

Heavy Metal Content in Pavement Mushrooms Harvested within the Urban Area of Sarajevo (Bosnia and Herzegovina) and an Assessment of Associated Health Risks

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ABSTRACT

This study investigated the ability of pavement mushrooms (*Agaricus bitorquis* (Quél.) Sacc.) to uptake heavy metals (Cu, Zn, Pb, Cr, Cd, and Ni) from the soil in Sarajevo's urban area and the potential health hazards related to their consumption. The levels of tested heavy metals in soil and mushroom samples were determined using the flame atomic absorption spectroscopy technique. The phytoextraction potential was estimated using bioaccumulation factor (BAF) analysis, while the evaluation of the non-carcinogenic, long-term risk to human health through the consumption of the studied mushrooms was performed using the Target Hazard Quotient (THQ) value. The study revealed that particular soils within the urban zone of Sarajevo are contaminated with Cu and Pb. The average content of tested heavy metals in the fruiting bodies of pavement mushrooms decreased in the order of Cu > Zn > Pb > Cr > Ni > Cd, regardless of the soils from which the mushrooms were collected. The BAF values obtained in this study indicated that pavement mushrooms have a high ability to accumulate Cd and Cu, while showing a limited ability to absorb Pb and Ni. The THQ values for all heavy metals analysed in pavement mushrooms were considerably lower than one for both adults and children, suggesting that consuming pavement mushrooms gathered from experimental sites poses no non-carcinogenic health risks related to the heavy metals studied.

HIGHLIGHTS

- Particular soils within the urban zone of Sarajevo are contaminated with Cu and Pb.
- The pavement mushrooms have a high ability to accumulate Cd and Cu.
- This report offers valuable insights into the potential health risks of consuming pavement mushrooms.

1. INTRODUCTION

Rapid urbanization, coupled with intensive industrialization and fast population growth, generates considerable quantities of pollutants, including toxic heavy metals, that adversely affect air and soil quality, particularly in urban areas (Tu et al., 2025). Toxic heavy metals, including cadmium (Cd), chromium (Cr), and lead (Pb), are recognized for their serious health implications for humans, stemming from their bioaccumulation and persistent nature in the environment. Sustained exposure to these pollutants has been correlated with the initiation of multiple

cancers, including those that affect the skin, lungs, and kidneys (Balali-Mood et al., 2021). Essential heavy metals vital for human existence, including zinc (Zn) and copper (Cu), can also be harmful and carcinogenic when ingested in excessive quantities (Khatoon et al., 2025). Consequently, the rising levels of heavy metals in the environment have emerged as a significant global environmental issue (Kholikulov et al., 2025).

The first step in resolving this issue is to monitor both the presence and the amounts of heavy metals in the environment. Up to now, investigations into the concentrations of heavy metals in the

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environment have shown that numerous mushroom species have a high ability to accumulate heavy metals (Ab Rhaman et al., 2021; Qin et al., 2024; Liu et al., 2025). Generally, fungal mycelium can accumulate heavy metals in concentrations significantly higher than the substrate on which it develops and lives. In the research conducted by Zhu et al. (2011), the ranges of Zn, Cd, Cr, and Pb in 14 different wild-growing edible mushrooms collected from Yunnan Province in China were 42.9-94.3, 0.06-0.58, 10.7-42.7, and 0.67-12.9 mg/kg, respectively. High concentrations of heavy metals in edible wild mushrooms were also observed in the study by Singh and Nyau (2020), ranging from 1.1 to 2.0 mg/kg for Pb, 46.9 to 141.8 mg/kg for Cu, 0.1 to 6.6 mg/kg for Cd, and 44.8 to 79.7 mg/kg for Co. This study found that the levels of heavy metals in a greater number of the mushrooms examined were above the threshold limits established by the World Health Organization (WHO, 2021). It follows from the above that there is a potential risk associated with the consumption of edible wild mushrooms that residents gather from natural or urban areas and use as food ingredients (Shackleton et al., 2017).

