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Urban garden soil pollution caused by fertilizers and copper-based fungicides application

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Summary: Urban gardening is an activity that has been rapidly increasing. The aim of this study was to point out the common mistakes in cultivation practices made by producers on small city areas. Total of 96 individual plots under vegetable crops were sampled (56 from garden plots of the city of Novi Sad, and 40 from field plots in the suburbs). There was no significant difference in the content of organic matter between these two groups of tested soils. The contents of readily available P_2O_5 and K_2O were significantly higher in garden soil than in the field plots for production of vegetables. According to the content of pseudototal copper, 39% of samples belonged to the category of critical concentration and/or above MAC in the urban soil. Obtained results prove the pollution of small area gardens due to high anthropogenic effect of excessive use of mineral fertilizers and copper-based fungicides.

Key words: fertilizing, gardens, soil pollution

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 & Gruda, 2015). The current extent of urban agriculture across the globe is very poorly understood. Highly frequent citation estimate is that of Smit et al. (1996) who suggested that 20 years ago 800 million people were actively engaged in urban agriculture (many as consumers), with 200 million farmers producing for the market. The global and regional extent of urban agriculture needs to be quantified far more rigorously (Hamilton et al., 2014). According to FAO data (FAO 1997), "urban" agriculture refers to small areas within the city (e.g. vacant plots, gardens, verges, balconies, containers) for growing crops and raising small livestock or milk cows for own-consumption or sale in neighbourhood markets. "Peri-urban" agriculture refers to farm units close to town that operate intensive semi or fully commercial farms to grow vegetables and other horticulture, raise chickens and other livestock, and produce milk and eggs. It should be pointed out that the main activity in urban and peri-urban agriculture is horticulture, especially vegetable production, while livestock activities are less frequent. Urban horticultural activities are increasing globally with at least 100 million people involved worldwide. With potential yields of up to 50 kg per m² per year and more, vegetable production is the most significant component of urban food production (Eigenbrod & Gruda, 2015). In addition, urban gardens are characterized by more crop rotations and biological diversity than peri-urban areas (Orsini et al., 2013; Eigenbrod & Gruda, 2015). 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,

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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 aquacultural practices, increased competition for land, water, energy, and labour, reduced environmental capacity for pollution absorption (FAO, 1997). Therefore, urban agriculture affects and is also affected by the urban environment (Orsini, et al., 2013). Eigenbrod & Gruda (2015) described more kinds of urban horticulture by the manner of cultivation. Traditional growing systems consist of home gardening, community gardening (collective cultivation of plants by various people on a shared area), continuous productive urban landscapes, or "edible cities" (integrating urban horticulture, green corridors, and areas for leisure outdoor activities into cities' infrastructures as essential elements). Innovative cropping systems are soilless cultures and organoponics. Indoor farming systems are building integrated agriculture, vertical farming and new technologies for indoor farming. Therefore, "field" in peri-urban and urban areas can vary from one hectare to one square meter for organoponic beds in buildings; the "field" can also be a pond to grow aquatic vegetables (De Bon et al., 2010). It should be pointed out that the urban agriculture includes other interrelated activities, such as the production and selling of agricultural inputs, and postharvest handling and marketing of agricultural produce (Orsini et al., 2013). Multi-functionality of urban horticulture has the following benefits: socioeconomic, cultural, educational, and recreational, ecological/environmental (Orsini et al., 2013). Benefits of urban agriculture must be actively managed at multiple scales for the benefit of humans and nonhumans (Taylor & Lovell, 2014).

