Environmental Health Engineering and Management Journal 2019, 6(1), 11–16
http://ehemj.com
doi 10.15171/EHEM.2019.02

Environmental Health Engineering and Management Journal

Original Article

Environmental Health Engineering and Management

Open Access Publish Free

The potential risk of heavy metals on human health due to the daily consumption of vegetables

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Abstract

Background: Vegetables are one of the most important components of daily food. Thus, this research was done to evaluate the potential risk of heavy metals on human health due to the consumption of vegetables distributed in the fruits and vegetables central market of Arak, Iran.

Methods: In this study, a total 45 samples from edible parts of parsley, mint, chard, fenugreek, cress, basil, coriander, lettuce, and cabbage distributed in the fruits and vegetables central market of Arak were randomly collected and the concentration of heavy metals including lead (Pb), cadmium (Cd), and arsenic (As) in these crop plants was measured using atomic absorption spectrophotometer (AAS). The non-carcinogenic risk of heavy metals intake through the consumption of the studied vegetables was evaluated for male and female using the Environmental Protection Agency (EPA) method.

Results: The highest and lowest Pb daily intake and Pb risk index was related to the consumption of cabbage and basil, respectively. And the highest daily intake of Cd and As was related to lettuce consumption, while the lowest daily intake of these metals was related to the consumption of coriander. Among the studied heavy metals, As had the highest hazard quotient (HQ) for non-carcinogenic diseases. The highest HQ belonged to As through lettuce consumption and the lowest one belonged to As through coriander consumption (58 g/day). The HQ for female was higher than that for male.

Conclusion: According to the results, the total hazard quotient (THQ) of non-carcinogenic diseases from the total studied vegetables was above the standard level. On the other hand, the HQ for female was higher than that for male.

Keywords: Human, Vegetables, Risk Factor, Arsenic, Lead

Citation: Baghaie AH, Fereydoni M. The potential risk of heavy metals on human health due to the daily consumption of vegetables. Environmental Health Engineering and Management Journal 2019; 6(1): 11–16. doi: 10.15171/EHEM.2019.02.

Article History:
Received: 10 October 2018
Accepted: 10 January 2019
ePublished: 2 February 2019

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Introduction

Vegetables are important sources of nutrient elements for human health such as potassium, fiber, and vitamins. Evidence from various studies suggests that daily consumption of vegetables can prevent the development of cardiovascular diseases and some cancers, especially gastrointestinal cancers (1-3). However, the consumption of vegetables grown in heavy metal-contaminated soils can lead to harmful metabolic and physiological effects on human body (4,5). High application of organic and inorganic fertilizers in the fields can lead to the accumulation of nitrates and heavy metals in crop plants, and consequently, the consumption of these products can threaten human health (6-8).

It is well known that lead (Pb), arsenic (As), and cadmium (Cd) are very toxic heavy metals for human health (9-11), that directly or indirectly enter human body (Figure 1). Soil and water pollution by heavy metals is one of the human societies problems, that reduce yield and quality of agricultural products and threaten human health (12,13). Pb is not a necessary element for human health, and its high intake has different harmful effects such as enzymatic and nervous problems, skeletal damages, and immune system damage (14). Exposure to As causes various problems such as skin damages, peripheral neuropathy, and vascular diseases (15). Moreover, chronic exposure to Cd causes different problems and diseases such as lung cancer, prostate problems, kidney disease, and osteoporosis. Even the intake of necessary elements with significant biological effects can threaten human health. Overall, after penetration of metals into cells, they are affected by oxidation and reduction (redox) potential, which can disturb the intracellular reactions in living cells (11).

Heavy metals enter human body through various pathways (Figure 1) such as inhalation, dust and air pollution, and

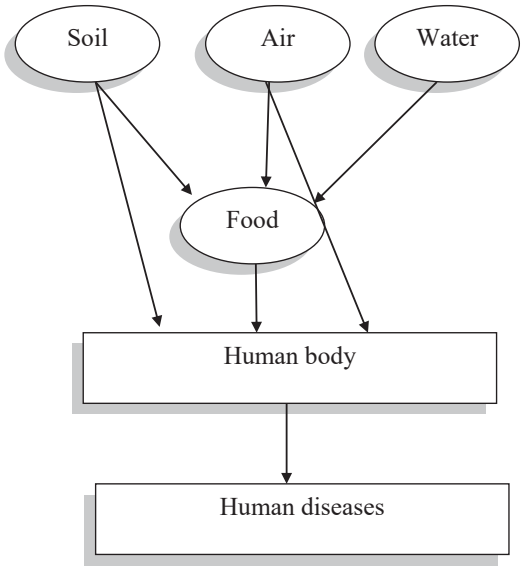

Figure 1. Different pathways of heavy metals entrance into human body.

