Topola/Poplar **2024**, 214, 5-16 e-ISSN: 2620-1593

OPEN ACCESS

DOI: 10.5937/topola2414005N
UDC: 582.623.2:549.25(497.11)

Original scientific paper

Distribution of trace elements in forest soils in the area of Northern Serbia

Vesna Nikolić Jokanović*[1], Dušan Jokanović[1], Kristina Živanović[2], Milica Ilić[1], Nevena Antanasijević[1], Tihomir Šoškić[2]

[1] University of Belgrade, Faculty of Forestry, Belgrade, Serbia
[2] University of Belgrade, Institute of Multidisciplinary Research, Belgrade, Serbia

* Corresponding author: Vesna Nikolić Jokanović; E-mail: vesna.nikolic@sfb.bg.ac.rs

Received: 1 July 2024; **Revised:** 8 July 2024; **Accepted:** 10 July 2024

Abstract: The research was conducted in the area of Northern Serbia. The lowland hygrophilous forests of Gornji Srem where pedunculate oak is the dominant tree species were studied. In the paper was investigated the content of essential and non-essential heavy metals (Cu, Zn, As, Mn, Co, Pb, Ni, Cd) on two different soil types: hydromorphic (fluvisol) and automorphic (chernozem). Three experimental plots were analyzed on each soil type. Soil loading with heavy metals was studied by soil horizons. Based on the obtained results, it was established that the concentrations of all elements are within the allowed concentrations, except for nickel (Ni), whose values on some experimental plots and horizons exceed the maximum allowed concentrations. Content of all investigated elements are higher on fluvisol, except for As, whose amount is similar on both soil types. The obtained results indicate that the loading of heavy metals in both soil types is within the allowed limits and there is no significant negative impact on the development and production characteristics of the forest ecosystems located in researched area.

Keywords: pedunculate oak, fluvisol, chernozem, heavy metals, contamination.

1. Introduction

From an ecological and productive point of view, pedunculate oak is the most important tree species in the lowland forests of Northern Serbia (Nikolić, 2017). The habitats where pedunculate oak is found (Figure 1) are characterized by high productivity, and one of the greatest problems we are facing when planning silvicultural measures is decline of this highly valuable species (Galić et al. 2013). Some authors (Dubravac and Dekanić, 2009; Nikolić Jokanović et al. 2023) state that pedunculate oak decline negatively affects hydrological regime, microclimate, and biological component of the soil. In order to reforest endangered areas (Dekanić, 1975), ecological (hydrological) preconditions must firstly be created to reintroduce species that were dominant in the past (*Quercus robur* and *Fraxinus excelsior*).

Nikolić Jokanović et al. (2024) investigated the watering regime in lowland pedunculate oak forests from the aspect of water quantity and accessibility and determined that on hydromorphic soils (fluvisol) the ratio of precipitation and groundwater is 1:2 in accessible soil moisture, while on automorphic soils (chernozem) this ratio is the same, but in favour of precipitation. Soil contamination with heavy metals is a serious problem which leads to a negative impact on soil properties and limiting useful functions related to production and the environment in total. The concern related to the presence of heavy metals in the soil does not originate only from their toxic effect on organisms living in the soil, but also refers to their immobility in various organic and inorganic colloids, whereby they can remain immobile for a long time before becoming again available to plants and other living organisms (Friedlova, 2010).

Vrbek and Pilaš (2004) found that the accumulation of a large amount of heavy metals over a long period of time in the organic part of the soil leads to the contamination of organisms in the soil, on which the development of pedogenetic processes largely depends. The negative effects of significantly increased concentrations of heavy metals on soil organisms can be detected when the content of zinc (Zn) exceeds 500 mg/kg, copper (Cu) above 20-100 mg/kg, and lead (Pb) above 50-250 mg/kg, while the limit values that can be tolerated in the soil are: for lead 50-100 mg/kg, copper 30-60 mg/kg, and zinc 100-200 mg/kg (Alberti et al. 1996; Vrbek and Pilaš, 2004). Many papers (Mayer 1987, 1991; Vrbek and Pilaš, 2000) note increased concentrations of lead, copper, zinc and cadmium in the soil of the flood zone of the lowland forests of central Croatia, which typologically belong to the same group of ecosystems that are located on the bank of the Sava River in the territory of Serbia. Microelements in soil can be present as a consequence of anthropogenic activities or natural processes (Adriano, 2001). The mobility of microelements in the soil depends on the initial concentration, the presence of other ions, adsorptive capacity and the form in which they are found (Lumsdon et al 1995; Yi et al. 2007). Forest woody species, according to a highly developed and branched root system, are able to accumulate and absorb large concentrations of heavy metals from the soil and thus greatly contribute to the drastic reduction of overall pollution (Stanković et al. 2015 a; Stanković et al. 2015 b). Namely, the well-developed root system of woody plants enables the extraction of pollutants from deeper soil layers, which, along with high organic production, contributes to effective soil decontamination compared to herbaceous species (Stanković and Jokanović 2017). One of the evidences of the successful survival of woody species on contaminated land is the wild trees that successfully grow on tailings and next to mining pits which means that the establishment of new forests has a great role in the decontamination of the environment and the creation of a healthier ecological environment (Stanković and Jokanović 2017).

The aim of the paper is to determine the loading of two types of forest soils with heavy metals in order to evaluate whether their presence is within the limits of allowed values and whether it affects the decline of investigated forest ecosystems.

