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Soil horizon-dependent heavy metals, and micro- and macro-elements distributions: A case study of Futoški park (Novi Sad, Serbia)

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Abstract: We analyzed macro- (Ca, Mg, and K) and microelements (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in soil from three depths that correspond to different soil horizons (0-60, 61-75, and 76-160 cm) from three sites in Futoški park (Novi Sad, Serbia), which was measured by using the atomic absorption spectrophotometry (AAS). In this study, we tested the influence of spatial arrangement and soil depth on the variation of micro- and macro-element contents using (i) two-way ANOVA with the site, soil depth, and their interactions as dependent variables, (ii) Tukey post-hoc test (for $p<0.05$), and (iii) principal component analyzes (PCA). Except for Cd, all measured samples are below of the limit value prescribed by the Serbian national legislation. Likewise, Cr is very close to the maximum allowed amount. According to the results of two-way ANOVA statistics, sites, soil depth, as well as their interaction statistically significantly influenced the content of all examined macro- and micro-elements in the analyzed soils. Following the PCA (which covers >90% of samples), surface horizons deviate from all three sites, and stronger deviations between the first and the other two horizons which are very similar were noted. In detail, on the surface horizon higher concentrations of K, Cu, Cr, Fe, Mn, Ni, and Zn were detected, opposite to Ca, Cd, and Mg.

Keywords: pollution, soil, heavy metals, macro-elements, microelements, urban forestry.

1. Introduction

Urbanization is one of the most important detrimental factors of the environmental scale on the global level (Bocquier, 2005). Also, urbanization is followed by industrialization in peri-urban areas and their synergy caused rapid degradation of the soils in urban areas during the 21st century (McIlwaine et al. 2017). Non-organic (e.g., Heavy Metals; HMs) same as organic pollutants (Polycyclic Aromatic Hydrocarbons (PAHs), Persistent Organic Pollutants (POPs), Polychlorinated Biphenyl (PCB), etc.) constantly accumulate into the urban ecosystems, especially in soils (Gao et al. 2016). Previous studies showed that various pollutants negatively affect human health as well as all living organisms in urban areas (Wang et al. 2018). In detail, HMs and PAHs are the most toxic and common anthropogenic pollutants in the air, soil, and water (Huber et al. 2016). Chen et al. (2010) in their study reported that soil is the most important sink of HMs.

Trees in urban areas are highly affected by built surroundings and pavements (Kostić et al. 2019). In stressful conditions, urban trees have to constantly adapt to the new unfavorable and polluted environments (Kebert et al. 2017; Kesić et al. 2020). Also, intensive climate change causes a high pressure on urban forests (Stojanović et al. 2015) and in synergy with pollution significantly degrades urban ecosystems. These changing environments, with intensive drought periods significantly reduce tree growth and condition (Dale and Frank, 2017; Kostić et al. 2021).

Ten elements: aluminum (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), oxygen (O), phosphorus (P), silicon (Si), and thallium (Ti) make over 99% of the total content of the Earth's surface. Their toxicity to humans, animals and plants differs. Due to their persistence, above-mentioned HMs are significant inorganic environmental pollutants, and their toxicity is a growing problem for ecological, evolutionary, nutritional, and environmental reasons (Benavides et al. 2005; Tzoraki and Papadopoulou, 2022). Within the process of phytoextraction, plants can absorb accessible HMs from the soil (phytoaccumulation), and by consuming them, they enter the animal and human body. Also, they can be washed away and get into drinkable water through groundwater.

A large number of literatures confirmed that HMs disturb the uptake and metabolism of the essential elements needed for the normal functioning of human body. All HMs can have toxic effects if they are present in the environment in high concentrations (Christensen, 1995), while in low concentrations, heavy metals in plants or animals are not toxic (Rehman et al. 2021) for humans and some of them are essential elements. For example, selenium (Se) is toxic in high concentrations, while in low concentrations it contributes to increasing the body's immunity (Ravaglia et al. 2000). Lead (Pb), cadmium (Cd), and mercury (Hg) are exceptions because they are toxic even in very low concentrations (Galal-Gorchev, 1991). The US EPA (Environment Protection Agency) has identified Pb, chromium (Cr), nickel (Ni), zinc (Zn), arsenic (Ar), Cd, copper (Cu), Hg, antimony (Sb), beryllium (Be), selenium (Se), silver (Ag) and Ti as the most dangerous polluting metals based on their potential human health risks (Council, 2003). The main human health risks associated with HMs are cardiovascular diseases, chronic anemia, cognitive impairment, cancer, kidney and nervous system damage, diseases of the skin, teeth, bones, etc. (Salomon and Cavagnaro, 2022; Shrivastava et al. 2015).