The current multi-functionality of urban horticulture will become crucial for the sustainability of city food supply in the future. To enhance sustainability, urban horticulture has to be integrated into the urban planning process, urban master plans and supported through policies (Orsini et al., 2013; Eigenbrod & Gruda, 2015). The promotion of the multiple functions of urban agriculture is a major challenge for the future. There is a growing need for documentation of the successful integration of urban agriculture into urban development, and on the conditions necessary for its social, economic and environmental sustainability (De Bon et al., 2010). Some authors raise questions on sustainability of urban agriculture compared to the conventional one (Mok et al., 2014). Orsini et al. (2013) emphasized that guidelines on appropriate urban and peri-urban agricultural practices are required, which can be properly understood and followed only with raised awareness in the population (all consumers, actors of the food chain, and policy makers as well) and a better education. The aim of this study was to indicate the common mistakes in cultivation practices (excessive use of agrochemicals) made by producers on small city areas by comparing soil quality from garden plots and field vegetable crops production. In this paper, suburb areas were not described by phrase "peri-urban", but "field plots soil" because tested area (City of Novi Sad) has no megalopolis character, and "field plots soil" of the suburbs has completely rural character.

There are no certain data on the use of mineral fertilizers and pesticides in the Republic of Serbia. Only data on the volume of imports and domestic production are monitored through the established system of institutional statistics. According to FAO data (FAOSTAT, 2017), Republic of Serbia had consumption of 157 kg/ha of fertilizers in 2014, which is close to European and world average (160 and 140 kg/ha, respectively). In the period 2006-2014, maximum fertilizer consumption was 220 kg/ha (2012), while minimum was 144 kg/ha (2010). According to the data, fertilizer consumption in the Republic of Serbia is very similar to neighbouring countries, although it is often stated that Serbia has much lower consumption than EU countries and region.

Material and Methods

Study area and sample collection

Novi Sad is the second largest city in Serbia after Belgrade, with population estimated to be about 370,000. It is located in the southern part of the Pannonian Plain on the Danube River. The subject of the study was quality of soil for production of vegetable crops both in small garden plots (area from 100 to 900 m^2) and field soil plots in the suburb areas (area from 0.5 to 4 ha). Total of 96 individual plots under vegetables were sampled; 56 out of that number came from garden plots in City of Novi Sad, and 40 from field plots in the suburban areas (Fig. 1).

The investigated area of Novi Sad is completely covered by Holocene alluvial deposits. These alluvial sediments are characterized by different grain size and textures that have been formed by The Danube River fluvial activity. The terrace consists of Holocene sand shoals, sandy clay and sand. Meandering of the Danube River created typical fluvial morphology including many point bars and related inter depressions. The whole part of Novi Sad area lies on a fluvial terrace with an elevation of 72-80 m above sea level (latitude 45° 15' N; longitude 19° 50' E). Autochthonous (indigenous) soil type is fluvisol according to World reference base for soil resources (WRB, 2014). According to the pedological map (Živković, 1972) and the shown figure (Fig. 1), all sites of urban garden soil belong to fluvisol soil type. Sites of field plots belong to the chernozem soil type, except for two sites (Veternik and Kovilj), which belong to fluvisol soil type.

The topsoil samples were taken from the depth 0-30 cm. This depth was chosen as a zone of the most active