Dowlati et al. (2021) reported that the ability of mushrooms to accumulate heavy metals from the soil is influenced by numerous factors, including the genetic characteristics of fungi, their growth stages, and various edaphic factors such as total and available heavy metal content, soil pH, organic matter, and clay content. Additionally, most mushrooms respond to exposure to heavy metals by synthesizing metallothionein-like proteins, which are essential for binding heavy metals, thereby promoting their accumulation in fruiting bodies (Aslam et al., 2025).

Agaricus bitorquis (Quél.) Sacc., commonly known as banded agaric, urban agaricus, or pavement mushroom, is a species of fungi that can be found in fields, meadows, and along the edges of pavements, and sometimes even erupts through asphalt. This mushroom is tasty, featuring a slightly dry and pungent scent (Zhao et al., 2023). In the Sarajevo region, it typically fruits from June to September, often in association with coniferous and deciduous trees. Its distribution in the Sarajevo urban area is relatively extensive, with occurrences noted at several sites, primarily in urban parks and promenades.

It is widely recognized that pavement mushrooms are abundant in nutrients and health-promoting components (Muszyńska et al., 2017; Usman et al., 2021). It is also a well-established fact

that they can accumulate heavy metals from polluted soils, but to date, this type of research has not been carried out in Bosnia and Herzegovina. This study aimed to assess the ability of pavement mushrooms to absorb certain heavy metals from the soil in Sarajevo's urban area and to evaluate the potential health risks for humans from consuming these mushrooms. This study is pioneering in evaluating the accumulation of heavy metals in the fruiting bodies of pavement mushrooms that grow in Bosnia and Herzegovina. In this light, this study provides valuable information for both authorities and citizens about the risk of consuming pavement mushrooms grown in the Sarajevo urban area.

2. METHODOLOGY

2.1 Materials

Pavement mushroom (*A. bitorquis*) is an edible white mushroom belonging to the *Agaricus* genus. It is distinguished by its “double-skirted” stem and its propensity to thrive in urban settings. Characterized by its stout and firm structure, this mushroom has a dry, smooth, greyish brown to off-white cap that varies from convex to flat, typically measuring 4 to 18 cm in diameter. The stipe ranges from 3 to 11 cm long and 1 to 4 cm thick. Notably, it possesses a robust upper ring that resembles a funnel, along with a more delicate, skirt-like lower ring. Initially, the gills exhibit a dark pink to clay colour and become chocolate brown upon reaching maturity. The spore print is dark brown (Lu et al., 2020; Yingying et al., 2023).

2.2 Chemicals

All used reagents were of analytical grade. HNO₃ (69%), HCl (37%), and H₂SO₄ (95%) were purchased from Merck (Darmstadt, Germany), whereas a 1 M KCl solution was obtained from Semikem, Sarajevo. Heavy metal stock solutions were prepared through the dilution of the respective 1,000 mg/L standards (Merck, Germany). Working solutions were prepared daily by suitable dilution using distilled water.

2.3 Experimental sites

The soil samples and fruiting bodies of the wild edible mushroom *A. bitorquis* were collected at weekly intervals from May to the end of June 2025 from four distinct sites within the urban area of Sarajevo (Figure 1).

The sites were as follows: (1) central part of Wilson's Promenade (43.853971° N, 18.400323° E),

(2) urban garden nestled in the heart of Franjo Rački Street at number 3 (43.853766° N, 18.403904° E), (3) meadow located near the western side of Wilson's Promenade (43.851689° N, 18.387352° E), and (4) walkway next to the M18 route (43.852857° N,

18.387405° E). All selected sites represented areas with a higher prevalence of these mushrooms, which is why they were chosen. In total, twelve *A. bitorquis* mushrooms were collected from site 1, eight from sites 2 and 3, and nine from site 4.



Figure 1. Experimental sites from which soil and mushroom samples were collected

2.4 Soil chemical analysis

At each site under investigation, soil samples weighing about 0.5 kg were taken just below the mushroom fruiting bodies at a depth of 10 to 30 cm. Soil pH was measured in 1 M KCl solution utilizing a pH meter at a ratio of 1:2.5 (ISO 10390, 2021). Organic matter content and the available forms of phosphorus and potassium were evaluated through the potassium dichromate redox method (ISO 14235, 1998) and the ammonium lactate (AL) method (Egnér et al., 1960), respectively.