Macro- and microelements found in the soil in excess of the allowed amounts are included in the food chain through the plants that absorb them, causing acute or chronic diseases in consumers (humans and animals). They participate in and influence numerous biochemical and physiological processes, therefore the lack or the excess of certain elements can cause metabolic and functional disorders in plants, and consequentially in the organisms of living beings (Taiz et al. 2015). Therefore, every initiative aimed to prevent and reduce pollution, from product design itself, waste management, controlled use of pesticides and fertilizers, to cleaner transportation and industry, as well as the introduction of mandatory education in educational institutions, contributes to the preservation of the environment. Prevention is the most effective and the cheapest long-term way to ensure healthy soils, water and air (Smith et al. 2013).

Due to their biological indestructibility, complex behavior in soil and long half-elimination time from organisms, HMs belong to the group of very dangerous pollutants. Unlike organic pollutants, they are not the subject to thermal decomposition and microbiological degradation (Mihailović, 2015). When assessing whether a soil is contaminated with HMs or not, an important indicator are the limit values for the maximum allowed amount of these elements in the soil. In the Republic of Serbia, the maximum allowed amount of polluting, harmful and dangerous substances in the soil is defined by the Regulation on the limit values of polluting, harmful and dangerous substances in the soil ("Službeni glasnik Republike Srbije", No. 30/2018 and 64/2019). This Regulation defines limit values only for agricultural soils, while for soils of other uses (industrial areas, playgrounds, parks, etc.) there is no legally prescribed maximum content of HMs (see Table 1).

Table 1. Limit maximum and remediation values of heavy metals in soil ("Službeni glasnik Republike Srbije", No. 30/2018 and 64/2019).
Tabela 1. *Maksimalne dozvoljene koncentracije teških metala u zemljištu ("Službeni glasnik Republike Srbije", Br. 30/2018 i 64/2019).*

Element	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Zn
LMV* ($mg \cdot kg^{-1}$)	/	0.8	100	36	/	/	/	/	/	35	85	140
RV ($mg \cdot kg^{-1}$)**	/	12	380	190	/	/	/	/	/	210	530	720

Note: (*) **Limit Minimum Values (LMV)** are those values at which the functional properties of the soil are fully achieved, that is, they indicate the level at which the sustainable quality of the soil is achieved; (**) **Remedial Values (RV)** are values that indicate that the basic functions of the soil are threatened or seriously impaired and require remedial, remedial and other measures.

In this study we have analyzed the content and concentration of macro- (Ca, Mg, and K) and micro-elements (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in the soil samples taken from the highly visited urban park in Novi Sad. Samples were taken from the different soil horizons from different depths to define their variation due to the spatial arrangement and soil depth. Hence, we treated two hypotheses: (i) soil type defines the soil capacity to accumulate investigated macro-and micro-elements; (ii) soil depth has an effect on macro-and micro-elements distribution in soil.

2. Material and methods

2.1. Site and climate characteristics

For this study Futoški park were chosen as a representative site of the study (Table 2; Figure 1). Futoški park is one of the most visited green areas in Novi Sad, second largest city in Republic of Serbia with around of 300.000 inhabitants. It is located in the immediate vicinity of the regional children's hospital as well as other important medical institutions. Futoški park is a large city park (~8 ha) located in a highly-urbanized and high-traffic area.

Across the park three representative sites were selected and soil profiles were opened. In detail, soil profiles description was explained in Pekeč et al. (2020). The pedological profiles were opened on three different microreliefs, in the lowest part of the park, Site 1 (78 m a.s.l.), the plain Site 3 (79 m a.s.l.), and in the highest area of the park, i.e. the elevation, Site 2 (80 m a.s.l.). The locations are spaced apart in such a way as to cover the entire surface of the park and to obtain the most favorable section of land in the park area. In detail description of soil properties were listed in Table 2.

Figure 1. Selected sites across the Futoški park in Novi Sad.
Figura 1. *Selektovani lokaliteti u Futoškom parku u Novom Sadu.*

Table 2. Soil properties of three first horizons (Pekeč et al. 2020).
Tabela 2. *Karakteristike prva tri horizonta zemljišta (Pekeč et al. 2020).*