2. Material and Methods

Forest area Gornji Srem includes forests and forest soil located in the northern part of Serbia, west from Sremska Mitrovica and along the way to the state border with Croatia (Figure 1). This forest area is a complex of high-quality hard and soft deciduous forests with pedunculate oak as the main species of these lowland associations. The properties of these forest soils depend on the mineralogical and textural composition of sediment that was deposited in this area until the construction of the protective embankment in 1932. With the construction of embankment, flooding stops and pedogenesis of these soils take place under the influence of atmospheric and groundwater, the prevailing climate and vegetation. In the area of Gornji Srem, within the two most represented forest types *Fraxineto-Quercetum roboris aceretosum* and *Carpino-Fraxino-Quercetum roboris caricetosum remotae* on hydromorphic soil type Fluvisol and automorphic soil type Chernozem, the total and plant-accessible content of following elements was determined: Cu (copper), Zn (zinc), As (arsenic), Mn (manganese), Co (cobalt), Pb (lead), Cd (cadmium) and Ni (nickel). On the investigated area, six experimental plots were identified (Figure 2), pedological profiles were opened, and soil system units were defined. Soil samples were collected individually from each pedological horizon for laboratory research at experimental plots. Determination of the total amount of trace elements by destruction with concentrated nitric acid was determined on the device Vista nPro – Varian by method of Inducing

Coupling Plasma ICP – OES. Determination of accessible amounts of trace elements was conducted by extraction with EDTA atomic absorption spectrophotometer Spektra-600, Varian, Flame technician; DM 8/1-3-023, on the machine Vista Pro – Varian, Method Inducing Coupling Plasma ICP-OES. As for analytical methods for determining trace elements content in the soil, it was already mentioned that the total metal content was calculated by destroying the soil with nitric acid.

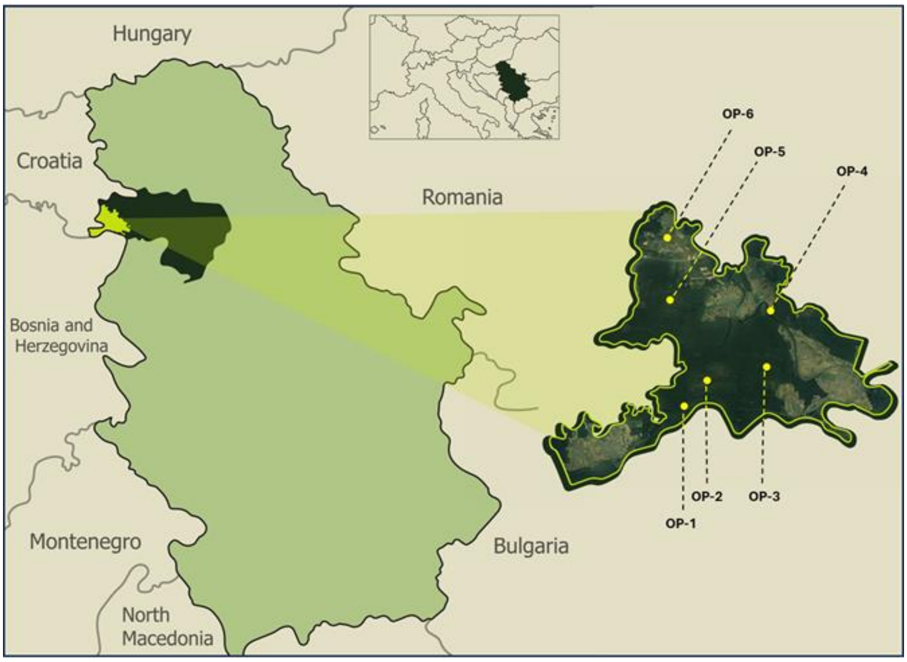

Figure 1. Investigated area of lowland forests in Northern Serbia (Gornji Srem).

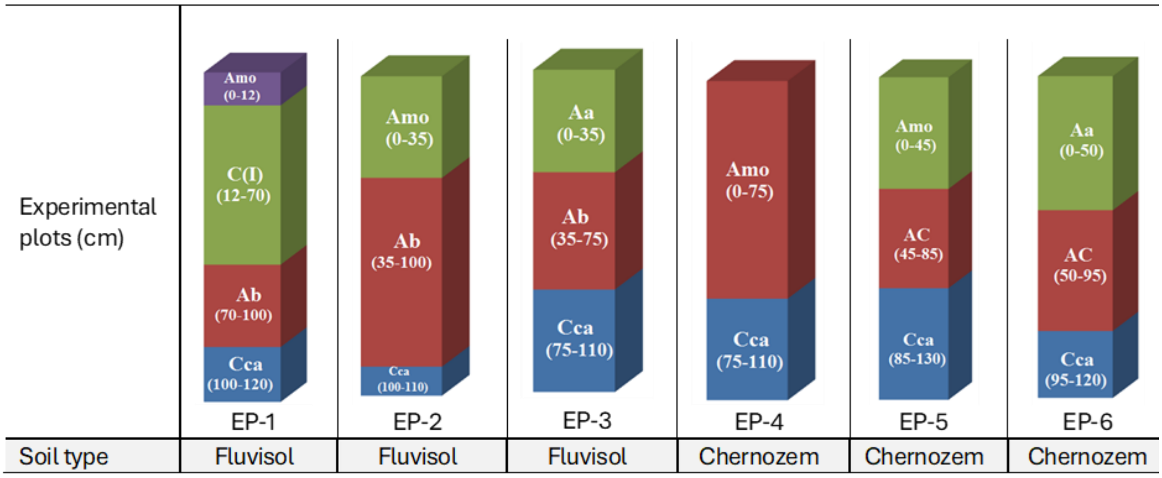

Figure 2. Schematic display of the pedological profile depth (cm) with marked horizons and type of vegetation in the experimental plots of the forest area of Gornji Srem.

3. Results

In the paper was analyzed total and accessible content of investigated heavy metals investigated both on Fluvisol and Chernozem through the soil horizons. There was also a calculated percentage proportion of availability of each microelement in relation to its total content. The obtained results range between minimal and maximal values.