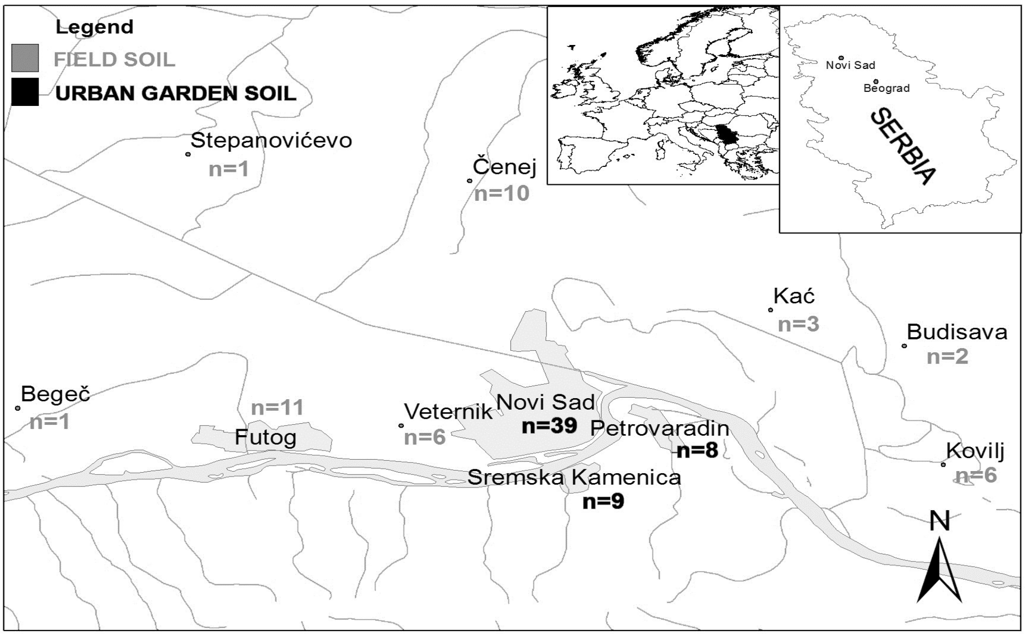

Figure 1. Locations of taken soil samples

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 (room temperature), milled and sieved to a particle size of <2 mm, in accordance with ISO 11464: 2006.

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 & Riehm, 1955), followed by spectrophotometry and flame photometry detection, respectively. Total N was determined according to the AOAC 972.43: 2000 method by elemental analysis on the CHNS analyser Vario EL III, Elementar. The samples were analysed for pseudototal contents of Cu, Zn, Co, 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°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.

Statistical analysis

Parameters of descriptive statistics: average, minimum, maximum value, standard deviation (st. dev.), coefficient of variation (CV) and standard error of mean (st. error) were performed. The significances of the differences in the soil properties between the garden and field plots soils were determined using the Duncan multiple range test ($p \leq 0.05$). In order to confirm the relationship among different chemical traits in soil, a Pearson's correlation analysis was applied to dataset. All statistical analyses were performed using the data analysis software system Statistica for Windows, version 12 (Dell, 2015).

Results

Basic soil properties: pH, $CaCO_3$, organic matter and total N content

pH value of garden soil ranged from 6.34 (slightly acid) to 7.86 (slightly alkaline) with an average value 7.21 (slightly alkaline) and it is significantly higher than in field plots. pH value of field soil ranged from 4.21 (highly acid) to 7.49 (slightly alkaline) with an average value 6.90 (neutral) with wider result range than in garden soils (Tab. 1). According to the content of available $CaCO_3$, tested samples belong to a category from limeless (0%) to highly calcareous soil (>10%). Content of $CaCO_3$ is significantly positively correlated to pH value in garden soils (r=0.55), while this correlation was not determined in field soils. According to average value of $CaCO_3$ content, garden soils belong to the category of calcareous, while field soils belong to medium calcareous soils with significant difference of these two categories and with wide range results (Tab. 1). The content of organic matter OM ranged from slightly humic to humic soil in garden plots, and in field plots up to highly humic soil, with wide range results. There is no significant difference in the content of organic matter between these two groups (Tab. 1). Total N content is highly correlated to the content of organic matter (r=0.71 garden; r=0.86 field). In addition, significant difference between the content of total N in graden and field soils for vegetable production was not determined (Tab. 1).

Content of readily available nutrients P_2O_5 and K_2O

Readily available P_2O_5 in garden soils ranged from medium to toxic levels with mean value 115.5 mg/100 g, which belongs to the toxic level. In field soils, the content of P_2O_5 ranged from very poor to toxic levels with mean value 31.5 mg/100 g, which belongs to high content. The results had wide range in both categories of soil usage. The content of P_2O_5 in garden soils was significantly higher than in field soils (Tab. 1). Based on the share of individual samples, half of the analysed garden soils belong to the category with toxic content of P_2O_5, while only 5% of field soils belong to this category (Fig. 2).

