RESEARCH ARTICLE

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Health Risks of Heavy Metals for Population via Consumption of Greenhouse Vegetables in Hamadan, Iran

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A-B-S-T-R-A-C-T

Background & Aims of the Study: The last 25 years have seen a remarkable increase in public concern about food contamination. Food and water are the main sources of our essential metals.These are also the media through which we are exposed to various toxic metalsAs such, this study aimed to assess the risks arising from the use of greenhouse vegetables, cucumbers, tomatoes and peppers in Hamadan Province.

Materials & Methods: Soil and plant samples were digested using wet digestion method ($HClO_4/HNO_3$, 2:1) ratio solution, and the concentrations of total As, Cd, Cu, Pb, and Zn were determined using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AE).

Results: High concentrations of elements As, Cd, Cu, Pb, and Zn were found in vegetables sampled from overused phosphate fertilized soils, which increased the daily intake of metals in food. The Health risk assessment values of all tested vegetables (pepper, cucumber and tomato) were below 1 in As and Cd. The health risk index (HRI) value above 1 indicated a relative health risk through the ingestion of contaminated vegetables .

Conclusions: Heavy metal concentrations should be periodically monitored in vegetables grown in contaminated soils. This study found that long-term fertilizer use led to a growing accumulation of heavy metals (HMs) in soils. It would also be beneficial to implement effective remediation technologies to minimize possible impacts on human health.

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Background

During the last decades, the increasing demand of food safety has stimulated research regarding the risk associated with consumption of foods contaminated by heavy metals and/or toxins (9). Heavy metal pollution of soil is one of the most important environmental problems throughout the world. In fact, heavy metals have a significant toxicity for humans, animals, microorganisms and plants (10). Heavy metals are ubiquitous in the environment, as a result of both natural and anthropogenic activities (12). This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metal is one of the major contaminants of our food resources. This problem gets more attention in all the world, generally and in developing countries specifically (15). The accumulation of heavy metals in greenhouse vegetable soil is one of the main reasons leading to the deterioration of soil quality and the contamination of agricultural products by heavy metals (30). Quality health and nutrition are considerable in two aspects: The desired compounds (e.g. vitamins, minerals, carbohydrates, fiber and essential activator reactions, undesirable compounds (e.g. heavy metals, nitrates, pesticides and pollution residues). Generally today, the relationship between nutrient concentrations and fruit quality is well-known and a lot of researches have been done in this area (1). About 30% of human cancers are caused by low exposure to initiating carcinogenic contaminants in the diet (20). Thus, the accumulation of heavy metals in the environment is considerable (14). The increasing reliance on agrochemicals for higher yields, especially in developing countries, is another important source of heavy metals in agricultural soils (21). Heavy metals can occur as impurities in natural materials and minerals, so heavy metals may be present in phosphorus fertilizers and other chemical fertilizers (6). Long-term application of phosphate fertilizers could result in the accumulation of heavy metals in the soil (7). Since the 1970s, many researchers have investigated Cd accumulation in the soil as a consequence of phosphate fertilizers and its effects on arable crops and pasture herbage (6). Since crops and vegetables take up heavy metals by absorption from contaminated soils or from atmospheric deposition from polluted air, heavy metal pollution in agricultural soil has serious negative influence on human health (21). The soil quality decline and food safety issues caused by the heavy metal contamination are now receiving extensive attentions (30). Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts (2). The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic (13). Excessive accumulation of these heavy metals in human bodies creates problems such as cardiovascular, kidney, nervous and bone diseases. It is known that serious systemic problems can develop as a result of increased accumulation of dietary heavy metals such as cadmium and lead in the human body. Heavy metals can impair important biochemical systems, constituting an important threat for the health of plants and animals (16). Due to the lack of information about the status of heavy metals in the greenhouse and also the fact that most of the current needs of the population comes through various vegetable cultivations greenhouse, this study aimed to assess the risks arising from the use of greenhouse vegetables, cucumbers, tomatoes and peppers in Hamadan Province.

