DETERMINATION OF CHROMIUM CONCENTRATION IN LEAFY VEGETABLES (PARSLEY, SPINACH, LETTUCE) AND FRUIT VEGETABLES (PEPPERS, EGGPLANT AND CUCUMBER) FROM AREAS NEAR A SMELTER FACTORIES

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Abstract: In recent decades, crop safety has been a significant issue in the production of plant-based food products. Heavy metals and metalloids are natural components of the earth's crust, but their presence in soil is increasing due to industrial activities, improper waste disposal, and the use of polluted water sources for irrigation. This contamination can lead to the accumulation of heavy metals in plants, which poses a risk to human health and the environment. The aim of this study is to determine the concentration of chromium (Cr) in leafy vegetables (parsley, spinach and lettuce) and fruit vegetables (peppers, eggplant and cucumber) grown in three different regions in Kosovo (Zvecan, Frasher and Polski) that are at different distances from a lead and zinc smelter factories. The analyses were carried out using microwave digestion and ICP-MS methods, following an accredited protocol for the determination of metal contaminants. The samples were dried, % dry matter and % water were determined for all samples. ICP analyses were performed on dry samples. The concentration of Cr is expressed in dry and fresh form of the samples. The results showed that the Cr content in leafy vegetables, wet weight ranged from 1.46 mg/kg to 6.99 mg/kg, while in fruit vegetables from 0.99 mg/kg to 2.66 mg/kg. The Cr concentrations in vegetables from settlements closer to the smelter factories (Zvecan and Polski) were higher compared to those from the farthest location from the smelter, Polski. The analysis showed that most of the leafy vegetable samples exceeded the permissible limit for Cr according to the World Health Organization. All leafy vegetable samples, except spinach and lettuce from the farthest Polish region, have Cr above the permissible limits. Of the fruit vegetables, only the peppers from Frasher had Cr above the permissible limit. Statistical analysis showed a strong positive correlation between the concentration of Cr in vegetables from different settlements. This means that different vegetables from the same area have the same trend of increasing and decreasing Cr concentration, i.e. in the areas closer to the smelter all vegetables have higher Cr concentrations, and in the area further from the smelter all vegetables have lower Cr concentrations.Due to the high concentrations of Cr in vegetables near the smelter factories, regular monitoring and taking steps related to decontamination of these areas are necessary. This research confirms the high concentrations of heavy metals in locally grown fruits vegetables and emphasizes the importance of continuous monitoring of the level of contamination to ensure the safety and health of consumers.
Keywords: chromium, determination, leafy vegetables, fruit vegetables

1. INTRODUCTION

Over the past decades, agricultural products safety has been one of the fundamental issues related to the production of plant-based food products (AlKhatib et al., 2022). Heavy metals and metalloids are part of the earth's crust and most of them are not degradable in the soil. At first, they are deposited on the soil surface, then absorbed by the roots of plants and then transferred and accumulated in their edible and inedible parts (Gupta et al., 2022). The high content of heavy metals in the soil comes from several sources. One of them is petrochemical activities that lead to oil spills, another cause of soil pollution with heavy metals is improper waste disposal, chemical discharges in inappropriate places. All these causes can cause serious health problems for the ecosystem and the human population (Sun et al., 2019). Additionally, expanding urbanization and industrialization, as well as geological and anthropogenic activities, also contribute to heavy metal contamination (Sultana et al., 2022). Contamination of vegetables with heavy metals should not be underestimated because vegetables are part of the daily human diet, whether consumed in raw or thermic processed form (Ali & Al-Qahtani, 2012; Jolly et al., 2013). It is a rich source of vitamins, minerals and fiber and also contains relatively high antioxidant activity (Ali & Al-Qahtani, 2012). All these nutrients help to minimize the risk of chronic diseases such as stroke, cancer, hypertension, diabetes, heart and respiratory diseases (Vignesh et al., 2024). Food contamination with heavy metals is one of the most important aspects of ensuring food quality (Ali et al., 2012).

Leafy vegetables tend to accumulate more heavy metals than fruit vegetabls because they have a larger leaf surface area, which on its merits leads to increased evaporation and at the same time to increased adsorption of atmospheric deposits (Gan et al., 2017; Pérez-Figueroa et al., 2023). The Millennium Development Goals set by the United Nations (UN) focus on achieving food security for all. With the increase in population, the need for more healthy food has increased. In order to achieve the goal, i.e. to produce more food, irregularities have emerged such as growing food on contaminated land or using untreated wastewater for irrigation. Such practices have led to the absorption of heavy metals, pathogens and other harmful toxins in food products (Ali & Al-Qahtani, 2012). The various strategies to mitigate the impact of heavy metals on human health by reducing their concentration include parameters such as the quality of the soil on which vegetables are grown and the quality of the water with which they are irrigated. In developing countries, the surveillance of vegetable contamination has not been very effective. Most areas where the vegetables are grown are in urban areas and for their irrigation are used domestic wastewater or polluted rivers (Alegbe et al., 2025).

