy metals (Cd, Pb, Zn, Cr, Cu, Ni and Fe) was determined in different parts of vegetables. As a result, it can be stated that there is no danger in using tube well water for irrigation of vegetables, in terms of heavy metal contamination. On the other hand, wastewater, and especially river water, irrigation may cause heavy metal accumulation in high concentrations. It is clearly understood from *DIM* and *BCF* values that wastewater and river water irrigated plants potentially have serious health risks. We concluded that using wastewater and river water for irrigation without any treatment will contaminate soil and vegetables seriously. To avoid casualty and health risk that may happen due to long-term wastewater and river water irrigation, it

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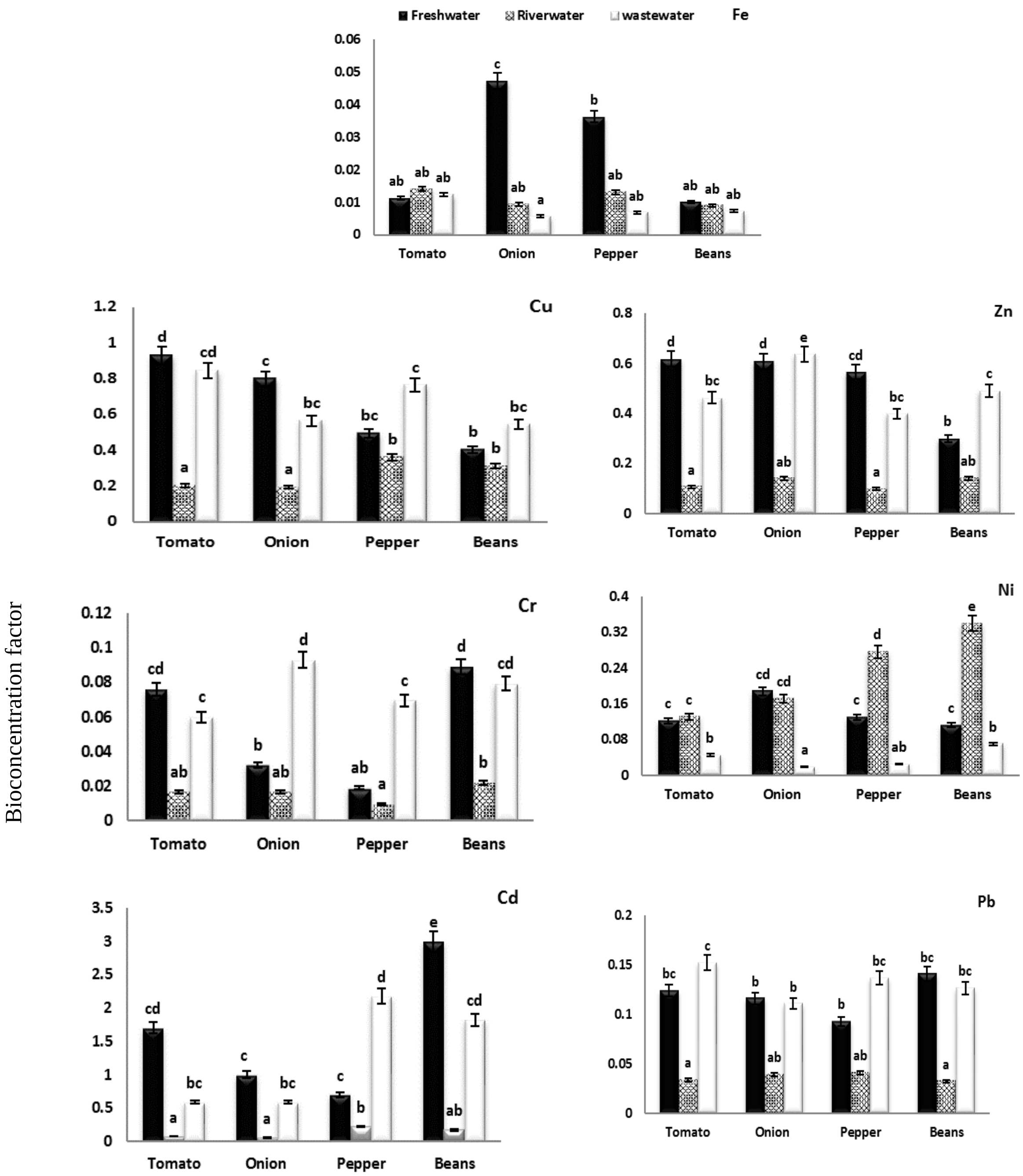