Extraction of heavy metals from soil samples was performed using acid digestion. Briefly, 3 g of air-dried, 1-mm sieved soil sample was placed in a crucible and ignited in a muffle furnace at 550°C for 6 h. The resulting ash was treated with 20 mL of aqua regia (a mixture of HCl and HNO₃ in a ratio of 3:1),

followed by heating on a hot plate for 1 h at 60°C. After the mixture cooled to room temperature, 10 mL of deionized water was added, followed by filtration through quantitative filter paper (Whatman, No. 42) into a 100 mL volumetric flask. The final volume was then brought to 100 mL with deionized water (ISO 11466, 1995).

2.5 Extraction of heavy metals from mushroom samples

Immediately following the harvest, all mushroom samples were transported in a portable refrigerator at a temperature of 10°C to the Laboratory of the Faculty of Agriculture and Food Sciences in Sarajevo, where they were stored at 4°C until further analysis. Before commencing the heavy metal extraction, mushroom samples were dried as follows:

fresh and cleaned mushroom samples (each weighing approximately 100 g) were dried in an oven at 40°C for three days and then ground into powder with an electric blender. The resulting powdered material was separately stored in resealable plastic bags.

Mushroom samples were digested according to the method described by [Lisjak et al. \(2009\)](#). Briefly, 2 g of dry mushroom powder samples were weighed and transferred to a crucible, and then ignited in a muffle furnace at 550°C for 6 h. Upon reaching room temperature, the resulting ash was treated with 10 mL of a mixture of HNO₃ and H₂SO₄ in a ratio of 2.5:1, followed by heating on a hot plate for 20 min at 60°C. After 30 min, 10 mL of deionized water was added; then the mixture was filtered through quantitative filter paper (Whatman, No. 42) into a 50 mL volumetric flask. The final volume was adjusted to the mark with deionized water. Heavy metal extraction was performed on the three mushroom samples from each experimental site.

2.6 Determination of heavy metals in soil and mushroom samples

Concentrations of the analysed heavy metals (Cu, Zn, Mn, Pb, Cr, Cd, Ni, Co) in soil and mushroom samples were measured according to the ISO 11047 method, utilizing atomic absorption spectrophotometry ([ISO 11047, 1998](#)) with a Shimadzu Model AA-7000 instrument (Shimadzu Instruments, Tokyo, Japan). Heavy metal concentrations in both soil and mushroom samples were expressed in mg/kg of dry weight.

2.7 Bioaccumulation factor (BAF)

Bioaccumulation factor (BAF) indicates the degree of metal bioaccumulation in plants/mushrooms compared to their concentration in the soil and is calculated using Equation 1 ([Ladislav et al., 2012](#)):

$$BAF = \frac{C_{\text{mushroom}}}{C_{\text{soil}}} \quad (1)$$

Where; C_{mushroom} represents the metal content in mushrooms (mg/kg) and C_{soil} represents the metal content in soil or other growth media.

2.8 Health risk analysis

The health risks of heavy metals due to consuming pavement mushrooms were evaluated using the target hazard quotient (THQ). According to the United States Environmental Protection Agency ([USEPA, 2011](#)), THQ is defined as the ratio of the

estimated daily intake (EDI) of a metal to its oral Reference Dose (RfD), and it was calculated using Equation 2 ([Nowakowski et al., 2021](#)):

$$THQ = \frac{\text{Estimated daily intake of metal (EDI)}}{RfD} \quad (2)$$

Where; RfD represents the oral reference dose for each specific contaminant, i.e., the highest level of contaminant at which no adverse health effects are expected. The RfD values established by the [USEPA \(2011\)](#) are as follows: 0.001 mg/kg/day for Cd, 0.003 mg/kg/day for Cr, 0.040 mg/kg/day for Cu, 0.020 mg/kg/day for Ni, 0.035 mg/kg/day for Pb, and 0.3 mg/kg/day for Zn. Any THQ value greater than 1 indicates a high health risk due to the consumption of contaminated food.

