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The health risk assessment of heavy metals in vegetables grown in Babol city, Iran

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Abstract

Objectives: Contamination of vegetables with heavy metals through contaminated water can lead to accumulation in the body of consumers. This study aimed to determine the heavy metal concentration in vegetables grown in Babol city, Iran.

Methods: A descriptive cross-sectional study was performed on 32 samples of vegetables (parsley, spinach, basil, tomatoes, cucumbers, potatoes, onions, and beans) by random sampling in the harvest season of 2021. Heavy metal content was assessed by atomic absorption.

Results: The highest mean concentration of copper, zinc, cadmium and lead in tested samples was 12.86, 68.67, 1.93, and 0.48 mg/kg fresh weight, respectively, which found in parsley and spinach samples. There was a significant difference between the mean concentrations of copper, zinc and lead among different vegetables ($P < 0.001$), but no significant difference was observed in the case of cadmium. The highest risk of non-cancerous diseases (HQ) for Zn in parsley and spinach were higher than threshold value of 1, and the main exposure pathway of heavy metals is ingestion.

Conclusion: This study showed that the main part of heavy metal accumulation occurs in leafy vegetables. Therefore, consuming leafy vegetables should be paid more attention to the vegetables grown around industrial areas.

Keywords: Heavy metals, Vegetables, Non-carcinogenic risk assessment.

Introduction

The uptake and accumulation of heavy metals in vegetables are influenced by many factors, including climate, atmospheric sediments, the concentration of heavy metals in soil and water, the quality of the soil where the plant grows, and the stage of crop ripeness at harvest.[1] Copper and zinc elements are essential for many human biological systems in appropriate and optimal amounts. In cases in which these elements are low for balanced plant growth, farmers use fertilizers containing microelements or even fungicides containing copper that increase the concentration of these elements in plants.[2]

Heavy metals such as cadmium, lead, chromium, and mercury are essential environmental pollutants found on plants' surfaces or fresh tissue.[3] Cadmium is of particular importance among heavy metals because plants can absorb it quickly, and its toxicity is around 20 times more than other heavy metals.[4] Soil and water pollution with heavy metals is one of the significant environmental issues in human societies that not only does it reduce yield and product quality; it endangers the sustainability of agricultural products and the health of society.[5] It is reported that approximately half of the average lead, cadmium, and mercury comes from foods with plant origin (fruits, vegetables, grains, and legumes).[6] Soil contamination with heavy metals may be widespread in

urban areas due to industrial activities in the past or the use of fossil fuels.[7] Heavy metals may enter the human body in various ways, such as inhaling dust and polluted air, entering metals directly into farmlands, and consuming heavy elements by plants grown in these areas, which will eventually lead to the entry of these elements into the human food chain.[8] Vegetables are an essential part of the human food chain. Because they contain carbohydrates, proteins, vitamins, minerals and microelements.[9] In recent years, especially among urban communities, the consumption of vegetables is increasing, and this is due to the increase in public awareness of the practical value of foods containing vegetables.[7] Vegetables are a good source of accumulation of all essential and toxic elements. Accumulation of heavy metals above the standard level, can threaten human health through the consumption of vegetable crops.[4] Given the importance of such foods and the consumption of contaminated vegetables in developing countries and, finally, the entry of heavy metals into the human food cycle, it is necessary to conduct regional studies and investigate the causes and factors of pollutants in agricultural products to investigate nutritional health of major consumed vegetables in province.[10] Therefore, this study aimed to analyze the total concentrations of heavy elements of copper, zinc, cadmium, and lead in many vegetables and soils of studied fields; and calculate the temporary tolerable threshold daily intake of these heavy elements.[2] Since the allowable limit for copper and zinc extraction is not defined in the Iranian National Standard.[11]

Objectives

Therefore, to compare these elements, the standard of the Joint Committee of the Food and Agriculture Organization of the United Nations and the World Health Organization (FAO/WHO),[12,13] and for cadmium and lead elements, the National Standard of Iran was used. Finally, the rate of exposure to diseases, which is resulted from the consumption of agricultural products in the Babol city (a city located in the north of Iran), was examined.

Methods

Babol County is situated between the latitude from (N 40°36′ to N36°35′) and longitude (E33°52′ to E43°51′) is in Mazandaran Province in Iran. The Babol Plain has an area of 1578 km2 and urban population of 230973. The mean annual temperature, rainfall, and mean humidity of this county are 15.9°C, 525.6 mm and 78%, respectively [Figure 1].

