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DETERMINATION OF CHROMIUM, ARSENIC AND NICKEL CONTENT IN THE AGRICULTURAL LAND OF THE MUNICIPALITY OF TOPOLA

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Abstract: *The content of potentially toxic elements chromium (Cr), arsenic (As) and nickel (Ni), in the agricultural land of the municipality of Topola was examined in this paper, with a presentation of geographic and natural characteristics of the municipality and the land use of agricultural land. The municipality has a central position in Serbia and it is characterized by favourable conditions for growing agricultural cultures. The content of Cr in the land in most cases is between the minimum limit value (MLV) and remediation value (RV), while the content of As on 87% of the examined areas is lower than the MLV, and the content of Ni on 94% of the areas is between the values of the MLV and the RV. It is necessary to take measures of prevention of the use of agricultural land for non-agricultural purposes and fragmentation of arable agricultural land as well as implementing the control of soil fertility.*

Keywords: agricultural land, potentially toxic elements, Cr, As, Ni, the municipality of Topola

UTVRĐIVANJE SADRŽAJA HROMA, ARSENA I NIKLA U POLJOPRIVREDNOM ZEMLJIŠTU OPŠTINE TOPOLA

Sažetak: *U radu je ispitan sadržaj potencijalno toksičnih elemenata, hroma (Cr), arsena (As) i nikla (Ni), u poljoprivrednom zemljištu opštine Topola, uz prikaz geografskih i prirodnih karakteristika opštine i strukture korišćenja poljoprivrednog zemljišta. Opština ima centralan položaj u Srbiji i odlikuje se povoljnim uslovima za gajenje poljoprivrednih kultura. Sadržaj Cr u zemljištu u najvećem broju slučajeva je između granične minimalne vrednosti (GMV) i remedijacione vrednosti (RV), dok je sadržaj As na 87% ispitivanih površina manji od GMV, a sadržaj Ni na 94% površina među vrednostima GMV i RV. Potrebno je preduzimanje mera na sprečavanju korišćenja poljoprivrednog zemljišta u nepoljoprivredne svrhe, sprečavanju usitnjavanja obradivog poljoprivrednog zemljišta i sprovođenje kontrole plodnosti zemljišta.*

Ključne reči: poljoprivredno zemljište, potencijalno toksični elementi, Cr, As, Ni, opština Topola

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1. INTRODUCTION

The greatest pressures on land in the Republic of Serbia represent decrease of content of organic matter, pollution and the change of way of land use, erosion processes and occurrence of landslides. Special problem is contamination of soil and increase of content of potentially toxic elements above remediation value (Ministarstvo zaštite životne sredine – Agencija za zaštitu životne sredine, 2020).

Soil resources contribute significantly to the provision of essential ecosystem goods and services. The presence of potentially toxic elements in agricultural land has become a significant global concern (Bigalke, 2017). Environmental contamination shows increasing tendencies, and monitoring of potentially toxic elements needs to be continuous to protect human public health.

Toxicity of potentially toxic elements is directly related to their accumulation in food. High amounts of these elements generate numerous health issues (Scutarașu & Trincă, 2023). Therefore, the quality of soil is directly related to human health.

The metal content found in soils stems from a combination of human activities and natural processes (Marrugo-Negrete, 2017). The contribution of metals from human activities is much greater than from natural processes (Desaules, 2012; Li et al., 2012; Teng et al., 2014).

High concentrations of potentially toxic elements in the soil represent great risk for agroecosystem, since they are very resistant. Remediation techniques of the soil polluted in such way are still very time-consuming and expensive, and due to the danger of potentially toxic elements entering the food chain via cultivated plants, the contaminated areas require a special way of land use as well as exclusion from primary plant production (Ninkov & Banjac, 2016).

Several studies on this subject have been published for the territory of Serbia (e.g., Belanović Simić et al., 2022; Gajic et al., 2012; Ministarstvo zaštite životne sredine – Agencija za zaštitu životne sredine, 2013, 2018; Ninkov et al., 2012), including the wider area of Šumadija administrative district (Ninkov et al., 2015; Ninkov & Banjac, 2016); however, with no particular reference to the area of the municipality of Topola.

Thus, the objective of this paper is to determine content of potentially toxic elements, chromium, arsenic and nickel in the agricultural land of the municipality of Topola (central Serbia, Šumadija administrative district).

The territory of the municipality of Topola is divided into 29 cadastral municipalities (CM) (Table 2). The research covered 28 cadastral municipalities, except the CM Topola (Varošica), because the land of all cadastral plots of the said CM belongs to urban development land. Location of the municipality of Topola is presented in Figure 1.