EDI quantifies the transfer of contaminants from plants or mushrooms to the human body, as calculated by Equation 3 ([Chukwuka et al., 2023](#)):

$$EDI = \frac{C \times IR}{\text{body weight}} \quad (3)$$

Where; C represents the heavy metal content in the analysed mushroom sample (mg/kg of dry weight); IR represents the daily ingestion rate of mushrooms per capita (0.0066 kg/person/daily), and BW represents body weight (for adults 70 kg, for children 24 kg) ([Senila et al., 2024](#)).

2.9 Statistical analysis

All the measurements were performed in triplicate on each mushroom sample and the results were expressed as mean±standard deviation. Data were analysed using one-way analysis of variance (ANOVA) followed by the least significant difference (LSD) tests at the 5% level ($p \leq 0.05$) to compare treatment means.

3. RESULTS AND DISCUSSION

In this study pavement mushrooms were collected from four distinct sites within the urban area of Sarajevo. Regardless of location, the studied soils were slightly alkaline, contained a very high level of organic matter, and were sufficiently supplied with available phosphorus and potassium ([Table 1](#)). Soils rich in organic matter and adequately supplied with nutrients are exceptionally favourable for mushroom growth, which may be one of the key reasons for the high prevalence of pavement mushrooms in the studied area. However, the chemical properties of

these soils are not typical for soils outside the urban area of Sarajevo, suggesting that the formation of soils at the experimental sites is the result of the intensive influence of anthropogenic factors. [Asabere et al. \(2018\)](#) indicated that urbanization factors, including

urban soil management, housing, traffic, construction, and waste, distinguish urban soils from those found in natural, semi-natural, and agricultural regions. These findings are in line with the findings of [Sager \(2020\)](#), [Zandybay et al. \(2024\)](#), and [Sun et al. \(2025\)](#).

Table 1. Chemical characteristics of the soil at the experimental sites

Parameter	Experimental site*			
	1	2	3	4
pH KCl	7.32	7.41	7.31	7.47
Organic matter (%)	9.44	6.21	6.81	15.79
Available P (mg/100 g)	24.83	21.66	30.11	22.11
Available K (mg/100 g)	35.33	30.11	38.45	31.03

* Experimental site: (1) central part of Wilson's Promenade; (2) urban garden nestled in Franjo Rački Street; (3) meadow located near the western side of Wilson's Promenade; (4) walkway next to the M18 route

In the current research, the soil at experimental sites 3 (west side of Wilson's Promenade) and 4 (walkway next to the M18 route) showed notably higher concentrations of Pb and Cu ([Table 2](#)), which can also be linked to anthropogenic influences, as these soils are located near roadways. [Hawari et al. \(2021\)](#) reported that most of the Cu and Pb found in soils near roadways are a result of emissions from vehicles. Similar observations were noted in the

studies conducted by [Lee et al. \(2021\)](#) and [Kholikulov et al. \(2024\)](#).

The mean levels of all other heavy metals studied, namely Zn, Cr, Cd, and Ni, in the soil samples analysed were beneath the threshold limits set by the legislation in Bosnia and Herzegovina ([Official Gazette of FBiH, 2022](#)). In accordance with this legislation, the maximum permissible levels for Cu, Zn, Pb, Cr, Cd and Ni in soils are set at 80, 200, 100, 100, 1, and 75 mg/kg, respectively.

Table 2. Heavy metal levels in soil samples collected from the experimental sites

Experimental site*	Heavy metals content (mg/kg dry weight)					
	Cu	Zn	Pb	Cr	Cd	Ni
1	35.1±1.6 ^c	51.3±7.3	74.8±6.2 ^c	7.6±0.9	0.16±0.02	24.9±3.2 ^b
2	36.0±1.4 ^c	58.8±4.9	82.3±6.5 ^c	9.7±1.3	0.16±0.02	26.9±3.1 ^b
3	49.2±3.4 ^b	56.7±3.3	143.1±17.6 ^b	8.2±0.9	0.14±0.02	34.9±3.1 ^a
4	83.6±4.6 ^a	59.9±4.6	218.1±12.9 ^a	9.4±0.7	0.15±0.03	39.5±3.7 ^a
F test	s.	n.s.	s.	n.s.	n.s.	s.
LSD _{0.05}	5.69	-	22.26	-	-	6.11

