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SADRŽAJ:

Heavy Metal Intake and Potential Carcinogenic Risks Through Consumption of Leafy Vegetables in Mostar

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Abstract

This study analyzed the concentrations of arsenic (As), lead (Pb), and cadmium (Cd) in Swiss chard (*Beta vulgaris* subsp. cicla) and collard greens (*Brassica oleracea* var. acephala) available on the market in the city of Mostar, with the aim of assessing potential carcinogenic risks for adults and children. Given that heavy metals are present in the environment and can accumulate in plants, understanding their concentrations and potential health impacts is particularly important. The United States Environmental Protection Agency (USEPA) considers an acceptable carcinogenic risk to fall within the range of 1×10^{-6} to 1×10^{-4}. The measured concentrations of heavy metals (As, Cd, and Pb) in Swiss chard (samples B1–B6) and collard greens (samples R1–R6) showed variability but were all below the maximum permissible levels set by the Official Gazette of Bosnia and Herzegovina No. 68/14. The estimated potential carcinogenic risk for adults ranged from $2.53x10^{-5}$ to $2.64x10^{-5}$ for Swiss chard and from $1.06x10^{-5}$ to $8.55x10^{-6}$ mg/kg/day for collard greens. Higher risks were calculated for children, ranging from $3.55x10^{-5}$ to $1.62x10^{-5}$ mg/kg/day for Swiss chard and from $1.13x10^{-5}$ to $7.81x10^{-6}$ mg/kg/day for collard greens. Although the concentrations of heavy metals in the analyzed samples were low and the associated risks fall within the USEPA-recommended limits, continuous monitoring and control of heavy metal concentrations are advised to ensure food safety and protect consumer health.

Key words: Swiss chard, collard greens, potential carcinogenic risk, children, adults.

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Introduction

Most toxic elements, including arsenic (As), cadmium (Cd), and lead (Pb), pose significant health risks due to their high solubility in water. Even at very low concentrations, these elements can have detrimental effects on human and animal health, as the body lacks efficient mechanisms for their elimination. Although food and water serve as primary sources of essential nutrients, they also act as pathways for exposure to toxic metals. The presence of these elements in food depends on several factors, including soil quality, environmental conditions, plant genotype, the use of fertilizers and pesticides that may contain metals, and contamination during production or through contact with metallic surfaces. Given these factors, the accumulation of toxic elements in food has become a serious concern in terms of food safety and potential health risks. Therefore, it is crucial to regularly monitor heavy metal concentrations in food and ensure they remain within the maximum residue limits established by national and EU regulatory authorities. In the absence of such limits, continuous monitoring and comparison with available literature data are necessary. Assessing dietary intake and monitoring metal levels in food are essential steps in risk assessment and in identifying potential contamination that could threaten public health. Excessive intake of heavy metals through diet can lead to numerous serious health problems. Since more than 90–95% of total daily exposure to heavy metals originates from dietary intake - while other exposure routes include inhalation and dermal contact (Bocio et al., 2005; Martí-Cid et al., 2008) understanding the risks associated with consuming contaminated food is crucial. Arsenic is the only element classified as carcinogenic to humans, with confirmed carcinogenic effects via both inhalation and ingestion. It is associated with various cancers, including lung, liver, skin, and bladder cancer (IARC, 2004; Kapaj et al., 2006). Additionally, arsenic is highly toxic and accumulates in the body. Cadmium has also been classified as „carcinogenic to humans“ (Group 1) by the International Agency for Research on Cancer (IARC, 1993) and as a Category 2 carcinogen by the European Union (OJEC, 2004). Although naturally present in soil, cadmium spreads through the environment due to human activities and is highly toxic (Zhu et al., 2011). Similarly, lead has no beneficial role in human metabolism and causes progressive toxic effects (Zhu et al., 2011). Lead exposure has been linked to symptoms such as insomnia, fatigue, hearing loss, and weight loss. Furthermore, the International Agency for Research on Cancer classified inorganic lead as „probably carcinogenic to humans“ (Group 2A) in 2006 (IARC, 2006).

In Mostar, as well as in other parts of Bosnia and Herzegovina, Swiss chard and collard greens play an important role in the local diet, particularly in traditional cuisine. These vegetables are widely used in various dishes due to their nutritional value and versatility in food preparation.
Swiss chard is highly popular, especially in Mediterranean cuisine. In Mostar, it is frequently used in salads, stews, soups, and side dishes. Swiss chard is rich in vitami – particularly vitamin K and folic acid – minerals, dietary fiber, and antioxidants. Its widespread use in the region is attributed to its flavor

and ease of preparation, and it is commonly consumed with potatoes or other vegetables. Collard greens also hold a significant place in the traditional cuisine of Mostar. They are often used in cooked dishes such as stews, soups, and meat-based meals (especially with lamb). Collard greens are rich in vitamins, calcium, and fiber, making them a particularly healthy dietary choice. Although not as widely consumed as Swiss chard, collard greens remain a valued component of Bosnian cuisine. The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) recommend a minimum daily intake of 400 grams of fruits and vegetables (excluding potatoes and other starchy tubers) for the prevention of chronic diseases such as cardiovascular disease, cancer, diabetes, and obesity.

