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Časopis izlazi u elektroničkom izdanju dva puta godišnje, krajem lipnja i prosinca, a predviđena su i dva specijalna izdanja tijekom godine iz biotehničkog područja.
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Riječ gostujuće urednice

Poštovani čitatelji Glasila Future,

Iznimno mi je zadovoljstvo predstaviti Vam ovo posebno izdanje časopisa „Glasilo Future“ koji donosi znanstvene i stručne radove na temu ljekovitog i samoniklog bilja te povrća, kao i njihove uloge u prehrani, zdravlju i održivom razvoju. Posebna vrijednost ovog broja ogleda se u interdisciplinarnom pristupu koji povezuje poljoprivredu, prehranu, okoliš i tradicionalna znanja, naglašavajući njihovu važnost u kontekstu suvremenih izazova.

Rad autorice Šukalić i suradnika koji se bavi procjenom potencijalnog nekarcinogenog rizika unosa teških metala putem konzumacije blitve (*Beta vulgaris* subsp. *cicla*) na području Mostara donosi značajan doprinos razumijevanju sigurnosti hrane i javnog zdravlja. Rezultati ukazuju na to da su koncentracije ispitivanih metala unutar zakonski dopuštenih granica, no ističu i potrebu za kontinuiranim praćenjem, osobito kada je riječ o osjetljivim skupinama poput djece.

Utjecaj dopunskog osvjetljenja na razvoj presadnica rajčice u zaštićenom prostoru prikazan je u radu (Bogevska et al.) koji naglašava važnost svjetlosti kao ključnog čimbenika u formiranju kvalitetnog sadnog materijala. Rezultati istraživanja jasno ukazuju na prednosti LED rasvjete u odnosu na druge izvore svjetla, čime se otvara prostor za daljnja istraživanja i unapređenje tehnologija kontroliranog uzgoja.

Istraživanje o utjecaju hidrolata aromatičnog bilja na klijavost sjemenki višegodišnjeg ljulja (Franin et al.) ističe potencijal hidrolata kao ekološki prihvatljivih bioherbicida. Dobiveni rezultati ukazuju na mogućnost njihove primjene u integriranoj i ekološkoj poljoprivredi, čime se doprinosi smanjenju uporabe sintetskih sredstava i zaštiti okoliša.

Inventarizacija samoniklog bilja na području Dube Pelješke (Dujmović Purgar et al.) donosi sveobuhvatan pregled flore ovog mediteranskog područja, s posebnim naglaskom na uporabnu vrijednost biljnih svojti. Analiza prehrambenih, ljekovitih, začinskih i drugih korisnih vrsta, kao i identifikacija endemičnih, ugroženih i invazivnih biljaka, predstavlja vrijedan temelj za očuvanje bioraznolikosti i održivo upravljanje lokalnim ekosustavima.

Etnobotaničko istraživanje provedeno u ruralnoj okolici Senja (Šimunović i Vitasović-Kosić) pruža vrijedan uvid u bogatstvo tradicionalnog znanja o korištenju ljekovitog i aromatičnog te drugog samoniklog bilja. Dokumentiranjem uporabe 93 biljne svojte i 6 vrsta gljiva, rad naglašava važnost prijenosa znanja između generacija te njegov potencijal u očuvanju kulturne baštine, razvoju održivog ruralnog turizma i lokalnih proizvoda.

Završno, rad autorice Židovec i suradnika, posvećen ljekovitim svojstvima i uporabi mirisave ljubice (*Viola odorata* L.) prikazuje ovu biljku kao iznimno vrijednu samoniklu vrstu bogate povijesti primjene u prehrani i narodnoj medicini. Pregled njene morfologije, fitokemijskog sastava i širokog spektra primjene dodatno potvrđuje njezin značaj u suvremenom i tradicionalnom kontekstu.

Vjerujem da će ovaj broj Glasila Future potaknuti daljnja istraživanja, razmjenu znanja i interdisciplinarni dijalog te biti koristan i inspirativan kako znanstvenicima i stručnjacima, tako i široj čitateljskoj publici.

