



Full length article

Impact of irrigation with wastewater on accumulation of heavy metals in soil and crops in the region of Marrakech in Morocco

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ABSTRACT

Actually, the accumulation of heavy metals by crops irrigated by wastewater has considered a serious environmental problem in many countries such as Morocco, where the wastewater irrigation has become a widespread practice. In this study, we were interested in highly toxic metals such as zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd) in water, agricultural soils and crops and their possible risk on human health in the region of Marrakech.

The physicochemical parameters pH, electrical conductivity, organic carbon and organic matter, were determined for the samples. Irrigated water, soil and vegetable samples for Zn, Cu, Pb and Cd concentrations and transfer factor from soils to plants (TF) were analyzed, daily intake of metals (DIM) and health risk index (HRI) were calculated.

The irrigated soil was contaminated with Zn (112.71 mg/kg), Cu (17.70 mg/kg), Pb (57.36 mg/kg) and Cd (11.22 mg/kg). The trend of heavy-metal concentrations in all samples was Zn > Pb > Cu > Cd. The daily intake (DIM) for Cd and Pb exceeded the permissible limits. The Health Risk Index (HRI) varied from 0.054–0.174 for Zn, 0.031–0.242 for Cu, 2.407–7.973 for Pb and 0–5.059 for Cd. The HRI was >1 for Cd and Pb indicating a potential health risk.

Our results revealed high risks indexes, heavy metal contaminated food crops in our study area, and consequently, a great health risk to the local human and animal populations. Thus, preventive measures must be taken to reduce heavy metal pollution of irrigation water and soils to protect both, human and animal health in Marrakech and Morocco.

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1. Introduction

Recently, the reuse of wastewater in agriculture has become a widespread practice in regions where water deficits are most pronounced (Hajjami et al., 2013). In general, this resource contains substantial amounts of beneficial nutrients and toxic pollutants, which are creating opportunities and problems for agricultural production, respectively (Alghobar and Suresha, 2017).

Therefore, long-term use of industrial or municipal wastewater in irrigation may lead to the accumulation of heavy metals in agricultural soils and plants (Singh et al., 2010). Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic or industrial application (Petrus and Warchol, 2005).

Contamination of agricultural soils and crops by heavy metals have considered one of a serious environmental problem due to their non-biodegradable nature and long biological half-life and also, their potential accumulation in different body parts (Radwan and Salama, 2006; Khan et al., 2010; Muhammad et al., 2011). Some heavy metals such as zinc (Zn), cadmium (Cd), lead (Pb) and copper (Cu) are mostly found as contaminants in vegetables (Kachenko and Singh, 2006).

Excessive accumulation of heavy metals in agricultural soils through irrigation wastewater threat residents lives who consume crops and/or vegetables grown in contaminated areas. Heavy metal contamination of foodstuffs is the first indicator of food safety and quality (Marshall, 2004; Radwan and Salama, 2006; Khan et al.,

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2008). contaminated food by heavy metals has toxic effects on human health and can seriously deplete some essential nutrients in the body that are further responsible of decreasing immunological defenses, intrauterine growth retardation, impaired psychosocial faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Lyengar and Nair, 2000; Türkdoğan et al., 2003; Arora et al., 2008).

Several studies show the potential risk to human health due to the accumulation of heavy metals in plants (Chauhan and Chauhan, 2014; Balkhair and Ashraf, 2016; Alghobar and Suresha, 2017). The level of health risks posed by wastewater with heavy metals was determined using different indices, including the transfer factor (TF), daily intake of metals (DIM) and health risk index (HRI) or health quotient (HQ) (Liu et al., 2005; Khan et al., 2008).

Heavy metals such as Cd and Pb have been shown to have carcinogenic effects (Jaishankar et al., 2014). Other metal elements such as copper (Cu) and zinc (Zn) are essential nutrients for human health, but they can be toxic in high concentrations (Rahman et al., 2014). For example, a Zn can reduce immune function and levels of high-density lipoproteins (Harmanescu et al., 2011), and Cu surplus can cause acute stomach and intestine aches, and liver damage (Rahman et al., 2014; Gaetke and Chow, 2003).

The main objectives of this study are primarily to quantify the concentration of these heavy metals (Zn, Cu, Pb and Cd) in irrigation wastewater, soil and crops cultivated in Marrakech region (Morocco) and to estimate the human and animal health risk caused by the daily intake of these metals through contaminated vegetables using the health risk index (HRI).