Materials and Methods

During 2024, samples of Swiss chard and collard greens were collected from six different locations in the wider area of Mostar. The Swiss chard samples were labeled B1 to B6, while the collard greens samples were labeled R1 to R6. The heavy metal concentrations in the plant material were analyzed using appropriate laboratory methods. After collection, Swiss chard leaves were prepared for analysis by chopping and homogenizing 50 leaves per location. From each site, three composite samples were prepared, and the average value was used for final calculation.

Analytical Methods

The determination of trace elements - lead (Pb), cadmium (Cd), and arsenic (As) in fruits and vegetables was performed using inductively coupled plasma mass spectrometry (ICP-MS) in accordance with the standard BAS EN 15763:2011, following microwave digestion as specified in BAS EN 13805:2015. For sample preparation, 1 g of homogenized plant material was weighed and treated with 20 mL of 60 % nitric acid (HNO_3). The mixture was gently heated for 2 hours. After cooling, 3 mL of hydrogen peroxide (H_2O_2) was added, followed by an additional 15 minutes of heating. This hydrogen peroxide treatment step was repeated. Upon cooling, 2 mL of perchloric acid ($HClO_4$) was added, and the mixture was gently evaporated until dense white fumes of perchloric acid appeared. After cooling, 5 mL of hydrochloric acid (HCl) was added, and the samples were quantitatively transferred into 50 mL volumetric flasks. The flasks were then filled to the mark with distilled water. The resulting solution was filtered through quantitative filter paper. Measurements were conducted using flame atomic absorption spectrometry (AAS) with an acetylene-air flame. The concentrations of heavy metals in the analyzed plant material were assessed against the maximum permissible levels (MPLs) established by the national Regulation on Maximum Allowed Levels for Certain Contaminants in Food (Official Gazette of BiH, 68/14).

Health Risk Assessment

Health risk is defined as the probability of adverse health effects occurring in an individual due to exposure to specific contaminants or groups of contaminants. This risk depends on three key factors: the type of contaminants present in food, the level of exposure, and the toxicity of the contaminants. The integration of these factors forms the foundation of most risk assessment protocols. Health risk assessment serves as a valuable tool for evaluating potential hazards associated with chemical exposure. Risk assessment specialists must possess the ability to conceptualize risk, predict and analyze its potential impacts, and make informed decisions based on these evaluations. A health risk assessment provides an overview of past, present, and future exposure to hazards in food, and it can be either qualitative and/or quantitative. It is based on scientific understanding of the contaminants' properties, exposure, dose, and toxicity (Šukalić et al., 2025). Two dimensions of risk, which are a combination of the probability or frequency of an adverse event and the magnitude of its consequences, must be considered. Risk assessment is a scientifically-based process for evaluating potential harmful impacts, consisting of: hazard identification, hazard characterization, exposure assessment, and risk characterization (Koese et al., 2023). Risk assessment is calculated using the equation provided by the United States Environmental Protection Agency (USEPA, 2012, USEPA, 1989) (1):

$$CDI = \frac{CxIRxEFxED}{ATxBW} \quad (1)$$

Where:

CDI is chronic daily intake

C is the concentration of the metal (mg/L);

IR is the chronic intake of vegetables in Europe, 51.55 g/day for adults and 29.74 g/day for children (Comprehensive European Food Consumption Database, Leafy vegetables, leafy brassica, EFSA, 2024);

ED is the exposure duration, 30 years for adults and 10 years for children;

EF is the frequency of exposure (days/year), 365 days/year for both adults and children;

BW is body weight (kg), 70 kg for adults and 25 kg for children;

AT is the average time of exposure in years for carcinogenic effects, calculated as ED × 70 years.

For carcinogens, risk is assessed as the incremental probability that an individual will develop cancer during their lifetime as a result of exposure to a potential carcinogen (Šukalić et al., 2025; Kuzman Katica et al., 2024). The carcinogenic risk assessment was calculated using the model for estimating carcinogenic hazards (2):

$$Risk_{input\ method} = \sum_{k=1}^{n} CDI_k \, CSF_k \quad (2)$$

It is considered that risks below 1×10^{-6} do not present significant health effects, risks between 1×10^{-6} and 1×10^{-5} are considered to have minor significant health effects, risks between 1×10^{-5} and 1×10^{-4} are of moderate range, risks between 1×10^{-4} and 1×10^{-3} are considered to have high health effects, and health effects above 1×10^{-1} are considered to have very high health effects (USEPA, 1989).

Table 1. CSF (Cancer Slope Factor) according to the literature data

Element	Cancer slope factor (mg/kg/day)	
	Oral CSF	Carcinogenic Classification according to USEPA [c]
Cadmium (Cd)	$3,8x10^{-1}$ [a]	1
Arsenic (As)	1,5[a]	1
Lead (Pb)	$8,5x10^{-3}$ [a,b]	B2

a) (Fouladi et al., 2021; Šukalić et al., 2025)

b) (Integrated Risk Information System; Leto et al., 2020)

c) 1 – Proven carcinogen to humans, B2 – Probable carcinogen to humans

Results and discussion

Table 2 presents the average concentrations of heavy metals in samples of Swiss chard (Beta vulgaris subsp. cicla) and collard greens (Brassica oleracea var. acephala), along with the maximum permitted levels established by relevant regulations.

