



## Treated municipal wastewater irrigation effect on lead content and health risks of nickel in soil and pepper in Shahrekord, Iran

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### ABSTRACT

Iran with an average annual precipitation of about 252 mm (413 BCM) and renewable freshwater resources of 130 BCM, has irregular distribution of water resources. Reuse of wastewater and treated effluents for agricultural irrigation has become an essential method to overcome the problems of water shortage, irrigation water supply and environmental pollution control. But wastewater irrigation could cause excessive accumulation of heavy metals in agricultural soils. Soil contamination with these elements leads to heavy metals uptake by crops and thus affects food chain. In this research we investigate the distribution of lead and nickel in pepper tissues after irrigation with wastewater. For this reason a pot experiment was carried out and a completely randomized design was used. Different percents of treated wastewater were applied for irrigation. Increasing the percent of wastewater had no significant effect on soil available lead and nickel concentrations. Soil available lead and nickel were still less than allowable. Wastewater irrigation did not and nickel tissue concentrations. Nickel health risk index values of less than 1 indicate a relative absence of health risks associated with the ingestion of fruits of pepper.

*Keywords:* Health risk index; Municipal wastewater; Lead; Nickel; Sweet chilli

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### 1. Introduction

Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals, and an increased metal uptake by food crops grown on such contaminated soils is often observed. Wastewater use for irrigation maybe useful for regions less than 500 mm precipitation, supplies plant nutrients and reduces environmental pollution [1]. In general, wastewater contains substantial amounts of beneficial nutrients and toxic heavy metals, which are creating

opportunities and problems for agricultural production, respectively [2].

Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety [3]. Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. Heavy metal accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals [4].

Vegetables cultivated in wastewater-irrigated soils take up heavy metals in enough large quantities to cause potential health risks to the consumers. The consumption of heavy metal-contaminated food can seriously

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deplete some essential nutrients in the body that are further responsible for decreasing immunological defenses, intrauterine growth retardation, impaired psycho-social faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates [5].

Wastewater irrigation is a widespread practice in the world and recently a number of articles have been published on wastewater-irrigated soils contaminated with heavy metals [4,6]. Several researchers have studied the heavy metal accumulation in crops, the factors responsible for it, and its effect on human and animal health [7]. However, an additional insight into metal uptake, accumulation and assessment of human health risks associated with wastewater-irrigated soils is still needed [5]. The objective of this study was to evaluate the impact of municipal wastewater on DTPA – extractable lead and nickel concentration of soil, lead and nickel concentration of pepper tissue.

## 2. Methods

Three chilli pepper (*Capsicum annuum* Var robustin seedlings were transplanted in each pot on May 29, 2007. The moisture of pots was held at field capacity. A completely randomized design was used. Five treatments included different percentages of wastewater (0%, 25%, 50%, 75% and 100%) in irrigation water.

### 2.1. Soil sampling and characterization

Soil samples were collected before and after planting. After transportation to the laboratory, soils were air dried, ground, and sieved to pass through a 2 mm screen. The extractable metals were extracted with the method of Lindsay and Norvell [8] (DTPA, w:v 1:2 soil/extract solution and 2 h on a reciprocal shaker). The concentration of lead and nickel in the extracts were analyzed by atomic absorption spectrophotometer (GBC 932 plus).

### 2.2. Food crop sampling and analysis

At harvest, plants were removed from each pot and were divided into aerial and root. Fruits from each pot were picked weekly from August 1 up to October 30, 2007. Plant parts were washed with deionized water to remove all visible soil particles and oven dried at 70 °C for 48 h. Plant samples were ground to a fine power and were analyzed for lead and nickel concentration. Lead and nickel were measured in the dry ash digested by atomic absorption spectrophotometer (GBC 932 plus) [9].

### 2.3. Daily intake of nickel

The daily intake of metals (DIM) was determined by the following equation.

$$\text{DIM} = (C_{\text{metal}} * C_{\text{factor}} * D_{\text{food intake}}) / B_{\text{average weight}} \quad (1)$$

where  $C_{\text{metal}}$ ,  $C_{\text{factor}}$ ,  $C_{\text{food intake}}$  and  $B_{\text{average weight}}$  represent the heavy metal concentrations in plants (mg/kg), conversion factor, daily intake of vegetables and average body weight, respectively. The conversion factor 0.092 was used to convert fresh green vegetable weight to dry weight. The average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg person<sup>-1</sup> d<sup>-1</sup>, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively [10].