the consumption of vegetables grown in the contaminated soils (16). Accordingly, assessment of the heavy metals health risk seems necessary (17-19), although reducing heavy metals concentration is a useful method for protection of human health (20).

Qishlaqi et al studied the impact of wastewater irrigation on soils and crops in Shiraz suburban area and reported that the Cd hazard quotient (HQ), due to the consumption of agricultural crops irrigated with untreated wastewater, was higher than the standard level (21). Nazemi el al investigated the heavy metals concentration in the vegetables cultivated in the suburbs of Shahroud county and reported that the risk index of the studied heavy metals enter human body by the consumption of cultural vegetables was higher than one, that was due to the land irrigation with urban and industrial wastewater contaminated with heavy metals (5). As heavy metals can play a role in the development of carcinogenic and non-carcinogenic diseases (22-24), assessment of risk index for these diseases due to the consumption of contaminated vegetables has an important role in promoting human health.

Kheirabadi et al investigated the carcinogenic risk of heavy metals in wheat and potato in Hamadan province and reported that the HQ of non-carcinogenic diseases in the exposure to each element was below the standard level (HQ = 1) (25).

Regarding the importance of vegetables to human health, it is necessary to evaluate the heavy metals concentration in the edible parts of vegetables in regional studies (22). Therefore, this research was done to estimate the health risk of heavy metals intake through the consumption of different vegetables distributed in the fruits and vegetables central market of Arak in 2017.

Materials and Methods

In order to investigate the health status of the vegetables distributed in the fruits and vegetables central market of Arak, nine types of vegetables including parsley, mint, chard, fenugreek, cress, basil, coriander, lettuce, and cabbage, were randomly selected. The weeds were separated from the vegetables and the edible parts of the vegetables were washed with water, and then, dried in an oven (60 to 65°C) and powdered with a mixer. Pb, As, and Cd were extracted from the vegetables using three acid (nitric acid, perchloric acid, and sulfuric acid) digestion method with the ratio 1:1:5 (16). The concentration of heavy metals was determined using atomic absorption spectrophotometer (AAS, Model 3030).

The risk index for Pb and Cd in vegetables distributed in the fruits and vegetables central market of Arak was calculated using the formula proposed by the U.S. Environmental Protection Agency (EPA) (25-27).

$$HQ = (DIM \times FI \times EF \times ED)/RFD \times BW \times AT)$$
$$THQ = \sum HQ \qquad \text{(Eq. 1)}$$

Where *DIM* is daily intake of heavy metals, *FI* is the fraction ingested from the contaminated source representing the fraction of consumed foodstuffs which enter the blood (equal to 0.4),

EF is the exposure frequency (day) that was considered 365 days. *ED* is the exposure duration (year) or the number of potentially exposed years, which was considered 6 and 37 years for children and adults, respectively. *BW* is the body weight (kg), which was considered 67.2 and 76.8 kg for adult male and female, respectively.

AT is the average time for non-carcinogenic diseases (365 day^{-1}× ED). *RFD* is the oral reference dose that was considered 0.003, 0.001, and 0.0003 for Pb, Cd, and As, respectively. *HQ* and *THQ* are hazard quotient and total hazard quotient, respectively (Eq. 1).

While the HQ is less than one, there is no adverse health effect as a result of exposure.

Results

Regardless of gender, the maximum and minimum Pb daily intake (DIM) was observed by considering the daily consumption of lettuce and basil (58 g/d) (16), with the amount of 0.00219 and 0.00027 mg Pb/kg/d. It should be noted that the Pb daily intake in female was higher than that in male. The highest daily intake of Cd and As was due to the consumption of the same amount of lettuce as mentioned for Pb. The lowest Cd daily intake was due to the consumption of 58 g fenugreek with 0.00008 mg Cd/kg/d. The minimum daily intake of As was due to the consumption of coriander with 0.00009 mg As/kg/d (Table 1). The Cd and As daily intake in female was higher than that in male.