	Site 1	**Site 2**	**Site 3**
Coordinate	N: 45° 15' 3.23" E: 19° 49' 39.87"	N: 45° 14' 59.16" E: 19° 49' 37.80"	N: 45° 15' 6.22" E: 19° 49' 41.00"
Vegetation	*Taxodium disctichum* (L.) Rich., *Populus alba* L., *Salix alba* L., grass	*Aesculus hyppocastanum* L., *Celtis sp.*, grass	*Celtis sp. Pinus nigra J.F.Arnold*, grass
Horizon description	Horizon (H) 1 (0-60 cm): dark brown loam, humus, in the lower part of the horizon with interlayers of wood remains and tree bark, the main mass of the root system of the surrounding trees in this horizon with a slight transition. H 2 (61-75 cm): lighter yellow-gray sand with visible oxidation-reduction processes, with the root system of plants, gently transitions into H 3 (76-160 cm): lighter gray-yellow sand, with redox processes present. Groundwater is not present at the bottom of the pedological profile.	H 1 (0-60 cm): dark brown loam, humus, with the main mass of roots at this depth, slightly passing into H 2 (61-75 cm): transitional gray to gray-brown fine sand, carbonate, extremely dry, with visible fine roots, slightly passing into H 3 (76-160 cm): gray fine sand, carbonate, extremely dry, without roots. Groundwater is not present at the bottom of the pedological profile.	H 1 (0-60 cm): dark brown loam, humus, with the presence of large roots at this depth, slightly changing into H 2 (61-75 cm): transitional gray to gray-brown fine sand, carbonate, extremely dry, with visible fine roots, slightly passing into H 3 (76-160 cm): gray layer of fine sand, carbonate, extremely dry, without roots. Groundwater is not present at the bottom of the pedological profile.

Climate in the sampling area is defined as temperate continental to modified continental, fully humid with warm summers (Kottek et al. 2006). The ten-year average annual temperature is 11.2°C, with an annual rank of 22.1°C and average precipitation of 603.1 mm (Bajsanski et al. 2016). The soil can be characterized as urbisol type, which is compacted, polluted and structurally deteriorated by anthropogenic activities (Ferreira et al. 2018).

2.2. Sampling and macro- and microelement measurements

Soil samples were collected in December 2019. In total, nine soil samples were taken from three investigated sites from three different depths (0-60, 61-75, 76-160 cm) within every site. Presented soil properties were measured in the laboratory of Institute of Lowland Forestry and Environment, University of Novi Sad.

Macro- (Ca, Mg, and K) and micro-elements (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in collected soil samples were measured using Atomic Absorption Spectroscopy (AAS), while the samples were prepared using microwave-assisted digestion technique. Approximately 1 g of oven-dried soils were ground and homogenized in a laboratory mill and then digested in 10 ml nitric acid and 2 ml 30% (v/v) hydrogen peroxide using a microwave-assisted digestion system (D series; Milestone, Bergamo, Italy) programmed for 45 min at 180°C using a microwave power of 900 W. Homogenates were then diluted to 50 ml with deionized water. Pretreated samples were processed in Atomic Absorption

Spectrophotometer (model FS AAS240/GTA120, Varian) using the acetylene/air burner flame technique for all metals quantification, whereas a nitrous oxide–acetylene flame was used for calcium content determination. Concentrations of metals were assessed by means of single-element hollow-cathode lamps and by multielement standard solutions whereas final soil metals amounts were expressed in $mg \cdot kg^{-1}$ per dry weight of soil. All measurements were done in triplicates., and their means were presented.

2.3. *Statistical data processing*

All data were processed in R (R, 2013). For this study we interpreted descriptive statistics (mean value (x) with standard errors (se)) while differences among soil depths and sites were analyzed using *two-way* ANOVA statistical test with Tuckey post-hoc test, with sites and soil depth as a dependent variables.

Results were interpreted with two statistically significance levels (*p*) <0.05 (statistically significant), and <0.01 (highly statistically significant).

3. Results and discussion

The concentration of calcium (Ca), magnesium (Mg), and potassium (K) in the analyzed dry soil samples ranged from 6.97 to 64.67 $mg \cdot g^{-1}$, 4.11 to 35.71 $mg \cdot g^{-1}$, and 0.72 to 2.53 $mg \cdot g^{-1}$, respectively. Average values and results of Tukey post-hoc test of the two-way ANOVA with site and horizon as dependent variables are shown in Figure 2.

