ORIGINAL ARTICLE

Evaluation of Carcinogenic and Non-Carcinogenic Risk of Heavy Metals Due to the Consumption of Vegetables Produced in the Greenhouse of Markazi Province

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Received: 2 October 2018
Revised: 20 November 2018
Accepted: 31 December 2018

Abstract

Background: High concentration of heavy metals and NO_3 in vegetables may pose serious health risks to humans. Therefore, this research was done to evaluate the carcinogenic and non-carcinogenic risk of heavy metals and NO_3 due to the consumption of most important greenhouse vegetables produced in Markazi province.

Methods: In this descriptive study, sampling of cucumber, tomato, and bell pepper produced in the greenhouses of Markazi province was done randomly and the concentration of Pb, Cd, Cu, Ni and NO_3 of them were determined. Non-cancer risk related to heavy metals and NO_3 sorption from vegetables was evaluated using the EPA method for men and women.

Results: The mean concentration of all the studied metals except Cu was in the allowable concentration range. The mean concentration of NO_3 in the cucumber was 300 mg/kg FW, which was about 1.5 times higher than the maximum allowable concentration of that in vegetables. The HQ of Pb, Cd, Ni, Cu and NO_3 for all population groups were smaller than 1. The results showed that NO_3 and Pb were the major risk contributor for the consumers. The excess lifetime cancer risks of Ni for all receptor groups were greater than 1×10^{-6}.

Conclusion: The results of this study showed that the total risk index of heavy metals and NO_3 through consumption of greenhouse vegetables grown in Markazi province was below one. Also, in the most age groups this index is greater for women related to the men.

Please cite this article as: Mokhtari K, Mazaheri H, Baghaie AH, Hassani Joshaghani A. Evaluation of Carcinogenic and Non-Carcinogenic Risk of Heavy Metals Due to the Consumption of Vegetables Produced in the Greenhouse of Markazi Province. J Health Sci Surveillance Sys. 2019;7(1):22-30.

Keywords: Lead, Cadmium, Vegetables, Risk factors, Environmental pollution

Introduction

Soil, water and air are the basic parameters of life on earth. Since the nineteenth century and the beginning of the industrial revolution, the environment has become increasingly polluted insofar as today environmental pollution is a serious threat to human health and other organisms. High concentration of heavy metals in human food is toxic and leads to acute and chronic diseases. Chronic skin, gastrointestinal and respiratory diseases have been reported from heavy metal toxicity.[1-3]

It is well known that some heavy metals such as cadmium (Cd) and lead (Pb) are highly toxic to plants, animals, and humans. These heavy metals do not have any benefit effect on the function of the human body. Neurological problems and different cancers are some adverse effects of heavy metal toxicity in human.[4-6]

Naturally, nitrate is in different media such as soil, water, and food. In the natural nitrogen cycle, bacteria convert nitrogen to nitrate, which is taken up by plants and incorporated into plant tissues. Human activities such as more application of nitrogen fertilizers as well as concentrated livestock and poultry farming have elevated nitrate concentration in the environment.[7] High concentration of nitrate in vegetables is considered a potential threat to human health. Nitrate may convert to nitrite and cause methemoglobinemia in the blood of infants, and gastric cancer in adults.[8]

Vegetables are an important part of a healthy diet, and evidence from various studies suggests that eating healthy vegetables can prevent heart disease and some cancers, especially gastrointestinal cancer. However, consumption of vegetables planted in contaminated soils can lead to serious metabolic and physiological detrimental effects on human health.[9, 10]

On the other hand, excessive use of mineral and organic fertilizers in the fields leads to the accumulation of nitrate and heavy metals in the plants; consequently, the consumption of crops grown in these soils can threaten the human health.[11-13]

Khoshgoftarmanesh et al. (2009) mentioned that the contamination of greenhouse vegetables with Pb and NO_3 is an important concern that has to be considered.[7] Khan et al. (2010) in a study on the potential risk of heavy metals for human health due to the consumption of vegetables grown in heavy metal polluted soils in northern Pakistan reported that consumption of those vegetables could have adverse effects on the human health. They also showed that the risk of heavy metals in the study area was higher for children compared with that for adults.[14]

Chari et al. (2008) have shown that the risk of Zn, Pb, and Cr on human health through the consumption of vegetables grown in the lands irrigated with wastewater is very high, and among different vegetables, the leafy types contain a higher concentration of heavy metals.[15]