The aim of this paper is to determine the concentration of Cr in leafy vegetables (parsley, spinach, lettuce) and fruit vegetables (peppers, eggplant and cucumber) grown in three different regions (Zvecan, Frasher and Polski) on the territory of the Republic of Kosovo.

2. MATERIALS AND METHODS

Materials

For the purposes of this paper, six types of vegetables were analyzed, divided into two groups: leafy vegetables (parsley, spinach, and lettuce) and fruit vegetables (peppers, eggplant, and cucumber).

Area of study

This study was conducted in three villages in the Kosovska Mitrovica region (42.883°N, 20.867°E) in Kosovo. Two of the villages - Zvecan (42°54'27"N, 20°50'25.01"E) and Frasher (42° 34' 59.88"N, 21° 00' 0.36"E) are near the lead and zinc smelter, and the third - Polski (43 25' 00", 25 39' 00") is further away from the smelter.

Preparation of the tests

All types of vegetables were previously thoroughly washed with clean water. The washed samples were then cut into small pieces and left to dry in a drying oven (Drying Oven SLN 15, Wodzisław Śląski, Poland) for a period of 24-30 hours depending on the type of vegetable. The dried vegetable samples were then homogenized and stored at room temperature until the time of Cr analysis.

Determination of water content in analyzed vegetables

The water content is determined by the formula (Heta & Pavlovska, 2024):

$W = (a/m) \cdot 100$

a - difference in mass of the sample before and after drying

m - mass of the fresh sample

W – water content in %

Determination of Cr in vegetables, dry weight

The determination of chromium (Cr) concentration in leafy and fruit vegetables was performed using an accredited method MKC EN ISO/IEC 17025:2018 for the determination of the content of 35 elements in different samples using microwave digestion and inductively coupled plasma mass spectrometry ICP-MS (model 7500cx, Agilent USA) - a flexible range method.

Determination of Cr in fresh vegetables

The concentration of Cr in fresh vegetables is calculated using the following formula (EPA, 2018; Zeneli et al., in press):

$$C_{ww} = C_{dw} \left[\frac{100 - W}{100} \right]$$

Where: C_{ww} is the concentration of Cr in fresh vegetables; C_{dw} is the concentration of Cr in the dry mass of vegetables; W is the water content in %.

Statistical data processing

Statistical data processing was performed using Microsoft Excel 2016. Statistical correlation and student's t-test on the concentration of Cr in vegetables from the different settlements were performed.

3. RESULTS AND DISCUSSIONS

The water content in the analyzed samples is given in Table 1.

Table 1. Water content in the analyzed vegetable samples

Water content (%)	Leafy vegetables			Fruit vegetables		
Settlement	Parsley	Spinach	Lettuce	Peppers	Eggplant	Cucumber
Zvečan	81,4	92,6	96,1	94,6	93,1	95,2
Frasher	83,7	91,6	92, 3	93,3	94,9	94
Polski	86,3	90,1	93,2	95,3	95,3	94,8

Source: authors' research

Parsley has the lowest water content, ranging from 81.4% in Zvečan to 86.3% in Polski. These values are in line with the results of 85-90% water in parsley (Mangkoltriluk et al., 2005).

Table 2 presents the values for Cr concentration in dry leafy and fruit vegetables.

Table 2. Cr concentration in vegetables, dry weight

Settlement	Cr in leafy vegetables, dry weight (mg/kg)			Cr in fruit vegetables, dry weight (mg/kg)		
	Parsley	Spinach	Lettuce	Peppers	Eggplant	Cucumber
Zvečan	37.6	40.2	40.4	41.4	31.7	33.7
Frasher	36.6	40.4	36.4	39.7	20.6	22.5
Polski	25.6	20.4	21.4	34.8	21.1	22.6

Source: authors' research

The content of chromium in the dry vegetables ranges from 20.4 mg/kg to 40.4 mg/kg in the leafy vegetables and from 20.6 to 41.4 mg/kg in the fruit vegetables. The presented results show that the Cr content in all leafy vegetables from Zvečan and Frašer is much higher compared to the same leafy vegetables from Polski.