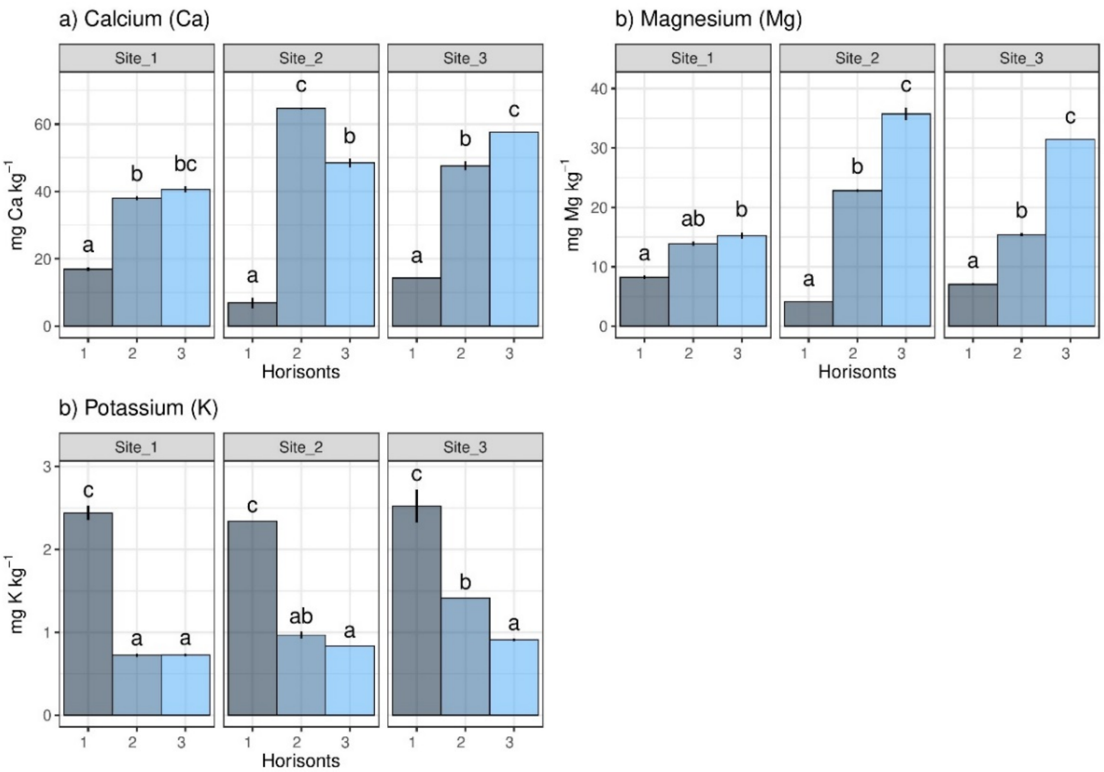

Figure 2. Concentration (x ± se) of Calcium, Ca (a), Magnesium, Mg (b), and Potassium, K (c), at three soil depths labeled as: 1 (0-60 cm), 2 (61-75 cm), and 3 (76-160 cm), with Tukey post-hoc test of two-way ANOVA with site and horizon as dependent variables for *p*<0.05.

Figura 2. *Koncentracija (x ± se) kalcijuma, Ca (a), magnezijuma, Mg (b) i kalijuma, K (c), na tri dubine koje su označene kao: 1 (0-60 cm), 2 (61 -75 cm) i 3 (76-160 cm), sa vrednostima Tukey post-hoc testa dvofaktorijalne ANOVA sa lokalitetom i horizontom kao zavisnim varijablama.*

The highest Ca content (Figure 2-a) is detected on Site 2 in the first horizon sampled from a depth of 60-75 cm. In Sites 1 and 3, it was observed that the Ca content increases related with depth, while these phenomena were not detected on the Site 1. Statistically significant influence of the soil depth on the difference in Ca concentration was observed on the Site 2, where the lowest specified concentration (6.97 mg·g^{-1}) was measured in the surface horizon, and the highest (64.67 mg·g^{-1}) in the second horizon. A Ca concentration in the deeper layers on Site 2 (76-160 cm depth) were about nine times higher than Ca content in the first surface layer (0-60 cm). The highest Mg content (Figure 2-b) was noted on Site 2 at the deepest horizon (76-160 cm). From all detected values within all investigated sites, it can be noted that with the increase in the soil depth of the horizon, the Mg content also constantly increases. The highest content of K (Figure 2-c) was detected in the first surface horizons of all three sites. In all three examined sites, there is no statistically significant difference (p<0.05) in the K content in the surface layers of the soil. The high content of K in the surface layers probably originates from the decomposition of fallen leaves. In all three examined sites, no statistically significant difference was observed between the central and deepest horizons, except in Site 3, where a slight decrease in K concentration was observed with increasing horizon depth. The results of the two-way ANOVA showed a statistically significant influence of sampling depth and location on the saliency of the examined elements.