3.1. Trace elements content on Fluvisol

The analysis of results related to total and accessible content of microelements and heavy metals on Fluvisol at the area of lowland forest of Gornji Srem shows the following:

Total content of Cu in fluvisol is between 20.12 mg/kg (experimental plot 3) in Cca horizon at the depth between 100 and 120 cm and maximal 30.3 mg/kg (experimental plot 1) in Cca horizon at the depth between 100 and 120 cm (Figure 3). Values of total Cu content are within maximum allowed concentration limits. Total content of Cu accessible to plants (Figure 4) in this soil type is between 1.28 mg/kg in Cca horizon at the depth between 75 cm and 110 cm (experimental plot 3) and maximal 8.31 mg/kg in IGso horizon at the depth until 12 cm (experimental plot 1). The percentage proportion of accessible Cu in the soil is between 5.31 % (experimental plot 2) in Cca horizon at the depth 100-110 cm and 32.96% (experimental plot 3) in Aa horizon at the depth until 35 cm.

Total content of Zn in fluvisol (Figure 3) varies between the lowest value of 57.85 mg/kg in Cca horizon at the depth between 75 and 110 cm (experimental plot 3) and the highest value of 99.9 mg/kg recorded in Amo horizon at the depth of 12 cm (experimental plot 1). As for Zn content available for plants (Figure 4), it is between minimum value of 0.61 mg/kg in Amo horizon at the depth of 35 cm (experimental plot 2) and maximum value of 3.82 mg/kg in Amo horizon at the depth of 12 cm (experimental plot 1). Precentage proportion of accessible Zn in the soil varies between 0.84 % (experimental plot 1) in IGso horizon at the depth between 12 and 70 cm, and in Amo horizon at the depth of 35 cm (experimental plot 2), as well, and 3.28% (experimental plot 1) in Amo horizon at the depth of 12 cm.

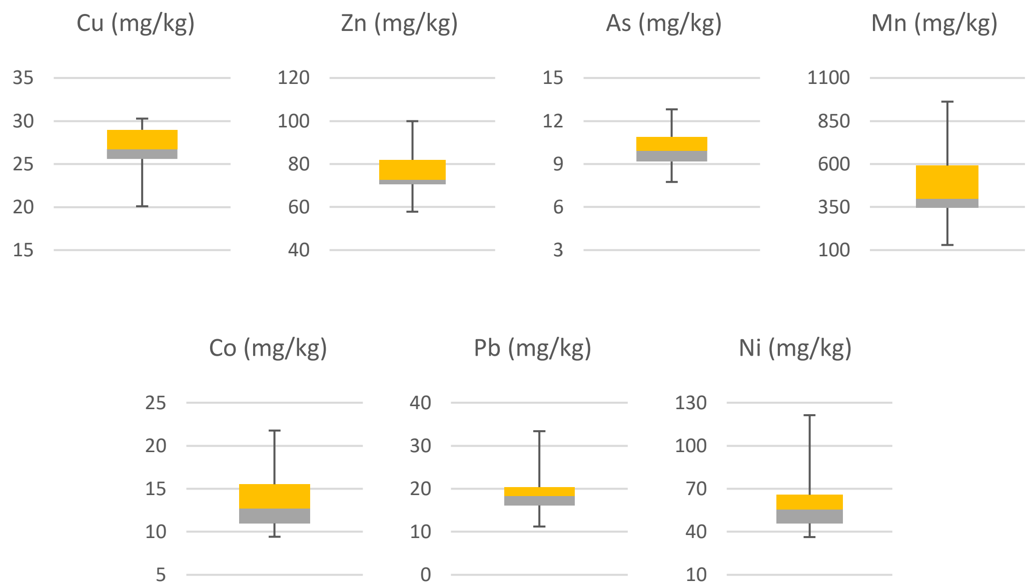

Figure 3. Total content of some microelements and heavy metals on Fluvisol in Gornji Srem.

Total content of As in fluvisol (Figure 3) ranges between 7.74 mg/kg in Ab horizon at the depth between 35 and 100 cm (experimental plot 2) and 12.82 mg/kg in Cca horizon at the depth 100-120 cm (experimental plot 1). Detected values of total As content are lower than maximal allowed concentration. In terms of As in the soil available to the plants (Figure 4), it is between 0.61 mg/kg (experimental plot 3) in Ab horizon at the depth from 35 cm to 75 cm and 1.37 mg/kg (experimental plot 1) in Cca horizon at the depth between 100 cm and 120 cm. Percentage proportion of available As content ranges from minimal value of 5.53% (experimental plot 3) in Ab horizon at the depth between 35 cm and 75 cm until maximal value of 11.71% (experimental plot 1) in IGso horizon at the depth between 12 cm and 70 cm.

As for total content of Mn in this soil type (Figure 3), it ranges between 128.6 mg/kg in Ab horizon at the depth between 35 cm and 75 cm (experimental plot 3) and 962 mg/kg in Amo horizon at the depth of 12 cm (experimental plot 1). Values of Mn in the soil available for plants (Figure 4) vary from 10.54 mg/kg (experimental plot 2) in Cca horizon at the depth between 100 cm and 110 cm and 306.1 mg/kg in Cca horizon at the depth between 100 cm and 120 cm (experimental plot 1). Percentage proportion of Mn accessible to the plants ranges between 3.59% (experimental plot 2) in Cca horizon at the depth between 100 cm and 110 cm and maximal 39.37% (experimental plot 1) in Cca horizon at the depth between 100 cm and 120 cm.