Figure 2. Bio-concentration of different metals in vegetables irrigated with Tube well Water (TW), Waste Water (WW) and River Water (RW). Bars labelled with different letters indicate significant differences among means determined by using Duncan's multiple-range test (P< 0.05). For a given metal, mean concentrations followed by the same letter are not significantly different

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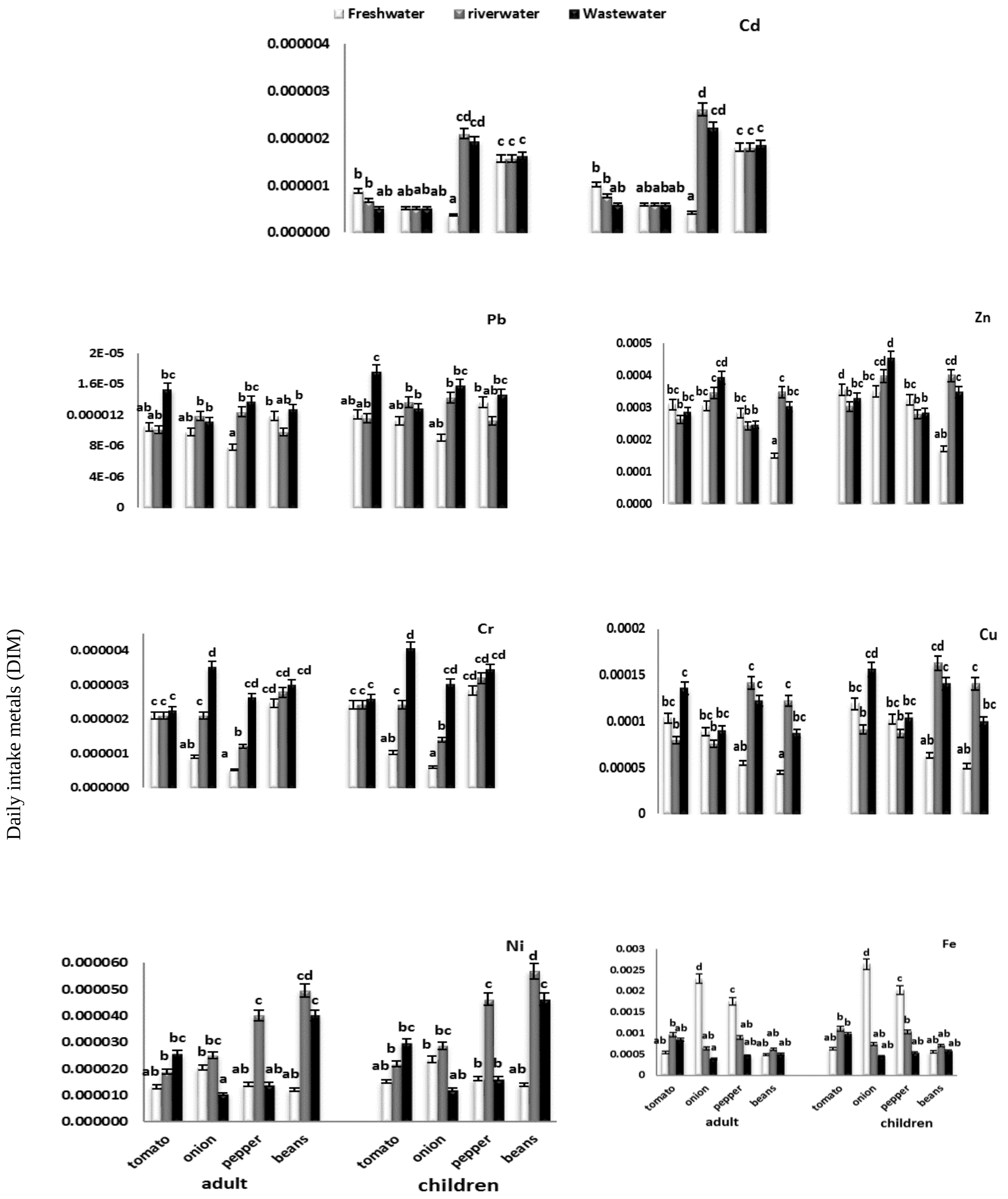