* Experimental site: (1) central part of Wilson's Promenade; (2) urban garden nestled in Franjo Rački Street; (3) meadow located near the western side of Wilson's Promenade; (4) walkway next to the M18 route; Different letters in the same column indicate statistically significant differences ($p \leq 0.05$); s-significant; n.s.-non significant

This study found no significant differences in the levels of Zn, Cr, and Cd among the tested soils. Conversely, a significant variation in the levels of Ni was observed among the soil samples that were analysed. In this context, the average concentrations of Ni from sites 3 (meadow located near the western side of Wilson's Promenade) and 4 (walkway next to the M18 route) were significantly higher than those from sites 1 (central part of Wilson's Promenade) and 2 (urban garden nestled in Franjo Rački Street). Increased concentrations of Ni in soils near roadways (sites 3 and 4) may arise from the abrasion of tires and

brake pads, as well as from gasoline residues. These observations correspond with the findings of [Radziemska and Fronczyk \(2015\)](#).

Numerous studies have revealed that mushrooms can accumulate certain heavy metals at much higher concentrations than the substrate on which they grow and thrive, indicating that mushrooms are equipped with a highly efficient mechanism that allows them to absorb certain heavy metals from the soil efficiently ([Širić and Humar, 2023](#); [Bucurica et al., 2024](#); [Stihi and Dumitrescu, 2025](#)). In this context, it is widely accepted that

mushrooms generally absorb a higher content of heavy metals compared to plants that grow in the same area (Liu et al., 2022).

The average values of Cu, Zn, Pb, Cr, Cd, and Ni in the fruiting bodies of pavement mushrooms collected from four different experimental sites are presented in Table 3.

The average content value of tested heavy metals in the fruiting bodies of pavement mushrooms decreased in the order of Cu > Zn > Pb > Cr > Ni > Cd, regardless of the experimental sites from which pavement mushrooms were collected. The levels of Cu and Pb exceed the recommended limits of 30 mg/kg for Cu and 0.3 mg/kg for Pb in food as set by the World

Health Organization (WHO, 2021). The presence of significant amounts of Cu and Pb in the tested pavement mushrooms is not unexpected, considering that some of the soils from which these mushrooms were collected are contaminated with these elements. The study conducted by Demirbas (2000) revealed that the pavement mushrooms exhibited lower concentrations of Cu and Pb in their fruiting bodies, with mean values of 26.4 mg/kg for Cu and 1.34 mg/kg for Pb, respectively. These results were also anticipated since the soil where these mushrooms grew had a lower content of Cu and Pb compared to the soil in the current study.

Table 3. Heavy metal levels (mg/kg, dry weight basis) in pavement mushroom samples collected from the experimental sites

Experimental site*	Heavy metals content					
	Cu	Zn	Pb	Cr	Cd	Ni
1	63.5±5.4 ^b	41.6±5.9 ^c	2.2±0.3 ^c	1.7±0.2	0.63±0.07 ^b	1.6±0.3 ^b
2	81.1±6.2 ^a	71.2±5.4 ^a	3.8±0.3 ^b	1.7±0.3	0.56±0.12 ^b	1.6±0.4 ^a
3	63.6±7.0 ^b	54.4±6.1 ^b	5.5±0.5 ^a	1.7±0.2	0.83±0.08 ^a	0.7±0.3 ^c
4	74.3±5.8 ^a	52.6±2.4 ^b	4.4±0.6 ^b	1.8±0.3	0.49±0.08 ^b	1.3±0.2 ^b
F test	s.	s.	s.	n.s.	s.	s.
LSD _{0.05}	9.61	9.82	0.81	-	0.16	0.48

* Experimental site: (1) central part of Wilson's Promenade; (2) urban garden nestled in Franjo Rački Street; (3) meadow located near the western side of Wilson's Promenade; (4) walkway next to the M18 route; Different letters in the same column indicate statistically significant differences ($p \leq 0.05$); s-significant; n.s.-non significant