### 2.4. Health risk index of nickel

The health risk index (HRI) for the locals through the consumption of contaminated vegetables was assessed based on the food chain and the reference oral dose (RfD) for each metal. The HRI <1 means the exposed population is assumed to be safe. Oral reference doses (RfD) for nickel is 2E-2 mg kg<sup>-1</sup> d<sup>-1</sup> [11].

Analysis of variance (ANOVA) was used to identify the effects of treatments and least significant difference (LSD) test was used to the comparison of means by STATISTICA 6.0 software.

## 3. Results and discussion

Some soil characteristics before planting are shown in Table 1. The soil is characterized by being basic with pH value of 8 and has a fine texture (Table 1).

The well water and wastewater characteristics used for irrigation are shown in Table 2. The concentrations of heavy metals in the wastewater are low and meet the standard for wastewater reuse in irrigation. Lead and nickel in Shahrekord wastewater are more than well water (Table 2). Given the fact that these metals could be accumulated in soil and plants with continuous use of wastewater in irrigation, therefore, their periodic monitoring should be an important component of wastewater management.

The effect of different percents of wastewater irrigation on soil lead and nickel content are shown in Fig. 1. Wastewater irrigation did not affect concentrations of soil lead and nickel ( $p < 0.05$ ). Soil available lead and nickel were still less than allowable (<100 mg/kg for lead and <50 mg/kg for nickel).

There is inconsistency on research findings on the impact of wastewater irrigation on soil heavy metals. Siebe [13] reported that the concentration of lead and cadmium in soil horizon (0–30 cm) that has been irrigated for more than 80 years were increased more than that irrigated under well water. Similar results were obtained by Brar et al. [14]. On the other hand, Mohammad and Mazahreh [15] mentioned that the concentrations

Table 1  
Some soil characteristics before planting

Parameters	pH	DTPA extractable Pb (mg/kg)	DTPA extractable Ni (mg/kg)	Texture	Bulk density (g/cm <sup>3</sup> )
3.5	8	1.85	0.88	Clay loam	0.91

Table 2  
Selected properties of the well water and treated wastewater

Parameters	pH	EC (dS/m)	TDS (mg/l)	Pb (mg/l)	Ni (mg/l)	Zn (mg/l)	Cu (mg/l)
Well water	7.85	0.38	243	0.08	0.00	0.04	0.02
Wastewater	7.78	1.15	801	0.18	0.02	0.14	0.05

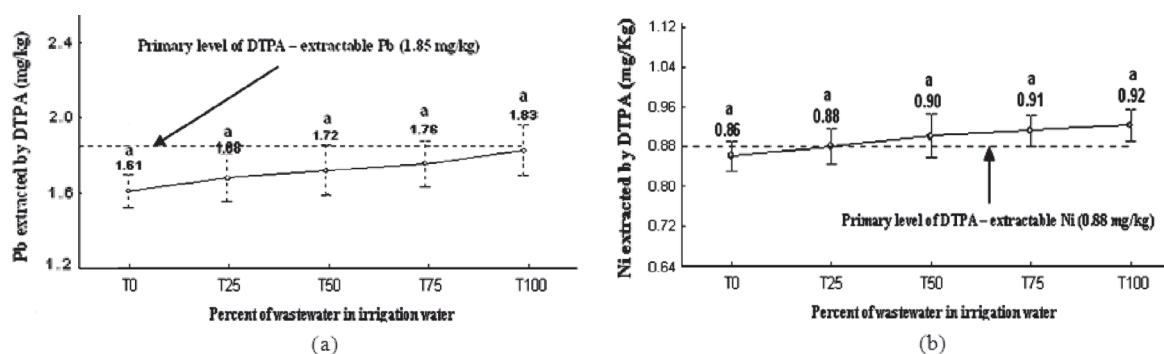


Fig. 1. Soil concentrations of lead (a) and nickel (b) in different treatments. Error bars show,  $\pm$  standard error. Mean values within the same letters are not significantly different at the 0.05 level (LSD Test).

of the soil lead and cadmium were not affected significantly by the wastewater irrigation. It could be caused directly from the wastewater composition or indirectly through increasing solubility of the indigenous insoluble soil heavy metals as a result of the chelation or acidification action of the applied wastewater [9].