2. Materials and methods

2.1. Study area

The current study was carried during spring 2016 in Marrakech city, Morocco. This region has a wastewater treatment plant (WWTP) with a capacity of 1.3 million of population equivalents (RADEEMA, 2012). The WWTP is located on a lot of 17 ha in the Tensift river bed downstream of the dam that allows the N7 (Safi Road) to cross the river. The wastewater discharged from the WWTP is directed through the irrigation channels into the fields

where farmers fetch to irrigate their crops. The Discharge point and irrigation area are located at latitude N31.69668°N, 31.70383°N and longitude 008.06380°W, 008.06928°W and at the elevation of approximately 454 and 379 meters above sea level, respectively (Fig. 1).

2.2. Water sampling and treatment

The water samples were collected along the canal from the discharge of raw sewage, from WWTP of Marrakech to the irrigation area. Samples of 10 liters were stored in polyethylene bottles, pre-washed with nitric acid (1%) and stored at 4 °C until analyses. Then, pH, electrical conductivity (EC) and heavy metals concentrations were measured according to standard methods (AFNOR, 1997).

2.3. Soil sampling and characterization

Fifteen representative soil samples from irrigation area were collected in a clean polyethylene bag from each plant sampling plot. The soil sub-samples were obtained from the depth of 0–20 cm using the soil auger. In the laboratory, all samples were air-dried in ambient conditions and passed through a 2-mm mesh sieve. Non-soil particles e.g. stones, wooden pieces, rocks, gravels, organic debris were removed. pH, electrical conductivity (EC), organic carbon (OC) and organic matter were measured according to soil analysis methods (AFNOR, 1994).

2.4. Plant sampling and identification

The common vegetables grown in the study area are Broad bean (*Vicia faba*), Durum Wheat (*Triticum turgidum*), soft wheat (*Triticum aestivum*), Oat (*Avena sativa*), Nettle (*Urtica dioica*), Broadleaf plantain (*Plantago major*), Alfalfa (*Medicago sativa*) and Mallow (*Malva sylvestris*). The detailed of the vegetable samples collected from the experimental sites are given in Table 1. 500 g of each plant was collected with three replications. In the laboratory, each individual vegetable was separated into root, leaf and seed sub-samples and properly washed with deionized water to remove all visible soil particles.

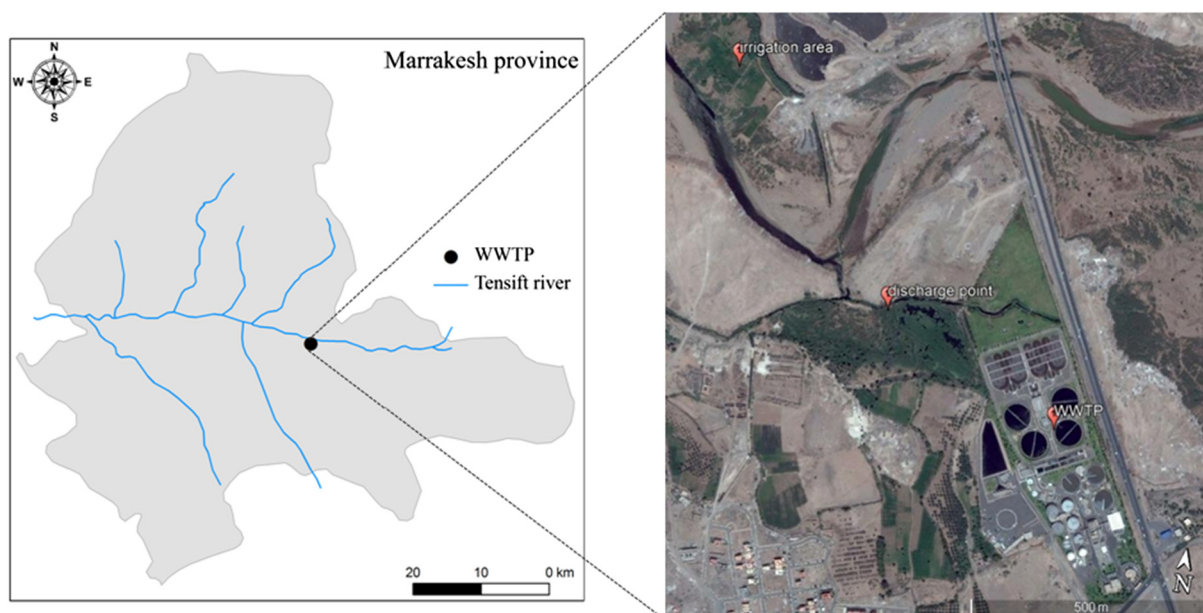


Fig. 1. Study area.