SalehiPour Baversad et al., in their study on the potential hazards of heavy metals in some agricultural products of Isfahan province reported that the cancer risk of as through wheat consumption is higher than that through the consumption of onion.[16] Also, Baba Akbari et al. evaluated the heavy metal risk indices through the vegetable consumption in Varamin city and concluded that the non-cancer risk index of Cd, Co, Cu, and Ni was low.[17]

This is notable that the cumulative effect of heavy metals can play a significant role in the development of different carcinogenic and non-carcinogenic diseases.[18, 19] Therefore, risk assessment of these diseases due to the consumption of heavy metals contaminated vegetables seems to be necessary.[20, 21] On the other hand, in recent decades protected cultivation significantly contributed to the production of fresh vegetables and this technology can play an effective role in reduction of the concentration of pollutants in vegetables.[22]

Overall, the greenhouse technology provides different resources to control the situations of temperature, humidity, light, CO_2 concentration, and water and nutrient availability.[23] Thus, indoor production of vegetables presents some advantages compared to outdoor production with regard to quality assurance.[24] However, some of the soils used for greenhouse cultivation of vegetables have elevated concentration of heavy metals. Additionally, the potential risk of greenhouse vegetables to NO_3 has been increased due to the intensive application of manure and chemical nitrogen fertilizers.[7]

Given the significant role of vegetables in human health and the possibility of high concentrations of heavy metals and NO_3 in edible parts of vegetables produced in the industrial area of Iran, such as Markazi province,[25] it is necessary to investigate the nutritional quality of vegetables produced in greenhouses of these area periodically and regionally.[26, 27] Therefore, this study was done to evaluate the potential hazard of heavy metals and NO_3 on human health due to consumption of the main greenhouse vegetables (cucumber, bell pepper and tomato) produced in Markazi province.

Materials and Methods

Twenty greenhouses were chosen in Markazi province, central Iran. At the time of harvest, cucumbers, tomatoes and bell peppers were collected from each greenhouse. In each sampling, 10 vegetable samples were randomly selected for analysis. The samples were washed in distilled water and cut into small pieces and placed in an oven at 70 °C until reaching a constant weight. Dry samples were combusted at 550 °C for 8 h, and heavy metals in the ash were extracted using 2 M HCl.[28] Concentrations of Pb, Ni, Cu and Cd in the digest solutions were determined by atomic absorption spectrometry (AAS) (Perkin-Elmer model 3030). The accuracy of Pb, Ni, Cd and Cu analysis was controlled by analyzing th certified standard materials and including blanks in digestion batches.

The nitrate concentration in vegetables was determined using the method described by Haftbaradaran.[29] Risk was estimated using the equations suggested by the United States environmental protection agency (USEPA).[30]

$ADD_i \ (mg/kg\text{-}day) = (CF \times IR \times FI \times EF \times ED)/(BW \times AT)$ [Eq.1]

Where:

CF=Contaminant concentration in food (mg kg^{-1})

IR=Ingestion rate (kg $meal^{-1}$)

FI=Fraction ingested from contaminated source (unit less)

EF=Exposure frequency (meals $year^{-1}$)

ED=Exposure duration (years),

BW=Body weight (kg)

AT=Averaging time (period over which exposure is averaged – days).

In this study, we assumed that cucumber, tomato and bell pepper consumption (IR) is about 108, 108 and 100 grams, per adult per day and 40, 40 and 10 grams per child per day, respectively.[22, 28]

The fraction ingested from the contaminated source (FI) is 0.4.[31]

Exposure frequency (EF) describes the number of meals per year.

The number of years one is potentially exposed to is used in this calculation as the exposure duration (ED). The exposure duration values actually used in the intake calculations are: 3 years for children in the ages range of 3 through 6 years; 7 years for males and females aged 7 through 14; 4 years for males and females in the age range of 14 through 18; 37 years for average men/old women aged 18 through 54; and 15 years for old men/old women in the age range of 55 through 70.[22] Individual body weight (BW) for males in the age groups of 3-6 years old, 7-14 years old, 14-18 years old, 18-55 years old, and 55-70 was considered to be 15.7, 29, 59.1, 76.4, 76.80, and 65.1kg, respectively. The body weight for female in the age groups of 3-6 years old, 7-14 years old, 14-18 years old, 18-55 years old and 55-70 yearsold was considered to be 14.5, 35, 56, 61, and 60.6 kg, respectively.[22, 32]

