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# "ECOLOGY OF URBAN AREAS 2016"

**Zrenjanin, 30th September 2016**
**Serbia**

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## V International Conference
## „Ecology of Urban Areas 2016“

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**30th September 2016**

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# THE QUALITY OF AGRICULTURAL SOILS NEAR INDUSTRIAL ZONES OF THE CITY OF NOVI SAD

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**ABSTRACT**

*Due to the rapid increase of the urban population, food production in cities has become a modern need. Urban agriculture affects the urban environment, and is simultaneously affected by it. The aim of this study was to analyse the quality of soils for safe food production. A total of 15 soil samples were collected from agricultural top soils (depth 0-30 cm) from the vicinity of the industrial zones of the City of Novi Sad, Serbia. The collected samples were analysed for basic soil properties and pseudo-total content of trace elements. Soil pH value was dominantly slightly alkaline, and it was in correlation with carbonate content, which is a natural characteristic of a wider area. According to the readily available $P_2O_5$, analysed soils fell within the interval from very poor (<5 mg/100g) to toxic content (>50 mg/kg). Content of readily available $K_2O$ fell within the interval from poor (5-10 mg/100g) to high level (25-50 mg/100g). None of the analysed samples exceeded MAC for agricultural soils regarding the content of trace elements (Cu, Zn, As, Pb, Cd, Ni, and Cr). Analysed agricultural soils are suitable for safe food production. Farmers do not apply rational doses of mineral fertilizers. Excessive use of mineral fertilizers might affect the urban environment, which indicates the necessity for a broader training of farmers regarding optimal fertilizer doses.*

**Key words**: *soil, phosphorus, potassium, trace elements*.

## INTRODUCTION

Agricultural production is traditionally linked to rural areas. Nowadays, we are witnessing the rapid increase of urban population, and the food production in cities has been imposed as a great need of modern human society. In 2007, for the first time in human history, the rate of population inhabiting urban centres overtook the rural one. Projections indicate that by 2020, 55% of the world population will live in the urban centres, and this percentage will rise up to 60% and 70% in 2030 and 2050, respectively. The urban population expansion is more pronounced in developing countries as the result of rural-to-urban migration and natural population growth (Orsini et al., 2013; Eigenbrod and Gruda, 2015).

Analyses indicate that city soils are more polluted that those in rural areas (De Bon et al., 2010). Urban and peri-urban agriculture – jointly referred to as UPA, is perceived as agricultural practices within and around cities which compete for resources (land, water, energy, labour) that could also serve other purposes to satisfy the requirements of the urban population. The opportunities include: access to consumer markets, less need for packaging, storage and transportation of food, potential agricultural jobs and incomes, non-market access to food for poverty-struck consumers, availability of fresh, perishable food, proximity to services, including waste treatment facilities, waste recycling and re-use possibilities. On the other hand, the risks include: environmental and health risks from inappropriate agricultural and aqua-cultural practices, increased competition for land, water, energy, and labour, as well as reduced environmental capacity for pollution absorption (FAO, 1997). Therefore, urban agriculture affects and is also affected by the urban environment (Orsini et al., 2013).

Novi Sad is the second largest city in Serbia after capital city Belgrade, with estimated population of about 370,000. It is located in the southern part of the Pannonian Plain on the Danube River. A large part of Novi Sad lies on a fluvial terrace with an elevation of 72-80 m above sea level (latitude 45$^o$ 15’ N; longitude 19$^o$ 50’ E). Potential sources of soils pollution in the city are related to industrial, commercial, agricultural activities, and automobile exhaust (Škrbić and Đurišić-Mladenović, 2013).

The aim of this study was to analyse the quality of soils for safe food production near industrial zones of the City of Novi Sad. Industrial emissions used to be the main source of pollution, but a set of legislative acts and general compliance with EU regulations decreased this, especially regarding monitoring emission to air, water and land, and setting limit values. Another reason for reduced environmental pollution in the City of Novi Sad is a significant decrease of industrial production due to economic crisis.