Table 1

Description of vegetable samples analyzed.

Species	Common name	Family	Order	Use
<i>Vicia faba</i>	Broad bean	Fabaceae	Fabales	Feed
<i>Triticum turgidum</i>	Durum wheat	Poaceae	Poales	Feed
<i>Triticum aestivum</i>	Soft wheat	Poaceae	Poales	Feed
<i>Avena sativa</i>	Oat	Poaceae	Poales	Feed
<i>Urtica dioica</i>	Nettle	Urticaceae	Rosales	Traditional medicine - Feed
<i>Plantago major</i>	Broadleaf plantain	Plantaginaceae	Lamiales	Traditional medicine - Feed
<i>Medicago sativa</i>	Alfalfa	Fabaceae	Fabales	Fodder Product - Traditional medicine
<i>Malva sylvestris</i>	Mallow	Malvaceae	Malvales	Traditional medicine - Feed

2.5. Heavy metals analysis

2.5.1. Digestion of vegetable and soil samples

All samples were dried in an oven at 75 °C for 72 h and then ground to powder. 0.5 g of each soil and vegetable samples were digested in the presence of aqua regia (mixture of nitric acid HNO₃ concentrated with hydrochloric acid HCl

(1:3)) overnight at room temperature. Then, the mixture was boiled for 2 h according to the standard method NF ISO 11466 (AFNOR, 1995). After cooling, the digested samples were filtered using Membrane (0.45 µm), the filtrate was diluted to 50 ml with deionized water and kept at room temperature for further analysis.

2.5.2. Heavy metals determination

Determination of the four heavy metals, Cu, Zn, Cd and Pb in the filtrate of samples was carried out and achieved by using UNICAM atomic absorption spectrophotometer (AAS).

The standard solutions were prepared for heavy metal determination by diluting a stock solution containing 100 ppm of single element AAS grade standard with distilled water. The standard solutions for the heavy metals were used to construct the calibration curves with the help of AAS. The Guideline for maximum limit of heavy metals (Zn, Cu, Pb and Cd) in irrigation water, soil and vegetable was adopted from the reference by WHO/FAO, European Union Standard and USEPA (Table 2).

2.6. Data analysis

2.6.1. Transfer factor (TF)

The bioaccumulation of metals in plants from soils can be predicted using a transfer factor (TF) (Kachenko and Singh, 2006):

$$TF = \frac{C_{\text{plant}}}{C_{\text{soil}}} \quad (1)$$

where

C_{plant} and C_{soil} represent the heavy metal concentration in edible part of vegetables and soils, respectively.

The transfer coefficient may differ considerably between plant, soil, and metal types under investigation (Alexander et al., 2006).

2.6.2. Daily Intake of Heavy Metals (DIM)

The daily intake of heavy metals DIM depends on both the metal concentration in crops and the amount of consumption of the respective food crop, following equation:

$$DIM = \frac{C_{\text{metal}} \times C_{\text{factor}} \times D_{\text{food intake}}}{BW_{\text{average}}} \quad (2)$$

where C_{metal}, C_{factor}, D_{food intake} and BW_{average} represent the heavy metal concentrations in plants (mg/kg), conversion factor (fresh vegetable weight into dry vegetable weight), daily intake of vegetables and average body weight, respectively.

The conversion factor 0.085 was used to convert fresh green vegetable weight to dry weight, as described by Rattan et al. (2005). The average daily vegetable intake for adults and children was considered to be 0.345 and 0.232 kg/person/day, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively (El fadeli et al. 2014). Upper tolerable daily intake limit (safe limits) for both adults and children through the consumption of vegetables were presented in Table 3.

2.6.3. Health Risk Index (HRI)

The health risk index is calculated by dividing daily intake of metals (DIM) by reference oral dose. This index represents the harmful to people in which consume vegetables contaminated with heavy metals. If the value of HRI is less than 1, people will safe to eat those kinds of vegetables (Cui et al., 2005).

$$HRI = \frac{DIM}{RFD} \quad (3)$$

Table 3

Upper tolerable daily intake limit for both adults and children (Chauhan and Chauhan, 2014).