Želim Vam ugodno i poticajno čitanje.

izv. prof. dr. sc. Sanja Radman

Glasilo Future

Stručno-znanstveni časopis

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SADRŽAJ:

Assessment of Potential Non-Carcinogenic Risk from Heavy Metal Intake through Swiss chard (*Beta vulgaris* subsp. *cicla*) Consumption in the Mostar Region

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Abstract

This study evaluated the potential non-carcinogenic health risks for adults and children associated with the intake of heavy metals (Cu, As, Cd, Pb) through Swiss chard (*Beta vulgaris* subsp. *cicla*) consumption in the Mostar region, Bosnia and Herzegovina. The concentrations of heavy metals in Swiss chard (*Beta vulgaris* subsp. *cicla*) were within the permitted national limits (Cu: 1.06–2.8 mg/kg, As: 0.004–0.014 mg/kg, Cd: 0.025–0.051 mg/kg, Pb: <LOQ–0.047 mg/kg). No significant differences were observed among samples from different market locations.

Risk assessment, based on body weight, intake rates, and reference doses, indicated low exposure levels in adults (Hazard Quotient, HQ < 1). Children showed higher Estimated Daily Intake (EDI) and HQ values, but these also remained below the safety threshold (HQ < 1).

Although all concentrations complied with regulatory standards, the comparatively higher intake in children may indicate potential long-term health concerns, especially when cumulative exposure from other dietary sources (cereals, fruits, vegetables, water) is considered. These results underline the importance of ongoing monitoring and preventive strategies to reduce potential heavy metal exposure, particularly in sensitive population groups.

Key words: Swiss chard (*Beta vulgaris* subsp. *cicla*), heavy metals, Hazard Quotient, Estimated Daily Intake.

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[5] Šukalić, A., Kuzman Katica, J. Hadžić, S., Mičijević, A., Alibegić, Dž., Nazdrajić, S. (2025). Assessment of Potential Non-Carcinogenic Risk from Heavy Metal Intake through Swiss chard (*Beta vulgaris* subsp. *cicla*) Consumption in the Mostar Region. *Glasilo Future, 8(4)*, 01–13.

Introduction

Today, a large quantity of food products available on the market does not undergo quality control, exposing consumers to the risk of consuming food with unverified safety. In the Western Balkans, a large share of food does not undergo adequate quality control, and although the agricultural sectors are important for the economy and employment, they remain underdeveloped and vulnerable to crises such as wars, pandemics, and supply disruptions (Jámbor, A., & Varga, Á. 2024) Due to the potential negative health effects resulting from long-term exposure to heavy metals, European and international food safety agencies have established health-based threshold values. These agencies have also developed risk assessment methodologies to protect human health. The fundamental elements of chemical hazard risk assessment include hazard identification, hazard characterization, exposure assessment, and risk characterization. The methodology for chemical contaminant risk assessment is defined by the World Health Organization (WHO), the U.S. Environmental Protection Agency (EPA), and the European Food Safety Authority (EFSA) (Šukalić et al., 2018). Swiss chard (*Beta vulgaris* subsp. *cicla*) is a biennial herbaceous plant used worldwide. Its primary health benefits include lowering blood sugar levels and providing essential nutrients such as calcium, iron, vitamin A, and riboflavin. This vegetable is increasingly becoming part of diets not only in the traditional Mediterranean region but also across Bosnia and Herzegovina. Plants such as garden orache, spinach, Swiss chard, nettle, and collard greens hold an important place in the traditional diet of the population of Bosnia and Herzegovina due to their distinctive flavor, color, and numerous health benefits. In addition to being rich in iron, these plants contain a wide range of nutrients such as zinc, magnesium, and calcium, and represent an affordable source of antioxidants, vitamins, and dietary fiber (Pazalja M. et al., 2023). Vegetables are a vital component of daily nutrition and represent economically significant crops. However, human activities such as mining, industrial processing, pesticide use, vehicle exhaust emissions, and the frequent application of organic manure in agriculture contribute to elevated concentrations of heavy metals in the environment (Cao et al., 2010). Vegetables can absorb heavy metals from soil or contaminated air, and long-term consumption of these metals can adversely affect human and animal health (Liu et al., 2013). Heavy metals such as cadmium and lead persist in soil for extended periods due to their non-biodegradable nature. They are difficult to remove through conventional agricultural practices and have a strong affinity for soil particles, yet they can bioaccumulate (Ullah et al., 2020). Arsenic, lead, chromium, and cadmium are of particular concern, as they may be present in food products and ingredients. Due to their ubiquitous presence in the environment, they pose a significant risk to human health, accumulating in water, animals, and plants—ultimately entering the food chain (Jaishankar et al., 2014). Studies have shown that heavy metals such as cadmium (Cd), chromium (Cr), and copper (Cu) occur naturally in water, soil, and biota. While they serve as essential micronutrients, they become toxic at elevated concentrations (Ntakirutimana et al., 2013). Exposure to arsenic can lead to various health issues, including damage to the skin, respiratory organs, heart, liver, and kidneys, as well as genotoxic and carcinogenic effects (Kapaj et al., 2006). Although industry and agriculture provide economic benefits through increased yields and revenues, their negative impacts on humans and the environment may result in additional costs that are often unaccounted for in business models (Stevenson, 2021). Heavy metals are particularly problematic due to their non-biodegradable nature, with harmful effects that can persist for decades or longer. According to Gujre et al. (2021), copper (Cu) is not considered a highly toxic element, but excessive concentrations may cause respiratory problems, dizziness, nausea, and diarrhea in humans. Given that plant consumption is one of the primary pathways for heavy metals (HM) to enter the food chain, continuous monitoring of food quality is essential (Antonious and Kochhar, 2009).