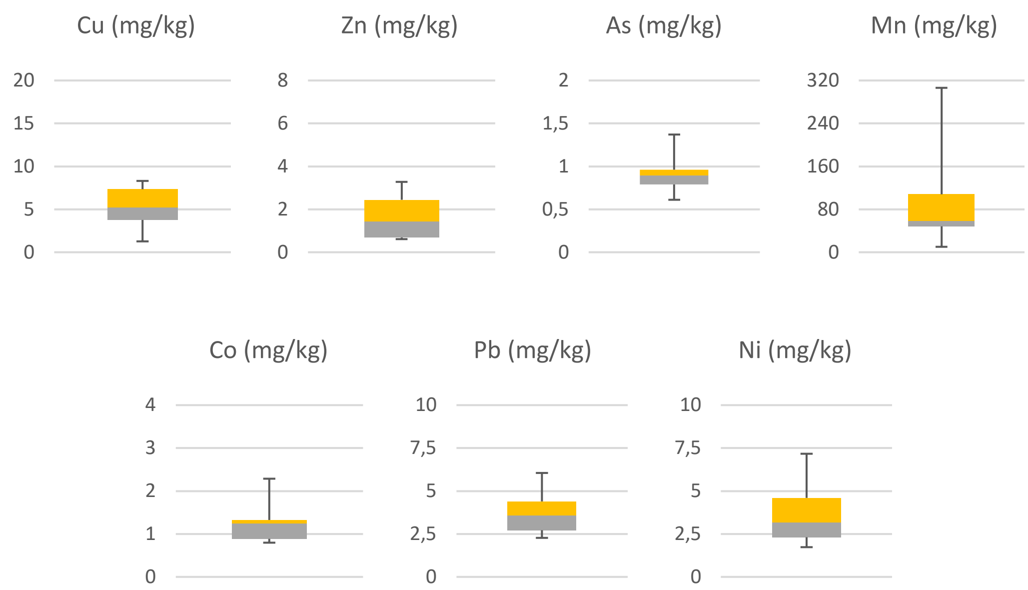

Figure 4. Accessible content of some microelements and heavy metals on Fluvisol in Gornji Srem.

Total content of Co in fluvisol (Figure 3) is between 9.43 mg/kg in Aa horizon at the depth of 35 cm (experimental plot 3) and 21.77 mg/kg in Ab horizon at the depth between 35 cm and 75 cm (experimental plot 3). As for Co content accessible to the plants (Figure 4), it ranges between 0.8 mg/kg in Ab horizon at the depth between 35 cm and 100 cm (experimental plot 2) and 2.29 mg/kg in Cca horizon at the depth between 100 cm and 120 cm (experimental plot 1). Percentage proportion of available Co is between 6.20% (experimental plot 3) in Ab horizon at the depth between 35 cm and 75 cm and 14.59% (experimental plot 1) in Cca horizon at the depth between 100 cm and 120 cm.

Total content of Pb (Figure 3) ranges between 11.21 mg/kg in Cca horizon at the depth between 75 cm and 110 cm (experimental plot 3) and 33.42 mg/kg in Amo horizon at the depth of 12 cm (experimental plot 1). Detected overall values are under maximal allowed concentrations. As for Pb accessible for the plants (Figure 4), it is between 6.06 mg/kg in Amo horizon at the depth of 12 cm (experimental plot 1), while percentage proportion of Pb available to the plants varies between 14.06% (experimental plot 2) in Ab horizon at the depth between 35 cm and 100 cm and 30.56% (experimental plot 2) in Cca horizon at the depth between 100 cm and 110 cm.

Total content of Ni in fluvisol (Figure 3) varies between 36.31 mg/kg in Cca horizon at the depth between 75 cm and 110 cm (experimental plot 3) and 121.40 mg/kg in Amo horizon at the depth of 12 cm (experimental plot 1). Higher Ni values from maximum allowed concentration are recorded at all horizons on experimental plot 1, then on experimental plot 3 in Ab horizon at the depth between 35 cm and 75 cm, and on experimental plot 2 in Amo and Ab horizons at the depth of 100 cm. As for Ni accessible content (Figure 4), it ranges from 1.74 mg/kg in Ab horizon at the depth between 30 cm and 100 cm (experimental plot 2) and 7.16 mg/kg in Cca horizon at the depth between 100 cm and 120 cm (experimental plot 1). Percentage proportion of accessible Ni in fluvisol is between 1.95% (experimental plot 1) in Amo horizon at the depth of 12 cm and 10.47% (experimental plot 1) in Cca horizon between 100 cm and 120 cm.

The obtained results related to the total content of Cd on all Fluvisol soil samples showed this element was not detected.

3.2. Trace elements content on Chernozem

The analysis of results related to total and accessible content of microelements and heavy metals on Chernozem at the area of lowland forest of Gornji Srem shows the following:

Total content of Cu in chernozem (Figure 5) is between 17.87 mg/kg (experimental plot 6) in Cca horizon at the depth between 95 cm and 120 cm and 26.49 mg/kg (experimental plot 5) in AC horizon at the depth between 45 cm and 85 cm. Values of total Cu content in this soil type are within maximum allowed concentrations. As for accessible Cu (Figure 6), it is between 0.7 mg/kg in Amo horizon at the depth of 45 cm (experimental plot 5) and 6.2 mg/kg in Aa horizon at the depth of 50 cm (experimental plot 6). The percentage proportion of accessible Cu varies between 3.47% (experimental plot 5) in Amo horizon at the depth of 45 cm and 27.92% (experimental plot 6) in Aa horizon at the depth of 50 cm.

Total content of Zn (Figure 5) on chernozem ranges between 48.42 mg/kg in Cca horizon at the depth between 95 cm and 120 cm (experimental plot 6) and 81.13 mg/kg in AC horizon at the depth between 45 cm and 85 cm (experimental plot 5). As for available forms of Zn (Figure 6), they are between 0.59 mg/kg in Aa horizon at the depth of 50 cm (experimental plot 6) with percentage proportion of 0.84% and 0.94 mg/kg in Cca horizon at the depth between 85 cm and 130 cm (experimental plot 5) with percentage proportion of 1.24%.

Total content of As (Figure 5) is between 8.40 mg/kg in Aa horizon at the depth of 50 cm (experimental plot 6) and 12.83 mg/kg in Cca horizon at the depth between 75 cm and 110 cm (experimental plot 4). Detected values of total As content are lower from maximum allowed concentrations. As for accessible As (Figure 6), it ranges between 0.57 mg/kg (experimental plot 4) in Cca horizon at the depth between 75 cm and 110 cm and 0.89 mg/kg (experimental plot 5) in Cca horizon at the depth between 85 cm and 130 cm. Percentage proportion of As accessible to the plants is between 4.44% (experimental plot 4) in Cca horizon at the depth between 75 cm and 110 cm and 9.29% (experimental plot 6) in Aa horizon at the depth of 50 cm.