Upper tolerable daily intake (mg day ⁻¹)	
Heavy Metals	Integrated Risk Information System (US EPA 2010)
Zinc (Zn)	40E–00
Copper (Cu)	10E–00
Lead (Pb)	2.40E–01
Cadmium (Cd)	6.40E–02

Table 2

Guideline for safe limits of heavy metals (Chauhan and Chauhan, 2014).

Samples	Standards	Zn	Cu	Pb	Cd
Water (mg/L)	WHO/FAO (2007)	2.0	0.20	5.0	0.01
	USEPA (2010)	2.00	1.00	0.015	0.005
Soil (mg/kg)	WHO/FAO (2007)	300–600	135–270	250–500	3.0–6.0
	USEPA (2010)	200	50	300	3.0
Plant (mg/kg)	WHO/FAO (2007)	60.0	40.0	5.0	0.2
	USEPA (2010)	–	–	–	–

Table 4

Oral reference doses ($\text{mg kg}^{-1} \text{ day}^{-1}$) for each heavy metal (Chauhan and Chauhan, 2014).

RFD ($\text{mg kg}^{-1} \text{ day}^{-1}$)		
Heavy Metals	Integrated Risk Information System (US EPA 2013)	FAO/WHO (Codex Alimentarius Commission, 2013)
Zn	–	$3.00\text{E}-01$
Cu	–	$4.00\text{E}-02$
Pb	$1.00\text{E}-03$	$4.00\text{E}-03$
Cd	–	$1.00\text{E}-03$

where

RFD = Oral Reference Dose.

The oral reference dose of each heavy metal is shown in Table 4.

2.7. Statistical analysis

Statistical analyses were carried out using the SigmaPlot Software program. The measurements were expressed in term of mean and standard deviation. The Comparison of two sites were done by a paired t-test. One-way ANOVA was applied for evaluating the significant difference between heavy metal concentration in vegetables grown in irrigation area.

3. Results and discussion

3.1. Sample characterization

The results of the physicochemical parameters of the wastewater discharged by the WWTP of Marrakech used in the irrigation of crops are presented in the Table 5. The average pH values for wastewater samples from discharge point and Irrigation area were 7.77 and 7.64 respectively. These values are within the permissible limit of WHO and FAO set for drinking and irrigation purposes (WHO, 2008). The tolerance limit of pH for irrigation water ranges from 6.0 to 9.0 (Singh et al., 2009). The mean electrical conductivity for wastewater at the two sampling points was $1622.33 \mu\text{S/cm}$ and $1515.33 \mu\text{S/cm}$ respectively. The comparison of the values of the electrical conductivity in the wastewater analyzed with the

Table 5

Average values of physico-chemical parameters and concentrations of heavy metals in wastewater from discharge point and irrigation area.

Parameters	Discharge point	Irrigation area	P value
pH	7.77 ± 0.047	7.64 ± 0.12	0.246
E.C ($\mu\text{S/cm}$)	1622.33 ± 83.56	1515.33 ± 96.44	0.360
Zn (mg/l)	1.59 ± 0.195	1.41 ± 0.375	0.522
Cu (mg/l)	0.102 ± 0.047	0.197 ± 0.214	0.686
Pb (mg/l)	1.417 ± 0.318	1.417 ± 0.358	0.949
Cd (mg/l)	0.0757 ± 0.006	0.086 ± 0.007	0.686

±: Standard deviation, P value: Level of significance for the differences between discharge point and irrigation area ($P > 0.05$: there is not a statistically significant difference between two sites)

Table 6

Characteristics of soils collected from the study area.

Physico-chemical parameters				Heavy metal concentrations			
pH	EC	Organic C (%)	%OM	Zn (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
7.81 ± 0.221	2.21 ± 0.122	4.87 ± 2.437	8.40 ± 4.202	112.71 ± 14.102	17.70 ± 5.285	57.36 ± 10.85	11.22 ± 1.09

±: Standard deviation.

water quality standards for irrigation can be deduced that these wastewater samples are acceptable for irrigation of crops (Moroccan Ministry of the Environment, 2002). The mean heavy-metal concentrations (mg/l) in wastewater between the sites were 1.59–1.41 for Zn, 0.102–0.197 for Cu, 1.417–1.417 for Pb and 0.0757–0.086 for Cd. The concentrations of heavy metals in wastewater channel were highest relatively for the Zn, followed by Pb, Cu, and Cd. Concentrations of Cu, Zn and Pb in the wastewater were below the permissible limits of heavy metals allowed in the irrigation water, but Cd exceeded the limit set by FAO/WHO (Table 1). Heavy metals that are present in wastewater used for irrigation tend to accumulate in the soils where there is a potential that they could become bioavailable for crops (Toze, 2006).