The effect of different percents of wastewater irrigation on lead and nickel tissue concentrations is shown in Table 3. Increasing the percent of wastewater had no significant effect on tissue concentrations of lead and nickel (Table 3).

This result may be explained by a high pH of primary soil (Table 1) that keep most trace metals immobilized

or low concentration of lead and nickel in primary soil (Table 1) and irrigation water and wastewater (Table 2). Mireles et al. [16] mentioned that some of heavy metals were found at concentrations above the potentially hazardous levels in soils; however, they accumulated in plants to a lower extent, probably because of the physical and chemical properties of soils that prevent their translocation to plants.

Daily intake of nickel and health risk index for nickel caused by the consumption of pepper fruit in different treatments are shown in Table 4. The data indicated that the HRI value was  $<1$ ; therefore, the health risks of

Table 3  
Tissue concentrations of lead and nickel in different treatments

Treatment	Percent of wastewater in irrigation water	Lead (mg/kg dry)			Nickel (mg/kg dry)		
		Fruit	Root	Aerial	Fruit	Root	Aerial
T0	0	2.14 <sup>a</sup>	7.42 <sup>a</sup>	5.65 <sup>a</sup>	1.62 <sup>a</sup>	4.78 <sup>a</sup>	2.77 <sup>a</sup>
T25	25	2.22 <sup>a</sup>	7.58 <sup>a</sup>	5.81 <sup>a</sup>	1.64 <sup>a</sup>	4.80 <sup>a</sup>	2.79 <sup>a</sup>
T50	50	2.25 <sup>a</sup>	7.69 <sup>a</sup>	6.29 <sup>a</sup>	1.67 <sup>a</sup>	4.86 <sup>a</sup>	2.82 <sup>a</sup>
T75	75	2.27 <sup>a</sup>	8.19 <sup>a</sup>	6.56 <sup>a</sup>	1.70 <sup>a</sup>	4.88 <sup>a</sup>	2.85 <sup>a</sup>
T100	100	2.30 <sup>a</sup>	8.22 <sup>a</sup>	7.19 <sup>a</sup>	1.73 <sup>a</sup>	4.91 <sup>a</sup>	2.87 <sup>a</sup>

<sup>a</sup>Mean values within the same column followed by different letters are significantly different at the 0.05 level (LSD test).

Table 4  
DIM and HRI for nickel caused by the consumption of pepper fruit in different treatments

Treatment	Percent of wastewater in irrigation water	C metal	DIM		HRI	
			Adults	Children	Adults	Children
T0	0	1.62	9.2E-4	1.06E-3	4.60E-2	5.29E-2
T25	25	1.64	9.3E-4	1.07E-3	4.66E-2	5.35E-2
T50	50	1.67	9.5E-4	1.09E-3	4.74E-2	5.45E-2
T75	75	1.70	9.6E-4	1.11E-3	4.83E-2	5.55E-2
T100	100	1.73	9.8E-4	1.13E-3	4.91E-2	5.65E-2

nickel exposure through the food chain was of no consequences and generally assumed to be safe.

There are various possible exposure pathways of pollutants to humans but the food chain is one of the most important pathways. As mentioned earlier, food crops were contaminated with heavy metals and the consumption of them can cause human health risks. The average metal concentrations of food crops were used for calculation of the HRI. The estimated dietary intakes of nickel, was far below the tolerable limits. In general, the RfD is an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime [11]. The daily nickel intake for both adults, and children through the consumption of pepper fruits in this study was less than RfD limit set by the US-EPA, IRIS [11]. The findings of this study regarding DIM and HRI suggest that the consumption of peppers grown in wastewater irrigated soils is nearly free of risks.

#### 4. Conclusions

Soil and crop concentrations of lead and nickel are not significantly affected by wastewater irrigation. Results of this research are limited to one growing season. This experiment must continue to evaluate the long-term effects of Shahrekord municipal wastewater on heavy metal accumulation in soil and plant. Research on other crops will be desirable. Continuous irrigation with wastewater may lead to accumulation of heavy metals. Therefore, these concerns should be essential components of any management of wastewater irrigation.

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