According to the data for a number of *Agaricus* species (Kosanić et al., 2017; Rashid et al., 2018), the concentrations of Ni and Cr are mostly below 2 mg/kg. This is in agreement with the present results. In contrast, the study by Širić et al. (2016) found higher mean values for Ni (3.62 mg/kg) and Cr (3.01 mg/kg) in the mushroom *Agaricus campestris*, indicating that the accumulation of Ni and Cr is species-specific. The study revealed a significant difference in the concentrations of Cu, Zn, Pb, Cd, and Ni in pavement mushrooms collected from four different experimental sites. The fruiting bodies of pavement mushrooms collected from experimental site 2 (an urban garden nestled in Franjo Rački Street) exhibited a significantly higher content of Zn and Ni compared to those gathered from other experimental sites. Conversely, the highest Pb content was observed in the fruiting bodies of the pavement mushrooms gathered from experimental sites 3 (a meadow located near the western side of Wilson's Promenade) and 4 (a walkway next to the M18 route). It was an expected outcome, taking into account that the soils at experimental sites 3 and 4 possess the highest content of Pb. There was no significant difference in Cr

content in pavement mushrooms among the experimental sites.

Bioaccumulation factor (BAF) is an important index for evaluating the ability of plants or mushrooms to transfer heavy metals from soil into their harvestable (edible) parts. A BAF value higher than 1 indicates that the mushroom has a strong capacity to accumulate the studied metal (Zakaria et al., 2021). Table 4 displays the BAF values for the heavy metals that were analysed.

In the current study, the highest BAF value was observed for Cd, while the least was noted for Pb and Ni. Various studies have demonstrated that mushrooms generally possess a significant ability to absorb and accumulate Cd in their fruiting bodies, indicating that Cd is one of the primary sources of health risks associated with edible mushrooms (Gałowska and Pietrzak-Fiećko, 2021; Ordak et al., 2025). However, the high BAF values of pavement mushrooms for Cd observed in this study should be interpreted cautiously due to the fact that the determined Cd content in all examined soils was relatively low.

Table 4. Bioaccumulation factor (BAF) of selected heavy metals in pavement mushrooms obtained from different sites

Experimental site*	Bioaccumulation factor					
	Cu	Zn	Pb	Cr	Cd	Ni
1	1.81	0.81	0.03	0.22	3.94	0.06
2	2.25	1.21	0.05	0.18	3.50	0.06
3	1.29	0.96	0.04	0.21	5.93	0.02
4	0.95	0.88	0.02	0.19	3.27	0.03

* Experimental site: (1) central part of Wilson's Promenade; (2) urban garden nestled in Franjo Rački Street; (3) meadow located near the western side of Wilson's Promenade; (4) walkway next to the M18 route

From a health point of view, low BAF values for Pb in pavement mushrooms are highly desirable since Pb is a well-established hazardous heavy metal that can cause a number of health hazards in humans (Jomova et al., 2025). In different studies, it was noted that the BAF values for Pb in mushrooms are below 1, suggesting that mushrooms typically possess a limited capacity to absorb Pb from the soil (Falandysz and Borovička, 2013; Mleczeek et al., 2025). On the other hand, Hacıoğlu et al. (2025) reported BAF values for Pb exceeding 1 in specific mushroom species in their study. These variations indicate that the mushrooms' ability to uptake Pb and generally heavy metals can vary widely depending on the mushroom species, heavy metal content in the soil and the soil's physical and chemical properties (Gebrelibanos et al., 2016). Among these soil properties, soil pH is considered the most important factor controlling the solubility and mobility of heavy metals. In alkaline conditions (high pH), most heavy metals, including Pb, tend to form insoluble precipitates like hydroxides, carbonates, or phosphates, thereby decreasing their bioavailability (Adamczyk-Szabela and Wolf, 2022). In this research, all the analysed soils where pavement mushrooms thrived showed an alkaline reaction, likely resulting in

reduced Pb absorption by the pavement mushrooms.

The BAF values for Cu and Zn in pavement mushrooms were observed to be in the ranges of 0.95-2.25 and 0.81-1.21, respectively, demonstrating that these mushrooms can efficiently transfer Cu and Zn from the soil to their fruiting bodies. High BAF values for Cu and Zn in various mushroom species were similarly reported in the studies of Budzyńska et al. (2022) and Wang et al. (2024). Many scientists argue that mushrooms do not possess effective mechanisms to restrict the transfer of Cu and Zn from the growth medium into their bodies, as these elements play a crucial role in numerous metabolic pathways and physiological functions in mushrooms (Wang et al., 2015; Golubkina et al., 2025). The outcomes of this study are in line with this hypothesis.