Table 6 presents the characteristics and total concentration of physico-chemical parameters in soils sampled at irrigation area. The average pH value of the soil samples was 7.81. The pH is one of the factors influencing the bioavailability and the transport of heavy metals in the soil. Heavy metal mobility decreases with increasing soil pH due to the precipitation of hydroxides, carbonates or the formation of insoluble organic complexes (Smith and Giller, 1992). The soil pH has a major influence on the mobility and bioavailability of heavy metals and its changes depend on pH of the wastewater used for irrigation (Nigam et al., 2001). Same studies reported that pH influences on bacterial populations associated with plants growing in metalliferous soils and potentially accumulating metals. These bacteria are referred to as plant growth promoting rhizobacteria (PGPR) (Nihorimbere et al., 2011; Sessitsch et al., 2013).

The mean of electrical conductivity in soil sample was $2.21 \text{ ms}/\mu\text{cm}$, classifying it as moderately saline according to Boulding (1994). Increase in conductivity has been shown to enhance the solubility of heavy metals, thus causing greater availability of metals to the plant from the soil (Ram et al., 2006; Singh et al., 2009).

The average value of organic carbon was 4.87%. Wastewater irrigation increased OC content of the soil, which may have resulted in an increase in organic complexing molecules of low molecular weight (LMW), which may serve as carriers of micronutrients including the heavy metals, and increased their uptake (Chen and Aviad, 1990). The mean concentration of organic matter in the studied soil was 8.40%. Rupa et al., (2003) noted that the higher levels of organic matter were found to increase the uptake of heavy metals in wheat plants. The mean concentrations (mg/kg) of Zn, Cu, Pb and Cd in studied soil were 112.71, 17.70, 57.36 and 11.22. The mean highest concentration recorded in the soil was for Zn followed by Pb, Cu and the minimum concentration was observed for Cd. The concentrations of Pb were found less than those reported by El fadeli et al., (2014) in region of Marrakech, while Zn, Cu concentrations were observed within their respective permissible limits set by WHO/FAO (2007) and USEPA (2010). However, the concentration of Cd was above the acceptable limits while the levels of heavy metals in soils. Continuous removal of metals by food crops (vegetables and cereals) grown at the wastewater irrigated soil and heavy metals leaching into the deeper layers of soil may be a reason of low concentration of heavy metals than the permissible limits (Singh et al., 2010).

Table 7 summarizes the concentration of heavy metals in the various parts of plant grown in this region. The results indicated

Table 7

The mean concentrations of heavy metals in plants.

Species	Edible Parts	Zn (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
<i>Vicia faba</i>	Root	77.255 ± 0.89	7.045 ± 0.18	45.73 ± 3.41	8.455 ± 0.86
	Leaves	73 ± 34.35	5.825 ± 2.38	18.35 ± 2.08	6.01 ± 2.62
	Pod	33.88 ± 2.18	2.905 ± 0.05	36.925 ± 11.24	11.185 ± 1.41
	Seed	58.585 ± 11.12	5.39 ± 1.15	30.775 ± 6.95	12.03 ± 0.80
<i>Triticum turgidum</i>	Root	118.295 ± 19.75	30.66 ± 6.62	56.445 ± 6.68	13.11 ± 2.81
	Leaves	54.76 ± 8.16	4.975 ± 0.76	44.26 ± 1.34	0.63 ± 0.44
	Seed	58.265 ± 5.99	2.275 ± 0.15	13.555 ± 1.77	ND
<i>Avena sativa</i>	Root	60.935 ± 3.05	8.505 ± 0.78	47.9 ± 7.70	3.055 ± 0.69
	Leaves	60.515 ± 0.72	6.865 ± 0.15	52.885 ± 22.22	2.175 ± 0.86
<i>Urtica dioica</i>	Root	104.685 ± 7.80	20.44 ± 4.69	83.09 ± 7.02	11.13 ± 1
	Leaves	74.965 ± 3.27	16.025 ± 2.34	32.555 ± 5.39	ND
<i>Plantago major</i>	Root	68.23 ± 4.48	8.705 ± 0.29	75.365 ± 13.04	12.37 ± 2.56
	Leaves	57.545 ± 13	4.505 ± 0.54	37.965 ± 6.48	8.355 ± 1.06
<i>Medicago sativa</i>	Root	73.905 ± 16.28	9.475 ± 0.71	49.925 ± 8.40	ND
	Leaves	86.355 ± 32.28	6.575 ± 0.04	24.67 ± 4.20	ND
<i>Triticum aestivum</i>	Root	47 ± 17.58	5.755 ± 1.87	38.075 ± 2.04	10.82 ± 1.88
	Leaves	31.14 ± 5.57	2.375 ± 0.09	35.88 ± 4.14	7.26 ± 0.69
	Seed	56.785 ± 14.99	3.925 ± 1.98	36.275 ± 9.35	ND
<i>Malva sylvestris</i>	Root	79.695 ± 9.36	10.53 ± 2.42	38.17 ± 3.73	6.095 ± 0.63
	Leaves	58.08 ± 1.80	7.085 ± 0.62	39.98 ± 6.68	4.69 ± 0.55
P value		0.539 [*]	0.008 ^{**}	0.041 ^{**}	0.006 ^{**}