Materials and methods

In 2024, Swiss chard (*Beta vulgaris* subsp. *cicla*) samples were collected from six locations in the wider area of Mostar city market, labeled B1 to B6. The concentrations of heavy metals in the plants were analyzed using relevant laboratory methods. After collection, the Swiss chard (*Beta vulgaris* subsp. *cicla*) leaves were prepared for analysis by grinding and homogenizing 50 leaves per sample. Three composite samples were prepared per location, with the mean value used in calculations. The determination of trace elements (lead, cadmium, and arsenic) was performed using inductively coupled plasma mass spectrometry (ICP-MS) according to BAS EN 15763:2011 following microwave digestion (BAS EN 13805:2015) (Šukalić et al., 2019; Šukalić et al., 2018). The heavy metal content was compared with Maximum Permissible Levels (MDK) as defined by the Regulation on Maximum Allowed Levels for Certain Contaminants in Food (Official Gazette 68/14, 2014). Copper content was determined using flame atomic absorption spectrometry (FAAS), where samples were first digested using acid decomposition with 5–10 mL of concentrated HNO_3 (65%) and 1–2 mL of H_2O_2 (30%) per approximately 0.5 g dried sample. After microwave digestion, solutions were diluted with deionized water to a 50 mL final volume. Calibration was performed using standard copper solutions (0.1–5 mg/L range) with absorbance measured at 324.7 nm.

Risk Assessment Methodology

Risk assessment represents a function of hazard and exposure (Adamu et al., 2015). It is defined as the process of evaluating both the probability of an adverse event occurring and the potential magnitude of harmful health effects resulting from environmental hazard exposure over a defined time period. The health risk assessment for each potentially toxic metal typically involves quantifying risk levels, expressed in terms of either carcinogenic or non-carcinogenic health effects (Lim et al., 2008). The assessment was conducted using standardized methods for estimating contaminant intake through food consumption. Key parameters included body weight, daily food intake rates, and established reference doses for each metal. For non-carcinogenic risk evaluation, the calculation followed the equation 1 provided by the United States Environmental Protection Agency (USEPA) (USEPA, 1989; Adimalla et al., 2020).

$$EDI = C \times IR \times EF \times ED / AT \times BW \quad (1)$$

Where:

- C is the concentration of the metal (mg/L);
- IR is the chronic intake of vegetables in Europe, 51.55 g per day for adults, and 29.74 g for children (Comprehensive European Food Consumption Database, section Leafy vegetables, leafy brassica EFSA, 2011);
- ED is the exposure duration, 30 years for adults, 10 years for children;
- EF is the exposure frequency (days/year), 365 days per year for both adults and children;
- BW is body weight (kg), 70 kg for adults, 25 kg for children;
- AT is the average time of exposure (years), ED × 365 days for (Risk assessment guidance for superfund, (USEPA, 2004).