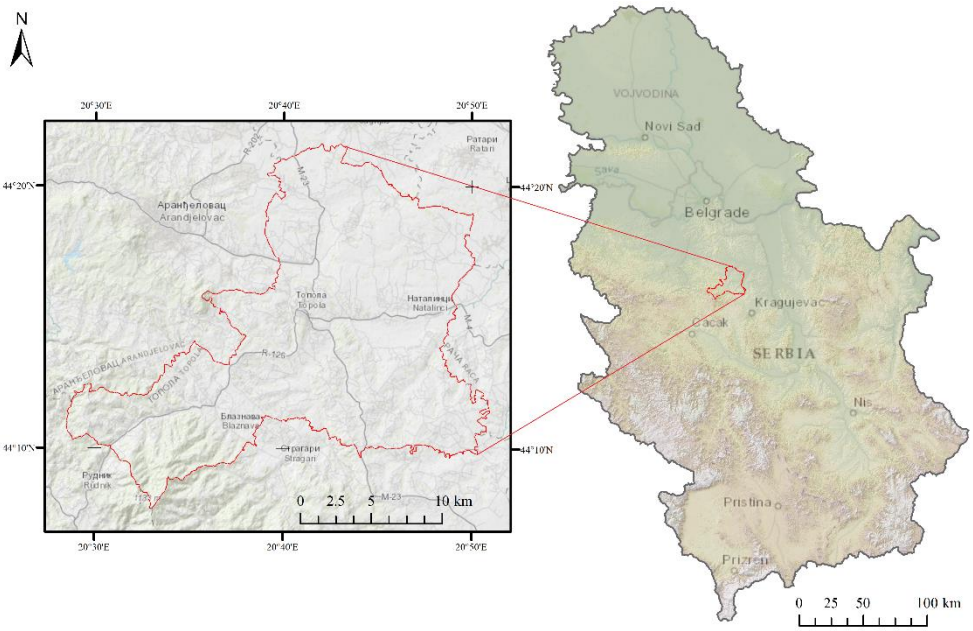

Figure 1. *Location of the municipality of Topola*

2. MATERIAL AND METHODS

Data from literature and statistical data on position and natural conditions of the municipality of Topola (relief, climatic characteristics, soil types, structure of agricultural land, etc.) (Agromedia, 2023; Opština Topola, 2017; J.P. Službeni glasnik SO Topola, 2017; Geosrbija, 2019) are collected and analysed in this paper.

Geographic and natural characteristics of the municipality of Topola are presented in Table 1. The municipality of Topola has a central position in the Republic of Serbia, it is located about 75 km from Belgrade and administratively belongs to Šumadija administrative district (Agromedia, 2023). It is characterized by favourable climatic, orographic, geological and pedological conditions for the development of forest vegetation and production of agricultural cultures (Opština Topola, 2017; J.P. Službeni glasnik SO Topola, 2017; Geosrbija, 2019).

According to the Annual Program of Protection, Arrangement and Use of Agricultural Land in the Territory of Topola Municipality for 2017 (Republički geodetski zavod, 2023), agricultural land spreads over 28,402.1817 ha. The largest part consists of arable land which occupies 70.82%. Orchards cover 18.23% of total agricultural area, meadows 6.44%, vineyards 4.50%. Pastures comprise 3.84% of total agricultural area, while other land occupies 2.31% (Table 2).

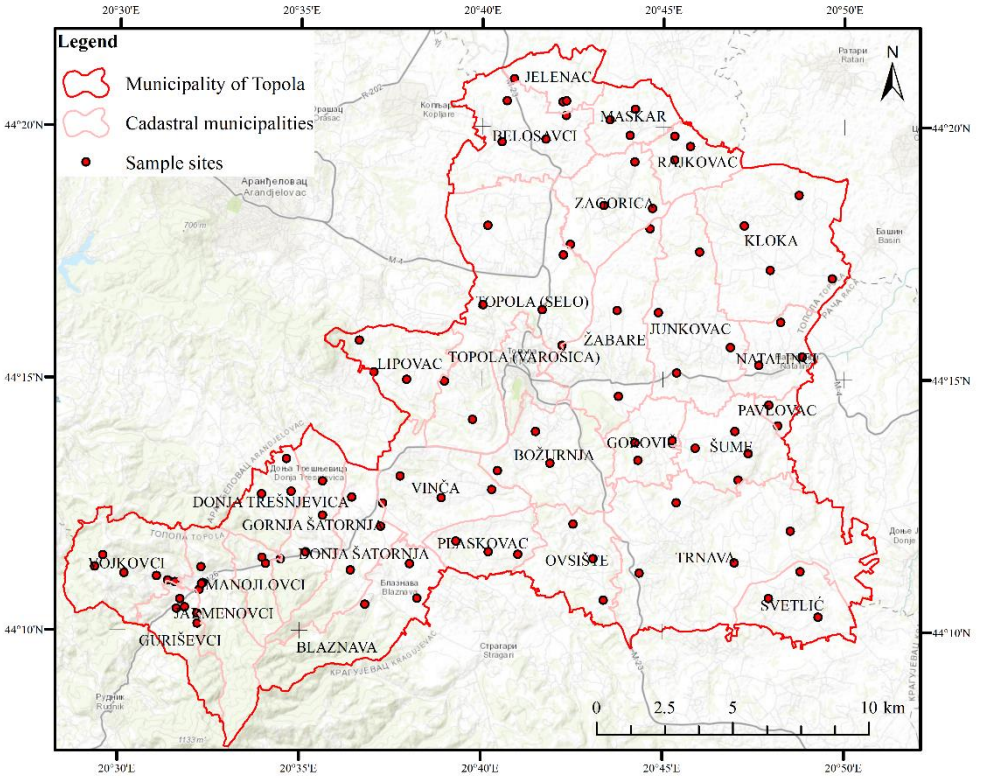

Figure 2. *Locations of soil sampling at CM in the municipality of Topola*

Table 1. *Geographical and natural characteristics of the municipality of Topola*