ND: Not detectable, ±: Standard deviation, P value: Level of significance for the differences between species.

^{*} No significant difference.^{**} Significance at $P \leq 0.05$.

that all metals in the food crops exceeded acceptable limits. The trend of heavy-metal concentrations in plants was $Zn > Pb > Cu > Cd$. Radwan and Salama (2006) have also found highest concentration of Zn and lowest of Cd in vegetables collected from Egyptian markets.

According to vegetable species, the lowest Zn concentration (31.14 mg/kg) was observed in *Triticum aestivum*'s leaves, while the highest (118.295 mg/kg) in *Triticum turgidum*'s roots. The lowest and highest Pb concentrations were observed in *Triticum turgidum* (13.555 mg/kg) seeds and *Urtica dioica*'s leaves (83.09 mg/kg). For Cu, the lowest concentration was detected in *Triticum turgidum* (2.275 mg/kg) from seeds, while the highest (30.66 mg/kg) was detected in *Triticum turgidum*'s roots. The highest Cd concentration (13.11 mg/kg) was observed in *Triticum turgidum*'s root. Balkhair and Ashraf (2016) had reported that vegetables accumulate a considerable amount of heavy metals, especially Pb, Cr, Cu and Zn, in the roots and leaves. Metal concentrations has shown variations in their availability to the plant, this may be attributed to differences in the uptake mechanism of individual ions and competition among the heavy metals for the absorption (Gothberg et al., 2004; Sinha et al., 2006). The interaction between different heavy metals occurs at root surface and also within the plant, which ultimately affects the uptake and translocation of heavy metals (Sharma et al., 2007). The accumulation of heavy metals also depends on plant age and plants parts (Liu et al., 2007).

The results from the present study and earlier reports (Liu et al., 2005; Muchuweti et al., 2006; Sharma et al., 2007) demonstrated that plants grown on irrigated soils by wastewater are contaminated with heavy metals and pose a health concern.

3.2. Health risk

In Morocco, many studies are focused on evaluation of heavy metals pollution in soil and vegetables (AL-Jaboobiet al., 2014; El fadeli et al., 2014), but information on the health risks of these pollutants is quite limited. The transfer factor (TF) from soil to crops is one of the factors of human exposure to metals through the food chain. In order to evaluate the health risk index HRI associated

with wastewater-irrigated soils, it is essential to assess the TF (Cui et al., 2004).

Fig. 2 showed the transfer factors calculated for heavy metal transfer from soils to vegetables. The mean TFs ranged from 0.277 to 0.801, 0.134 to 0.905, 0.319 to 0.922 and 0 to 0.744 for Zn, Cu, Pb and Cd, respectively. These results indicated that there is not a significant difference between the four metals. These differences might be related to heavy metal-binding capacity to roots (Toth et al., 2009), available metals, interactions between physicochemical parameters, and the plant species grown in these soils (Bose and Bhattacharyya, 2008). The absorption and accumulation of heavy metals in plant tissues depend upon many factors, including temperature, moisture, organic matter, pH and nutrient availability, whereas the presence of organic matter has been reported to increase the uptake of zinc (Zn), chromium (Cr), lead (Pb) and copper (Cu) in the wheat plant (Rupa et al., 2003).