The Hazard Quotient (HQ) is a dimensionless parameter used to characterize non-carcinogenic health risks. It represents the probability of an individual experiencing adverse health effects from exposure to a substance. The HQ is calculated as the ratio of the Estimated Daily Intake (EDI), representing the cumulative exposure dose, to the chronic Reference Dose (RfD) for a specific heavy metal (measured in mg/kg/day), as expressed by the following equation 2:

$$\mathrm{HQ} = \frac{\mathrm{EDI}}{\mathrm{RfD}} \quad (2)$$

For n heavy metals, the cumulative non-carcinogenic effect on a population is calculated by summing the Hazard Quotients (HQ) of all individual heavy metals, resulting in the Hazard Index (HI) as defined in reference (U.S. Environmental Protection Agency 1989). An HI value exceeding 1 indicates a potential risk of adverse non-carcinogenic health effects that may warrant concern, while values below 1 suggest that adverse effects are unlikely. The calculation of this parameter follows the equation 3:

$$I = \sum_{k=1}^{n} HQ_k = \sum_{k=1}^{n} \frac{EDI}{RfD} \quad (3)$$

Table 1. *Oral Reference Doses (RfD) According to Literature Data*

Metal	RfD (oral)	Reference
As	3.00E-4	(Pipoyan et al., 2019)
Pb	4.00E-3	(USEPA, 2011)
Cu	4.00E-2	(Taylor et al., 2023)
Cd	1.00E-3	(Pipoyan et al., 2019)

Results and discussion

The results for the concentrations of heavy metals in Swiss chard (*Beta vulgaris* subsp. *cicla*) samples are presented in Table 2. The table provides a detailed overview of the contents of copper (Cu), arsenic (As), cadmium (Cd), and lead (Pb) in the analyzed samples, including the limits of quantification (LOQ) and a comparison with the maximum permissible concentrations (MPC) according to the official Bosnian-Herzegovinian regulation (Official Gazette BiH 68/14). These data provide insight into the safety of consuming Swiss chard in the context of heavy metal presence.

Table 2. *Average concentration of heavy metals in Swiss chard (Beta vulgaris* subsp. *cicla) samples (mg/kg)*

Sample	Cu	As	Cd	Pb
B1	2.800	0.014	0.038	0.046
B2	1.660	0.006	0.045	<LOQ
B3	2.110	0.004	0.046	<LOQ
B4	2.010	0.005	0.025	<LOQ
B5	2.210	0.012	0.034	0.047
B6	1.060	0.012	0.051	<LOQ
MDK (Official Gazette BiH 68/14)	5	0.3	0.20	0.30
LOQ	—	0.004	0.004	0.020

The concentrations of heavy metals in the analyzed Swiss chard (*Beta vulgaris* subsp. *cicla*) samples were found within the following ranges: copper (Cu) 1.060-2.800 mg/kg, arsenic (As) 0.004-0.014 mg/kg, cadmium (Cd) 0.025-0.051 mg/kg, and lead (Pb) below the limit of quantification (<LOQ) to 0.047 mg/kg. These values were compared with the maximum permissible levels established by the Regulation on Maximum Permissible Levels for Certain Contaminants in Food (Official Gazette 68/14), which are consistent with the guidelines set by the Food and Agriculture Organization/World Health Organization (FAO/WHO) for leafy vegetables. All analyzed samples demonstrated heavy metal

concentrations below the regulatory limits specified in the aforementioned regulation. These findings establish a scientific basis for evaluating potential health risks associated with the consumption of this vegetable.

Table 3. *Results of the EDI, HQ, and HI assessment for adults*

Sample	As (EDI)	Pb (EDI)	Cd (EDI)	Cu (EDI)	As (HQ)	Pb (HQ)	Cd (HQ)	Cu (HQ)	HI
B1	1.03E-05	3.39E-05	2.80E-05	2.06E-03	3.44E-02	8.47E-03	2.80E-02	5.16E-02	0.12
B2	4.42E-06	—	3.31E-05	1.22E-03	1.47E-02	—	3.31E-02	3.06E-02	0.08
B3	2.95E-06	—	3.39E-05	1.55E-03	9.82E-03	—	3.39E-02	3.88E-02	0.04
B4	3.68E-06	—	1.84E-05	1.48E-03	1.23E-02	—	1.84E-02	3.70E-02	0.07
B5	8.84E-06	3.46E-05	2.50E-05	1.63E-03	2.95E-02	8.65E-03	2.50E-02	4.07E-02	0.10
B6	8.84E-06	—	3.76E-05	7.81E-04	2.95E-02	—	3.76E-02	1.95E-02	0.09