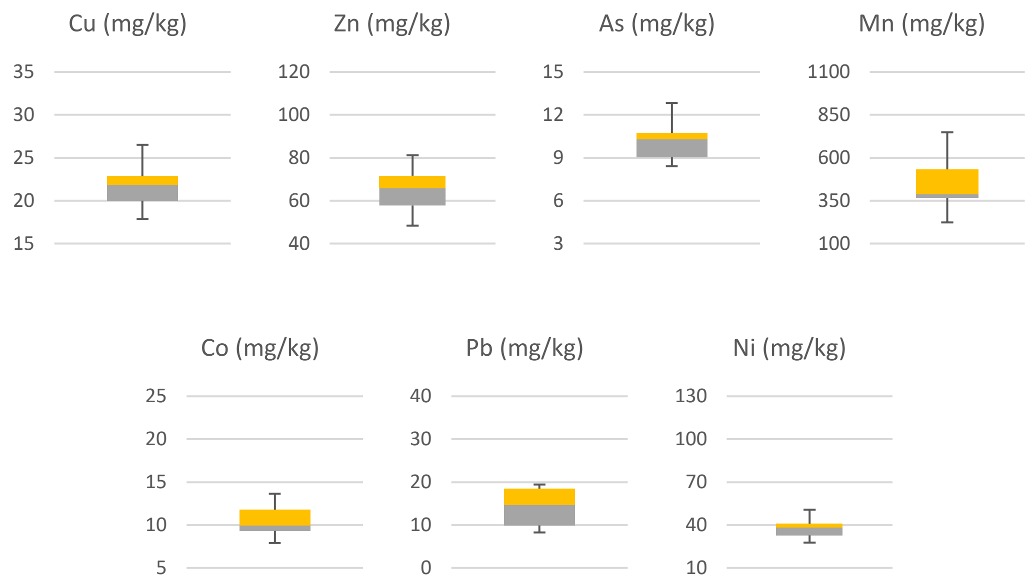

Figure 5. Total content of some microelements and heavy metals on Chernozem in Gornji Srem.

Total content of Mn (Figure 5) in this soil type ranges between 223.6 mg/kg in Aa horizon at the depth of 50 cm (experimental plot 6) and 748.1 mg/kg in Cca horizon at the depth between 75 cm and 110 cm (experimental plot 4). In terms of Mn available to the plants (Figure 6), it is between 16.58 mg/kg (experimental plot 6) in Aa horizon at the depth of 50 cm and 157.5 mg/kg in AC horizon at the depth between 45 and 85 cm (experimental plot 5). The percentage proportion of available Mn is between 4.44 % (experimental plot 4) in Cca horizon at the depth between 75 cm and 110 cm and 23.79% in AC horizon at the depth between 45 cm and 85 cm (experimental plot 5).

Total content of Co (Figure 5) on chernozem is between 7.92 mg/kg in Cca horizon at the depth between 95 cm and 120 cm (experimental plot 6) and 13.66 mg/kg in AC horizon at the depth between 45 cm and 85 cm (experimental plot 5). In terms of Co accessible to the plants (Figure 6), it ranges from 0.52 mg/kg in Cca horizon at the depth between 85 cm and 130 cm (experimental plot 5), and the same content was recorded in Amo horizon at the depth of 75 cm (experimental plot 4), up to 1.12 mg/kg in AC horizon at the depth between 45 cm and 85 cm (experimental plot 5). The percentage proportion of accessible Co is between 4.01% (experimental plot 4) in Amo horizon at the depth of 75 cm and 8.20% (experimental plot 5) in AC horizon at the depth between 45 cm and 85 cm.

Total content of Pb (Figure 5) is between 8.30 mg/kg in Cca horizon at the depth between 95 cm and 120 cm (experimental plot 6) and 19.42 mg/kg in Amo horizon at the depth of 75 cm (experimental plot 4). Detected values are lower than maximum allowed concentrations. As for Pb accessible to the plants (Figure 6), it ranges between 2.02 mg/kg in Cca horizon at the depth between 95 cm and 120 cm (experimental plot 6) and 4.13 mg/kg in Aa horizon at the depth of 50 cm (experimental plot 6). The percentage proportion of Pb accessible to the plants is from 15.43% (experimental plot 5) in Cca horizon at the depth between 85 cm and 130 cm to 29.92% (experimental plot 6) in AC horizon at the depth from 50 cm to 95 cm.

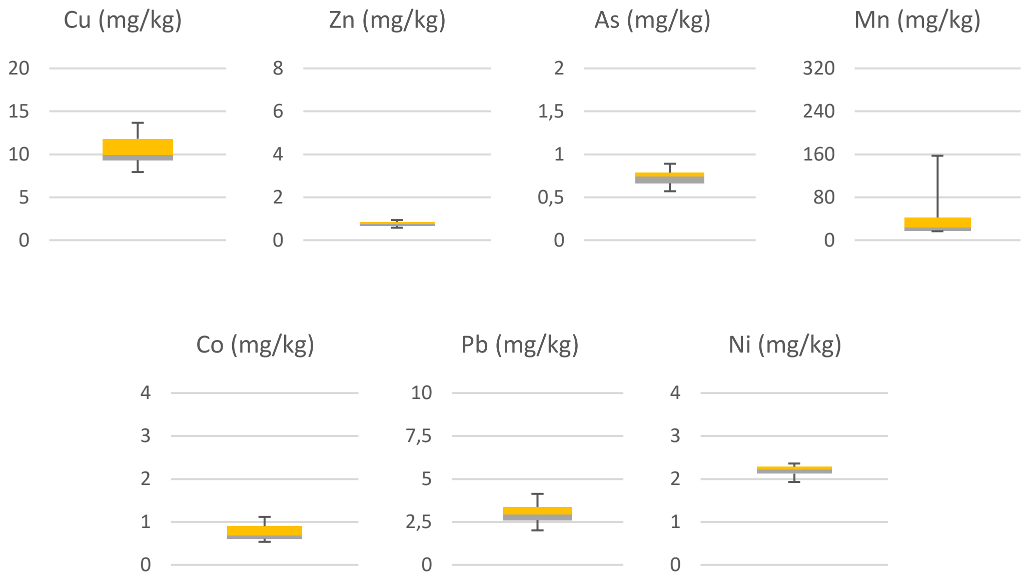

Figure 6. Accessible content of some microelements and heavy metals on Chernozem in Gornji Srem.