Table 2. Average concentrations of heavy metals in Swiss chard and collard greens samples (mg/kg)

Sample	Arsenic (As)	Cadmium (Cd)	Lead (Pb)
R1	0.009	0.013	<LOQ
R2	0.011	0.049	<LOQ
R3	0.009	0.036	<LOQ
R4	0.01	0.049	0.02
R5	0.009	0.013	<LOQ
R6	0.011	0.049	<LOQ
B1	0.014	0.038	0.046
B2	0.006	0.045	<LOQ
B3	0.004	0.046	<LOQ
B4	0.005	0.025	<LOQ
B5	0.012	0.034	0.047
B6	0.012	0.051	<LOQ
MDK (Official Gazette 68/14)	0.3	0.20	0.30

The average concentrations of cadmium in cabbage reported by Jurić et al. (2016) ranged from 0.015 to 0.018 mg/kg, arsenic from 0.018 to 0.029 mg/kg, and lead from 0.020 to 0.027 mg/kg. In comparison with our study, cadmium concentrations were slightly higher but remained below the Maximum Allowed Concentration (MAC), while arsenic levels were lower (0.004-0.014 mg/kg). Lead was detected in only three samples, with concentrations ranging from 0.020 to 0.047 mg/kg. These findings are consistent with those reported by Jurić et al. (2016).

Table 3. presents the concentrations of As, Cd, and Pb in vegetables and their contamination sources according to various international studies.

Table 3. Examples of vegetable contamination with heavy metals and potential sources of pollution in different countries

Vegetables	Heavy Metals (mg/kg)	Sources of Contamination	Country / Reference
Brassica L. spp., *Cucurbita* L. spp., *Solanum* L. spp., *Cucumis sativus* L., *Phaseolus vulgaris* L., *Amaranthus tricolor* L., *Cichorium endivia* L., *Lactuca sativa* L., *Apium graveolens* L., *Allium tuberosum* Rottler ex Spreng., *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc., *Zizania caduciflora* (Turcz. ex Griseb.) Turcz. ex-Stapf, *Luffa cylindrica* (L.) M.Roem., *Capsicum annuum* L., *Spinacia oleracea* L., *Benincasa hispida* (Thunb.) Cogn., *Raphanus sativus* L., *Glebionis coronaria* (L.) Cass. ex Spach, *Solanum lycopersicum* L., *Coriandrum sativum* L.	As (0.006 – 0.019), Cr (0.017 – 0.103), Pb (0.029 – 0.123)	Contaminated irrigation water, use of fertilizers and pesticides, emissions from industrial and transport gases, harvesting, storage, and marketing processes	China (Liang G. et al., 2019)
Cabbage, carrot, onion, spinach, tomato	Cu (0.92 – 9.29), Mn (0.04 – 373.38), Zn (4.27 – 89.88)	Organic and inorganic fertilizers, agrochemicals	South Africa (Bvenura C. & Afolayan A.J., 2012)
Rice and leafy vegetables, legumes and stalks	Cd (0.01 – 3.61)	Irrigation water from rivers or nearby reservoirs, mining activities (manganese, vanadium, and pyrite)	China (Chen H. et al., 2018)
Vegetables (lettuce, Swiss chard, and strawberry)	As (0.43 – 0.8), Pb (0.84)	Urban community gardens	USA (Cooper A.M. et al., 2020)
Vegetables (tomato, potato, spinach, onion, beetroot, parsley)	Cd (0.89), Pb (5.81), Cr (3.67)	Soil contamination, atmospheric deposition during transportation	Serbia (Arsenov D. et al., 2016)

Research on heavy metal concentrations in vegetables reveals significant variations attributable to different contamination sources. In China, studies of Brassica species reported arsenic levels of 0.006-0.019 mg/kg, chromium 0.017-0.103 mg/kg, and lead 0.029-0.123 mg/kg, with primary contamination sources including polluted irrigation water, fertilizer and pesticide use, industrial and transport emissions, as well as harvesting, storage, and sales processes (Liang et al., 2019). South African analyses of cabbage, carrots, onions, spinach, and tomatoes detected copper (0.92-9.29 mg/kg), manganese (0.04-373.38 mg/kg), and zinc (4.27-89.88 mg/kg), with contamination linked to organic/inorganic fertilizers and agrochemicals (Bvenura and Afolayan, 2012). Additional Chinese research identified cadmium concentrations of 0.01-3.61 mg/kg in rice, leafy vegetables, legumes, and stems, primarily originating from contaminated river and irrigation water, as well as mining activities involving manganese, vanadium, and pyrite (Chen et al., 2018). In the United States, analysis of urban shared agricultural land revealed arsenic (0.43-0.8 mg/kg) and lead (0.84 mg/kg) concentrations in lettuce, chard, and strawberries, indicating the impact of urban pollution (Cooper A.M. et al., 2020). A study conducted in Serbia indicates the presence of cadmium (0.89 mg/kg), lead (5.81 mg/kg), and chromium (3.67 mg/kg) in tomatoes, potatoes, spinach, onions, beets, and parsley, with the sources of contamination linked to industrial soil pollution and atmospheric deposition during transport (Arsenov D. et al., 2016). These results highlight the global problem of vegetable contamination with heavy metals, with sources of pollution associated with agricultural practices, industrial emissions, mining, and urban pollution. Continuous monitoring and the implementation of appropriate measures are necessary to reduce the accumulation of these toxic elements in the food chain. Table 4 shows the CDI for arsenic, lead, and cadmium in chard and collard greens, and based on the obtained results, the total risk (RI) for adults was calculated. The results indicate different risk levels depending on the type of vegetable, with particular attention given to cadmium, which is considered one of the most dangerous heavy metals for human health.