To evaluate the health risk index of heavy metals, it is essential to estimate the level of exposure by quantifying the routes of exposure of a pollutant to the target organisms. There are various possible exposure pathways of pollutants to humans, but the food chain is one of the key pathways of heavy metal exposure to humans (Muchuweti et al., 2006). Therefore, to assess the potential human health risks in this area, both the DIM and HRI for adults and children were calculated (Table 8).

The oral reference dose (RFD) is the daily exposure of individuals to toxins or pollutants that can pose no appreciable hazard over their lifetime. The RFD values for the toxic metals Zn, Cu, Pb and Cd are $3.00E-01$, $4.00E-02$, $4.00E-03$ and $1.00E-03$ mg kg⁻¹ day⁻¹ respectively (FAO/WHO (Codex Alimentarius Commission, 2013)). When the HRI exceeds 1.0, there is concern for potential health effects (Huang et al., 2008). In our study, the heavy metals, except for Zn and Cu, have HRI > 1, indicating a possible future risk for human health via the intake of food crops. Balkhair and Ashraf (2016) had also observed a high risk due to consumption of vegetables grown under wastewater irrigated areas of Saudi Arabia. They also observed that children are more affected than adults. Pb and Cd are very toxic metals in humans and previous research has

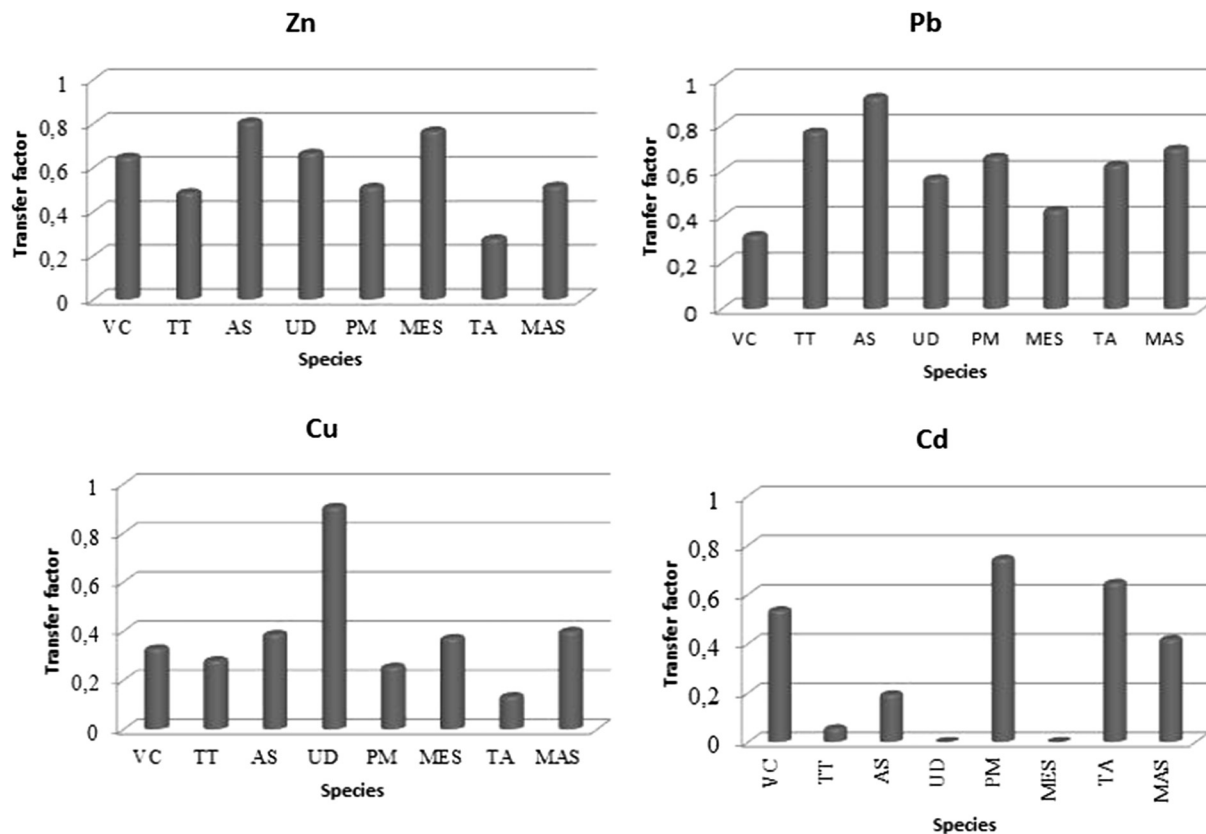


Fig. 2. Metal transfer factors for agricultural crops in the study area. VC: *Vicia faba*, TT: *Triticum turgidum*, AS: *Avena sativa*, UD: *Urtica dioica*, PM: *Plantago major*, MES: *Medicago sativa*, TA: *Triticum aestivum*, MAS: *Malva sylvestris*.