## MATERIALS AND METHODS

### Study area and sample collection

Total of 15 soil samples were collected from 15 agricultural field plots from the vicinity of three large industrial zones in Novi Sad (North I, II, IV), near asphalt facility in the village of Rumenka, and in the vicinity of the public waste disposal site (Figure 1). These plots plots were under different crops, as can be seen in Table 1. The topsoil samples were taken from the depth 0-30 cm. This depth was chosen as a zone of the most active root systems of vegetable crops. The samples were taken using a soil drill agrochemical probes and stored in polyethylene bags. One composite sample represented 20-25 subsamples from random points in each sampling site. The initial quantity of samples was approximately 1.5 kg. The soil samples were air-dried at room temperature, milled and sieved to a particle size of <2 mm, in accordance with ISO 11464: 2006.

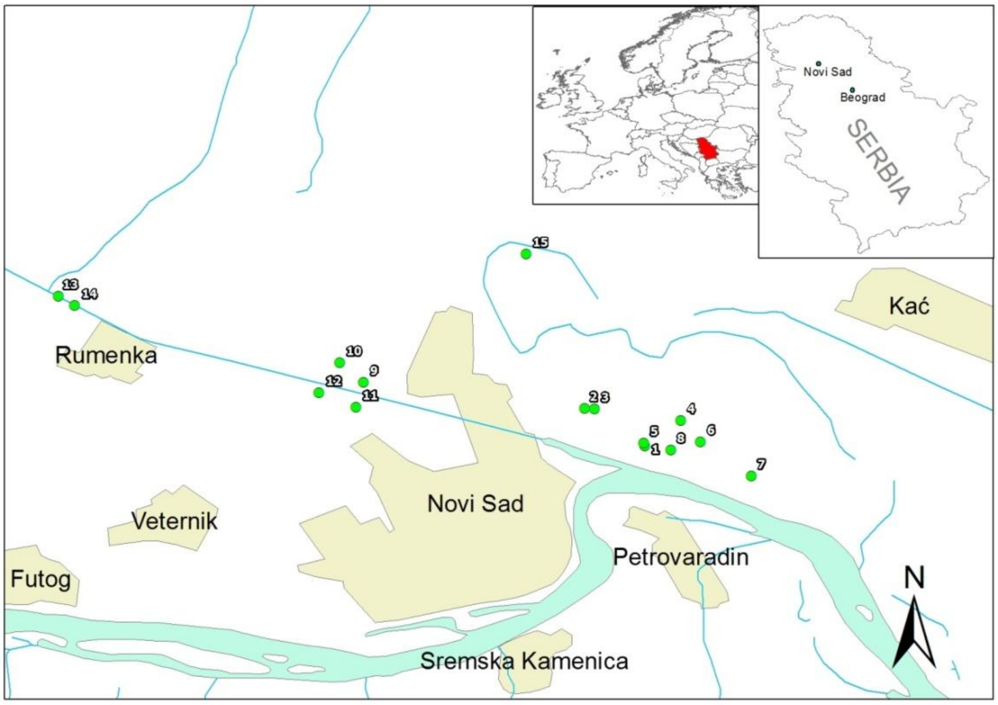


*Figure 1. Locations of collected soil samples*

### Laboratory analysis

All laboratory analyses were performed in the Laboratory for Soil and Agroecology of the Institute of Field and Vegetable Crops, Novi Sad, Serbia, accredited according to the standard ISO/IEC 17025: 2005.

The pH value 1:5 (V/V) suspension of soil in 1 mol/L KCl was determined using glass electrode according to ISO 10390: 2005. The carbonate content, as $CaCO_3$ content, was determined according to ISO 10693: 1995 volumetric method. The organic matter (OM) content was measured by oxidation using the sulphochromic oxidation method by ISO 14235: 1998. Available phosphorus ($P_2O_5$) and available potassium ($K_2O$) were determined by ammonium lactate extraction (Egner and Riehm, 1955), followed by spectrophotometry and flame photometry detection, respectively.