No.	Characteristics	Description
1	Position	Central Serbia, Šumadija administrative district. The distance from Belgrade is about 75 km[1].
2	Climate	Temperate continental climate. Mean annual air temperature is 11°C, Total annual precipitation is 721.3 mm, average annual relative humidity is 72%, and mean annual cloud cover is 5.2 tenths[2].
3	Relief	The lowland stretches along the middle course of the Jasenica and the Kubršnica rivers, and mountainous relief consists of the slopes of Rudnik and Venčac. Karst forms of relief are represented (saucer-shaped and funnel-shaped sinkholes and limestone pavements)[2].
4	Altitude range	The lowland of up to 200 m of absolute altitude occupies 36.2% of the territory of the municipality, altitude range from 200 to 500 m occupies 56.4%, hilly and mountainous relief from 500 to 1000 m occupies 6.4%, and only 1% of the territory of the municipality is higher than 1000 m of absolute altitude [2].
5	Slope	Terrains with the slope of up to 5% occupy about 38% of the area of the municipality; slope from 5 to 20% occupies 43%, and slope exceeding 20% occupies 19% of the area of the municipality[2].
6	Geological substrate	Serpentinites and serpentinized peridotites; Alevrolites, sandstones, marls; Clastic, pelitic and carbonatic formations; Deluvial sediments[4].
7	Types of soil	Alluvial soils (fluvisols), vertisols, eutric cambisols, acidic brown soils (dystric cambisols) and luvisols. Vertisol occupies the largest area of the total arable land of the municipality, followed by medium acidic and very acidic soils[3].

Source: *[1]Agromedia (2023); [2] Opština Topola (2017); [3] J.P. Službeni glasnik SO Topola (2017); [4] Geosrbija (2019).*

Ploughland dominates over other ways of use of the agricultural land. 52 cadastral plots with arable land of different classes were analysed. Second most

common way of use are orchards. Soils under orchards were analysed on 29 plots. Soils covered with meadows were analysed on 13 plots, with vineyards on 4 plots and soils under pastures on 2 plots. (Table 2).

Agricultural land from 100 cadastral plots was analysed through field work on the territory of the municipality of Topola. (Figure 2). Changes of land use were determined by field inspection during the soil sampling and recorded on 28 cadastral plots planned for analysis, in relation to data from electronic cadastre of real estate (Republički geodetski zavod, 2023).

Table 2. *Overview of the areas of agricultural land according to CM and cultures*

No.	Cadastral municipality	Agricultural land (ha)							
		Arable agricultural land (ha)					Pastures	Other land	Total
		Ploughland	Orchards	Vineyards	Meadows	Total			
		1	2	3	4	5(1+2+3+4)	6	7	8(5+6+7)
1	Belosavci	1081.25	134.18	22.35	112.36	1350.14	4.21	24.68	1379.03
2	Blaznava	477.91	207.86	50.67	16.74	753.17	58.35	21.69	833.21
3	Božurnja	720.79	183.55	86.90	27.62	1018.87	69.80	26.04	1114.70
4	Vinča	581.88	495.88	72.35	35.88	1186.00	6.86	30.23	1223.08
5	Vojkovci	373.69	94.61	8.44	121.72	598.46	197.56	14.24	810.27
6	Gornja Šatornja	470.20	150.83	30.34	40.77	692.14	38.57	17.90	748.61
7	Gorovič	460.66	67.34	26.61	25.64	580.24	8.53	9.66	598.43
8	Guriševci	92.87	62.39	3.52	83.76	242.55	74.86	5.71	323.12
9	D. Trešnjevica	243.58	104.31	14.90	51.17	413.96	36.53	10.46	460.96
10	Donja Šatornja	428.63	171.52	52.88	26.56	679.59	43.54	18.78	741.91
11	Žabare	1100.22	173.40	97.65	28.30	1399.56	63.87	33.04	1496.47
12	Zagorica	647.00	134.83	41.49	159.91	983.23	30.07	17.22	1030.52
13	Jarmenovci	164.35	129.10	10.80	62.23	366.48	81.11	14.22	461.81
14	Jelenac	428.11	81.49	6.58	7.12	523.31	1.99	10.10	535.40
15	Junkovac	1299.39	254.73	49.56	61.93	1665.61	17.70	30.23	1713.54
16	Kloka	1795.06	208.64	54.52	63.50	2121.72	27.06	30.97	2179.75
17	Lipovac	456.41	120.32	85.68	8.39	670.81	20.68	23.77	715.26
18	Manojlovci	89.07	73.13	6.35	23.55	192.09	39.80	6.80	238.70
19	Maskar	456.92	43.83	5.40	81.23	587.38	2.84	9.51	599.74
20	Natalinci	490.51	64.27	2.68	77.61	635.07	5.16	33.09	673.31
21	Ovsište	543.29	166.11	59.93	23.79	793.12	60.50	17.65	871.27
22	Pavlovac	81.10	24.48	7.28	14.30	127.17	6.21	4.04	137.42
23	Plaskovac	368.39	202.18	35.59	22.19	628.35	2.49	10.28	641.12
24	Rajkovac	396.57	50.80	13.22	75.38	535.97	1.06	9.81	546.84
25	Svetlić	525.72	135.27	20.26	48.56	729.81	15.30	13.30	758.41
26	Topola (varoš)	181.19	81.68	32.85	6.16	301.87	4.50	45.11	351.48
27	Topola (selo)	2013.43	325.44	121.39	273.73	2733.98	49.93	74.18	2858.09
28	Trnava	2265.51	729.49	142.92	90.61	3228.54	107.53	76.04	3412.10
29	Šume	643.56	188.56	36.12	46.10	914.35	15.19	18.10	947.63
ha		18877.27	4860.23	1199.24	1716.81	26653.54	1091.81	656.83	28402.18
%		70.82	18.23	4.50	6.44	93.85	3.84	2.31	100.00

Source: *Opština Topola (2017)*

In each analysed plot soil was sampled from two depths (0–30 cm and 30–60 cm). An average sample consisting of 20-25 individual samples was taken for laboratory analyses. Sampling of individual samples for forming the average sample

was performed in a checkerboard layout or diagonally, depending of the shape of the plot. Soil sampling was done with a spade and an "Eijkelkamp" type probe. The content of potentially toxic elements, chromium (Cr), arsenic (As) and nickel (Ni) in the soil, soluble in aqua regia, was determined for each soil sample. Concentrations of harmful and dangerous substances in soil samples, after their digestion in aqua regia, were determined by means of inductively coupled plasma (ICP–OES, Vista–Pro, Varian).