Figure 3 Comparison of heavy metals intake by adult and children through vegetables irrigated with Tube well Water (TW), Waste Water (WW) and River Water (RW). Bars labelled with different letters indicate significant differences among means determined by using Duncan's multiple-range test (P< 0.05).

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is recommended that vegetables be monitored regarding the content of the heavy metals.

REFERENCES

1. Al-busaidi, A., Shahroona, B., Al-yahyai, R. and Ahmed, M. 2015. Heavy Metal Concentratıons In Soils and Date Palms Irrıgated By Groundwater and Treated Wastewater. *Pak. J. Agric. Sci*, **52**: 129–134.
2. Alexander, P.D., Alloway, B.J. and Dourado, A.M. 2006. Genotypic Variations in the Accumulation of Cd, Cu, Pb and Zn Exhibited by Six Commonly Grown Vegetables. *Environ. Pollut.*, **144**: 736–45. doi:10.1016/j.envpol.2006.03.001
3. Amin, N., Hussain, A., Alamzeb, S. and Begum, S. 2013. Accumulation of Heavy Metals in Edible Parts of Vegetables Irrigated with Waste Water and Their Daily Intake to Adults and Children, District Mardan, Pakistan. *Food Chem.*, **136:** 1515–23. doi:10.1016/j.foodchem.2012.09.058
4. APHA. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th Edition, American Public Health Association, Baltimore. PP??
5. Arora, M., Kiran, B., Rani, S., Rani, A., Kaur, B.and Mittal, N. 2008. Heavy Metal Accumulation in Vegetables Irrigated with Water from Different Sources. *Food Chem.,* **111:** 811–815. doi:10.1016/j.foodchem.2008.04.049
6. Chopra, A. K. and Pathak, C. 2015. Accumulation of Heavy Metals in the Vegetables Grown in Wastewater Irrigated Areas of Dehradun, India with Reference to Human Health Risk. *Environ. Monit. Assess.,* **187:** 1–8. doi:10.1007/s10661-015-4648-6
7. D. Demirezen, A. Aksoy. 2006, Heavy Metal Levels in Vegetables in Turkey are Within Safe Limits for Cu, Zn, Ni and Exceeded for Cd and Pb. *Journal of Food Quality*, **29** : 252-265.
8. Dikinya, O. and Areola, O. 2010. Comparative Analysis of Heavy Metal Concentration in Secondary Treated Wastewater Irrigated Soils Cultivated by Different Crops. *Int. J. Environ. Sci. Technol.,* **7:** 337–346. doi:10.1007/BF03326143
9. Dilek, D. and Aksoy, A. 2005. Heavy Metal Levels ın Vegetables ın Turkey are Wıthın Safe Limıis for Cu, Zn, Ni and Exceeded for Cd and Pb. *J. Food Qual.,* **29:** 252–265. doi:10.1111/j.1745-4557.2006.00072.x
10. Duman, F. and Kar, M. 2012. Temporal Variation of Metals in Water, Sediment and Tissues of the European Chup (*Squalius cephalus* L.). *Bull. Environ. Contam. Toxicol.*, **89:** 428–433. doi:10.1007/s00128-012-0679-7
11. FAO. 1985. *Water Quality for Agriculture*. Irrigation and Drainage Paper.No.?????
12. FAO/WHO. 1993. *Food Additives and Contaminants*. Joints FAO/WHO Food Standard Programme ALINORM.
13. Farooq, R., Khan, S., Shahbaz, S., Khan, M. A. and Sadique, M. 2009. Health Risk Assessment of Heavy Metals for Population via Consumption of Vegetables. *World Appl. Sci. J.,* **6:** 1602–1606. doi:10.14737/journal.aavs/2015/3.1.58.70
14. Ferri, R., Donna F., Smith, D. R., Guazzetti S., Zacco, A., Rizzo L., Bontempi E., Zimmerman, N. J. and Lucchini, R. G. 2012. Heavy Metals in Soil and Salad in the Proximity of Historical Ferroalloy Emission. *J. Environ. Prot. (Irvine, Calif.),* **3:** 374–385.
15. Ghorbani, H., Hafezi Moghads, N. and Kashi, H. 2015. Effects of Land Use on the Concentrations of Some Heavy Metals in Soils of Golestan Province, Iran. *J. Agr. Sci. Tech.*, **17:** 1025–1040.
16. Gupta, N., Khan, D. K. and Santra, S. C. 2008. An Assessment of Heavy Metal Contamination in Vegetables Grown in Wastewater-Irrigated Areas of Titagarh, West Bengal, India. *Bull. Environ. Contam. Toxicol.*, **80:** 115–118. doi:10.1007/s00128-007-9327-z
17. Gupta, S., Satpati, S., Nayek, S. and Garai, D. 2010. Effect of Wastewater Irrigation on Vegetables in Relation to Bioaccumulation of Heavy Metals and Biochemical Changes. *Environ. Monit. Assess.,* **165:** 169–177. doi:10.1007/s10661-009-0936-3
18. Islam, M. S., Ahmed, M. K., Habibullah-Al-Mamun, M. and Raknuzzaman, M. 2015. The Concentration, Source and Potential Human Health Risk of Heavy Metals in the Commonly Consumed Foods in Bangladesh. *Ecotoxicol. Environ. Saf.,* **122:** 462–469. doi:10.1016/j.ecoenv.2015.09.022