In this research, sampling was performed on 7 types of vegetables produced in Babol, including (parsley, spinach, basil, tomatoes, cucumbers, potatoes, onions and beans). From each vegetable, 4 samples were randomly chosen from the beginning, middle and end parts of the field to show the average condition of each field in terms of heavy metal contamination under study. Therefore, 21 samples of main vegetables were harvested. It should be noted that sampling was done when the agricultural products were ready to be harvested by local farmers. The collected samples were placed in polyethylene nylons to prevent wastage of plant moisture and then transferred to the University of Science and Technology Laboratory, Faculty of Chemistry. After separating the weeds from the vegetables in the laboratory, their eatable part was detached and washed with distilled water, and dried in an oven at 60 to 65 °C. Then, they were crushed via an electric mill. Then 1g of the plant samples were poured separately into 100 mL containers, and 15 mL of a mixture of three acids (70% purity nitric acid, 65% perchloric acid and 70% sulfuric acid) (1: 1: 5) was added. Next, the solutions were digested at 80°C until they became apparent. Using distilled water, it reached the volume of 50 ml, and the solutions were prepared to measure the concentration of heavy elements.[14]

Figure 1. The map of sampling place of vegetables in Babol County, Mazandaran Province, Iran

Finally, the concentrations of heavy elements of copper, zinc, cadmium, and lead in the studied vegetables were determined using an atomic absorption spectrometer (Model Avanta^{P}, GBC, Australia). To estimate the concentration of the elements based on fresh weight, the dry matter of each type of vegetable must be obtained. Therefore, some fresh vegetables were taken in three replications and after weighing, they were placed in an oven at 105 $^{\circ}C$ for 24 h, each plant's dry matter was obtained separately.[15].

The EDI index value depends on the concentration of heavy metals in vegetables and the number of vegetables consumed. This index is set for adults. For this purpose, by using the formula we estimate the studied metals' daily intake (EDI).[16,17] In addition, the non-carcinogenic risk of heavy metals can be determined.[18]

In this regard, EDI is the daily intake of vegetables and RFD is the reference dose of food in terms of, which is measured.[19] The reference dose (RfD) for non-carcinogenic effects was for lead (0.0035), cadmium (0.001), copper (0.1) and zinc (0.3) mg/kg/day.[20] Based on the result of equation (2), if THQ> 1, there is an unacceptable risk of non-carcinogenic effects on health, but if it is THQ < 1, there is no obvious risk to the exposed population.[21]

Statistical analysis

The continuous variables were expressed as the mean ± SD, and the categorical variables were presented as a percentage and frequency. All statistical analyses were performed with SPSS (version 16.0, SPSS Inc, Chicago, IL, USA).

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. This work was approved by the Ethics Committee of Tehran University of Medical Science, Iran (IR.Bmsu.rec1396.004).

Results

The average concentration of copper and lead in cucumber was higher than onion and potato. The mean concentrations of copper, zinc, cadmium and lead in parsley samples were 6.63±0.3, 68.67±33.3, 0.06±0.04, and 0.06±0.04 0.5±0.16 mg/kg, respectively. The highest and lowest concentration of cadmium was found in spinach and beans, respectively. Also, the maximum and minimum level of lead was detected in spinach and cucumbers, respectively. The highest mean concentrations of cadmium and lead belonged to the group of leafy vegetables [Table 1].

Table 1. Mean and standard deviation of heavy metals (mg/kg) in vegetables

Vegetables	**Cu** (Mean±SD)	**Zn** (Mean±SD)	**Cd** (Mean±SD)	**Pb** (Mean±SD)
Parsley	6.67±0.3	68.67±3.33	0.06±0.04	0.5±0.16
Spinach	5.42±0.34	63.31±3.2	0.04±0.44	0.48±0.16
Potatoes	1.7±0.55	15.73±1.79	0.03±0.01	0.20±0.18
Onions	1.06±0.30	14.3±1.74	0.01±0.08	0.18±0.05
Basil	2.46±0.34	32.39±3.33	0.032±0.04	0.16±0.16
Tomatoes	1.36±0.20	16.68±0.70	0.027±0.022	0.19±0.43
Cucumbers	3.86±0.65	51.21±5.22	0.02±0. 36	0.088±0.52
Beans	2.86±0.65	58.21±5.22	0.01±0. 39	0. 067±0.52

As previously mentioned, according to the results obtained [Table 2], the level of heavy metal intake can be calculated by consuming the mentioned vegetables and for a 70 Kg adult human. The results showed that in all selected vegetables, due to the high concentration of Zinc, compared to other heavy elements, the daily intake of zinc was higher than other elements, followed by copper. While the highest daily cadmium intake was related to consuming both basil and spinach (0.0006) mg kg^{-1} d^{-1}. Therefore, according to the results displayed in Table 2, the highest number of heavy elements of copper, zinc, cadmium and lead entering the gastrointestinal tract of consumers in the study area were 0.25, 0.33, 0.0006 and 0.0022 mg kg^{-1} d^{-1}, respectively that belonged to potatoes, Parsley, Spinach and Spinach. On the other hand, as shown in Figure 2, the potential for disease incidence was obtained by consuming all the studied vegetables and for copper, zinc, cadmium and lead were 0.835, 1.11, 0.632 and 0.6626, respectively.