The obtained numerical data was processed employing descriptive and univariate statistical methods. The soil content of potentially toxic elements in depths of 0–30 cm and 30–60 cm and for two types of land use (ploughland and other) was analyzed independently. Descriptive statistics included determining the following basic parameters: minimum value (MIN), maximum value (MAX), mean value ($\overline{X}$), standard deviation (SD) and coefficient of variation (CV%). The significance of the statistical difference between the means was determined using the Student's t-test. Before performing the t-test, raw data was tested for the normality. The variables departed from the normality were subjected to Box-Cox transformation (Box and Cox, 1964). All statistical analyses were performed with Statgraphics Centurion (ver. XVI.I; 2009, Statpoint Technologies, Inc., Warrenton, VA).

The Regulation on the program of systematic monitoring of soil quality by means of indicators for assessing the risk of soil degradation and the methodology for the development of remediation programs (J.P. Službeni glasnik RS, 88/2010), defines the MLV and the remediation values of concentrations of dangerous and harmful substances and the values that can indicate significant soil contamination (Table 3).

Minimum Limit Values (MLV) define the values at which the functional properties of the soil have been fully achieved, i.e. they indicate the level at which the sustainable quality of the soil has been achieved. **Remediation values** (RV) relate to the values which indicate that the basic functions of the soil are endangered or seriously damaged and require remediation, recovery and other measures (J.P. Službeni glasnik RS, 88/2010).

Table 3. *Minimum limit values (MLV) and remediation values (RV) of concentrations of dangerous and harmful substances*

	Chromium (Cr)	Arsenic (As)	Nickel (Ni)
	mg/kg		
MLV	100	29	35
RV	380	55	210

Source: *J.P. Službeni glasnik RS, 88/2010*

3. RESULTS AND DISCUSSION

3.1. The Content of Cr in the Agricultural Land of the Municipality of Topola

Chromium belongs to the useless and potentially toxic elements for plants. Minimum limit value for this element in the soil is 100 mg/kg of the soil and its remediation value is 380 mg/kg.

In the territory of the Topola municipality the average value of the chromium content in the surface layer of all analysed agricultural land amounts to 128.22 mg/kg. Soil layer at the depth of 30–60 cm contains 129.93 mg/kg. In the surface layer the content of chromium in the soil of all analysed plots was ranging between 32.77 and 1157.69 mg/kg, and in the deeper analysed layer between 53.13 and 1104.25 mg/kg.

In the territory of the Topola municipality 47.0% of agricultural land areas is characterized with the content of chromium below the MLV in the surface layer 0–30 cm deep (Table 4; Figure 3), and on 51% of the areas the amount of chromium in the soil is between the MLV and the RV. In the soil layer 30–60 cm deep a content of chromium larger than the MLV is recorded on 53% of the areas, and on 45% of the areas smaller than the MLV. On 2% of the analysed areas in both analysed layers the amount of chromium in the soil exceeds RV.

In the soil under vineyards on 40% of the areas the registered amount of chromium was smaller than the MLV and on 60% of the areas between the MLV and the RV (Table 4; Figure 3).

Under orchards, on 50% of the areas the registered amount of chromium in the soil was smaller than the MLV and on 46.43% areas it was between the MLV and the RV. On 3.57% of the areas the registered amount of chromium in the soil was exceeding the RV.

In the soil of meadows on 15.38% of the areas the amount of chromium was smaller than the MLV, and on 84.62% of areas it was between the MLV and the RV. In none of the plots under the meadows were the amounts of chromium in the soil higher than the RV.

Table 4. *The content of chromium (Cr) in the analysed soil of the Topola municipality*

Soil category	0–30 cm		30–60 cm	
	Number of plots	%	Number of plots	%
Below the detection limit <0.1 mg/kg	0	0.0	0	0.0
Smaller than the MLV <100 mg/kg	47	47.0	45	45.0
Between the MLV and the RV 100–380 mg/kg	51	51.0	53	53.0
Larger than the RV >380 mg/kg	2	2.0	2	2.0
Total	100	100.0	100	100.0

Under the ploughland, on 51.92% of the plots the registered amount of chromium in the land is smaller than the MLV and on 46.15% of the areas it is between the MLV and the RV. On 1.92 % of areas under the ploughland the amount of chromium in the soil is larger than the RV. On both analysed areas under the

pastures the amount of chromium in the soil was found to be lower than the MLV (Table 5).