19. Khan, S. A., Liu, X., Shah, B. R., Fan, W., Li, H., Khan, S. B. and Ahmad, Z. 2015. Metals Uptake by Wastewater Irrigated Vegetables and Their Daily Dietary Intake in Peshawar, Pakistan. *Ecol. Chem. Eng. Sci.*, **22:** 125–139. doi:10.1515/eces-2015-0008
20. Kumar Sharma, R., Agrawal, M. and Marshall, F. 2007. Heavy Metal Contamination of Soil and Vegetables in Suburban Areas of Varanasi, India. *Ecotoxicol. Environ. Saf.*, **66:** 258–266. doi:10.1016/j.ecoenv.2005.11.007
21. Li, Y., Wang, Y., Gou, X., Su, Y. and Wang, G. 2006. Risk Assessment of Heavy Metals in Soils and Vegetables around Non-Ferrous Metals Mining and Smelting Sites, Baiyin, China. *J. Environ. Sci.*, **18:** 1124–1134. doi:10.1016/S1001-0742(06)60050-8
22. Liu, W., Zhao, J., Ouyang, Z., Söderlund, L. and Liu, G. 2005. Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing , China. *Environ. Int.*, **31:** 805–812. doi:10.1016/j.envint.2005.05.042
23. Orisakwe, O. E., Nduka, J. K., Amadi, C. N., Dike, D. O. and Bede, O. 2012. Heavy Metals Health Risk Assessment for Population *via* Consumption of Food Crops and Fruits in Owerri, South Eastern, Nigeria. *Chem. Cent. J.*, **6:** 77. doi:10.1186/1752-153X-6-77
24. Osma, E., Ilker Ozyigit, I., Leblebici, Z., Demir, G., Serin, M., Osma, E., Ozyigit, I. I., Leblebici, Z., Demir, G. and Serin, M. 2012. Determination of Heavy Metal Concentrations in Tomato (*Lycopersicon esculentum* Miller) Grown in Different Station Types. *Rom Biotechnol. Lett.*, **17.**
25. Ozturk, F., Duman, F., Leblebici, Z. and Temizgul, R. 2010. Arsenic Accumulation and Biological Responses of Watercress (*Nasturtium officinale* R. Br.) Exposed to Arsenite. *Environ. Exp. Bot.*, **69:** 167–174. doi:10.1016/j.envexpbot.2010.03.006
26. Rattan, R. K., Datta, S. P., Chhonkar, P. K., Suribabu, K. and Singh, A. K. 2005. Long-Term Impact of Irrigation with Sewage Effluents on Heavy Metal Content in Soils, Crops and Groundwater: A Case Study. *Agric. Ecosyst. Environ.*, **109:** 310–322. doi:10.1016/j.agee.2005.02.025
27. Rahmani G. N. H., Stenberg S. P. K. Bioremoval of Lead from Water Using Lemna Minor. *Biores. Tech.* **70**:225–230. doi: 10.1016/S0960-8524(99)00050-4.
28. Ravet, K., Touraine, B., Boucherez, J., Briat, J. -F., Gaymard, F. and Cellier, F. 2009. Ferritins Control Interaction between Iron Homeostasis and Oxidative Stress in Arabidopsis. *Plant. J.*, **57:** 400–12. doi:10.1111/j.1365-313X.2008.03698.x
29. WHO. 2002. *Evaluation of Certain Food Additives and Contaminants.* Thirty-Seventh Report of the Joint FAO/WHO Expert Committee on Food Additives, World Health Organ Tech Rep Ser 1–186.
30. WHO/EU. 1990. *Who, Cadmium Environmetnal Health Criteria.* World Helath Organization, Geneva.
31. Yang, Q. W., Xu, Y., Liu, S. J, He, J. F. and Long, F. Y.2011. Concentration and Potential Health Risk of Heavy mMetals in Market Vegetables in Chongqing, China. *Ecotoxicol. Environ. Saf.*, **74:** 1664–1669. doi:10.1016/j.ecoenv.2011.05.006