The samples were analysed for pseudo-total contents of Cu, Zn, Co, As, Pb, Cd, Ni and Cr after microwave digesting the soil in concentrated $HNO_3$ and $H_2O_2$ (5 $HNO_3$ : 1 $H_2O_2$, and 1 : 12 solid : solution ratio) by stepwise heating up to 180$^o$C using a Milestone Vario EL III for 55 min. The concentrations of the elements were determined by ICP-OES (Vista Pro-Axial, Varian). Quality control was periodically carried out with IRMM BCR reference materials 143R and deviations were within ±15% of the certified values.

## RESULTS AND DISCUSSION

### Basic soil properties

Soil pH value ranged from 5.69 (slightly acid) to 7.62 (slightly alkaline) with an average value 6.91±0.60 (neutral) (Table 1). Based on the share of individual samples, soil pH was dominantly slightly alkaline. Soil pH is an important parameter that reflects the course of other physical and chemical reactions in the soil. Initially, pH is conditioned by pedogenic factors, but at the same time it is affected by anthropogenic factors due to fertilization, practice in managing organic matter, occurrence of acid rains, etc. Neutral reaction of soils is desirable because it implies lower availability of heavy metals.

*Table 1: Basic soil properties*

| No | Location | Crop | pH in KCl | $CaCO_3$ % | Organic matter % | AL-$P_2O_5$ mg/100g | AL-$K_2O$ mg/100g |
|---|---|---|---|---|---|---|---|
| 1 | North IV-1 | vegetable | 7.12 | 10.4 | 4.46 | 81.9 | 14.7 |
| 2 | North IV-2 | orchard | 7.37 | 14.5 | 2.64 | 10.1 | 5.8 |
| 3 | North IV-3 | soybean | 6.55 | 19.3 | 2.12 | 138.5 | 30.5 |
| 4 | North IV-4 | soybean | 7.35 | 11.9 | 2.99 | 16.6 | 12.7 |
| 5 | North IV-5 | vegetable | 7.36 | 15.6 | 3.49 | 54.4 | 10.0 |
| 6 | North IV-6 | maize | 7.24 | 15.0 | 3.55 | 10.3 | 12.7 |
| 7 | North IV-7 | wheat | 7.32 | 19.7 | 2.50 | 15.8 | 13.1 |
| 8 | North IV-8 | oilseed rape | 7.22 | 12.8 | 4.58 | 6.0 | 10.7 |
| 9 | North I-1 | soybean | 5.84 | 0.2 | 2.54 | 7.8 | 28.5 |
| 10 | North I-2 | soybean | 6.13 | 0.6 | 2.78 | 6.2 | 29.4 |
| 11 | North II-1 | alfalfa | 5.69 | 0.3 | 2.22 | 3.5 | 21.7 |
| 12 | North II-2 | maize | 6.61 | 0.6 | 3.14 | 29.0 | 30.5 |
| 13 | Rumenka-1 | strawberry | 7.06 | 0.8 | 3.37 | 12.7 | 29.3 |
| 14 | Rumenka-2 | maize | 7.16 | 1.9 | 2.18 | 11.3 | 24.5 |
| 15 | Waste site | soybean | 7.62 | 13.5 | 2.39 | 22.0 | 10.0 |
| Min | | | 5.69 | 0.2 | 2.12 | 3.50 | 5.81 |
| Max | | | 7.62 | 19.7 | 4.58 | 138.50 | 30.52 |
| Average ±SD | | | 6.91 ±0.60 | 9.1 ±7.50 | 3.00 ±0.77 | 28.41 ±37.07 | 18.94 ±9.05 |

According to the carbonate content, as $CaCO_3$ content, tested samples belong to a category from slightly calcareous (<2%) to highly calcareous soil (>10%) (Table 1). According to average value of $CaCO_3$ content, soils belong to the category of calcareous (5-10%) with a wide range of results (Table 1). Carbonate content in soils is always correlated with soil pH. Such pH and carbonate content is a natural characteristic of a wider area (Milić et al. 2011).