In the fruit vegetables, the highest concentrations of Cr were determined in peppers from the village of Zvechan (41.4 mg/kg), and the lowest in eggplant from the village of Frasher (20.6 mg/kg).

Table 3 presents the concentration of Cr in fresh leafy and fruit vegetables.

Table 3. Cr concentration in leafy and fruit vegetables, wet weight

Settlement	Cr in leafy vegetables, wet weight (mg/kg)			Cr in fruit vegetables, wet weight (mg/kg)		
	Parsley	Spinach	Lettuce	Peppers	Eggplant	Cucumber
Zvečan	6.99	2.97	1.58	2.24	2,19	1,62
Frasher	5.97	3.39	2.80	2.66	1,05	1,35
Polski	3.51	2.02	1.46	1.64	0,99	1,18
WHO/FAO	2,3					

Source: authors' research

The results presented in Table 3 show that the leafy vegetables have higher concentrations of Cr than the fruit vegetables. The highest concentrations of Cr of all vegetables in all settlements are found in parsley. Among fruit vegetables, the highest concentrations in all settlements are found in peppers. The lowest concentration of Cr is found in eggplant from Polski (0.99 mg/kg), and the highest in parsley from Zvečan (6.99 mg/kg). According to the World Health Organization WHO, the permissible limit of chromium concentration in plants is 2.30 mg/kg (Adekiya et al., 2018). When comparing the maximum permissible concentration presented by WHO with our results, it can be noted that of the analyzed leafy vegetables, spinach from the village of Polski and lettuce from the villages of Zvechan and Polski do not exceed the maximum permissible concentration of Cr. Leafy vegetables from all other settlements have Cr above the permissible limits. Among fruit vegetables, only peppers from Frasher have Cr above the permissible limits (2.66 mg/kg)

Alegbe et al., (2025) analyzed heavy metals in various vegetables, including lettuce. The study was conducted at the University of Science and Technology in Kumasi (the capital of the Ashanti region in Ghana). The concentration of Cr determined by the authors ranged from 0.87 mg/kg to 1.65 mg/kg. In the period from September 2009 to October 2011, Arsenov et al., (2016) analyzed the concentration of heavy metals in green markets in Novi Sad, Serbia. The concentration of Cr in spinach was 3.67 µg/g in 2011 and 1.74 µg/g in 2010. Table 4 presents the coefficient of correlation for the concentration of Cr in the analyzed vegetables between the settlements.

Table 4. Correlation coefficient of concentration of Cr in vegetables grown in different settlements

	Zvecan	Frasher	Polski
Zvecan	1		
Frasher	0.895	1	
Polski	0.955	0.982	1

Source: authors' own calculations

Table 3 shows that there is a strong positive correlation between the vegetables that was taken from different settlements. The lowest correlation has the vegetables from Zvečan and Frašer, and the highest the vegetables from Frašer and Polski.

Table 5. Student's t-test between the concentration of Cr in vegetables grown in different settlements

	Zvecan-Frasher		Zvecan-Polski		Frasher-Polski	
Mean value	2.932	2.870	2.932	1.800	2.970	1.800
Value of t-test	0.056		1.235		1.320	
Optained p-value	0.957		0.245		0.216	
Critical valuer for t	2.228					

Source: authors' own calculations

The results presented in Table 5 show that although there is a difference in the mean value of Cr concentration in vegetables from the different analyzed regions around Kosovska Mitrovica, it is not statistically significant because the obtained p values (0.957; 0.245 and 0.216, respectively for the concentration of Cr in vegetables grown in Zvečan-Fraser, Zvečan-Polski and Frašer-Polski) are higher than 0.05.

4. CONCLUSIONS

The research shows that the concentration of chromium (Cr) in leafy and fruit vegetables varies depending on the location of cultivation. All types of vegetables from the most distant place Polski have the lowest concentrations of Cr compared to vegetables from the places closer to the smelter (Zvečan and Frašer). In most of the leafy vegetables, the concentration of Cr is above the permissible limits according to WHO/FAO, and among the fruit vegetables only the peppers from Frasher exceed the maximum permissible limit.The correlation for Cr between vegetables collected from different settlements is strong and positive. The results of Student's t-test show that there is no statistically significant difference between the concentrations of Cr in the analyzed vegetables from the villages of Zvečan, Frašer and Polski.

These results indicate the need for further research for the factors that influence to the accumulation of Cr in different types of vegetables.

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