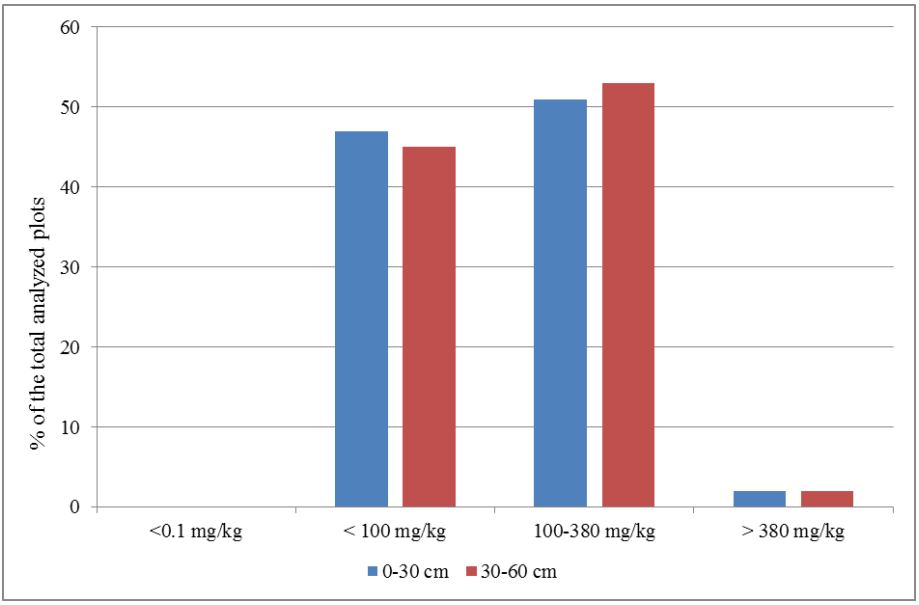

Figure 3. *Categories of soil according to the content of chromium (Cr) for the municipality of Topola*

Table 5. *Representation of soil categories according to the content of chromium (Cr) by cultures*

Soil category	Culture				
	Vineyard	Orchard	Meadow	Ploughland	Pasture
Below the detection limit <0.1 mg/kg	0	0	0	0	0
Smaller than the MLV <100 mg/kg	2	14	2	27	2
Between the MLV and the RV 100–380 mg/kg	3	13	11	24	0
Larger than the RV >380 mg/kg	0	1	0	1	0
Total	5	28	13	52	2

3.2. The Content of As in the Agricultural Land of the Topola Municipality

Arsenic is a potentially toxic element whose MLV and RV in the soil amount to 29 mg/kg and 55 mg/kg, respectively. The average content of arsenic in the analysed agricultural land of the Topola municipality in the surface layer amounts to 20.87 mg/kg, and in the deeper analysed layer 20.58 mg/kg. In the surface layer (0–30 cm) the content of arsenic ranges from 6.42 to 161.44 mg/kg, and in the deeper analysed layer (30–60 cm) from 9.17 to 129.12 mg/kg.

On all analysed plots under vineyards, orchards, meadows, ploughland and pastures in the territory of the municipality of Topola, in the surface layer (0–30 cm), the amount of arsenic is smaller than the MLV (on 87 plots), while the amount of arsenic between the MLV and the RV was found on 11 plots. The amount of arsenic whose concentration exceeds the RV was found on 2 plots (Table 6; Figure 4).

Similar values appear also in the deeper analysed layer (30–60 cm). The amount of arsenic smaller than the MLV was found on 87 plots, while the amount of arsenic between the MLV and the RV was found on 12 plots. The amount of arsenic with concentrations exceeding the RV was found only on one plot.

Table 6. *The content of arsenic (As) in the analysed soil of the Topola municipality*

Soil category	0–30 cm		30–60 cm	
	Number of plots	%	Number of plots	%
Below the detection limit <0.1 mg/kg	0	0.0	0	0.0
Smaller than the MLV <29 mg/kg	87	87.0	87	87.0
Between the MLV and the RV 29–55 mg/kg	11	11.0	12	12.0
Larger than the RV >55 mg/kg	2	2.0	1	1.0
Total	100	100.0	100	100.0

It was found that four plots under vineyards contain arsenic in the amount smaller than the MLV (< 29 mg/kg) and one plot with the content of arsenic between the MLV and the RV (29 mg/kg–55 mg/kg) (Table 7).

On 26 plots under orchards the found content of arsenic is smaller than the MLV. On one plot the content of arsenic is between the MLV and the RV and on one plot the amount of arsenic exceeds the MLV.

The content of arsenic in the amount smaller than the MLV was found in samples from 10 plots under meadows, while on three plots it was found that they contain arsenic in the amount between the MLV and the RV.

45 plots under ploughland were found to have the content of arsenic below the MLV, six with the content of arsenic between the MLV and the RV and one plot with the content of arsenic exceeding the RV. All pastures are on the soil with the amount of arsenic smaller than the MLV.

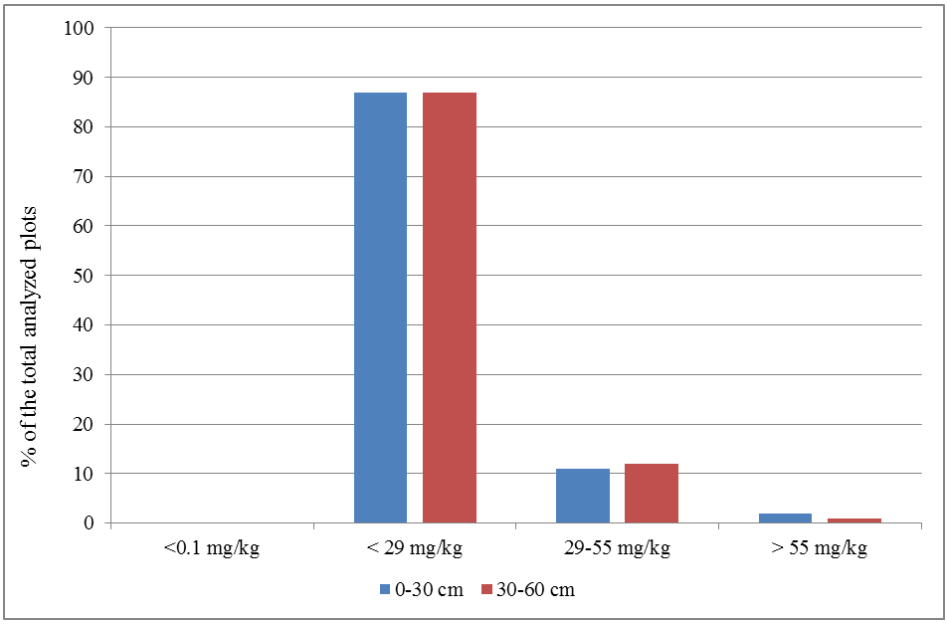

Figure 4. *Categories of soil according to the content of arsenic (As) for the municipality of Topola*