The content of organic matter (OM) ranged from slightly humic to humic soil. According to the average value of organic matter content, soils belong to the category of humic (3-5%) (Table 1). Study on the role of OM in metal mobility presents apparently contradictory results. Soil OM has a high binding capacity for cationic and organic contaminants, which might lead to immobilization of metal ions. In other studies, however, the degradation of OM released low molecular weight of organic acids that bound metals and increased metal solubility. As reported by Murray et al. (2011), compost amendment increased the accumulation of metals in the vegetables.

Readily available $P_2O_5$ in agricultural soils ranged from very poor (<5 mg/100 g) to toxic levels (<100 mg/kg) with mean value 28.41 ±37.07 mg/100 g, which belongs to the high content (50-100 mg/100 g). Based on the share of individual samples, four of the analysed agricultural soils belong to the category over optimum content (>25 mg/100g) (Table 1).

Readily available $K_2O$ in agricultural soils ranged from poor to high levels with mean value 18.94 ±9.05 mg/100 g that belongs to optimum level. The results had wide range in both nutrients parameters (readily available $P_2O_5$ and $K_2O$ content) (Table 1).

Despite many efforts to increase productivity, water and fertilizers are the major inputs used in agricultural production to provide disease- and pest-resistant varieties and to develop techniques for small areas (De Bon et al. 2010). According to Milić et al. (2011), the soil of broader study area (South Bačka) used for field crop production, averagely contains 33% of areas that have the optimum P levels, while 30% of areas has higher than this level (dominantly in high P class, 21%). In that study 44% of areas had the optimum level of K, while K content above this level was found in 51% of areas (dominantly in high K class, 45%). Such distribution of nutrients in broader study area is a consequence of irrational and excessive use of fertilizers, and in case of K content – present pedological soil loess, which is naturally rich in potassium. Excessive nutrient levels in urban garden soils were studied worldwide (Witzling et al. 2011; Abdulkadir et al. 2013; Gregory et al. 2015; Joimel et al. 2016; Yesilonis et al. 2016). Authors indicate the importance of education and soil testing, which is insufficiently practiced. Excessive use of fertilizers in urban gardens is a serious pressure on urban environment, since these nutrients can enter open watercourses and ground water by rinsing (Cheng et al. 2014; Pfeifer and Bennett, 2011).

**Heavy metals content**

Urban soils carry greater risk of pollution by heavy metals from anthropogenic sources. The largest sources of this contamination are heavy industry and run-off from highway drains. The degree and direction of the slope from the interstate toward the soil plot is an important factor (Trammell et al. 2011). Exposure of the human population to potentially toxic elements (PTE), such as lead (Pb), copper (Cu), chromium (Cr), nickel (Ni), and zinc (Zn) in agricultural soils may occur through inhalation of particles or through the consumption of soil or vegetables and fruit grown in contaminated soils (Boim et al. 2016).

The concentration of heavy metals in urban grown vegetables is strictly related to the site in the city where plants are grown. When plants are cultivated near pollution sources (e.g. main roads), risks of heavy metal accumulation increases (about 1.5-fold when vegetables are grown 10 m from the road as compared to 60 m away) (Antisari et al. 2015). Risk assessment of heavy metals in soils is especially important for vacant lots slated for urban agriculture in post-industrial city (Sharma et al 2015).

According to the criteria for MAC (Maximum Available Concentration) for agricultural land (Official Gazzette RS 23/1994), no agricultural soil samples exceeded MAC (Table 2).