Table 2. EDI values for eight types of vegetables

Vegetables	Cu	Zn	Cd	Pb
Parsley	0.0314	0.33	0.0001	0.00021
Spinach	0.0254	0. 341	0.0006	0.0022
Potatoes	0.25	0.076	0.0002	0.0009
Onions	0.0057	0.005	0.0001	0.0008
Basil	0.0066	0.16	0.0006	0.0009
Potatoes	0.00041	0.078	0.00011	0.0009
Cucumbers	0.0181	0.248	0.00009	0.00049
Beans	0.621	0.28	0.00006	0.0003

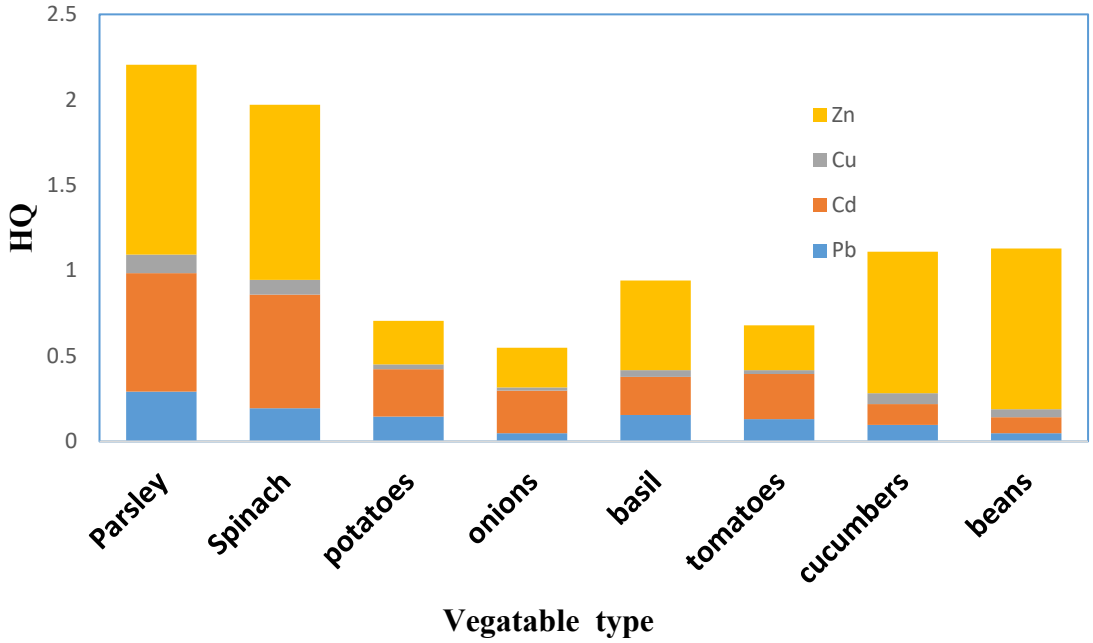

Figure 2. HQ value for eight types of vegetables

Discussion

In this study, the concentrations of lead, cadmium, zinc and copper were determined based on the fresh weight of the samples including parsley, spinach, basil, tomatoes, cucumbers, potatoes, onions, and beans. To compare and evaluate the level of contamination of the mentioned elements in the produced vegetables, the standard was used. The highest concentration of copper was related to beans with an average of 12.68 mg/kg fresh weight and its lowest concentration was associated with onion products (1.06 mg/kg fresh weight). As previously mentioned, the average concentration of copper in all analyzed products was lower than the FAO/WHO.[22] In contrast, In the study of Tahsin et al., the concentration of heavy metals in all vegetable samples was higher than the allowable limit.[23]

The importance of zinc and copper is because of their role in metabolic processes. Toxic effects include nausea, indigestion, vomiting, diarrhea, and damage to the liver parenchyma.[24] According to Table 2, the mean zinc concentrations in parsley, spinach, basil, potatoes, onions, tomatoes, cucumbers and beans were obtained 80.1, 27.6, 41.97 and 50.9, respectively. Only the concentration of zinc in parsley and spinach was higher than the FAO/WHO standard and in other products.[22] The average concentration of zinc was less than the standard. In other products, zinc concentration was within the allowable range and these products were healthy and free of any accumulation of zinc. The average concentration of zinc in potatoes was 15.7. According to the National Standard Institute of Iran reports, the standard concentration of cadmium for leafy and tubers vegetables are 0.05 and 0.1 mg/kg, respectively.[22] The average concentration of cadmium in parsley, spinach, basil, potato, onion, tomatoes, cucumbers and beans were estimated to be 0.08, 0.03 and 0.02 mg/kg fresh weight respectively, which the highest cadmium concentrations belonged to the spinach