Aims of the study: The objective of this study was to assess the risks arising from the use of greenhouse vegetables, cucumbers, tomatoes and peppers in Hamadan Province.

Materials & Methods

Soil sampling and analysis

Soil samples were collected from the soil surface (0–20 cm) of greenhouses in 3 cities in Hamadan province in western Iran. 108 soil samples were collected from greenhouses. Soil samples were air-dried and ground before being passed through a 2-mm sieve prior to analysis. Each sample from each treatment received three replicate analyses.

Soil samples were digested using wet digestion method ($HClO_4/HNO_3$, 2:1) ratio solution (17), and the concentrations of total As, Cd, Cu, Pb, and Zn were determined using inductively coupled plasmaatomic emission spectroscopy (ICP-AES).

Crop sampling and analysis

Plant samples (cucumber, tomato, pepper) were collected from the same sites where the soils were collected. Crop samples were washed three to four times with distilled water to remove foreign material. They were then digested in triplicate to minimize error, with HNO_3 and $HClO_4$ in a 2:1 ratio until a transparent solution was obtained (17). The heavy metal concentrations were determined using ICP-AES.

Data analysis

Estimated Daily Intake of metals

The human pathway of exposure to heavy metals by the ingestion of contaminated crops has been studied by many researchers (2,5,15). The daily intake of metals (DIM) by this exposure pathway was determined using the following equation:

$$\mathrm{EDI} = \mathrm{C} \times \frac{\mathrm{F_{IR}}}{\mathrm{W_{AB}}}$$

Estimated daily intake of heavy metals from vegetables consumption was obtained, where (EDI) (mg/(kg body weight (bw)·d)) is Estimated daily intake of HMs from vegetable. *C* (mg/g fresh weight (fw)) is an average weighted HM content in the edible portion of the vegetable, and is calculated by multiplying the normalization-transformed mean HM content in vegetables by their corresponding percentage of consumption. F_{IR} (g/(d·person)) is a daily vegetable consumption (3). As reported in literature, the average *F*IR for all inhabitants, and for adults and children in Iran is 100g/(d·person) (32). W_{AB} is the average body weight (63.9 kg for adult, 32.7 kg for children) (3).

Health risk index

A health risk assessment for consumers based on their intake of metal-contaminated crops was characterized using a health risk index (HRI). There was no obvious risk to the exposed population if the HRI is below1, but a risk was present if the HRI isabove 1. The HRI was calculated using the following equation (27):

$$\mathrm{HRI} = \frac{\mathrm{DIM}}{\mathrm{RfD}}$$

Where the reference oral doses (RfD) for Cu, Zn, Pb, Cd, and As were 0.04, 0.3, 0.0035, 0.001, and 0.0003 mg kg^{-1} day^{-1} in this study, respectively (26).

Results

Heavy metal concentrations in plants

The concentrations of As, Cd, Cu, Pb, and Zn (miligram/gram, dry weight basis) in plants are shown in Fig. 1. The As, Cu and Zn levels in all tomato samples and As, Cu levels in cucumber samples were within the FAO/WHO Standards, but the Cd levels in 3 type of crops in greenhouses in Hamadan city were above recommended levels. As, Cd, Cu, Pb, and Zn concentration in 22.3%, 75.6%, 22.62%, 75.2% and 33% of samples surpassed the standard values.

The concentrations of heavy metals found in pepper, cucumber and tomato samples are presented in Table 1. Compared with concentrations found in typical plants in the literature, most of the samples were highly contaminated with Cd and Pb.

The HRI values of all tested vegetables (pepper, cucumber and tomato) were above1 in As and Cd (Table 2), which indicated a relative health risk associated with the ingestion of contaminated vegetables grown on overused phosphate-fertilized soils. This result agrees with the conclusions of the study by Harmanescu et al. (12). The difference between the HQ and/or the HRI may be related to the estimated reference oral doses (26).

Discussion

The toxic effects of heavy metals in plants have been studied for many years, but positive and negative results have been reported, depending on the test material and the evaluated metal (31). Compared with inhalation and dermal contact exposure, food consumption has been identified as the major pathway (18). Vegetable is the staple food for much of the world and plays an important role in human diets (28). A number of studies have shown heavy metals as important contaminants of the vegetables (24).