Exposure is averaged over a specified period of time. In general, this period, or averaging time (AT), is the product of ED and 365 days/year for non-carcinogenic effects and the 25500 days (70 years x 365 days/year) for carcinogenic effects.[33]

Non-carcinogenic effects were determined by dividing the intake from the Eq. 1 by the reference dose (RfD) of each contaminant that is shown in Eq. 2.[30]

HQ=E/RfD [Eq. 2]

HQ=Non-cancer hazard quotient

E=Exposure level (or intake) (mg/kg-day)

RfD=Reference dose (mg/kg-day).

$HI=\sum HQ_i$ [Eq. 3]

Carcinogenic effect of the heavy metals was calculated by multiplying the intake from the Eq. 1 by the slope factor (Eq. 4).[32]

Carcinogenic Risk=CDI*SF [Eq. 4]

CDI=Chronic daily intake averaged over 70 years (mg/kg-day)

SF=Slope Factor $(mg/kg\text{-}day)^{-1}$.

Oral reference doses (RfD) were considered to be 0.004, 0.001, 0.02, 0.037, and 1.6 mg kg^{-1} day^{-1} for Pb, Cd, Ni, Cu and NO_3 and Ni, respectively. The slope factor for Cd was 0.38 mg kg^{-1} day^{-1}, for Pb it was 8.5×10^{-3}, and for Ni 9.1×10^{-1} mg kg^{-1} day^{-1}.

Results

The mean concentration of the studied heavy metals and NO_3 in cucumber, tomato and bell peppers are shown in Table 1. The highest and lowest concentration of Pb was observed in bell pepper and cucumber. Also, the same trend was observed for Cd and Ni. In the case of Cu, the highest (1.04 mg/kg) and lowest (0.44mg/kg) mean concentration of that belonged to the bell peppers and tomato samples. The mean concentration of NO_3 was considerably greater in cucumber (300 mg/kg) as compared to tomato (100 mg/kg) and bell pepper (61 mg/kg).

The daily intakes of Pb, Cd, Cu, Ni and NO_3 for all receptor groups are shown in Table 2. The highest and lowest daily intakes of all studied heavy metals and NO_3 were found in boys aged 7-14 years and men aged 18-55 years, respectively. On the other hand, in all population groups, consumption of bell pepper and cucumber had the highest contribution in the intake of heavy metal and NO_3, respectively.

The non-carcinogenic risks (HQ) for the heavy metals and NO_3 through consumption of cucumbers, tomato and bell peppers produced in greenhouses of Markazi province for different population groups (based on age and gender) are presented in Table 3. Among the NO_3 and metals, NO_3 had a relatively

Table 1: Mean concentration of heavy metals and NO3 in the studied samples (mg/kg)

Vegetable type	Pb	Cd	Ni	Cu	NO3
Cucumber	0.16	0.02	0.08	0.81	300
Tomato	0.25	0.03	0.11	0.44	100
Bell pepper	0.32	0.06	0.14	1.04	61
WHO standard (mg/kg)					
	0.5	0.1	0.15	0.2	200

Table 2: Daily intake of heavy metals and NO3 (mg/ kg BW day) via consumption of the studied vegetables for different population groups