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انباشت فلزات سنگین در سبزیجات آبیاری شده با منابع مختلف آب و مصرف روزانه آنها در منطقه Nevsehir

ز. لبلبیسی، و م. کار

چکیده

در پژوهش حاضر، اثر منابع مختلف آب آبیاری در جذب فلزات(شامل Cd، Pb، Zn، Cr،Cu، Niو Fe) به وسیله گوجه فرنگی (*Solanum lycopersicum*)، پیاز (*Allium cepa L*)، فلفل (*Capsicum annuum L*) و لوبیا (*Phaseolus vulgaris L*) کاشته شده در استان Nevsehir با استفاده از روش اسپکتروسکوپ نوری -پلاسما القایی (ICP-OES) تعیین شد. غلظت فلزات سنگین در سبزیجات آبیاری شده با فاضلاب و آب رودخانه به طور معناداری ($p<0.05$) بیشتر از آب چاه بود و از حد مجاز WHO/FAO تجاوز می کرد. در قسمت های خوردنی سبزیجات، بیشینه انباشت Fe و Cr در پیاز، Zn و Pb در گوجه فرنگی ، و به دنبال آنها Niدر لوبیا بود در حالیکه مقدار Cd و Cu در فلفل زیاد بود. همچنین، ضریب غلظت زیستی (BCF)و مصرف روزانه فلزات (DIM)محاسبه شد و مشخص گردید که DIM در حد بی خطر بود چرا که حد مصرف رژیم غذایی روزانه Cu، Fe، Zn، و Mn در افراد بالغ به ترتیب در محدوده 1/2 تا 3 میلی گرم، 10 تا 50 میلی گرم، 5 تا 22 میلی گرم، و 2 تا 22 میلی گرم می تواند تغییر کند. در نتیجه، فاضلاب و آب رودخانه برای کشاورزی و به ویژه برای آبیاری مناسب نبودند زیرا مقادیر زیاد آلودگی فلزات در خاک به مسایل بهداشتی متعددی منجر می شود.

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