Nonetheless, it is significant to point out that at high concentrations, Zn and Cu might negatively influence mushroom growth and development. Many mushroom species exhibited abnormal morphological changes when subjected to environments rich in Zn and Cu (Golubeva et al., 2020; Robinson et al., 2021).

The established THQ values for each heavy metal found in pavement mushrooms are summarized in Table 5.

Table 5. THQ values for heavy metals in pavement mushrooms collected from different sites

Experimental site*	Target hazard quotient											
	Cu		Zn		Pb		Cr		Cd		Ni	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
1	0.149	0.437	0.013	0.035	0.006	0.017	0.053	0.156	0.059	0.173	0.008	0.022
2	0.191	0.558	0.022	0.065	0.010	0.029	0.053	0.156	0.053	0.154	0.008	0.022
3	0.150	0.558	0.017	0.049	0.015	0.043	0.053	0.156	0.078	0.223	0.003	0.010
4	0.175	0.511	0.017	0.048	0.012	0.034	0.057	0.165	0.046	0.135	0.006	0.018

* Experimental site: (1) central part of Wilson's Promenade; (2) urban garden nestled in Franjo Rački Street; (3) meadow located near the western side of Wilson's Promenade; (4) walkway next to the M18 route

The THQ values for all heavy metals tested in pavement mushrooms were much lower than 1 for both adults and children, suggesting that the consumption of pavement mushrooms collected from

experimental sites has no non-carcinogenic, long-term risk to human health in terms of contamination with the heavy metals examined. To better assess health risks, the THQ of a range of heavy metals can be

further summed to calculate the hazard index (HI), which reflects the combined health risk associated with exposure to several heavy metals. If the HI exceeds 1, it means the health risk is elevated. From the results shown for THQ for each heavy metal analysed, it is evident that the HI values would not reach the critical threshold that suggests a greater health risk for those consuming the mushrooms studied. However, this observation requires careful consideration, as the amounts of certain heavy metals assessed, specifically Cu and Pb, were above the acceptable thresholds set by the WHO. In this context, it is essential to acknowledge that the continuous intake of pavement mushrooms gathered from Sarajevo's city area may potentially result in a serious health hazard.

4. CONCLUSION

This study's findings reveal that particular soils within the urban zone of Sarajevo are contaminated with Cu and Pb. The mean concentrations of heavy metals in the fruiting bodies of pavement mushrooms collected from soil at the experimental sites in Sarajevo's urban area were observed to decrease in the following order: Cu > Zn > Pb > Cr > Ni > Cd. The BAF values obtained for the heavy metals tested indicated that pavement mushrooms have a strong capacity to accumulate Cd and Cu, while showing a limited ability to absorb Pb and Ni from the soil at the experimental sites. The observed BAF values for Cd and Cu ranged from 3.27 to 5.93 and from 0.95 to 2.25, respectively. In contrast, the ranges for Pb and Ni were 0.02 to 0.05 and 0.02 to 0.06, respectively. The THQ values for all heavy metals analysed in pavement mushrooms were significantly below 1 for both adults and children, suggesting that the consumption of pavement mushrooms collected from experimental sites has no significant non-carcinogenic risks to human health in relation to the heavy metals studied. While calculated THQ values suggest negligible non-carcinogenic risk at typical consumption rates, the exceedance of food safety limits for Cu and Pb indicates that frequent or long-term consumption could still pose potential health concerns.

AUTHOR CONTRIBUTIONS

Conceptualization, A.H. and S.M.; Methodology, A.H.; Software, A.T.; Validation, J.A., A.H. and D.P.; Formal Analysis, J.A. and S.M.; Investigation, S.M. and A.H.; Resources, J.A.; Data Curation, S.M.; Writing-Original Draft Preparation, S.M.; Writing-Review and

Editing, A.H., D.P., A.T., and J.A.; Supervision, S.M.; Project Administration, S.M.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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