The highest and lowest Pb HQ was due to the daily consumption of 58 g lettuce and basil, respectively (12)

Table 1. Mean daily intake of heavy metals via consumption of vegetables distributed in the fruits and vegetables central market of Arak in 2017

Heavy Metal	Gender	Heavy metals intake (mg/kg/d)									Total intake
		Cabbage	Lettuce	Coriander	Basil	Cress	Fenugreek	Chard	Mint	Parsley	
Pb	Female	0.00144	0.00219	0.00058	0.00027	0.00172	0.00104	0.00040	0.00043	0.00066	0.00873
	Male	0.00126	0.00192	0.00050	0.00023	0.00150	0.00091	0.00035	0.00037	0.00057	0.00761
Cd	Female	0.00024	0.00034	0.00023	0.00016	0.00016	0.00010	0.00030	0.00019	0.00013	0.00185
	Male	0.00021	0.00029	0.00020	0.00016	0.00014	0.00008	0.00026	0.00016	0.00011	0.00159
As	Female	0.00027	0.00030	0.00009	0.00016	0.00019	0.00026	0.00023	0.00022	0.00019	0.00191
	Male	0.00023	0.00026	0.00007	0.00014	0.00016	0.00022	0.00020	0.00019	0.00016	0.00163

with 0.73 and 0.09 mg Pb/kg/d, respectively (Table 2). The highest As HQ was observed via the daily consumption of 58 g lettuce, while the lowest one was due to the consumption of the same amount of coriander (Table 2). However, the HQ of As for female was higher than that for male. As shown in Figure 2, the highest and lowest ratio of THQ was estimated to body intake of AS and Cd.

Discussion

According to the results of this study, the Pb daily intake by the consumption of cress, coriander, lettuce, and cabbage was significantly lower than the safe level recommended by the World Health Organization (WHO) (0.003 mg Pb/kg/d) (28). However, the quality of these vegetables should be evaluated periodically. It is worth mentioning that Pb daily intake via the consumption of the studied vegetables in female was higher than that in male. It can be due to the lower body weight of female compared to male. Salehipour Baversad et al investigated the potential hazard of heavy metals on human health due to the consumption of some agricultural products of Isfahan province and reported that the Pb daily intake through the consumption of agricultural products was lower than the standard level recommended by the WHO (29). Tabande and Taheri also reported the high concentration of heavy metals in leafy vegetables grown in Zanjan province. They mentioned that industrial activities have important effects on heavy metals entrance into the food chain (16). On the other hand, Rehman et al investigated the transfer of heavy metals from soils to vegetables and associated human health risks at selected sites in Pakistan and concluded that there was no significant health risk for the local consumers through consumption of these food crops (30).

Huang et al investigated the heavy metals concentration in vegetables and the health risk to population in Zhejiang, China and concluded that there was no heavy metals contamination in their studied vegetables. However, considerable attentions should be paid to the potential contamination of heavy metals, especially Cd, in vegetables (31). Therefore, further studies are required to investigate the concentration of heavy metals in food chain in different regions periodically.

The Pb HQ due to the consumption of the studied vegetables was below one (HQ<1), indicating that there was no serious health risk related to Pb intake through the consumption of these vegetables. Although, this is not

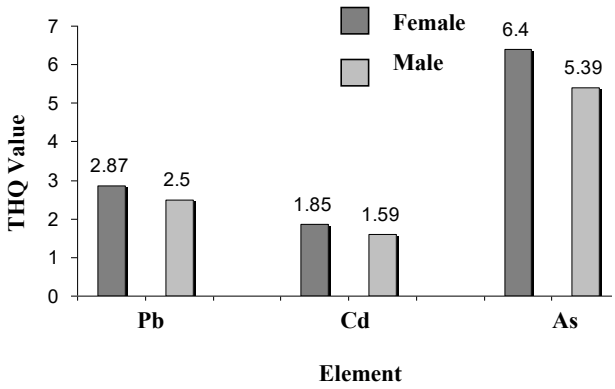

Figure 2. THQ value according to gender.