Table 4. Assessment of Carcinogenic Risk (RI) for Adults from Heavy Metal Intake through Consumption of Swiss Chard and collard greens:

	Sample	CDI As (mg/kg/day)	CDI Pb(mg/kg/day)	CDI Cd(mg/kg/day)	RI
Swiss chard	B1	1.48×10^{-5}	2.76×10^{-7}	1.02×10^{-5}	2.53×10^{-5}
	B2	6.36×0^{-6}		1.21×10^{-5}	1.84×10^{-5}
	B3	4.24×10^{-6}		1.23×10^{-5}	1.66×10^{-5}
	B4	5.30×10^{-6}		6.71×10^{-6}	1.20×10^{-5}
	B5	1.27×10^{-5}	2.82×10^{-7}	9.12×10^{-6}	2.21×10^{-5}
	B6	1.27×10^{-5}		1.37×10^{-5}	2.64×10^{-5}
Total risk $\sum B1 + B2 + B3 + B4 + B5 + B6$		5.61×10^{-5}	$5{,}58 \times 10^{-7}$	6.41×10^{-5}	$1{,}21 \times 10^{-4}$
Collard greens	R1	4.25×10^{-6}		1.55×10^{-6}	5.80×10^{-6}
	R2	5.19×10^{-6}		5.86×10^{-6}	1.11×10^{-5}
	R3	4.25×10^{-6}		4.31×10^{-6}	8.55×10^{-6}
	R4	4.72×10^{-6}	5.35×10^{-8}	5.86×10^{-6}	1.06×10^{-5}
	R5	4.72×10^{-6}		3.71×10^{-6}	$8.43\ 10^{-6}$
	R6	4.72×10^{-6}		8.25×10^{-6}	1.30×10^{-5}
Total risk $\sum R1 + R2 + R3 + R4 + R5 + R6$		2.79×10^{-5}	5.35×10^{-8}	2.95×10^{-5}	5.75×10^{-5}

Interpretation of Potential Risks for Adults

Swiss Chard:

Arsen (As) is present in all analyzed samples, with the highest intake recorded in sample B1 ($1.48x10^{-5}$ mg/kg/day). The total risk from arsenic is $5.61x10^{-5}$ mg/kg/day, which represents a moderately high risk that requires careful monitoring, as arsenic can cause long-term negative effects, including cancer and damage to internal organs (Smith et al., 2002). Lead (Pb) is present in very low concentrations, especially in sample B1 (2.76× 10-7 mg/kg/day), which results in a very low total risk from lead (2.82× 10-7 mg/kg/day). This level is well below critical thresholds, and the risk from lead is considered negligible, which is consistent with findings from other studies that also indicate low lead presence in plant crops (Jiang et al., 2017).

Cadmium (Cd) is present in significant amounts, especially in sample B1 ($1.02x10^{-5}$ mg/kg/day). The total risk from cadmium is $6.41x10^{-5}$, indicating a moderate risk. Given that cadmium can cause serious health problems, including kidney and bone damage, attention must be given to its concentration in food (WHO, 2011). The total risk for Swiss Chard is $1,21\times 10^{-4}$, which indicates a moderate risk, with particular emphasis on cadmium and arsenic.

Collard greens:

Arsen (As) is also present in significant quantities in all analyzed samples, with the highest intake recorded in sample R1 (4.25×10^{-6} mg/kg/day). The total risk from arsenic is $5.61x10^{-5}$, indicating a moderate risk similar to that of Swiss Chard, but with slightly higher risk due to higher concentrations in several samples. Lead (Pb), as in Swiss Chard, has very low intake, with the highest concentration recorded in sample R4 (5.35×10^{-8} mg/kg/day), resulting in a minimal total risk from lead (2.82×10^{-7} mg/kg/day). This level does not raise concern either. Cadmium (Cd) is present in all analyzed samples, with the highest intake observed in sample R2 (5.86×10^{-6} mg/kg/day). The total risk from cadmium for collard greens is $6.41x10^{-5}$ mg/kg/day , indicating a moderate risk, but slightly higher compared to Swiss Chard due to higher concentrations of cadmium in some samples. The total risk for collard greens is 1.21×10^{-4} mg/kg/day, which is a slightly higher risk compared to Swiss Chard. The higher risk results from a combination of higher concentrations of arsenic and cadmium in some samples, which requires more careful monitoring of the consumption of this plant. Although both vegetables, Swiss Chard and collard greens, had low risk for lead in most samples, arsenic and cadmium still represent significant sources of risk. Given their presence in the analyzed samples, it is recommended to carefully monitor the consumption of these foods, especially for long-term health effects. Collard greens shows a slightly higher total risk due to higher concentrations of arsenic and cadmium in some samples, while Swiss Chard shows a moderate risk with significant influence from cadmium and arsenic. This research aligns with broader literature on human health and the impact of heavy metals from food. Similar studies have been conducted by Jiang et al. (2017), who also highlighted the risk of cadmium and arsenic in vegetables, and by Smith et al. (2002), who emphasized the long-term health consequences of arsenic exposure through diet. In Table 5, the CDI values for arsenic, lead, and cadmium in Swiss Chard and collard greens are presented, and based on the obtained results, the total risk (RI) for children is calculated. The results show differences in risk depending on the type of vegetable, taking into account specific factors for children, who are more susceptible to contamination due to their lower body mass and greater absorption of heavy metals.