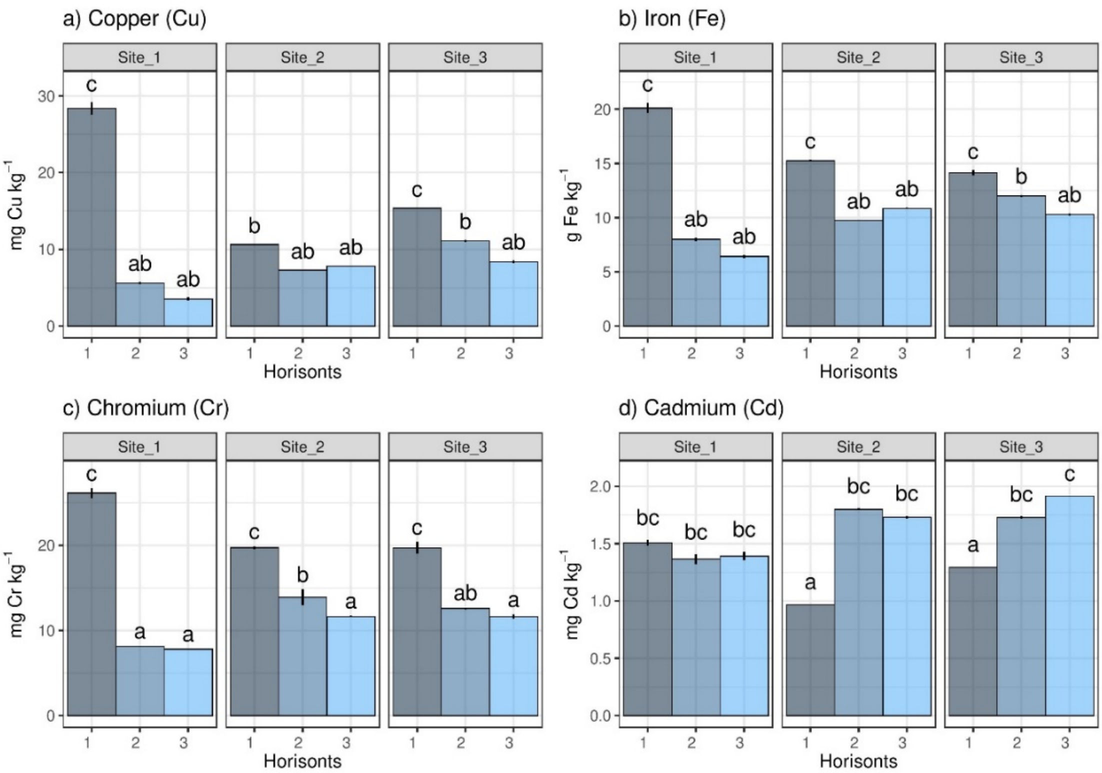

Figure 3. Concentration (x ± se) of Copper, Cu (a), Iron, Fe (b), Chromium, Cr (c), and Cadmium, Cd (d) at three soil depths labeled as: 1 (0-60 cm), 2 (61-75 cm), and 3 (76-160 cm), with Tukey post-hoc test of two-way ANOVA with site and horizon as dependent variables for p<0.05.

Figura 3. *Koncentracija (x ± se) bakra, Cu (a), gvožđa, Fe (b), hroma, Cr (c) i kadmijuma, Cd (d), na tri dubine koje su označene kao: 1 (0-60 cm), 2 (61 -75 cm) i 3 (76-160 cm), sa vrednostima Tukey post-hoc testa dvofaktorijalne ANOVA sa lokalitetom i horizontom kao zavisnim varijablama.*

The Copper (Cu) concentrations determined in the soil ranged from 3.54 to 28.37 mg·kg^{-1} of dry soil mass, while significantly higher concentrations in the examined soil were detected for iron (Fe), and ranged from 6416.24 to 20118.76 mg·kg^{-1} of dry weight soils. Chromium (Cr) and cadmium (Cd) concentrations determined in soil ranged from 7.80 to 26.14 mg·kg^{-1} and 0.96 to 1.91 mg·kg^{-1} of dry weight soils.

Figure 3-a shows the decreasing trend of Cu concentrations at all three analyzed sites with the increment of soil depth. At Site 2, there were no statistically significant differences between the medium and deeper soil horizons, opposite to the other two other examined sites, where higher Cu concentrations were observed with the soil depth increments. For example, Cu content detected in the third soil horizon at Site 1 is drastically lower (up to eight times) compared to Cu content in the surface horizon of the same site. Increased concentrations of Cu in the surface layers indicate the anthropogenic influence, considering the location of the park and vicinity to one of the busiest roads. The highest Fe content was recorded in the sample of the surface horizon at Site 1. The measured values of Fe content indicate a trend of decreasing Fe content with increasing soil depth at Sites 1 and 3, while the lowest value was detected in the samples from Site 2 in the soil sample of the second horizon (Figure 3-b). High concentrations of Fe are not the 'problematic issue' in the urban area, because Fe is not a dangerous element. Fe is important in plant nutrition and is necessary as a crop macronutrient in agriculture.