Table 7. *Representation of soil categories according to the content of arsenic (As) by cultures*

Soil category	Culture				
	Vineyard	Orchard	Meadow	Ploughland	Pasture
Below the detection limit <0.1 mg/kg	0	0	0	0	0
Smaller than the MLV <29 mg/kg	4	26	10	45	2
Between the MLV and the RV 29–55 mg/kg	1	1	3	6	0
Larger than the RV >55 mg/kg	0	1	0	1	0
Total	5	28	13	52	2

3.3. The Content of Ni in the Agricultural Land in the Territory of the Topola Municipality

Nickel is one of the essential microelements of nutrition, i.e. plants cannot survive if there is no nickel in the soil. However, in higher concentrations it can be toxic. The minimum limit value for nickel in the soil amounts to 35.0 mg/kg of the soil, and remediation value is 210 mg/kg.

The average content of nickel in the analysed agricultural land of the municipality of Topola in the surface layer amounts to 97.37 mg/kg, and in the deeper analysed layer 101.60 mg/kg. In the surface layer (0–30 cm) the content of nickel ranges from 17.86 to 893.72 mg/kg, and in the deeper analysed layer (30–60 cm) from 32.33 to 980.24 mg/kg.

On all analysed plots under vineyards, orchards, meadows, ploughland and pastures in the territory of the Municipality of Topola, in the surface layer (0–30 cm), the amount of nickel smaller than the MLV, i.e. less than 35 mg/kg, was found on two plots, while the amount of nickel between the MLV and the RV was found on 94 plots. The amount of nickel with concentrations exceeding the RV was found on four plots. Similar situation is also in the deeper analysed layer (30–60 cm). The amount of nickel smaller than the MLV was found on one plot. The amount of nickel between the MLV and the RV was found on 95 plots and the amount of nickel exceeding the RV was found on 4 plots (Table 8; Figure 5).

Table 8. *The content of nickel (Ni) in the analysed soil of the municipality of Topola*

Soil category	0–30 cm		30–60 cm	
	Number of plots	%	Number of plots	%
Below the detection limit <0.1 mg/kg	0	0.0	0	0.0
Smaller than the MLV <35 mg/kg	2	2.0	1	1.0
Between the MLV and the RV 35–210 mg/kg	94	94.0	95	95.0
Larger than the RV >210 mg/kg	4	4.0	4	4.0
Total	100	100.0	100	100.0

Analysed plots under vineyards contain nickel in the amount smaller than the MLV. One plot under orchards contains nickel in the amount smaller than the MLV, 25 plots are with the nickel content between the MLV and the RV and two

plots have nickel content above the RV. The content of nickel in the amount between the MLV and the RV is determined on 12 plots under meadows, while one plot contains nickel in the amount exceeding the RV. On one plot under ploughland nickel content below the MLV was found. On 50 plots under ploughland nickel content is between the MLV and the RV and on one analysed plot the amount of nickel is exceeding the RV. Soil under pastures on all analysed plots contains the amount of nickel between the MLV and the RV (Table 9).

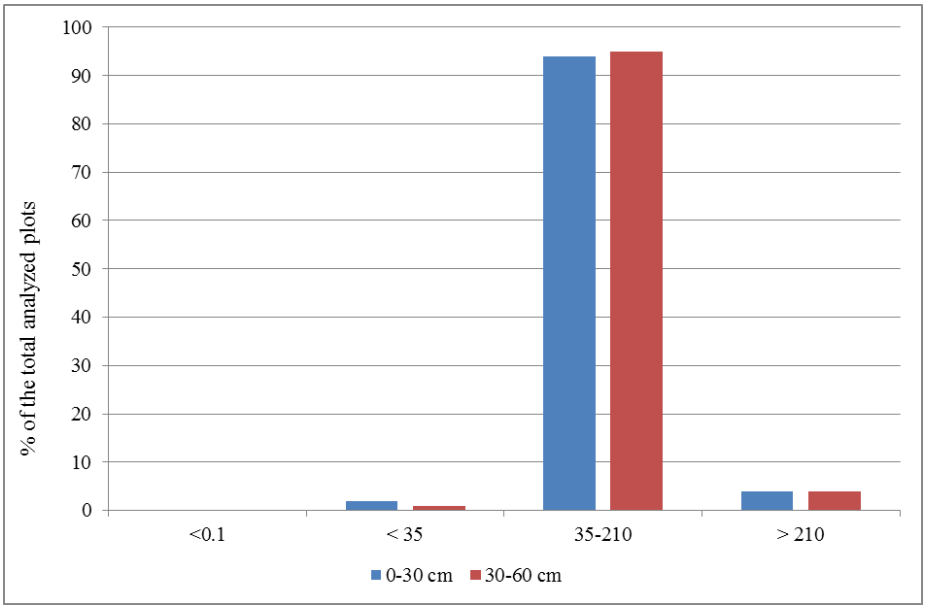

Figure 5. *Categories of soil according to the content of nickel (Ni) for the municipality of Topola*

In the researched area the largest part of the total agricultural area is ploughland (70.82%); 18.23% are orchards, 6.44% are meadows, 4.50% vineyards and 3.84% are pastures, while other land comprises 2.31% of the area.