Table 5. Assessment of carcinogenic risk (RI) for children from the intake of heavy metals through the consumption of Swiss Chard and collard greens:

	Sample	CDI As (mg/kg/day)	CDI Pb (mg/kg/day)	CDI Cd (mg/kg/day)	RI
Swiss chard	B1	$2.00x10^{-5}$	3.72×10^{-7}	$1.37x10^{-5}$	$3.41x10^{-5}$
	B2	8.56×10^{-6}		$1.63x10^{-5}$	$2.48x10^{-5}$
	B3	5.70×10^{-6}		$1.66x10^{-5}$	$2.23x10^{-5}$
	B4	7.13×10^{-6}		9.0310^{-6}	$1.62x10^{-5}$
	B5	$1.71x10^{-5}$	3.80×10^{-7}	$1.23x10^{-5}$	$2.98x10^{-5}$
	B6	$1.71x10^{-5}$		$1.84x10^{-5}$	$3.55x10^{-5}$
Total risk ∑〖B1+B2+B3+B4+B5+B6〗		$7.56x10^{-5}$	7.52×10^{-7}	$8.63x10^{-5}$	1.63×10^{-4}
Collard greens	R1	5.72×10^{-6}		2.09×10^{-6}	7.81×10^{-6}
	R2	6.99×10^{-6}		7.89×10^{-6}	$1.49x10^{-5}$
	R3	5.72×10^{-6}		5.80×10^{-6}	$1.15x10^{-5}$
	R4	6.3610^{-6}	7.2×10^{-8}	7.89×10^{-6}	$1.43x10^{-5}$
	R5	6.36×10^{-6}		$4.99x10^{-6}$	$1.13x10^{-5}$
	R6	6.36×10^{-6}		$1.11x10^{-5}$	$1.75x10^{-5}$
Total risk ∑〖R1+R2+R3+R4+R5+R6〗		$3.75x10^{-5}$	7.2×10^{-8}	$3.98x10^{-5}$	$7.73x10^{-5}$

Interpretation of potential risks for children

Swiss Chard:

Arsen (As) is present in all analyzed samples, with the highest intake recorded in sample B1 ($2.00x10^{-5}$ mg/kg). The total risk from arsenic for children is $7.56x10^{-5}$ mg/kg/day, indicating a moderate risk. Considering that children have a higher sensitivity to toxins, arsenic exposure could increase the risk of developing cancer and other chronic diseases (Smith et al., 2002). Lead (Pb) is present in very low concentrations, especially in sample B1 (3.72×10^{-7} mg/kg/day), which results in a very low total risk from lead (7.52×10^{-7} mg/kg/day). While lead can negatively affect children's development, its presence in Swiss chard is minimal, suggesting a low threat to children's health in this case. Cadmium (Cd) is present in significant amounts, particularly in sample B1 ($1.37x10^{-5}$ mg/kg/day). The total risk from cadmium for children is $8.63x10^{-5}$, indicating a moderate risk. Cadmium is known for its negative impact on kidneys and bone development, especially in children, making it a significant factor in assessing the risk of food contamination (WHO, 2011). The total risk for Swiss chard is 1.63×10^{-4} mg/kg/day, representing a moderate risk for children, with particular emphasis on cadmium and arsenic.

Collard Greens:

For collard greens, the total risk for children is calculated as follows:

Arsenic (As) is present in all analyzed samples, with the highest intake recorded in sample R1 (5.72×10^{-6} mg/kg/day). The total risk from arsenic for children is $3.75\text{x}10^{-5}$ mg/kg/day , indicating a moderate risk, although it is lower than in Swiss chard. Given the risks associated with chronic arsenic exposure, it is recommended to limit the consumption of vegetables with higher concentrations of this metal. Lead (Pb) is present in minimal concentrations in all analyzed samples, with the highest intake recorded in sample R4 (7.2× 10-8 mg/kg/day). The total risk from lead for children is 7.2×10^{-8} mg/kg/day, indicating a negligible risk. Cadmium (Cd) is present in all analyzed samples, with the highest intake recorded in sample R2 (7.89×10^{-6} mg/kg/day). The total risk from cadmium for children is $3.98\text{x}10^{-5}$ mg/kg/day, which is a moderate risk. Given cadmium's negative impact on kidney and bone development in children, it is important to monitor the concentration of this metal in vegetables. The total risk for collard greens is $7.73\text{x}10^{-5}$ mg/kg/day , indicating a moderate risk, with emphasis on cadmium and arsenic. This risk is slightly lower than that for Swiss chard, but caution is still advised in consumption, especially for children. Although both types of vegetables, Swiss chard and collard greens, had low risk for lead in most samples, the greatest risk comes from cadmium and arsenic. This underscores the importance of carefully monitoring dietary habits and the consumption of vegetables that may be contaminated with these heavy metals. Given their presence in the analyzed samples, it is recommended to carefully monitor the consumption of these foods, particularly for long-term health effects. Further research is also recommended to ensure the safe consumption of these plants, especially in areas with potential soil and water contamination. Collard greens show a slightly higher total risk due to higher concentrations of arsenic and cadmium in some samples, while Swiss chard shows a moderate risk, with significant effects from cadmium and arsenic.