The highest Cd content was measured in the surface horizon at Site 1. At all three sites, a trend of decreasing Cd concentrations was observed with the increment of horizon depth (Figure 3-c). Data analysis did not show statistically significant differences at all sites between the central and the deepest horizons considering Cd content. The dependance of this element to the different horizon depth levels was characterized with different trends. On the histogram (Figure 3-d) at Site 3, the trend of increasing values of Cd content is followed with the increment of the horizon depth. While at Site 1 there are no statistically significant differences in the Cd content between the horizons, at Site 2 the significant statistical difference was detected in the surface horizon in which lower concentration of Cd was measured compared to the values detected in the deeper horizons. The obtained values of Cd concentration are below the limited values defined by the Regulation on limit values of polluting, harmful and dangerous substances in soil ("Službeni glasnik Republike Srbije", No. 30/2018, and 64/2019). The proximity of one of the main streets next to the Futoški park may be one of the reasons for higher Cd concentrations in the soil samples.

Significant deviations were found between the analyzed concentrations of manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) in the analyzed soils. The differences between the minimum and maximum measured concentrations were up to five times. The concentrations of Mn, Ni, Pb and Zn in the soil were measured in the localities and ranged from 114.48 to 341.20 $mg \cdot kg^{-1}$, 13.47 up to 33.54 $mg \cdot kg^{-1}$, 17.74 to 40.17 $mg \cdot kg^{-1}$ and 16.35 to 101.89 $mg \cdot kg^{-1}$ of dry soil mass (see Figure 3).

The highest concentration of Mn was detected in the surface horizon from Site 1, while the lowest detected content was found in the second horizon from the same site. With the increase in the depth of the soil profile, the trend of decreasing values of Mn concentration was noted (Figure 3-a). Likewise, statistically significant differences in Mn content between the second and third horizons were not established. The highest Ni content was detected in the soil sample of the surface horizon from Site 1, while the lowest concentration was noted in the sample of the deepest horizon of the same profile. The bar chart (Figure 3-b) shows a Ni decreasing trend with increasing soil depth. The content of Ni in the surface horizons on Site 1 (33.54 $mg \cdot kg^{-1}$) and Site 3 (29.33 $mg \cdot kg^{-1}$) is close to the limit value (35.00 $mg \cdot kg^{-1}$) defined by national regulations of the Republic of Serbia. The highest Pb concentration was recorded in the upper horizon at Site 1 (Figure 3-c) and it was about 40 ppm, which is twice as much as in the deeper soil layers. In other horizons of all sites, there is no significant difference in Pb content. Also, there is a slight trend of decreasing Pb values with increasing depth of the horizon at all three sites. It is possible that the increased Pb concentration in Site 1 is a consequence of fuel combustion, which originates from the exhaust gases of motor vehicles that use gasoline with Pb additives. The measured content of Pb in all horizons is below the limit values prescribed by the National Regulation on limit values of polluting, harmful and dangerous substances in the soil. The highest Zn content was recorded in the surface horizon, and the lowest in the third horizon of the pedological profile from the Site 1 (Figure 3-d). A somewhat higher Zn content was also recorded in the surface horizon at the Site 1. Also, in all three sites, Zn content in the deep horizon is significantly lower than in the surface layer. Only at Site 2, no statistically significant differences in Zn content between the surface horizon of the surface and deeper soil layers were found. High Zn concentrations may be due to lead emissions from fuel combustion, which is often accompanied by zinc emissions. Also, higher concentrations of Zn were found in surface horizons located near streets where traffic is frequent, which indicates that the increased content of Zn in the park's soil is a consequence of atmospheric deposition and traffic.