The estimated daily intake of heavy metals (As, Pb, Cd, and Cu) through Swiss chard *(Beta vulgaris* subsp. *cicla*) consumption, as shown in Table 3, reveals that EDI values varied across samples, with the highest arsenic (As) intake in sample B1 (1.03E-05 mg/kg/day), highest cadmium (Cd) in sample B6 (3.76E-05 mg/kg/day), maximum copper (Cu) in sample B1 (2.06E-03mg/kg/day), and lead (Pb) detectable in only two samples, peaking in sample B5 (3.46E-05 mg/kg/day). Hazard Quotient (HQ) values for all metals remained below 1 in every sample, indicating no significant non-carcinogenic risk, with the highest values being 3.44E-02for arsenic (sample B1), 3.76E-02 for cadmium (sample B6), 5.16E-02 for copper (sample B1), and 8.65E-03 for lead (sample B5). The cumulative Hazard Index (HI), calculated as the sum of all HQ values per sample, also remained below the safety threshold of 1 for all samples, ranging from 0.04 (sample B3) to 0.12 (sample B1), confirming no significant health risk to adult consumers. While these results demonstrate safe consumption levels, future research should focus on cadmium and copper due to their relatively higher contribution to risk assessment, and should include comprehensive dietary studies comparing total heavy metal intake with reference doses (RfD) or tolerable daily intakes (TDI) to better evaluate potential long-term health effects.

Table 4 presents the calculated acceptable daily intake (EDI) and hazard quotient (HQ) values for heavy metals in the samples, along with the total hazard index (HI) for children, enabling analysis of potential health risks. The EDI values varied across metals, with the highest exposures recorded in sample B1: arsenic (As) at 2.66E-05 mg/kg/day, lead (Pb) at 8.75E-05 mg/kg/day, cadmium (Cd) at 7.22E-05mg/kg/day, and copper (Cu) at 5.32E-03mg/kg/day. All HQ values remained below 1, indicating no significant non-carcinogenic risk, though the highest values were observed for arsenic in sample B1 (8.87E-02), cadmium in sample B6 (9.70E-02), copper in sample B1 (0.13), and lead in sample B5 (2.23E-02). While the highest HI value of 0.32 (sample B1) suggests moderate risk for children, all values remained below the safety threshold of 1, though consistently higher than adult values. These findings recommend implementing protective measures in sampling areas and establishing continuous environmental monitoring to safeguard children's health. Nowadays, in situ immobilization of metals, phytoremediation, and biological techniques have proven to be the most effective solutions for the removal of metal(loid)s from soil (Dhaliwal, S.S., et al., 2020).

Table 4. *Calculation of EDI, HQ, and HI for children*

Sample	As (EDI)	Pb (EDI)	Cd (EDI)	Cu (EDI)	As (HQ)	Pb (HQ)	Cd (HQ)	Cu (HQ)	HI
B1	2.66E-05	8.75E-05	7.22E-05	5.32E-03	8.87E-02	2.19E-02	7.22E-02	0.13	0.32
B2	1.14E-05	—	8.56E-05	3.16E-03	3.80E-02	—	8.56E-02	7.89E-02	0.20
B3	7.60E-06	—	8.75E-05	4.01E-03	2.53E-02	—	8.75E-02	1.00E-01	0.11
B4	9.51E-06	—	4.75E-05	3.82E-03	3.17E-02	—	4.75E-02	9.55E-02	0.17
B5	2.28E-05	8.94E-05	6.46E-05	4.20E-03	7.60E-02	2.23E-02	6.46E-02	0.11	0.27
B6	2.28E-05	—	9.70E-05	2.02E-03	7.60E-02	—	9.70E-02	5.04E-02	0.22

Comparative studies reveal varying contamination levels across regions: Sapunar-Postružnik et al. (1996) reported average Pb (0.094 mg/kg) and Cd (0.024 mg/kg) concentrations in Croatian vegetables, while our study showed lower ranges (Pb: 0.015 - 0.020 mg/kg; Cd: 0.013 - 0.069 mg/kg). Vitali et al. (2007) found no significant differences in heavy metal concentrations between war-affected and unaffected Croatian areas, with cabbage samples meeting safety standards but 40% of potato samples exceeding Pb limits. Similarly, Khair Un Nisa et al. (2020) documented significant Cu, Pb, Ni, and Cd contamination in Pakistani produce, highlighting geographical variations in heavy metal contamination patterns.