Vegetable type	3-6	7-14	14-18	18-55	55-70	3-6	7-14	14-18	18-55	55-70
Group gender: men										
	Pb					**Cd**				
Cucumber	0.00013	0.00023	0.00011	0.00009	0.00010	0.000017	0.00029	0.000014	0.000011	0.000013
Tomato	0.00021	0.00037	0.00018	0.00014	0.00016	0.000025	0.000044	0.000021	0.000017	0.000019
Bell pepper	0.00068	0.00044	0.00023	0.00017	0.00019	0.000013	0.000083	0.000044	0.000031	0.000037
	Ni					**Cu**				
Cucumber	0.000068	0.00011	0.000058	0.000045	0.000053	0.00069	0.0012	0.00059	0.00046	0.00053
Tomato	0.000094	0.00016	0.000080	0.000062	0.000073	0.00037	0.00065	0.00032	0.00025	0.00029
Bell pepper	0.000029	0.00019	0.000094	0.000073	0.000086	0.00022	0.0014	0.00070	0.00054	0.00063
	NO3									
Cucumber	0.25	0.44	0.21	0.17	0.19					
Tomato	0.085	0.14	0.073	0.056	0.066					
Bell pepper	0.013	0.084	0.041	0.031	0.037					
Group gender: women										
	Pb					**Cd**				
Cucumber	0.00015	0.00019	0.00012	0.00010	0.00012	0.000018	0.000025	0.000015	0.000013	0.000014
Tomato	0.00022	0.00030	0.00019	0.00016	0.00018	0.000027	0.000037	0.000023	0.000021	0.000022
Bell pepper	0.000073	0.00036	0.00022	0.00020	0.00022	0.000013	0.000068	0.000043	0.000039	0.000041
	Ni					**Cu**				
Cucumber	0.000073	0.000098	0.000061	0.000056	0.000058	0.00074	0.0010	0.00062	0.00057	0.00059
Tomato	0.00010	0.00014	0.000084	0.000077	0.000080	0.00040	0.00054	0.00034	0.00031	0.00033
Bell pepper	0.000032	0.00016	0.00010	0.000091	0.000098	0.00023	0.0011	0.00072	0.00068	0.00070
	NO3									
Cucumber	0.27	0.37	0.23	0.20	0.22					
Tomato	0.091	0.12	0.077	0.070	0.072					
Bell pepper	0.014	0.069	0.044	0.041	0.042					

Table 3: Non-carcinogenic hazard quintet (HQ) of heavy metals and NO3 via consumption of the studied vegetables for different population groups

Vegetable type	3-6	7-14	14-18	18-55	55-70	3-6	7-14	14-18	18-55	55-70
Group gender: men										
	Pb					**Cd**				
Cucumber	0.034	0.060	0.029	0.023	0.027	0.017	0.030	0.015	0.011	0.013
Tomato	0.053	0.093	0.046	0.035	0.041	0.026	0.045	0.022	0.017	0.020
Bell pepper	0.068	0.119	0.058	0.045	0.053	0.051	0.089	0.044	0.034	0.040
	Ni					**Cu**				
Cucumber	0.003	0.006	0.003	0.002	0.003	0.019	0.033	0.016	0.012	0.015
Tomato	0.005	0.008	0.004	0.003	0.004	0.010	0.018	0.009	0.007	0.008
Bell pepper	0.001	0.01	0.005	0.004	0.005	0.006	0.039	0.019	0.015	0.017
	NO3					**Total risk (HI)**				
Cucumber	0.16	0.28	0.13	0.10	0.12					
Tomato	0.053	0.093	0.046	0.035	0.041	0.42	0.95	0.47	0.36	0.43
Bell pepper	0.008	0.053	0.026	0.020	0.023					
Group gender: women										
	Pb					**Cd**				
Cucumber	0.037	0.049	0.031	0.028	0.029	0.018	0.025	0.015	0.014	0.014
Tomato	0.057	0.077	0.048	0.044	0.045	0.027	0.035	0.026	0.021	0.022
Bell pepper	0.018	0.091	0.057	0.052	0.053	0.015	0.069	0.046	0.039	0.040
	Ni					**Cu**				
Cucumber	0.0040	0.005	0.0037	0.0032	0.0034	0.022	0.027	0.018	0.015	0.017
Tomato	0.0050	0.007	0.0049	0.0043	0.0045	0.011	0.015	0.010	0.007	0.009
Bell pepper	0.0020	0.008	0.0053	0.0049	0.0050	0.006	0.032	0.020	0.017	0.019
	NO3					**Total risk (HI)**				
Cucumber	0.17	0.23	0.14	0.13	0.13					
Tomato	0.057	0.077	0.048	0.044	0.045	0.45	0.80	0.50	0.45	0.46
Bell pepper	0.009	0.044	0.027	0.025	0.026					

Table 4: Carcinogenic risk value of Pb, Cd and Ni via consumption of the studied vegetables for different population groups