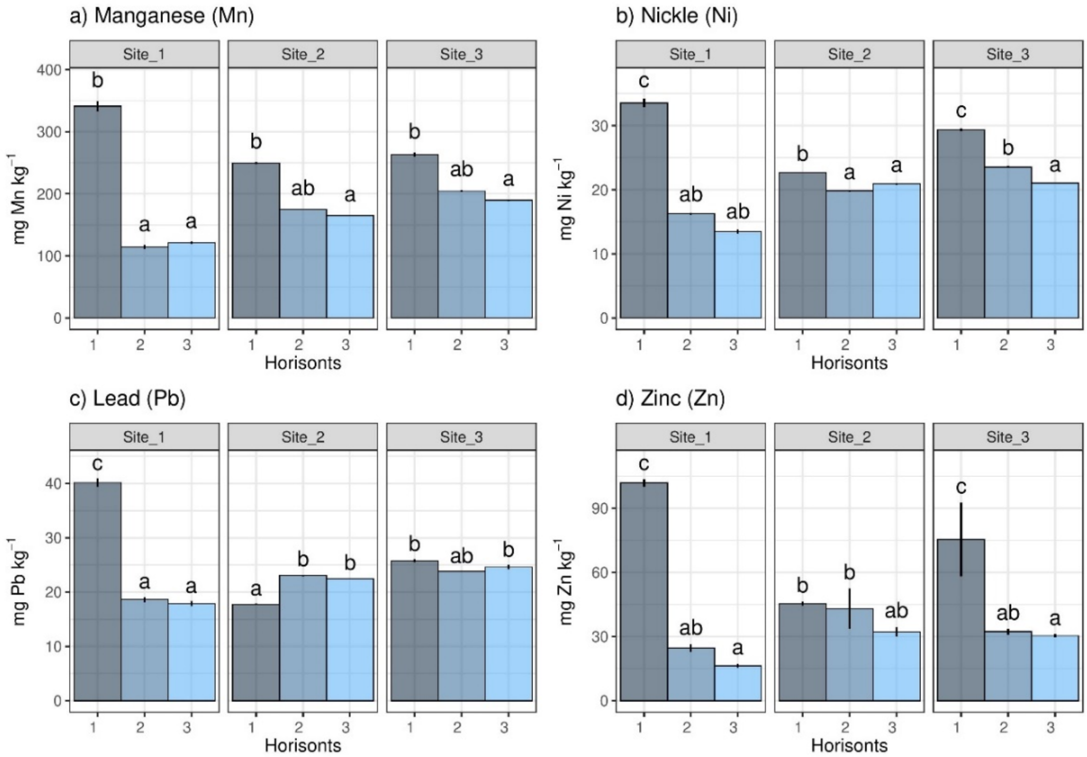

Figure 4. Concentration (x ± se) of Manganese, Mn (a), Nickle, Ni (b), Lead, Pb (c), and Zinc, Zn (d) at three soil depths labeled as: 1 (0-60 cm), 2 (61-75 cm), and 3 (76-160 cm), with Tukey post-hoc test of two-way ANOVA with site and horizon as dependent variables for p<0.05.

Figura 4. *Koncentracija (x ± se) mangana, Mn (a), nikla, Ni (b), olova, Pb (c) i cinka, Zn (d), na tri dubine koje su označene kao: 1 (0-60 cm), 2 (61 -75 cm) i 3 (76-160 cm), sa vrednostima Tukey post-hoc testa dvofaktorijalne ANOVA sa lokalitetom i horizontom kao zavisnim varijablama.*

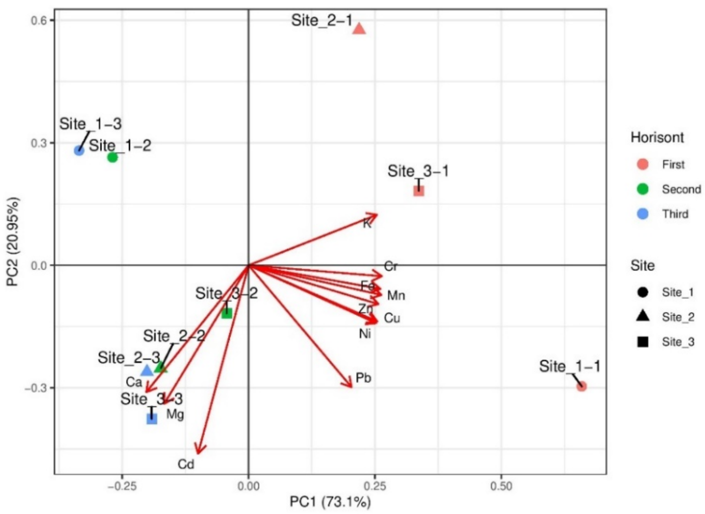

Figure 5. Principal component analyzes (PCA) of two first principal components (PC) for nine collected samples (3 sites × 3 depths).

Figura 5. *Analiza glavnih komponenti (PCA) prve dve komponente (PC) za devet uzoraka (3 lokaliteta × 3 dubine).*

Table 3. An overview of macro- and microelements presence is urban soils.
Tabela 3. *Pregled detektovanih koncentracija mikro- i makrokomponenata u urbanim zemljištima.*

Study area	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Ca	Mg	K	References
Futoški park, Serbia	1.52	14.6	10.9	11866.3	202.59	22.29	23.79	44.66	37.23	17.11	1.43	This study
Futoški park, Serbia	1.04	33.2	15.4	ND	258.28	27.12	71.24	57.76	/	/	/	(Galić et al. 2009)
Novi Sad, Serbia	ND	28.0	38.8	ND	368.60	28.70	82.30	100.30	/	/	/	(Mihailović, 2015)
Berlin, Germany	0.50	18.1	18.5	8180.0	256.00	5.30	40.60	101.00	/	1.21	8.72	(Birke and Rauch, 2000)
Balikešir, Turkey	39.00	301.0	71.0	29558.0	764.00	97.00	36.00	114.00	36.75	5.53	2.72	(Dartan et al. 2015)
Tamil Nadu, India	ND	48.1	ND	42488.9	553.00	32.61	/	71.20	0.61	2.15	15.43	(Chandrasekaran et al. 2015)

Legend: The presence of macro- and micro-elements is urban soils is expressed in $mg \cdot kg^{-1}$.