Readily available K_2O in garden soils ranged from medium to toxic levels with mean value 43.1 mg/100 g that belongs to high level. In field soils, the content of K_2O ranged from medium through high to harmful levels, with mean value 29.0 mg/100 g, which, also, belongs to high content. The results had wide range in both categories of soil usage. Same as the content of P_2O_5, the content of K_2O in garden soils was significantly higher than in field soils (Tab. 1). Based on the share of individual samples, a third of analysed garden soils belong to category with K_2O content very high to harmful, and 2% is in toxic class. In the soil of field plots, 8% of tested samples had very high to harmful content of K_2O (Fig. 3).

Heavy metals content

The content of pseudototal Cu, Zn and Cd was significantly higher in garden than in field soil (Tab. 2). Contrary, contents of Co and Cr were significantly higher in field soil than in garden plots. According to the contents of Ni and Pb, there was no significant difference between these two soil categories (Tab. 2). According to the criteria for MAC (Maximum Available Concentration) for agricultural land (Official Gazzette RS 23/1994), eight samples of garden soil exceeded MAC for Cu content, one for Pb and nine for Ni content. Only one sample in field soils exceeded MAC and that was for Ni content. In garden soils, Cu content ranged from 18.0 to 422.0 mg/kg, mean value was 68.0 ± 70.7 mg/kg. Soil under arable vegetable production had Cu content from 12.9 to 64.6 mg/kg, mean value was 23.3 ± 7.8 mg/kg (Tab. 2). Average Cu content in soil under field vegetable production was close to background concentration for Vojvodina soils, that is 17.1 mg/kg (Kastori, 1993). Based on soil analysis from garden plots of the City of Novi Sad, only one quarter

Table 1. Statistical summary and difference of basic soil properties between urban garden and field soil for vegetable production

Variable	pH 1M KCl	$CaCO_3$ [%]	OM [%]	N [%]	P_2O_5 [mg/100g]	K_2O [mg/100g]
Garden soil – Average	7.21^a	9.96^a	3.16^a	0.185^a	115.5^a	43.1^a
Garden soil – Minimum	6.34	0.34	1.32	0.069	10.3	12.7
Garden soil – Maximum	7.86	25.26	4.94	0.302	334.5	102.5
Garden soil – St. dev.	0.29	5.57	0.79	0.05	85.22	19.49
Garden soil – CV [%]	4.07	55.89	24.93	25.03	73.79	45,22
Garden soil – St. Error	0.04	0.74	0.11	0.01	11.39	2.60
Field plots – Average	6.90^b	3.53^b	2.86^a	0.185^a	31.5^b	29.0^b
Field plots – Minimum	4.21	0.00	1.38	0.089	1.7	14.1
Field plots – Maximum	7.49	21.44	6.11	0.298	203.0	68.0
Field plots – St. dev.	0.55	4.11	1.06	0.06	37.33	12.33
Field plots – CV [%]	7.93	116.53	37.25	32.07	118.47	42.44
Field plots – St. Error	0.09	0.65	0.17	0.01	5.90	1.95

Values are marked with same letter do not differ statistical significance (according to the Duncan multiple range test, $p \leq 0.05$)