Total content of Ni (Figure 5) in chernozem is between 27.75 mg/kg in Cca horizon at the depth between 95 cm and 120 cm (experimental plot 6) and 50.78 mg/kg in AC horizon at the depth between 45 cm and 85 cm (experimental plot 5). The aforementioned value (50.78 mg/kg) is the only one a little bit over the maximum allowed limit on Chernozem. Accessible content of Ni (Figure 6) is between 1.93 mg/kg in Amo horizon at the depth of 75 cm (experimental plot 4) and 2.36 mg/kg in Aa horizon at the depth of 50 cm. Percentage proportion of accessible Ni is between 4.45% (experimental plot 5) in AC horizon at the depth between 45 cm and 85 cm and 5.99% (experimental plot 5) in Cca horizon at the depth between 85 cm and 130 cm.

The obtained results related to the total content of Cd on all Chernozem soil samples showed this element was not detected.

4. Discussion

The highest intensity of pedunculate oak decline was detected in soils with the largest amount of hard accessible water (Galić et al. 2013; Nikolić Jokanović et al. 2024), which can be related to the absence of supplementary watering by flood waters, as well as insufficient amount of groundwater. As for development features of pedunculate oak lowland forests (Nikolić Jokanović et al. 2024), it is very important to note that water from precipitation is retained in capillary and gravity pores, as well as that water in the soil is located in pores smaller than capillary ones, so that water is not available to vegetation. Water originating from precipitation is mostly consumed by plants during evapotranspiration, so that only 15-20% reaches the physiologically active layer of the soil where it is available to the root system of plants. Bearing in mind the increasingly intense global warming that is expected in the future, as a result, an increased deficit of water in the soil can be expected, which will be reflected in mass trees decline. Galić et al. (2013) relates the degree of decline to the C/N ratio in the sense that a higher intensity of decline was detected in areas where this ratio was higher, which is connected with the opening of the canopy and faster mineralization of organic matter.

Stefanovics et al. (1999) state that lead, cadmium, mercury and nickel are the most toxic to the environment. As for lead, its maximum allowed concentration in agricultural soils in the Republic of Serbia is up to 100 mg/kg (Kadović and Knežević, 2002). Based on the results obtained in our paper, the average values of the total amount of lead on both soil types (fluvisol and chernozem) are within the allowed limits, while the average values of the accessible amount of lead are very low and do not significantly affect the productivity and fertility of the soil. The presence of lead was not detected in groundwater samples analyzed for fluvisol and chernozem in the Gornji Srem area (Nikolić Jokanović et al. 2019). Galić et al. (2013) found a medium lead load in the majority of analyzed soil samples, and bearing in mind that this metal accumulates over time in the soil, it is recommended to monitor its concentration, which reaching a value of 50 mg/kg can cause negative effects on the soil.

Nickel content increased in soils during the second half of the 20th century due to increasingly intensive oil refining (Stefanovits et al. 1999). Galić et al. (2013) found increased soil loading with this metal compared to maximum allowed concentrations in all forest types, which largely correlates with the results obtained in our paper. On the other hand, Nikolić Jokanović et al. (2019) found for groundwater samples that the concentration of nickel on chernozem reached the maximum value, while the values recorded on fluvisol were within allowed limits. Although the origin of nickel is mainly geochemical and therefore it is found in forms that cause its mobility in the soil and accessibility for uptake by the root system of plants to be low, it is necessary to carry out permanent monitoring of this heavy metal (Dozet et al. 2011). Antić-Mladenović (2004) detected elevated concentrations of nickel in Pomoravlje and explain that this is a consequence of alluvial-deluvial processes due to which nickel from mountain Rudnik accumulates in this area. Di Giuseppe et al. (2014) recorded high concentrations of chromium and nickel in alluvial soils formed from the sediments of the Po River and established that this elevated contamination is not the result of human action, but rather the geological-lithological past of the investigated area.

Galić et al. (2013) deduce that the concentrations of zinc, copper and manganese are within the limits of the maximum allowed values, which coincides with the results obtained in our paper. On the other hand, Nikolić Jokanović et al. (2019) found increased concentrations of Zn and Mn in groundwater samples in the Sava alluvium for both soil types, however, taking into account that highly toxic metals such as cadmium, mercury and lead were almost never detected, the quality of the analyzed water was at a satisfactory level. Some authors (Di Giuseppe et al. 2014) state that increased copper concentrations are mainly the result of human activities, while among the potentially toxic heavy metals that should be monitored in terms of bioavailability and the possibility of entering the food chain, chromium does not have the necessary mobility and does not pose a threat to unlike nickel.

Di Giuseppe et al. (2014) investigated the mobility and bioavailability of heavy metals in alluvial soils in northern Italy and found that the average values of chromium, cobalt, copper, lead and zinc, as well as the maximum concentrations of arsenic are within the limits of the defined allowed values, however, the aforementioned authors state the paradox that the legislative framework in Italy does not define the threshold (critical concentrations) of heavy metals in agricultural soils, where toxic elements can be transferred to the edible parts of the plant. The characteristics of each metal in terms of maximum allowed concentrations and bioavailability are more important than the total concentration for defining geochemical risk assessment (Filgueiras et al. 2004; Farkas et al. 2007). Otherwise, the bioavailability of metals in the soil depends a lot on the properties of the soil – among these characteristics, the most important is the pH of the soil solution, which strongly affects the speciation and mobility of metals both in the soil as a whole and particularly in the soil solution (Mühlbachova et al. 2005; Zeng et al. 2011). Soil organic matter is also an important soil property that affects the availability of trace metals, where it can reduce or increase the mobility of metals (Du Laing et al. 2009).