The PCA analyzes showed a deviation between the first and second PC groups. At all three sites stronger deviations we noted between the first and other two horizons. The first surface horizonts (at Sites 2 and 3) were defined with content of K, while deeper horizons at the same sites are very close and they were defined with content of Ca, Mg, and Cd. The surface horizon on the Site 1 highly differed from the rest of the data, due to the dominantly higher concentration of majority of the analyzed HMs which is expected because this site is in the closest vicinity to the street and is most exposed to the anthropogenic pollutants among the investigated sites.

An overview of previously published results of micro-element concentrations in soils in Futoški park as well as some representative cities from the same climate zones in Europe is given in Table 3. Comparison of the results with other research indicates that the calculated mean value of Cd concentration in this study is higher than the value obtained in the study of Galić et al. (2009), which points to an increase in Cd in the soil as a consequence of anthropogenic action. The obtained mean values of the content of Cr, Cu, Mn, Ni and Zn are slightly lower compared to the same locality. It is possible that the significantly higher mean value of Pb concentration (71.24 $mg \cdot kg^{-1}$ (Galić et al. 2009)) than the value obtained in this study (23.79 $mg \cdot kg^{-1}$) indicates the consequences of the used of leaded gasoline for cars. Based on the results obtained in the research of Mihailović (2015), it is noted that of all the examined metals, the greatest contamination of the soil of Novi Sad is Mn and Zn, followed by Pb and Cu.

Higher values of Cr, Cu, Fe, Pb and Zn concentrations were detected in the vicinity of industrial areas around Berlin (Birke and Rauch, 2000). In relation to the mentioned research, in this work, elevated values of Cd, Fe and Ni contents were detected. A comparison of the mean values of microelement concentrations obtained in this research with other results of heavy metal concentrations in soil in Novi Sad and the world indicate that the soil in Futoški park can be polluted with HMs as a result of human activity.

An overview of published research results on the content of macro-elements (Ca, Mg and K) in the soils of representative cities in the world is given in Table 2. By analyzing 4000 samples of the surface soil layer (0-20 cm), Birke and Rauch (Birke and Rauch, 2000) conclude that the distribution of K is mainly of natural origin, and that elevated concentrations of Mg, in addition to industrial and commercial areas, indicate the anthropogenic origin of this element. Then, Dartan et al. (2015) state in their research that Ca, Mg and K in the examined samples are of lithogenic origin. Higher concentrations of Mg and K were observed among the heavy metals studied at different sampling locations in the Jelagiri Hills of India (Chandrasekaran et al. 2015). A comparison of the results with other studies showed that the mean values of Ca and Mg concentrations obtained in this study are higher than the values obtained in soil analysis studies in Berlin, Balikeshire and in the Indian state of Tamil Nadu.

4. Conclusions

This research examined the values of macro- (Ca, Mg, and K) and microelements (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in soil samples in Futoški park, using the atomic absorption spectrophotometry (AAS) analytic technique. It was established that the content values of Ca, Cd, and Mg show an increasing trend with the increment of the soil profile depth, while the values of Cr, Cu, Fe, K, Mn, Ni, and Zn content show a decreasing trend with depth increment.

Examined soil, which is located in close vicinity of the frequent streets, is not threatened by Pb from exhaust gases. The contents of Cr, Cu, Ni, Pb, and Zn are below the limit values defined by the Regulation on limit values of polluting, harmful and dangerous substances in soil ("Službeni glasnik Republike Srbije", No. 30/2018 and 64/2019) of Republic of Serbia, but taking in mind that the value of the Cr content detected in the surface horizons of the Site 1 and Site 3 was near to the defined limit value. The value of Cd content in all soil samples was above the limit value prescribed by the aforementioned Regulation.

According to the results of the ANOVA statistical test, site and soil depth, as which interaction showed to be statistically significant, do influence the content of all examined macro- and micro-elements in the analyzed soils in Futoški park, except the content of Zn. This confirmed the hypothesis that both spatial arrangement and soil depth have an influence on the content and distribution of the analyzed elements in the soil.

Finally, presented results indicate that the presence of macro- and micro-elements in soil collected in Futoški park is within the prescribed limits, except for the content of Cd. With the possibility that areas and the quality of the urban greenery could decrease in the near future, due to the tendency of the urbanization and population growth, it is necessary to continue the research and intensive monitoring of the soil quality in all parks in Novi Sad, especially taking into the account the importance of urban green spaces for human health and well-being.

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