Table 8

Daily intake of metal (DIM) and health risk index (HRI) for individual heavy metals caused by the consumption of different agricultural crops grown in the study area.

Vegetable Species	Individuals		Zn	Cu	Pb	Cd
<i>Vicia faba</i>	Adults	DIM	0.038 ± 0.018	0.003 ± 0.001	0.010 ± 0.001	0.003 ± 0.001
		HRI	0.128 ± 0.006	0.076 ± 0.031	2.407 ± 0.273	3.153 ± 0.374
	Children	DIM	0.044 ± 0.021	0.004 ± 0.001	0.011 ± 0.001	0.004 ± 0.002
		HRI	0.147 ± 0.069	0.088 ± 0.036	2.767 ± 0.314	3.624 ± 0.580
<i>Triticum turgidum</i>	Adults	DIM	0.029 ± 0.004	0.003 ± 0	0.023 ± 0.001	0.000
		HRI	0.096 ± 0.014	0.065 ± 0.010	5.805 ± 0.172	0.330 ± 0.281
	Children	DIM	0.033 ± 0.005	0.003 ± 0	0.027 ± 0.001	0.000
		HRI	0.110 ± 0.016	0.075 ± 0.011	6.673 ± 0.202	0.380 ± 0.265
<i>Avena sativa</i>	Adults	DIM	0.032 ± 0	0.004 ± 0	0.028 ± 0.012	0.001 ± 0
		HRI	0.106 ± 0.001	0.090 ± 0.002	6.936 ± 0.912	1.141 ± 0.795
	Children	DIM	0.036 ± 0	0.004 ± 0	0.032 ± 0.013	0.001 ± 0.001
		HRI	0.122 ± 0.001	0.103 ± 0.002	7.973 ± 0.349	1.312 ± 0.516
<i>Urtica dioica</i>	Adults	DIM	0.039 ± 0.002	0.008 ± 0.001	0.017 ± 0.003	-
		HRI	0.131 ± 0.006	0.210 ± 0.031	4.270 ± 0.706	-
	Children	DIM	0.045 ± 0.002	0.010 ± 0.001	0.020 ± 0.003	-
		HRI	0.151 ± 0.007	0.242 ± 0.035	4.908 ± 0.812	-
<i>Plantago major</i>	Adults	DIM	0.030 ± 0.007	0.002 ± 0	0.020 ± 0.003	0.004 ± 0
		HRI	0.101 ± 0.024	0.059 ± 0.007	4.979 ± 0.849	4.383 ± 0.468
	Children	DIM	0.035 ± 0.008	0.003 ± 0	0.023 ± 0.004	0.005 ± 0.001
		HRI	0.116 ± 0.028	0.068 ± 0.008	5.724 ± 0.976	5.039 ± 0.636
<i>Medicago sativa</i>	Adults	DIM	0.045 ± 0.017	0.003 ± 0	0.013 ± 0.002	-
		HRI	0.151 ± 0.056	0.086 ± 0.001	3.235 ± 0.551	-
	Children	DIM	0.052 ± 0.019	0.004 ± 0	0.015 ± 0.003	-
		HRI	-	-	-	-

shown that the food chain is the main pathway of lead transfer from the environment to human (El fadeli et al., 2014).

The current study is very important in terms of health perspectives, because it aimed to estimate the level of contamination by detecting the route of exposure to the humans from the consumption of heavy metals in food crops.

4. Conclusion

Continuous irrigation of agricultural lands by wastewater for several years increased heavy metals in soils and plants. The results of the study clearly indicate that the wastewater-irrigated soils were moderately enriched with Zn, Cu, Pb, and Cd, while

the crops contaminations exhibited variations relative to FAO/WHO permissible limit. Therefore, the dietary intake of these vegetables results in long term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure.

The Health Risk Index (HRI > 1) indicated also that Cd and Pb contamination in most of the vegetables had potential for human health risk due to consumption of plants grown in this area having long term uses of waste water for irrigation. Therefore, this region needs effective measures to cure the toxic metal contamination.

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