Vegetable type	3-6	7-14	14-18	18-55	55-70	3-6	7-14	14-18	18-55	55-70
Group gender: men										
	Pb					**Cd**				
Cucumber	9.9×10^{-8}	2.0×10^{-7}	5.7×10^{-8}	4.0×10^{-7}	1.9×10^{-7}	1.2×10^{-8}	2.5×10^{-8}	7.1×10^{-9}	5.0×10^{-8}	2.4×10^{-8}
Tomato	1.5×10^{-7}	3.1×10^{-7}	8.9×10^{-8}	6.3×10^{-7}	3.0×10^{-7}	1.9×10^{-8}	3.8×10^{-8}	1.0×10^{-8}	7.6×10^{-8}	3.6×10^{-8}
Bell pepper	1.9×10^{-7}	4.0×10^{-7}	1.1×10^{-7}	8.1×10^{-7}	3.8×10^{-7}	3.7×10^{-7}	7.6×10^{-8}	2.1×10^{-8}	1.5×10^{-7}	7.2×10^{-8}
	Ni									
Cucumber	5.3×10^{-6}	1.0×10^{-5}	3.0×10^{-6}	2.1×10^{-5}	1.1×10^{-5}					
Tomato	7.3×10^{-6}	1.4×10^{-5}	4.1×10^{-6}	2.9×10^{-5}	1.5×10^{-5}					
Bell pepper	2.3×10^{-6}	1.7×10^{-5}	4.9×10^{-6}	3.5×10^{-5}	1.8×10^{-5}					
Group gender: women										
	Pb					**Cd**				
Cucumber	1.0×10^{-7}	1.7×10^{-7}	6.0×10^{-8}	5.1×10^{-7}	2.0×10^{-7}	1.4×10^{-8}	2.1×10^{-8}	7.5×10^{-9}	6.3×10^{-8}	2.7×10^{-8}
Tomato	1.6×10^{-7}	2.6×10^{-7}	9.3×10^{-8}	7.9×10^{-7}	3.2×10^{-7}	2.3×10^{-8}	3.1×10^{-8}	1.1×10^{-8}	9.5×10^{-8}	3.9×10^{-8}
Bell pepper	2.1×10^{-7}	3.3×10^{-7}	1.3×10^{-7}	1.0×10^{-6}	4.1×10^{-7}	4.2×10^{-8}	6.3×10^{-8}	2.5×10^{-8}	1.9×10^{-7}	7.8×10^{-8}
	Ni									
Cucumber	5.7×10^{-6}	8.9×10^{-6}	3.3×10^{-6}	2.7×10^{-5}	1.04×10^{-5}					
Tomato	7.8×10^{-6}	1.2×10^{-5}	4.4×10^{-6}	3.7×10^{-5}	1.42×10^{-5}					
Bell pepper	2.6×10^{-6}	1.5×10^{-5}	5.3×10^{-6}	4.4×10^{-5}	1.68×10^{-5}					

higher potential health risk (Table 3). On the other hand, among the metals, Pb had the highest potential health risk. Also, among different population groups the highest and lowest NO_3 or metals HQ value was recorded for boys aged 7-14 years and men aged 18-55 years (Table 3). The HQ of each contaminant due to the consumption of cucumber and bell pepper was less than 1 for all population age groups.

The cumulative non-carcinogenic risk (HI) values which evaluate the risk from exposures to multiple contaminants from multiple sources are shown in Table 3. As seen in this Table, the HI values ranged between 0.36 and 0.95 for boys aged 7-14 years and men 18-55 years, respectively (Table 3). Additionally, NO_3 and Pb were the major risk contributors for consumers.

The carcinogenic risks for the Pb, Cd, and Ni through consumption of cucumber, tomato and bell pepper produced in greenhouses of Markazi province for different population groups (based on age and gender) are presented in Table 4. It is necessary to mention that it was not possible to calculate the cancer risk potential of other studied elements due to the lack of slope factor of them in different databases. As shown in Table 4, among Pb, Cd, and Ni, the highest and lowest calculated cancer risk belonged to the Ni and Pb, respectively. Also, among different population groups, the highest and lowest cancer risk value was observed in boys aged 7-14 years and men aged 18-55 years (Table 4).