Numerous studies differ in their conclusions regarding the extent to which soil contamination with heavy metals affects the respiration process – Tobon-Kaplon et al. (1995) state that under stress conditions, more resistant organisms react with increased respiratory activity because oxygen consumption increases with the contamination process, while sensitive organisms react with a lower intensity of respiration. Giller et al. (1998) investigated the variable properties of an accessible soil substrate that was mineralized at the time when respiration intensity was measured and found that the effect of heavy metals on respiratory activity is strongly influenced by the content of clay minerals, organic matter and other factors which affect the cation exchange capacity of the soil. Brookes (1995) and Giller et al. (1998) state that the disruption of metabolic processes in the plant is a good indicator of the negative effect of heavy metals on the soil microflora. Heavy metals inhibit enzyme reactions by binding to the substrate, creating complexes with the substrate, blocking reactive functional groups of enzymes or reacting with the enzyme-substrate complex (Mikanova, 2006). It should be noted that the effect of heavy metals on soil microorganisms is not always the same (Wood, 1995; Nannipieri et al. 1997) since it depends on many physical and chemical characteristics of the soil such as: amount of pollutants, soil type, temperature, soil water content, pH, connection between soil minerals and organic matter.

Concentrations of trace elements are less dependent on geology than nutrient concentrations, while mean values of copper, lead and zinc in forest soils of Singapore are similar to the concentrations obtained in our paper (Leitgeb et al. 2019). Zhou et al. (1997) obtained slightly higher average values of the analyzed elements which can be related to modified environmental conditions. The content of arsenic in agricultural soils in Malaysia exceeds 60 mg/kg (Zarcinas et al. 2004) which is 4-5 times higher than the average concentrations of this toxic element in our paper. One of the main reasons for high concentrations of arsenic in agricultural soils is related to the fact that this heavy metal occurs naturally on soils created on igneous rocks, which must be taken into consideration when defining the maximum allowed concentrations of this element.

5. Conclusions

The obtained results in the paper show that concentrations of all analyzed essential (Ni, Mn, Zn, Cu, Co) and non-essential (As, Pb, Cd) heavy metals are within normal limits apart from nickel whose concentrations are over maximum allowed values at both investigated soils on the majority of experimental plots. What's more, cadmium was even not detected in both investigated soil types. Compared to agricultural soils, where, in order to increase the yield, chemical agents are used to a large extent, on the studied forest soils in Gornji Srem, the content of heavy metals is significantly lower, especially when it comes to toxic non-essential heavy metals such as arsenic and lead. The obtained values of accessible heavy metals are significantly lower compared to their total amounts, which indicates the great phytoextraction potential of lowland forests for the uptake and accumulation of these elements. By comparing the concentrations of essential heavy metals (Ni, Cu, Zn, Mn, Co) which are necessary for plants for photosynthesis, nitrogen fixation, transcription of DNA molecules on the investigated soils, slightly higher average values were detected on fluvisol than on chernozem. On the other hand, non-essential heavy metals (Pb, As, Cd) do not have any physiological and biochemical role in plant metabolism and at low concentrations show a toxic effect. The mean content of arsenic is approximately the same, while the concentration of lead is much higher on fluvisol. Although the values of heavy metals obtained on the investigated soils in lowland pedunculate oak forests are within allowed limits, it is necessary to conduct permanent monitoring taking into consideration climate changes that lead to disturbances in ecosystems and affect forests decline.

6. References

1. Adriano, D.C. (2001): Trace elements in terrestrial environments: Biogeochemistry, Bioavailability, and Risks of Metals. Springer, New York.
2. Alberti, G., Hauk, B., Kohler, H.R., Storch, V. (1996): Dekomposition. Qualitative und quantitative Aspekte und deren Beeinflussung durch geogene und anthropogene Belastungsfaktoren. Ecomed-Verlag, Landsberg, 490.
3. Antić-Mladenović, S. (2004): Hemija nikla i hroma u zemljištima sa njihovim prirodno visokim sadržajima. Doktorska disertacija, Univerzitet u Beogradu – Poljoprivredni fakultet. Beograd, Srbija.
4. Brookes, P.C. (1995): The use of microbiological parameters in monitoring soil pollution by heavy metals. Biology and Fertility of Soils 19: 269-279.
5. Dekanić, I. (1975): Utvrđivanje najpogodnijih vrsta drveća i metoda obnove opustošenih površina sušenjem hrasta lužnjaka. Šumarski list 4-5: 119-128.
6. Di Giuseppe, D., Vittori Antisari, L., Ferronato, C., Bianchini, G. (2014): New insights on mobility and bioavailability of heavy metals in soils of the Padanian alluvial plain (Ferrara Province, northern Italy). Geochemistry 74(4): 615-623.
7. Dozet, D., Nešić, Lj., Belić, M., Bogdanović, D., Ninkov, J., Zeremski, T., Dozet, D., Banjac, B. (2011): Poreklo i sadržaj nikla u aluvijalno-deluvijalnim zemljištima Srema. Ratarstvo i povrtarstvo 48: 369-374.
8. Du Laing, G., Rinklebe, J., Vandecasteele, B., Meers, E., Tack, F.M.G. (2009): Trace metal behaviour in estuarine and riverine floodplain soils and sediments: a review. Science of the Total Environment 407: 3972-3985.
9. Dubravac, T., Dekanić, S. (2009): Struktura i dinamika sječe suhih i odumirućih stabala hrasta lužnjaka u Spačvanskom bazenu od 1996. do 2006. godine. Šumarski list 7-8: 391-405.
10. Farkas, A., Erratico, C., Vigano, L. (2007): Assessment of the environmental significance of heavy metal pollution in surficial sediments of the River Po. Chemosphere 68: 761-768.
11. Filgueiras, A.V., Lavilla, I., Bendicho, C. (2004): Evaluation of distribution, mobility, and binding behaviour of heavy metals in surficial sediments of Louro River (Galicia, Spain) using chemometric analysis: a case study. Science of the Total Environment 330: 115-129.
12. Friedlova, M. (2010): The influence of heavy metals on soil biological and chemical properties. Soil and Water Research 5 (1): 21-27.
13. Galić, Z., Ivanišević, P., Klašnja, B., Kebert, M. (2013): Soil heavy metals contents in the most important types oak forests affected by different degrees of drying. Topola 191/192: 73-82.
14. Giller, K.E., Witter, E., McGrath, S.P. (1998): Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils. Soil Biology and Biochemistry 30: 1389-1414.
15. Kadović, R., Knežević, M. (2002): Teški metali u šumskim ekosistemima Srbije. Šumarski fakultet Beograd, 278.
16. Leitgeb, E., Ghosh, S., Dobbs, M., Englisch, M., Michel, K. (2019): Distribution of nutrients and trace elements in forest soils of Singapore. Chemosphere 222: 62-70.
17. Lumsdon, D.G., Evans, L.J., Bolton, K.A. (1995): The influence of pH and chloride on the retention of cadmium, lead, mercury, and zinc by soils. Journal by Soil Contamination 4: 137-150.
18. Mayer, B. (1987): Rezultati prvih istraživanja olova, kadmijuma, sumpora i fluora u tlu nizinskih šuma bazena Kupčina. Šumarski list 1-2: 19-27.