In Table 6, a comparative review of the total potential carcinogenic risk is shown, as well as the increased risk for children compared to adults.

For chard, the total carcinogenic risks for children are higher compared to adults, with arsenic (As) risk increased by 1.95 times, lead (Pb) by 1.94 times, and cadmium (Cd) by 2.22 times. For collard greens, the risk is also higher for children, although to a lesser extent; arsenic (As) risk increased by 0.96 times, lead (Pb) by 1.85 times, and cadmium (Cd) by 1.03 times. The increased risk for children can be explained by several factors. First, children have lower body weight and faster metabolic rates, making them more susceptible to toxic substances. Additionally, due to their rapid growth and development, there is a higher potential for bioaccumulation of heavy metals. Moreover, children typically have a higher food intake per kilogram of body weight, which may further elevate their exposure to toxic substances in plants. Also, children's typical diets may differ from those of adults in terms of the types of vegetables consumed, which can influence the amount of heavy metals ingested. Hernandez et al. (2018) reported that children are particularly vulnerable to heavy metal poisoning due to their lower body weight and increased food consumption relative to adults. Piñeiro et al. (2021) discussed how dietary intake of heavy metals can affect children's health, particularly in contexts where local diets are rich in vegetables that may be contaminated with pollutants, including cadmium and arsenic. The WHO (2014) also emphasized that children are more sensitive to toxins, including heavy metals, due to their developmental stage, specific metabolism, and greater nutrient needs for growth. In the study „Assessment of Non-Carcinogenic and Carcinogenic Health Risks from Heavy Metals in Cooked Beans and Vegetables in Punjab, Northern India," (Kharkwal et al., 2023) concentrations of heavy metals (Pb, Cd, As, Cr, Ni, Cu, and Zn) were analyzed in cooked bean and vegetable samples collected from different locations. The highest concentrations of As, Cd, and Pb were recorded in samples from urban areas (1.44×10^{-5}, 8.21×10^{-5}, 1.30×10^{-3}), while lower values were found in rural areas.

Table 6. Comparative Overview of Total Risk (RI)

Metal	Total Risk (Swiss Chard) – Adults	Total Risk (Swiss Chard) – Children	Risk Increase in Children	Total Risk (Collard greens) – Adults	Total Risk (Collard greens) – Children	Risk Increase in Children
As (Arsenic)	$5.61 \text{x} 10^{-5}$	$7.56 \text{x} 10^{-5}$	↑ 1.95 increased	$2.79 \text{x} 10^{-5}$	$3.75 \text{x} 10^{-5}$	↑ 0,96 increased
Pb (Lead)	5.58×10^{-7}	7.52×10^{-7}	↑ 1.94 increased	5.35×10^{-8}	7.2×10^{-8}	↑ 1,85 increased
Cd (Cadmium)	$6.41 \text{x} 10^{-5}$	$8.63 \text{x} 10^{-5}$	↑ 2,22 increased	$2.95 \text{x} 10^{-5}$	$3.98 \text{x} 10^{-5}$	↑ 1.03 increased
RI (Total risk index)	1.21×10^{-4}	1.63×10^{-4}	↑ 0,42 increased	$5.75 \text{x} 10^{-5}$	$7.73 \text{x} 10^{-5}$	↑ 1.98 increased

The plant species with the highest cadmium accumulation was spinach, where Cd concentrations in leaves exceeded maximum allowable levels (MAL) in more than half of the analyzed samples from various sites (54%). Lead (Pb) concentrations in spinach also exceeded MAL values (3.0 µg/g, Serbian regulation) in 46% of all tested samples (Pajević et al., 2018). In our study, the concentrations of As, Cd, and Pb were within legally prescribed limits. R. Sharifi et al. (2018) calculated cancer risk (CR) and determined that consumption of cultivated leafy vegetables could result in cancer development in 50 out of 10,000 adults and 200 out of 10,000 children. The analysis of carcinogenic risk associated with the intake of heavy metals through vegetable consumption shows significant differences across countries and types of vegetables. In a study conducted in the United States, carcinogenic risk was identified in lettuce, chard, and strawberries for arsenic (2.48×10^{-4}) and lead (2.48×10^{-4}), while cadmium was not present in significant amounts (Cooper A.M. et al., 2020). In Serbia, high values of carcinogenic risk were recorded in tomatoes, potatoes, spinach, onions, beets, and parsley for cadmium (5.81×10^{-4}) and lead (5.81×10^{-4}) (Arsenov D. Et al., 2016). In Turkey, carcinogenic risk in tomatoes, potatoes, spinach, and peppers was estimated for arsenic (5×10^{-5}) and lead (4×10^{-4}), while cadmium was not found in significant concentrations (Yilmaz S. Et al., 2015). A similar study in India reported carcinogenic risk for arsenic (1.2×10^{-4}) and lead (1.6×10^{-4}) in tomatoes, spinach, and peppers, with cadmium not being detected in significant amounts (Chakraborty et al., 2019). The highest carcinogenic risk values were observed in leafy vegetables in China, where arsenic reached 3.50×10^{-4}, cadmium 2.58×10^{-3}, and lead 4.91×10^{-6} (Huang et al., 2024). These findings suggest that leafy vegetables may pose a higher risk due to their ability to accumulate heavy metals from both soil and atmosphere. Overall, the results indicate a global concern regarding the contamination of vegetables with carcinogenic heavy metals, with various factors such as industrial pollution, pesticide use, and soil quality significantly affecting the level of risk. Ongoing monitoring and the implementation of appropriate measures to reduce contamination are essential for protecting public health.