Discussion

The maximum permissible concentration of Pb, Cd, and Ni in the edible parts of vegetables is 0.5, 0.1, and 0.15 mg /kg FW.[7, 34] Therefore, the mean concentration of these elements in the studied samples of cucumber, tomato and bell pepper were in the allowable concentration limit (Table 1). However, due to the negative effects of these metals on human health, their presence in the edible part of these vegetables should be considered. Khoshgoftarmanesh et al. (2009) surveyed the nutritional quality of greenhouse products in Qom province and mentioned that Pb concentration in the bell pepper samples produced in this province is about 1.3 times higher than the standard limit.[7] It should be noted that the presence of Pb in the edible part of greenhouse products is not only related to the absorption of this element from the soil, since it has been reported that the transfer of Pb to the edible part of plants as a result of deposition of this element in the soil or binding with the root tissues is low.[35] In this regard, Aghili et al. mentioned that the presence of Pb in the edible part of greenhouse products is partly related to the type of fuels used in greenhouse heating systems and the presence of Pb as impurities in the pesticides used in the greenhouse.[22]

The presence of Cd in the edible part of the greenhouse products indicates the entrance of Cd into these products in different ways. According to the reports of other researchers, phosphate fertilizers as well as zinc-containing fertilizers are important sources of Cd entry into the agricultural soil and subsequently the plant, which is very important in the greenhouse environment due to the high use of chemical fertilizers.[7, 22] In this regard, the results of the analysis of different chemical fertilizers distributed in Iran showed that the concentration of cadmium in phosphate fertilizers and zinc sulfate fertilizers varied from 3.11 to 25.61 and 2.21 to 26.36 mg / kg, respectively.[22]

Zafarzadeh et al., by determining the concentration of different heavy metals in cucumber and tomato samples distributed in the fruit and vegetable centeral market of Gonbad and Gorgan cities, showed that the mean concentrations of Cd and Pb in the analyzed samples exceeded the WHO limit.[36] Nazemi et al., in a study on the Pb and Cd concentrations in the greenhouse products of Shahroud suburb, reported that the average concentration of Pb and Cd in the studied greenhouse products was higher than the WHO standard. They mentioned that soil pollution with heavy metals is the main reason of heavy metal concentration in these products.[37]

As to Cu, it should be mentioned that it is one of the essential elements in the body's metabolism and that deficiency may disrupt the body; on the other hand, its high concentration in the body is toxic.[38] According to the World Health Organization (WHO), the maximum permissible concentration of Cu in fruits and vegetables is 0.2 mg/kg FW.[39] Comparison of this limit with the mean concentrations of this element in the studied samples shows that the concentration of Cu in the greenhouse crops studied is higher than the healthy limit of this element (Table 1). Copper, as an essential trace element, is a common pollutant in greenhouses. Due to the intensive production methods and environmental conditions in the greenhouse, the possibility of fungal and bacterial plant diseases development is very common.[40] Therefore, in the greenhouse cultivation fungicides and bactericides, which increase the Cu concentration in the greenhouses soils and products due to the presence of Cu in their structures, are used extensively.[40, 41] In this regard, Aghili et al. (2012), through estimating the concentration of micronutrients and macronutrients in the edible parts of greenhouse-grown vegetables compared to the field-grown vegetables mentioned that the Cu concentration in greenhouse soils and vegetables is significantly higher than that in the field soils and vegetables.[42] On the other hand, the difference in the concentration of heavy metals in cucumbers with tomatoes and peppers is mainly due to the differences in the ability of different plants to the uptake of heavy metals.[43]

The maximum permissible level of NO_3 in the edible parts of vegetables is 200 mg /kg FW.[44] Accordingly, we can mention that the mean NO_3 concentration in the greenhouse cucumber was about 1.5 times higher as compared with the standard limit. Khoshgoftarmanesh et al. (2009) reported that the concentration of NO_3 in cucumber and bell pepper samples collected from the greenhouses of Qom province was 406 and 61 mg/kg FW, respectively. These researchers revealed that high concentrations of NO_3 in greenhouse products were mainly related to poor nutritional management and high application of chemical fertilizers and animal manure.[7]

Determining the daily intake of heavy metals and NO_3 through the consumption of the above-mentioned greenhouse products (Table 2) showed that daily intake of Pb for all receptor groups was less than 0.003 mg/kg body weight provided by the World Health Organization although in the age group of 7-14 years, the daily intake was close to the upper level of healthy limit. Khoshgoftarmanesh et al. in a study on the nutritional quality of greenhouse products in Qom province mentioned that Pb and NO_3 were the most important pollutants in greenhouses of Qom province.[7]

The tolerable daily intake of Cd, Ni and Cu are 0.173, 0.017 and 0.05 mg / kg, respectively.[31] As shown in Table 2, the estimated total daily intakes of Cd, Ni and Cu via consumption of the intended amount of greenhouse products for all receptor groups were less than the tolerable daily intake.