*Table 2: Heavy metals content*

| No | Location | Cu | Zn | Co | As | Pb | Cd | Ni | Cr |
|---|---|---|---|---|---|---|---|---|---|
| | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| 1 | North IV-1 | 40.2 | 111.9 | 9.6 | 5.1 | 31.5 | 0.37 | 32.5 | 23.6 |
| 2 | North IV-2 | 18.8 | 56.2 | 8.8 | 7.9 | 17.8 | 0.36 | 24.2 | 28.4 |
| 3 | North IV-3 | 44.2 | 91.1 | 10.7 | 13.5 | 22.5 | <0.10 | 33.0 | 34.8 |
| 4 | North IV-4 | 27.7 | 88.3 | 11.6 | 10.4 | 19.0 | <0.10 | 36.7 | 53.0 |
| 5 | North IV-5 | 34.1 | 112.5 | 11.4 | 8.0 | 30.4 | <0.10 | 35.6 | 34.5 |
| 6 | North IV-6 | 30.2 | 85.9 | 11.5 | 6.7 | 26.7 | 0.28 | 34.5 | 39.3 |
| 7 | North IV-7 | 25.4 | 69.5 | 11.1 | 8.9 | 28.1 | 0.34 | 34.6 | 24.9 |
| 8 | North IV-8 | 25.1 | 90.0 | 10.9 | 10.2 | 29.5 | 0.52 | 33.3 | 38.9 |
| 9 | North I-1 | 23.8 | 60.3 | 13.0 | 6.0 | 26.4 | 0.29 | 36.5 | 30.8 |
| 10 | North I-2 | 25.2 | 83.1 | 13.9 | 14.0 | 26.3 | 0.47 | 43.2 | 58.2 |
| 11 | North II-1 | 24.4 | 57.5 | 13.8 | 7.9 | 26.5 | 0.29 | 37.1 | 30.1 |
| 12 | North II-2 | 28.1 | 92.1 | 15.0 | 13.9 | 28.1 | 0.55 | 43.6 | 54.8 |
| 13 | Rumenka-1 | 24.2 | 68.1 | 12.4 | 9.0 | 20.8 | 0.14 | 36.3 | 44.6 |
| 14 | Rumenka-2 | 26.1 | 81.9 | 14.1 | 9.1 | 24.6 | 0.26 | 45.5 | 63.2 |
| 15 | Waste site | 14.7 | 88.9 | 6.7 | 5.5 | 15.4 | <0.10 | 19.5 | 22.9 |
| MAC | | 100.0 | 300.0 | / | 25.0 | 100.0 | 2.00 | 50.0 | 100.0 |
| Min | | 14.7 | 56.2 | 6.7 | 5.1 | 15.4 | 0.14 | 19.5 | 22.9 |
| Max | | 44.2 | 112.5 | 15.0 | 14.0 | 30.4 | 0.55 | 45.5 | 63.2 |
| Average ±SD | | 26.6 ±7.5 | 80.4 ±17.4 | 11.8 ±2.2 | 9.4 ±2.9 | 24.4 ±4.8 | 0.35 ±0.1 | 35.3 ±6.7 | 39.9 ±13.2 |

Average copper content in soil was 26.6±7.5 mg/kg, which is higher than background concentration for Vojvodina soils of 17.1 mg/kg (Kastori, 1993). Anthropogenic effect is indicative based on previous studies (Ralev et al., 2003; Ninkov et al.; 2012) as a consequence of the application of copper based fungicides.

Average content of pseudo-total zinc in agricultural soils was 80.4±17.4 mg/kg. Zinc in soil near roads could have been deposited by the wear and tear of vehicle bodies with common galvanizing of steel surfaces (Jim, 1998). In the others studies (Škrbić and Đurišić-Mladenović, 2013; Joimel et al. 2016), zinc content was also higher in urban garden soils then in cultivated soils. In studies at the same site (City of Novi Sad), the origin of Zn from anthropogenic sources was confirmed (Mihailović et al., 2015).

Average content of pseudo-total cobalt in agricultural soils was 11.8±2.2 mg/kg. Cobalt pseudo-total content does not have MAC defined in the Regulation on agricultural soils. Content of Co was above background limit for European soils which is 20 mg/kg (Houskova and Montanarella, 2006). According to previous studies at the same site (the City of Novi Sad), the mean value of Co in urban soil was 7.3 (Mihailović et al., 2015), or 14.3 mg/kg (Škrbić and Đurišić-Mladenović, 2013), while in rural soil it was 15.7 mg/kg (Škrbić and Đurišić-Mladenović, 2013), at 0-10 cm soil depth.