Conclusion

This research is of great importance as it provides insight into the levels of heavy metal contamination in agricultural products available on the market. Given that the consumption of food contaminated with heavy metals can have serious health consequences, the study contributes to a better understanding of the risks faced by the consumer population. The analyzed samples from the Mostar market enabled the identification of potential sources of contamination and highlighted specific issues related to food safety. The most significant findings of the study pertain to the detection of heavy metal concentrations in various agricultural products, particularly in kale (collard greens) and other types of vegetables. These results indicate the need for stricter quality control in the market, as well as increased oversight of agricultural production and food transportation. This research also emphasizes the importance of education and raising awareness among consumers regarding the risks associated with consuming contaminated food, as well as the need for better regulation and standardization of the food market. The results suggest that additional efforts should be made to improve agricultural practices and to implement rigorous controls in the marketplace to ensure food safety and protect consumer health. In addition, the study points to the necessity for continued monitoring of heavy metal levels in food available on the market, along with the introduction of effective control mechanisms and preventive measures that can minimize health risks. The implementation of these recommendations could contribute to reducing negative impacts on human health and preserving ecological balance in the region.

References

Bocio, A., Blanch, J., Llobet, J.M., Domingo, J.L. (2005). Levels of cadmium, mercury, and lead in human milk from the Spanish population. *Environmental International*, *31*(4), 447–453. https://doi.org/10.1016/j.envint.2004.11.008

Bvenura, C., Afolayan, A.J. (2012). Heavy metal contamination of vegetables cultivated in home gardens in the Eastern Cape, South Africa. *South African Journal of Science*, *108*(9/10), 1–6. https://doi.org/10.4102/sajs.v108i9/10.696

Chen, H., Yang, X., Wang, P., Wang, Z., Li, M., Zhao, F.J. (2018). Dietary cadmium intake from rice and vegetables and potential health risk: A case study in Xiangtan, southern China. *Science of the Total Environment*, *639*, 271–277. https://doi.org/10.1016/j.scitotenv.2018.05.050

Cooper, A.M., Felix, D., Alcantara, F., Zaslavsky, I., Work, A., Watson, P.L., Pezzoli, K., Yu. Q., Zhu, D., Scavo, A.J., Zarabi, J., Schroeder, J.I. (2020). Monitoring and mitigation of toxic heavy metals and arsenic accumulation in food crops: A case study of an urban community garden. *Plant Direct*, *4,* 1–12. https://doi.org/10.1002/pld3.198

Piñeiro, X. F., Ave, M. T., Mallah, N., Caamaño-Isorna, F., Jiménez, A. N. G., Vieira, D. N., Bianchini, F., & Muñoz-Barús, J. I. (2021). Heavy metal contamination in Peru: implications on children's health. *Scientific reports*, *11*(1), 22729. https://doi.org/10.1038/s41598-021-02163-9

Fouladi, M., Rouzbahani, M.M., Roshan, S.A., Alipour, S.S. (2021). Health risk assessment of potentially toxic elements in cultivated rice (*Oryza sativa*) with emphasis on environmental contamination. *Toxin Reviews*, *40*(4), 1019–1034.

Hernandez, F., Vicente-García, C., Parsons, D. S., and Navas-Enamorado (2018). Environmental contamination by heavy metals and its implications for children's health: A review. *Environmental Science and Pollution Research*, *25*(32), 31947–31959. https://doi.org/10.1007/s11356-018-3310-2

Huang, J.L., Li, Z.Y., Mao, J.Y., Chen, Z.M., Liu, H.L., Liang, G.Y. et al. Da-Biao Zhang , Ping-Jing Wen , Zhao-Yu Mo , Yue-Ming Jiang (2024). Contamination and health risks brought by arsenic, lead, and cadmium in a water–soil–plant system nearby a non-ferrous metal mining area. *Ecotoxicology and Environmental Safety*, *270,* 115873. https://doi.org/10.1016/j.ecoenv.2023.115873

International Agency for Research on Cancer – IARC. (1993). *Some naturally occurring substances: Food items and constituents, heterocyclic aromatic amines, and mycotoxins*. IARC Monographs, Vol. 56. Lyon.