In the case of NO_3, the maximum allowable absorption of this component is 3.7 mg/kg body weight per day.[44] Therefore, in all the studied population groups the calculated NO_3 uptake was lower than its maximum allowable absorption. Additionally, cucumber and bell pepper were the most and less predominant contributors in total NO_3 uptake, respectively, which could be related to the higher application of NO_3 fertilizers in cucumber greenhouses as compared to bell pepper greenhouses.[7] However, the daily intake of heavy metals through consumption of bell pepper for all receptor groups, except for the age group of 3-6 years, was higher than the intake of these elements due to the consumption of other products, which is related to the higher concentration of these metals in bell pepper as compared to the cucumber and tomatoes samples (Table 1).

The HQ value of individual heavy metals or NO_3 through the consumption of vegetables should be less than one in order not to have the explicit hazards for the presence of these contaminants in the whole life of an area through the consumption of vegetables.[45] According to the results of our study, the non-cancer hazard quotient (HQ) of individual heavy metal or NO_3 through the consumption of the studied products of Markazi province in all population groups was smaller than one (Table 3). However, the total risk factor (HI) in boys and girls aged 7-14 years was 0.95 and 0.80, respectively, which is close to one, indicating that the nutritional quality of greenhouse vegetables should be considered more. Aghili et al. in a study on the quality of greenhouse vegetables grown in Isfahan province reported that the HQ for all population groups via consumption of greenhouse cucumbers and bell peppers was smaller than 1.[22] Also, the results of our study showed that NO_3 and Pb accounted for about 40 and 22% of HI, respectively (Table 3).

Tabandeh et al. in an investigation on the status of Pb, Cd and Zn in some vegetables grown in different farms of Zanjan province concluded that the HQ value due to the consumption of vegetables grown in Zanjan province was below one.[28]

Kheirabadi et al. in their study on the risk of heavy metals in the soil and major crops (wheat, potato, and corn) grown in Hamadan province reported that the HQ values for all age groups were higher than 1, suggesting that the adults and children in their study region may experience a potential non-cancer risk through the consumption of heavy metal via wheat, corn and potato, and soil ingestion. They also mentioned that in Hamedan province plant foods, particularly wheat and soil ingestion, are the major routes of human exposure to heavy metal.[30]

Determining the cancer risk of Pb, Cd and Ni from consumption of the studied vegetables indicated that Ni was a major cancer risk contributor for the consumers (Table 4), which is due to the higher cancer risk potential of Ni as compared to the Pb and Cd. Overall, the acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000).[31] Comparison of these ranges with calculated cancer risks of Cd, Pb and Ni in this study indicated that community is not exposed to cancer risk of Pb and Cd via consumption of greenhouse products grown in Markazi province. However, calculated cancer risk for Ni was higher than 1×10^{-6}, indicating that the cancer risk, related to Ni is in the range of acceptable risk (Table 4).

Chari et al. studied the heavy metals risk of vegetables grown in wastewater-irrigated lands and concluded that the risk of exposure to Cr and Pb through the consumption of these vegetables was high and among the vegetables, leafy ones had higher concentrations of different heavy metals.[15]

Conclusion

The mean concentration of all the studied heavy metals except for Cu in the studied greenhouse products of Markazi province was within the permissible range of heavy metal concentrations provided by the WHO. Nitrate concentration in bell pepper and tomato samples was also in the permissible range, while in the cucumber samples it was higher than the standard limit. The most vulnerable population groups to the presence of the studied heavy metals and NO3 in the greenhouse products were boys and girls aged 7-14 years. Among the studied elements, NO_3 and Pb had the highest coefficient of risk for non-cancerous diseases and Ni had the highest coefficient of risk for cancer diseases. Due to the relatively high NO_3 and Cu content, as well as the presence of contaminants such as Pb and Cd in greenhouse products, it is suggested that the role of nutritional management, and plant cultivars should be studied to reduce the concentration of this contaminant in edible parts of greenhouse vegetables.

Acknowledgement

The authors gratefully thank Islamic Azad University of Arak Branch for supporting this research.

Conflict of Interest: None declared.

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