Table 9. *Representation of soil categories according to the nickel (Ni) content by cultures*

Soil category	Culture				
	Vineyard	Orchard	Meadow	Ploughland	Pasture
Below the detection limit <0,1 mg/kg	0	1	0	1	0
Smaller than the MLV <35 mg/kg	5	25	12	50	2
Between the MLV and the RV 35–210 mg/kg	0	2	1	1	0
Larger than the RV >210 mg/kg	5	28	13	52	2
Total	5	28	13	52	2

The results of the research indicate that the content of Cr in the agricultural land of the municipality of Topola in most cases is between the MLV and the RV;

the content of As is mostly smaller than the MLV and the content of Ni is usually between the MLV and the RV.

According to Ninkov et. al., 2015, the content of nickel in the agricultural land under vineyards of Šumadija district is between the MLV and the RV, which is in line with the results for the municipality of Topola.

The results of the research of agricultural land from 2012 in Zlatibor, Morava, and in smaller part of Raška district showed excess of Cr and Ni content. The amount of nickel is exceeding the RV in 16% out of 364 samples, and the amount of Cr is exceeding the RV in 12% of the analysed samples. The average content of Cr in the examined soils is 131.63 mg/kg, and the average content of arsenic is 7.51 mg/kg (Ministarstvo zaštite životne sredine - Agencija za zaštitu životne sredine, 2013). According to the results for the municipality of Topola the average content of Cr is 128.22 mg/kg, the average content of arsenic is 20.87 mg/kg (larger content is in the soils of Zlatibor, Morava and part of Raška district), the content of chromium exceeds the RV on only 2% of the samples and the content of nickel on 4% of the analysed samples.

The results of the examination of agricultural land in 2016 and 2017 (South-east Serbia) showed that the content of As was exceeding the RV in 27% of the samples and in the municipality of Topola on 2% of the samples. The content of Cr and Ni in part of south-east Serbia is between the MLV and the RV (Ministarstvo zaštite životne sredine - Agencija za zaštitu životne sredine, 2018). Similar results were obtained for Cr and Ni for the municipality of Topola.

The state of agricultural land protection in the analysed municipality requires taking measures to prevent the use of agricultural land for non-agricultural purposes, then to prevent fragmentation of arable agricultural land and to conduct control of soil fertility.

3.4. Statistical analysis

The results of descriptive statistics and t-test for soil content of potentially toxic elements in two soil depths and for two main types of land use are presented in Table 10. The soil content of Cr in the depth of 0–30 cm ranged from 48.73 mg/kg to 632.78 mg/kg for ploughland and from 32.71 mg/kg to 1157.69 mg/kg for other types of land use. The content of this potentially toxic element in the depth of 30–60 cm ranged from 53.13 mg/kg to 399.39 mg/kg for ploughland and from 54.39 mg/kg to 1104.25 mg/kg for other land use. On the other hand, the soil content of As in the depth of 0–30 cm ranged from 6.42 mg/kg to 61.88 mg/kg for ploughland and from 8.12 mg/kg to 161.44 mg/kg for other land use. The content of the same potentially toxic element in the depth of 30–60 cm ranged from 9.17 mg/kg to 47.68 mg/kg for ploughland and from 10.63 mg/kg to 129.12 mg/kg for other land use. Finally, the soil content of Ni in the depth of 0–30 cm ranged between 31.66 mg/kg and 302.91 mg/kg on ploughland and from 17.86 mg/kg to 893.72 mg/kg for other land use. The content of the same potentially toxic element in the depth of 30–60 cm ranged between 32.33 mg/kg and 189.75 mg/kg for ploughland and between 36.16 mg/kg and 980.24 mg/kg for other land use. As can be seen from the values of CV, all analyzed variables are characterized by very high variability. Based on the results of t-test, there is no statistical difference between the mean values of the soil content of

the analyzed potentially toxic elements in two depths and for two types of land use ($P > 0.05$), except for Ni in the soil depth of 30–60 cm ($P = 0.0397$). Specifically, the results show that the mean value of Ni content in the soil depth of 30–60 cm was significantly higher for other types of land use compared to ploughland. Given that this value is lower than RV, and it is found in the deeper soil layer, it can be argued that it is a result of natural pedological factors.

Table 10. *Descriptive statistics and t-test for soil content of potentially toxic elements (mg/kg) in two depths and for two types of land use in the municipality of Topola*

Land use		Cr		As		Ni	
		Depth (cm)					
		0–30	**30–60**	**0–30**	**30–60**	**0–30**	**30–60**
Ploughland	$\bar{X}$	116.08	115.66	19.78	19.12	82.26	82.87
	SD	81.16	54.65	10.17	8.06	47.86	39.01
	CV%	69.92	47.25	51.39	42.15	58.17	47.07
	MIN	48.73	53.13	6.42	9.17	31.66	32.33
	MAX	632.78	399.39	61.88	47.68	302.91	189.75
Other	$\bar{X}$	141.36	145.40	22.05	22.17	113.73	121.89
	SD	157.65	149.39	21.80	17.40	127.04	138.90
	CV%	111.52	102.75	98.84	78.51	111.70	113.95
	MIN	32.71	54.39	8.12	10.63	17.86	36.16
	MAX	1157.69	1104.25	161.44	129.12	893.72	980.24
t-test	t	-1.01	-1.50	-0.61	-1.10	-1.57	-2.08
	P	0.3132	0.1359	0.5457	0.2725	0.1203	**0.0397**

Note: *Boldfaced values denote statistically significant differences between the means at the 95% confidence level*

4. CONCLUSION

Based on this research it can be concluded that the largest part of total agricultural area on the researched area consists of ploughland (70.82%).

The content of chromium (Cr) in the soils of municipality of Topola is in most cases between minimum limit value (MLV) and remediation value (RV). In a large number of cases the content of Cr is lower than MLV.