International Agency for Research on Cancer – IARC. (2004). *Cadmium*. IARC Monographs, Vol. 58. Lyon.

International Agency for Research on Cancer – IARC. (2006). *Inorganic and organic lead compounds*. IARC Monographs, *87.* Lyon.

Jiang, X., Xu, Y., Shen, Z., & Zhang, W. (2017). Heavy metal contamination of vegetables and health risk assessment in an urban area of China. *Environmental Pollution*, *223*, 482–491.

Jurić, D., Puntarić, D., Gvozdić, V., Vidosavljević, D., Lončarić, Z., Puntarić, A., Šijanović, S. (2016). Cabbage (*Brassica oleracea* var. *capitata*) as a potential indicator of wartime contamination by metals and metalloids in eastern Croatia (ICP-MS method). *Acta Agriculturae Scandinavica, Section B – Soil and Plant Science*, *67*(3), 270–277. https://doi.org/10.1080/09064710.2016.1259651

Kapaj, S., Peterson, H., O'Day, P., Renaud, G., Punoš, P. (2006). Human and environmental health implications of heavy metals exposure. *Reviews in Environmental Health*, *21*(1), 1–9. https://doi.org/10.1515/REVEH.2006.21.1.1

Kharkwal, V., Choudhary, M., Bains, K., Bishnoi, M. (2023). Non-carcinogenic and carcinogenic health risk assessment of heavy metals in cooked beans and vegetables in Punjab, North India. *Food Science & Nutrition*, *11*(12), 7581–7593. https://doi.org/10.1002/fsn3.3678

Koese, A., Šukalić, A., Leto, A., Mičijević, A., Komlen, V. (2023). Human health risk assessment of intake Cd and Cu from agricultural soils in Mostar and Tomislavgrad. *Glasilo Future*, 6(5–6), 13–28. https://doi.org/10.32779/gf.6.5^{-6} .2

Kuzman Katica, J., Šukalić, A., Šupljeglavić Jukić, A., Alibegić, D. (2024). Ecological and health risk assessment of lead (Pb) in agricultural soil near the municipal landfill in the city of Mostar, Bosnia and Herzegovina. *AgroLife Scientific Journal*, *13*(2), 147–158. https://doi.org/10.17930/AGL2024213

Liang, G., Gong, W., Li, B., Zuo, J., Pan, L., Liu, X. (2019). Analysis of heavy metals in foodstuffs and an assessment of the health risks to the general public via consumption in Beijing, China. *International Journal of Environmental Research and Public Health*, *16,* 909. https://doi.org/10.3390/ijerph16060909

Leto, A., Šukalić, A., Mičijević, A. (2020). Assessment of carcinogenic health risk of As, Cd, Pb, and Ni from tobacco smoke. U: Karabegović, I. (ur.), *New Technologies, Development, and Application III* (str. 128). Springer. https://doi.org/10.1007/978-3-030^{-4}6817-0_86

Martí-Cid, R., Llobet, J.M., Castell, V., Domingo, J.L. (2008). Dietary intake of arsenic, cadmium, mercury, and lead by the population of Catalonia, Spain. *Biological Trace Element Research*, *125*(2), 120–132. https://doi.org/10.1007/s12011-008-8165-8

Pajević, S., Arsenov, D., Nikolić, N., Borišev, M., Orčić, D., Župunski, M., Mimica – Dukić, M. (2018). Accumulation of heavy metals in vegetable crops and health risk assessment in Serbia. *Environmental Monitoring and Assessment*, *190*, 459. https://doi.org/10.1007/s10661-018-6743-y

Pravilnik o maksimalno dopuštenim količinama za određene kontaminante u hrani. (2014). *Službeni glasnik BiH*, br. 68/14.

Sharifi, R., Moore, F., Keshavarzi, B. i Badiei, S. (2018). Assessment of health risks of arsenic exposure via consumption of crops. *Exposure and Health*, *10,* 129–143. https://doi.org/10.1007/s12403-017-0250-1

Šukalić, A., Mačkić, S., Alibegić, D., Kovačić, M. (2025). *Analiza i procjena rizika u okolišu i hrani*. Mostar: Univerzitet „Džemal Bijedić" u Mostaru. ISBN: 978-9926-434-74-8

United States Environmental Protection Agency – USEPA. (1989). *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A)*. Washington: USEPA. Dostupno na: https://rais.ornl.gov/documents/HHEMA.pdf

United States Environmental Protection Agency – USEPA. (2012). *Guidelines for Water Reuse*. EPA/600/R-12/004. Washington: Office of Wastewater Management. Dostupno na: http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf

World Health Organization – WHO. (2011). *Cadmium in food*. Geneva: WHO.

World Health Organization – WHO. (2014). *Children's health and environment: A review of the evidence*. Copenhagen: WHO Regional Office for Europe.

Zhu, Y., Wei, W., Zhang, Y., Li, H., Chen, Z. (2011). Phytoremediation of Cd and Pb contaminated soil by *Sedum plumbizincicola*. *Environmental Science and Pollution Research*, *18*(9), 1569–1572. https://doi.org/10.1007/s11356-011-0511-2

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