Table 5. *Comparative Analysis of Heavy Metal Concentrations (As, Cd, Pb, Cu) in vegetables from various studies*

Reference	Country/City	As	Cd	Cu	Pb
(Hiller et al., 2022)	Slovakia/Bratislava	0.20	0.20	8.17	0.42
(Hiller et al., 2022)		0.01	0.02	0.61	0.03
(Misenheimer et al., 2018)	Puerto Rico/San Juan	0.87			2.90
(Margenat et al., 2019)	Spain/Barcelona	3.38×10^{-4} - 8.41×10^{-4}	0.01–0.02	0.49–0.76	0.05–0.16
(Cao et al., 2010)	China/Jiangsu		0.03	0.55	0.06
(Samsøe-Petersen et al., 2002)	Denmark/Copenhagen	<dl	0.02–0.03	0.46–0.92	<dl–0.12
(Folens et al., 2017)	Belgium/Ghent	0.49	0.61		5.96

Reference	Country/City	As	Cd	Cu	Pb
(Warming et al., 2015)	Denmark/Copenhagen	0.06–0.21	0.24–0.38	5.99–8.66	0.56–1.56
(Douay et al., 2015)	France/Noaelles-Godault		6.76		2.72
(Linger et al., 2017)	Turkey/Kayseri		0.34	59.9	9.70
(Zhang et al., 2018)	Brazil/Recife	0.37	<dl	11.6	2.42
(Mendez et al., 2008)	North-western Portugal	0.01–0.02	0.006–0.01	0.24–0.45	0.01–0.04

Table 5 presents research on heavy metals (As, Cd, Pb, and Cu) concentrations in vegetables worldwide according to different authors Comparative studies from various regions demonstrate consistent patterns in heavy metal risk assessment. Calderon et al. (2023) reported hazard coefficients and indices below 1 in Chile and Mexico, though noted that prolonged exposure to average arsenic concentrations (0.2 mg/kg) in Chile could represent a potential carcinogenic risk factor. Similarly, Zhang et al. (2006) found that while hazard quotients (HQ) for Cd, Cu, Pb, and Zn in Chinese vegetables remained below 1 for adults, children's HQ values exceeded thresholds due to their lower body mass and higher relative food intake - findings that align with our study's results. Contrasting results were reported by Shahid et al. (2016), who identified hazardous levels of Cd, Ni, and Pb in certain vegetables (*Lactuca sativa, Spinacia oleracea*, and *Benincasa hispida*), with health risk indices exceeding 1 for Cd and Pb. In our study, however, all HI values were below 1, indicating that there was no health risk for children. Xue et al. (2017) reported minimal lifetime health risks from vegetable consumption in Ghana, though cautioned about potential bioaccumulation effects - results consistent with our adult population findings. Zhang et al. (2017) further corroborated these concerns, documenting elevated health risk indices for Cd, Pb, and Cu in various vegetable species.

Conclusion

This study indicates that, in our research, there were no health risks associated with heavy metal contamination in Swiss chard (*Beta vulgaris* subsp. *cicla*) for either children or adults, as the concentrations of arsenic (As), lead (Pb), cadmium (Cd), and copper (Cu) were all within the legally permitted maximum allowable concentrations (MAC) according to current European regulations. The hazard quotient (HQ) values indicate potential health risks for vulnerable groups, with children consistently showing higher HQ values than adults and cadmium emerging as the most hazardous metal. Comparative analysis with European and global studies shows that metal concentrations in this study align with reported averages. However, geographic variations exist, with industrialization, traffic, and agricultural activities identified as key contributors to heavy metal accumulation in market vegetables.These findings emphasize the need for ongoing monitoring of heavy metals in soil and food, careful selection of vegetable growing locations, public education about health risks, and protective measures for vulnerable groups, especially children. Samples B1, B5, and B6, with their higher HI values, require particular attention regarding children's metal intake, warranting further research to ensure their safety. The cumulative effect of prolonged exposure may increase health risks, necessitating consideration of overall dietary exposure and potential synergistic effects between metals. Additionally, factors such as nutritional status, genetic predisposition, and general health may influence metal absorption and toxicity, calling for more comprehensive research. Children face greater risks of non carcinogenic effects from heavy metals in vegetables due to their physiological characteristics, whereas adults are less susceptible, though measures to reduce dietary heavy metal exposure remain important for all populations, including regular monitoring of agricultural products and implementation of preventive measures against soil and water contamination.

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