19. Mayer, B. (1991): Penetration des metaux lourds (Pb, Cu, Zn) a l' interieur des sols forestiers des valle de la Croatie septentrionale par courents d' eaou inondee pollue. 10e Congres forestier mondial, Paris.
20. Mihajlović, A. (2015): Fizičke karakteristike zemljišta i distribucija teških metala na gradskom području Novog Sada. Doktorska disertacija, Univerzitet u Novom Sadu - Prirodno-matematički fakultet, Departman za fiziku. Novi Sad, Srbija.
21. Mikanova, O. (2006): Effects of heavy metals on some soil biological parameters. Journal of Geochemical Exploration 88: 220-223.
22. Mühlbachova, G., Simon, T., Pechova, M. (2005): The availability of Cd, Pb and Zn and their relationships with soil pH and microbial biomass in soils amended by natural clinoptilolite. Plant, Soil and Environment 51: 26-33.
23. Nannipieri, P., Badalucco, L., Landi, L., Pietramellara, G. (1997): Measurement in assessing the risk of chemicals to the soil ecosystem. In: Zelikoff JT (ed.): Exotoxycology: Responses, Biomarkers and Risk Assessment. OECD Workshop, New York, 507-534.
24. Nikolić Jokanović, V., Jokanović, D., Savić, R., Petrović, J., Anđelković, A. (2019): Water contamination in pedunculate oak hygrophilous forests. Fresenius Environmental Bulletin 28 (11A): 8432-8437.
25. Nikolić Jokanović, V., Jokanović, D., Savić, R., Petrović, N., Marinković, M., Tubić, B., Vasić, I. (2024): Soil moisture regime in lowland forests – quantity and availability of water. Journal of Hydrology and Hydromechanics 72 (1): 15-24.
26. Nikolić Jokanović, V., Lazović, A., Šoškić, T., Živanović, K. (2023): Monitoring of groundwater level fluctuations at flooded area of lowland forests of the Sava River (Serbia). Reforesta 16: 55-65.
27. Nikolić, V. (2017): Uticaj režima vlaženja na karakteristike staništa hrasta lužnjaka (*Quercus robur* L.) u Ravnom Sremu. Doktorska disertacija, Univerzitet u Beogradu – Šumarski fakultet. Beograd, Srbija.
28. Stanković, D., Ivetić, V., Ocokoljić, M., Jokanović, D., Oljača, R., Mitrović, S. (2015 a): Manganese Concentration in Plants of the Protected Natural Resource, Kosmaj, in Serbia. Archives of Biological Sciences 67 (1): 251-255.
29. Stanković, D., Jokanović, D., Veselinović, M., Letić, Lj., Jović, Đ., Karić, D. (2015 b): Zinc Concentration in woody and herbaceous plants at Kosmaj Area, Serbia. Fresenius Environmental Bulletin 24 (11): 3672-3675.
30. Stanković, D., Jokanović, D. (2017): Pollutants in plants, environmental role of woody and herbaceous plants. Lambert Academic Publishing 1-54.
31. Stefanovics, P., Filep, G.Y., Fuleky, G.Y. (1999): Talajtan. Mezogazda kiado Budapest, 1-469.
32. Tobon-Kaplon, M.A., Bloem, J., Romkens, P.F.A.M., Ruiter, P.C. (2005): Functional stability of microbial communities in contaminated soils. Oikos 111: 119-129.
33. Vrbek, B., Pilaš, I. (2000): Pedoekološke značajke šuma „Žutica". Radovi Šumarskog Instituta 35(1): 13-36.
34. Vrbek, B., Pilaš, I. (2004): Teške kovine (Pb, Cu i Zn) u tlu šume hrasta lužnjaka i običnoga graba. Radovi Šumarskog Instituta 39(2): 169-184.
35. Wood, M. (1995): Environmental Soil Biology. The University Press, Cambridge, 1-150.
36. Yi, L., Hong, Y., Wang, D., Zhu, Y. (2007): Determination of free heavy metal ion concentrations in soils around a cadmium rich zinc deposit. Geochemical Journal 41(4): 235-240.
37. Zarcinas, B.A., Ishak, C.F., McLaughlin, M.J., Cozens, G. (2004): Heavy metals in soils and crops in Southeast Asia. Environmental Geochemistry and Health 26: 343-357.
38. Zeng, F.R., Ali, S., Zhang, H.T., Ouyang, Y.N., Qiu, B.Y., Wu, F.B., Zhang, G.P. (2011): The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants. Environmental Pollution 159: 84-91.

39. Zhou, C.Y., Wong, M.K., Koh, L.L., Wee, Y.C. (1997): Soil lead and other metal levels in industrial, residential and nature reserve areas in Singapore. Environmental Monitoring and Assessment 44: 605-615.