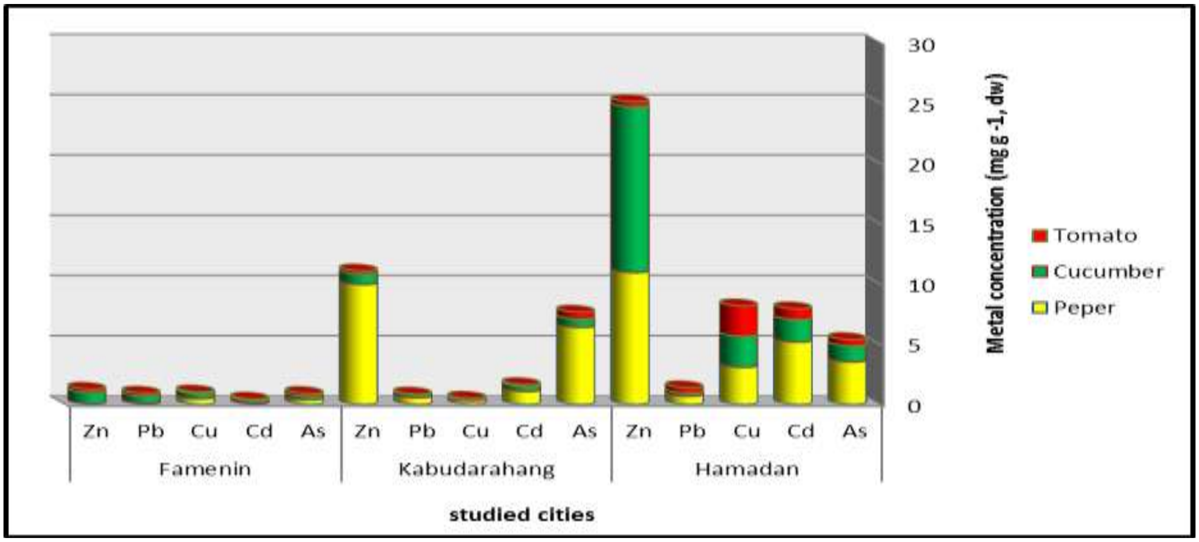

Figure 1) Metal concentrations (mean, n=108) in plants

Table 1) Range and mean of heavy metals concentration (mg g^{-1} dry weight; n=108) in plant samples grown in greenhouse

		Pepper		Cucumber		Tomato	
		range	**mean**	**range**	**mean**	**range**	**mean**
Hamadan	**As**		3.53	0.2-0.41	1.33	0.15-1.46	0.53
	Cd	0.2-9.3	5.17	0.51-3.67	1.87	0.09-1.6	0.9
	Cu	0.4-5.7	3.08	0.29-4.32	2.57	0.13-4.4	2.53
	Pb	0.1-1.4	0.69	0.09-0.39	0.26	0.012-0.61	0.44
	Zn	0.04-14.6	10.94	0.26-18.08	13.75	0.1-0.92	0.43
Kabudarahang	**As**	0.18-10.02	6.39	0.08-1.02	0.69	0.19-1.15	0.58
	Cd	0.9-6.8	1.08	0.19-0.66	0.41	0.13-0.21	0.16
	Cu	0.1-0.29	0.28	0.55-1.56	1.01	0.01-0.38	0.16
	Pb	0.2-1.03	0.57	0.05-0.67	0.24	0.01-0.12	0.06
	Zn	6.2-15.1	9.95	0.002-0.02	0.08	0.24-0.27	0.26
Famenin	**As**	0.09-0.73	0.38	0.1-0.8	0.3	0.06-0.59	0.24
	Cd	0.3-0.49	0.11	0.03-0.91	0.47	0.09-0.15	0.13
	Cu	0.6-1.2	0.47	0.3-4.09	1.44	0.04-0.26	0.13
	Pb	0.07-0.19	0.11	0.09-0.96	0.65	0.05-0.73	0.25
	Zn	0.003-3.09	0.05	0.1-7.02	0.94	0.2-0.28	0.28