group. In contrast, the cadmium concentrations in all studied products were lower than the Iran National Standard.[22] In the study of Bahamuka et al., The mean concentrations of cadmium and lead in vegetables were 0.2 and 3.95 mg / kg, respectively the amount of cadmium is less than the previous study and the amount of lead is higher.[25] A study conducted by Zohrehvand et al., mean concentrations of Pb, Cd, Cu and Zn in vegetables were 10.39, 2.51, 7.20 and 31.84 mg/kg, respectively. The results showed that lead and cadmium levels in vegetables are above the recommended levels.[26] Rarnos et al., stated that cadmium is a mobile metal and easily absorbed from the root surface of plants and moves to their woody tissue and accumulates in the upper parts of the plant.[27] Thus, the accumulation of cadmium in the aerial parts of the plant will be more than the ground parts (tubers or roots). In the collected potato products and leafy vegetables, the average concentration of cadmium was 0.2 and 0.8, respectively.[28] These results were similar to the performed research in Isfahan, Iran.[29]

Lead is a toxic metal that plants can usually be absorbed and accumulated without changing their appearance. Therefore, in many plants, the accumulation of lead will be hundreds of times higher than the allowable and limit.[30] According to the reports of the Institute of Standards and Industrial Research of Iran, the allowable limit of lead concentration in parsley, spinach, basil and beans is estimated 0.2 and in potatoes, onions, tomatoes and cucumber was estimated to be 0.1.[22] Also, the maximum allowable concentration of lead in the World Health Organization has been reported 0.3 mg/kg fresh weigh.

In the present study, the mean concentration of lead in parsley, spinach, basil, potato, onion, tomato and cucumber were reported to be 0.34, 0.06 and 0.02, respectively. The mean concentration of lead in parsley, spinach, basil with a significant difference was obtained at the level of 1% above the Iran National Standard. Nazemi et al., in their study concluded that the average concentration of metals in vegetables with standard values is significantly different.[31] However, the average concentration of lead in potatoes, onions, tomatoes and cucumbers was lower than the National Standard of Iran, although their difference from the Iranian standard was not significant. Therefore, the range of lead concentration in parsley, spinach, basil vegetables was obtained higher than the National Standards of Iran[22] and the Joint Committee of the Food and Agriculture Organization of the United Nations and the World Health Organization.[15,32] The average concentration of lead in potatoes was 0.4.

As shown in the results, with the consumption of various vegetables produced in the province, the number of heavy elements entering the gastrointestinal tract was less than the tolerable threshold daily consumption. Similar to the present work Arfainia et al., indicated that the highest metal intake was related to spinach and lettuce.[33] The hazard quotient is an appropriate factor for assessing the risk of contaminated food Heavy metals.[34] The parameter of disease incidence for all heavy elements was obtained less than one. Hence, the food health of the consumers of the agricultural products in this study is guaranteed and is in a safe range and away from the effects of diseases. In a study on vegetables around Shiraz, the potential risk for cadmium from agricultural products in this area was higher than one, which is not consistent with the results of this study.[35] The researchers stated that some plants spread cadmium in the roots and others, such as lettuce, in the leaves. Therefore, the type of plant also has a significant effect on the rate of absorption. The major accumulation of heavy elements zinc, cadmium and lead was in the group of leafy vegetables, which is higher than other mentioned products. This finding is similar to the results of other researchers.

Conclusions

The present study showed that the lead and cadmium content in parsley and spinach can cause concern because it was above the tolerable amounts. Chronic daily consumption of lead, cadmium, zinc and copper through the consumption of vegetables was very low and these products did not seem to pose a health risk to consumers. Compared to other crops, leafy vegetables are good absorbers of heavy elements that with more transpiration, most of the heavy elements accumulate in the stems and leaves of these plants. Because of their broad leaves, they are more prone to physical contamination with dust. Contrary to lead and zinc contamination in the mentioned products (parsley, spinach and basil) and consuming them, the daily intake of heavy elements to the human gastrointestinal tract was less than the National Standard of Iran. Generally, the high concentration of heavy metals in crops can be attributed to agricultural chemicals such as phosphate fertilizers, organic fertilizers, nitrogen chemical fertilizers, and pesticides and microbicides.

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Competing interests

The authors declare that they have no competing interests.

Abbreviations

Food and Agriculture Organization of the United Nations and the World Health Organization: FAO/WHO;

Reference dose: RfD.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. This work was approved by the Ethics Committee of Tehran University of Medical Science, Iran. (IR.Bmsu.rec1396.004).

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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