Average content of pseudo-total arsenic in agricultural soils was 9.4±2.9. Generally, the analysed soils are not at risk of environmental pollution with arsenic, which is good news since it is an extremely toxic metal.

Average content of pseudo-total lead in agricultural soils was 24.4±4.8. Lead is one of the most common contaminants in urban areas with its origin in vehicle exhaust gases (Davies, 1995). Tendency of lowering lead concentration in soil is still slow even after it was forbidden as gasoline additive due to its habit to accumulate in soil and bind to soil components. In previous studies at the same site (the City of Novi Sad), Pb content was higher in urban soil than in rural (Škrbić and Đurišić-Mladenović, 2013), while it was confirmed that lead originated from anthropogenic source (Mihailović et al., 2015; Sharma et al., 2015). In the soil of gardens of the City of Chicago, the overall mean lead level was 135 ppm; individual soil samples from gardens ranged from 10 to 889 ppm, a level high enough to cause concern (Witzling et al., 2011).

Average content of pseudo-total cadmium in agricultural soils was 0.35±0.1. According to previous studies at the same site (the City of Novi Sad), the mean value of Cd in urban soil was 1.59, and in rural 1.73 mg/kg (Škrbić and Đurišić-Mladenović, 2013), at the 0-10 cm soil depth.

Average content of pseudo-total nickel in agricultural soils was 35.3±6.7. Some other cases were reported where Ni content in broader study area was above the MAC, and their geochemical origin was confirmed (Dozet et al., 2011). According to previous studies at the same site (City of Novi Sad), mean value of Ni in urban soil was 28.7 (Mihailović et al., 2015), or 23.2 (Škrbić and Đurišić-Mladenović, 2013) mg/kg, and in rural soil it was 29.8 mg/kg (Škrbić and Đurišić-Mladenović, 2013), at 0-10 cm soil depth.

Average content of pseudo-total chromium in agricultural soils was 39.9±13.2. In the same case as Ni, some studies reported where Cr content in broader study area was above the MAC, and their geochemical origin was confirmed (Sekulić et al., 2011)

Since heavy metals content was below MAC value in the whole study, none of the analysed field plots near industrial zones has quality limited by those elements.

## CONCLUSION

Soil pH was dominantly slightly alkaline, and it was correlated with carbonate content, which is a natural characteristic of a wider area. According to the readily available $P_2O_5$, analysed soils fell within the interval from very poor (<5 mg/100g) to toxic content (>50 mg/kg). Content of readily available $K_2O$ fell within the interval from poor (5-10 mg/100g) to high level (25-50 mg/100g). None of the analysed samples exceeded MAC for agricultural soils regarding the content of trace elements (Cu, Zn, As, Pb, Cd, Ni, and Cr). Analysed agricultural soils are suitable for safe food production. Farmers do not apply rational doses of mineral fertilizers. Excessive use of mineral fertilizers might affect the urban environment, which indicates the necessity for a broader training of farmers regarding optimal fertilizer doses.

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## REFERENCES

Abdulkadir, A., Leffelaar, P.A., Agbenin, J.O., Giller, K.E. (2013). Nutrient flows and balances in urban and peri-urban agroecosystems of Kano, Nigeria. *Nutrient Cycling in Agroecosystems*, 95, 231–254.

Antisari, L.V., Orsini, F., Marchetti, L., Vianello, G., Gianquinto, G. (2015). Heavy metal accumulation in vegetables grown in urban gardens. *Agronomy for Sustainable Development*, 35, 1139–1147.

Boim, A.G.F., Melo, L.C.A., Moreno, F.N., Alleoni, L.R.F. (2016). Bioconcentration factors and the risk concentrations of potentially toxic elements in garden soils. *Journal of Environmental Management*, 170, 21–27.