Table 2. The HQ of heavy metals in vegetables distributed in the fruits and vegetables central market of Arak in 2017

Heavy Metal	Gender	HQ								
		Cabbage	Lettuce	Coriander	Basil	Cress	Fenugreek	Chard	Mint	Parsley
Pb	Female	0.48	0.73	0.19	0.09	0.57	0.34	0.13	0.14	0.20
	Male	0.42	0.63	0.16	0.07	0.50	0.30	0.11	0.12	0.19
Cd	Female	0.24	0.34	0.23	0.16	0.16	0.10	0.30	0.19	0.13
	Male	0.21	0.29	0.20	0.14	0.14	0.08	0.26	0.16	0.11
As	Female	0.90	1.10	0.30	0.53	0.63	0.86	0.76	0.73	0.63
	Male	0.76	0.86	0.23	0.46	0.53	0.73	0.66	0.63	0.53

the only entrance way of heavy metals into the human body that should be considered. According to the results of Figure 1, the THQ of each heavy metals due to the consumption of all studied vegetables were higher than the safe level (THQ>1), which is harmful to human health and should be considered. The highest Pb HQ was related to the consumption of lettuce, which is consistent with the results of the study of Mohajer et al (32).

As shown in Table 1, the Cd daily intake was below the standard level (0.001 mg/kg/d) (32), that is a positive point in environmental studies and implies the safety of vegetables distributed in the fruits and vegetables central market of Arak. According to this table, the HQ of each vegetables is in the standard range (HQ=1), but total consumption of the studied vegetables increased the HQ over the standard level with a mean of 1.85 and 1.59 for female and male, respectively (Figure 1).

Kheirabadi el al investigated the risk of heavy metals in soil and crops grown in Hamedan province and concluded that children and adults in the study area were exposed to the non-carcinogenic diseases due to the entrance of heavy metals into the food chain (25). Loutfy et al reported that oral intake is the main way of heavy metals entrance into the body compared with other ways, such as inhalation and dermal contact. Low weight and low IQ in newborn children are the adverse effects of heavy metals intake (33). According to Table 1, the daily intake of arsenic caused by the consumption of each of the studied vegetables is below the standard level, which is 0.015 mg As/kg/d (34). As a positive point, the As daily intake though the consumption of all studied vegetables was also below the standard level (29). However, Table 2 shows that the HQ of the As daily intake through the consumption of lettuce distributed in the fruits and vegetables central market of Arak was higher than the standard level (HQ = 1) in both gender groups. It may be due to the soil contamination by As, where vegetables were cultivated.

Among the studied heavy metals, the highest THQ belonged to As through the consumption of all studied vegetables distributed in the fruits and vegetables central market of Arak. The highest As HQ confirms this matter clearly. The study of Salehipour Baversad et al also showed that the THQ of AS was higher than that of Pb (29). Chary et al also showed that the THQ of Cd, Pb, and Zn through the consumption of contaminated vegetables is very high. In addition, they reported that leafy vegetables absorb high levels of heavy metals (35). Khan et al also reported that the consumption of vegetables grown in the industrial zone of northern Pakistan have adverse effects on human health. In addition, they mentioned that Pb in adults and Cd, Cu, and Pb in children cause harmful effects on human health (36). Amin et al evaluated the concentration of As, Cd and Pb in potatoes in southeast of Isfahan and concluded that the Pb and Cd concentration is higher than the standard level but the As concentration is below the standard level (37).

Conclusion

The results of this study showed that the highest daily intake of Pb, Cd, and As was due to the consumption of lettuce distributed in the fruits and vegetables central market of Arak in 2017, which was higher in female compared to male. In addition, the highest and lowest daily intake of the studied vegetables heavy metals belonged to Pb and Cd. As had the highest risk of non-carcinogenic diseases. However, climatic conditions, soil contamination and type of the metal can affect the heavy metal concentration. Thereby, further regional studies at different times are required to investigate these factors.

Acknowledgments

The authors would like to thank the Islamic Azad University of Arak for supporting this research.

Ethical issues

The authors hereby certify that this manuscript is the original work of the authors, all data collected during the study are as stated in this manuscript, and no data from this study has been or will be published elsewhere separately.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors were equally involved in the collection, analysis, and interpretation of the data. All authors critically reviewed, refined, and approved the manuscript.

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