The content of arsenic (As) in the soils of the municipality of Topola is lower than the MLV on 87% of the examined areas, and on 11% of the areas it is between the MLV and the RV. Only on 2% of the areas the content of this element in the soil exceeds the RV.

The content of nickel (Ni) in the soils of the municipality of Topola is between the MLV and the RV on 94% of the examined areas. On 2% of the areas it is lower than the MLV and on 4% it exceeds the RV.

The state of agricultural land protection in the municipality of Topola requires taking measures to prevent the use of agricultural land for non-agricultural purposes and fragmentation of arable agricultural land as well as to conduct control of soil fertility in this municipality.

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DETERMINATION OF CHROMIUM, ARSENIC AND NICKEL CONTENT IN THE AGRICULTURAL LAND OF THE MUNICIPALITY OF TOPOLA

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Summary

Soil pollution with the increase of potentially toxic elements content above the remediation value is a pronounced problem in the Republic of Serbia. This paper presents the results of examination of the content of potentially toxic elements, chromium (Cr), arsenic (As) and nickel (Ni), in the agricultural land of the municipality of Topola, with an overview of general and natural characteristics of the municipality and the land use of agricultural land. The objective of the research is determination of the content of potentially toxic elements, chromium, arsenic and nickel in the agricultural land of the municipality of Topola.

The research is based on the processing of the data from literature on position and natural conditions of the Topola municipality, field work on the territory of the municipality

(100 cadastre plots) with soil sampling from two depths (0–30 cm, 30–60 cm) and laboratory analyses. The Official Gazette of the Republic of Serbia (88/2010), defines minimum limit values (MLV) and remediation values (RV) of concentrations of dangerous and harmful substances, as well as the values that can indicate significant contamination of the soil.

Geographical and natural characteristics of the Topola municipality indicate that this municipality has a central position in the Republic of Serbia, it belongs to Šumadija administrative district and is characterised by favourable climatic, orographic, geological, and pedological conditions for production of agricultural cultures (Geosrbija, 2019; Opština Topola, 2017; Službeni glasnik SO Topola, 2017). The largest part of the total agricultural area on the researched area consists of ploughland (70.82%). Based on the laboratory analyses of the content of potentially toxic elements in the agricultural land of the municipality it is noted that the content of Cr is in most cases between the MLV and the RV, or lower than the MLV. The content of As is on 87% of the researched areas lower than MLV, and on 11% of the areas its values are between the MLV and the RV. The values of Ni are between the MLV and the RV on 94% of the areas.

Based on the present state of protection of agricultural land in the municipality of Topola it can be concluded that it is necessary to undertake measures of prevention of the use of agricultural land for non-agricultural purposes, and fragmentation of arable agricultural land, as well as to conduct the control of soil fertility in the territory of this municipality.

UTVRĐIVANJE SADRŽAJA HROMA, ARSENA I NIKLA U POLJOPRIVREDNOM ZEMLJIŠTU OPŠTINE TOPOLA

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Rezime

Zagađivanje zemljišta, sa povećanjem sadržaja potencijalno toksičnih elemenata iznad remedijacione vrednosti, izražen je problem u Republici Srbiji. U ovom radu su prikazani rezultati ispitivanja sadržaja potencijalno toksičnih elemenata, hroma (Cr), arsena (As) i nikla (Ni), u poljoprivrednom zemljištu opštine Topola, uz pregled osnovnih i prirodnih karakteristika opštine i strukture korišćenja poljoprivrednog zemljišta. Cilj istraživanja je utvrđivanje sadržaja potencijalno toksičnih elemenata, hroma, arsena i nikla u poljoprivrednom zemljištu opštine Topola.

Istraživanje se zasniva na obradi literaturnih podataka o geografskom položaju i prirodnim uslovima opštine Topola, terenskom radu na području opštine (100 katastarskih parcela) sa uzorkovanjem zemljišta na dve dubine (0–30 cm, 30–60 cm) i laboratorijskim analizama. Službenim glasnikom Republike Srbije (88/2010), definisane su granične minimalne vrednosti (GMV) i remedijacione vrednosti (RV) koncentracija opasnih i štetnih materija, kao i vrednosti koje mogu ukazati na značajnu kontaminaciju zemljišta.

Geografske i prirodne karakteristike opštine Topola ukazuju na to da ova opština ima centralan položaj u Republici Srbiji, pripada Šumadijskom upravnom okrugu i odlikuje se povoljnim klimatskim, orografskim, geološkim i pedološkim uslovima za proizvodnju poljoprivrednih kultura (Geosrbija, 2019; Opština Topola, 2017; Službeni glasnik SO Topola, 2017). Najveći deo ukupne poljoprivredne površine na istraživanom području čine oranice (70,82%). Na osnovu laboratorijskih analiza sadržaja potencijalno toksičnih elemenata u poljoprivrednom zemljištu opštine, zapaža se da se sadržaj Cr u najvećem broju slučajeva nalazi između GMV i RV, ili je manji od GMV. Sadržaj As je na 87% ispitivanih površina manji od GMV, a na 11% površina je u vrednostima između GMV i RV. Ni je na 94% površina u međuvrednostima GMV i RV.

Na osnovu sadašnjeg stanja zaštite poljoprivrednog zemljišta u opštini Topola može se zaključiti da je potrebno preduzeti mere na sprečavanju korišćenja poljoprivrednog zemljišta u nepoljoprivredne svrhe i sprečavanju usitnjavanja obradivog poljoprivrednog zemljišta, kao i sprovođenje kontrole plodnosti zemljišta na području ove opštine.