Table 2) DIM and HRI (on dry weight basis) for individual heavy metals caused by the consumption of contaminated vegetables

Individuals	**Pepper**					**Cucumber**					**Tomato**				
	As	**Cd**	**Cu**	**Pb**	**Zn**	**As**	**Cd**	**Cu**	**Pb**	**Zn**	**As**	**cd**	**Cu**	**Pb**	**Zn**
Adults															
DIM	0.0072	0.0034	0.0023	0.0007	0.010	0.01	0.009	0.0021	0.005	0.0049	0.00069	0.0011	0.0021	0.00029	0.00050
HRI	2.4	3.4	0.057	0.2	0.33	3.33	0.9	0.05	0.14	0.01	2.3	1.1	0.05	0.08	0.001
Children															
DIM	0.14	0.00	0.00	0.00	0.02	0.00	0.00	0.04	0.00	0.009	0.001	0.00	0.00	0.000	0.000

		64	45	13	1	2	17	2	1	6	3	21	40	58	97
HRI	4.66	6.4	0.11	0.37	0.07	6.66	1.7	0.1	0.28	0.3	4.33	2.1	0.1	0.16	0.03

Vegetables take up heavy metals and accumulate them in their edible and inedible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants. A number of serious health problems can develop as a result of excessive uptake of dietary heavy metals (2). Therefore, DIM and HRI for adults and children consuming vegetables grown on contaminated soils were estimated. The highest DIMs for the metals As, Cd, both in adults and children, came from the consumption of vegetables. This indicated that adults and children consuming vegetables grown in greenhouse condition ingested high amounts of the metals studied. The HRI value of >1 indicated a relative health risk through the ingestion of contaminated vegetables. In addition, it was apparent that the intake of a single metal via the consumption of compared with adults. The contamination of crops grown in heavy metal contaminated soils has led to an increased public awareness of health hazards resulting from the consumption of contaminated crops (2,5,15,19,23). Although adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues and is even increasing in some areas. For example, Arsenic is still common in wood preservatives, and tetraethyl lead remains a common additive to petrol, although this use has decreased dramatically in the developed countries (13). Higher concentrations of metals in crops with higher HRIs or health quotients (HQ) were reported by Yang and Bo (3,29).

Animal experiments have suggested that cadmium may be a risk factor for cardiovascular diseases, but studies of humans have not been able to confirm this (13). Results from present and previous studies (11,21) demonstrate that the enrichment of Cd in greenhouse soils was mainly attributable to the heavy use of phosphatic and organic fertilizers (21). Demirezen et al. (8) showed that the concentrations of Cd and Pb in studied vegetables were above the recommended levels.

Conclusions

With the rapid development of industry and the economy, more and more pollutants are being released into the environment. Heavy metal pollution in agricultural soils has become an important issue both in developed and developing countries. Appropriate measures should be taken to effectively control heavy metal levels in vegetable soils, and thus protect human health. This study focused on the analysis of the heavy metal content and its accumulation in vegetables in Hamadan province in Iran. According to the results of the current study, long-term phosphate fertilizer use led to moderate accumulation of Cd, Pb, and Zn and a significant buildup of Cd in the soils of Hamadan province. Widespread use of arsenic as pesticides has significantly contributed to the elevation of arsenic concentrations in soils. The HRI value of >1 indicated a relative health risk through the ingestion of contaminated vegetables. Since crops and vegetables take up heavy metals by absorption from contaminated soils or from atmospheric deposition from polluted air, heavy metal pollution in agricultural soil has serious negative influence on human health. Excessive accumulation of heavy metals in agricultural soils may not only result in environmental contamination, but lead to elevated heavy metal uptake by crops, which may affect food quality and safety. There is also an increasing concern regarding food safety due to environmental pollution.

Footnotes

Conflict of Interest:

The authors declare no conflict of interest.

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