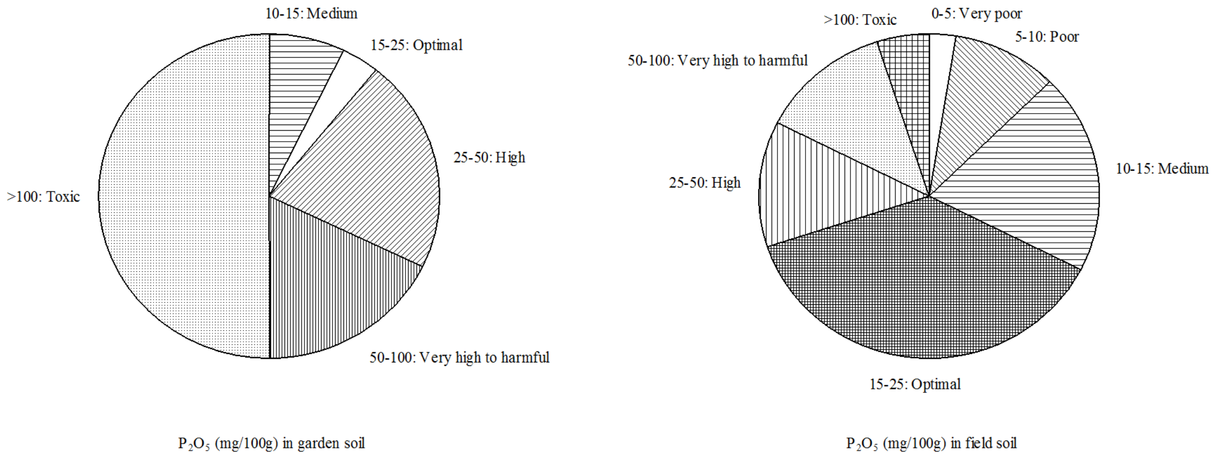

Figure 2. Distribution of soil samples by categories of readily available phosphorus

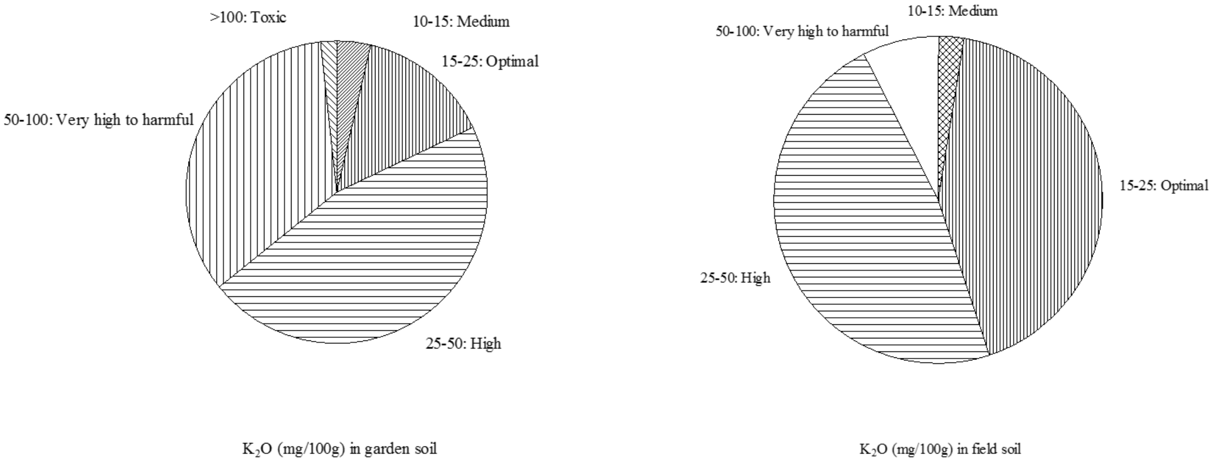

Figure 3. Distribution of soil samples by categories of readily available potassium

of samples was at the level of background Cu concentration (<30 mg/kg) (Fig. 4). Cu content above the background and below the critical concentration (30 -60 mg/kg) was recorded in 36% of samples. Pseudototal Cu above the critical concentration and below MAC (60-100 Cu mg/kg) was determined in one quarter of tested soil samples from the gardens. A total of 9% of tested gardens was in the interval above MAC (100-200 Cu mg/kg), while 5% of tested garden areas had above 200 mg/kg Cu (Fig. 4). Cu content above 200 mg/kg requires recovery and remediation of the soil (Hinsenveld 1991; Regulation RS 88/10).

Average content of pseudototal Zn in urban garden soils was 115.4 ± 39.0, while in field plots it was 66.4 ± 12.0 mg/kg. Content of Zn is statistically higher in the soils of gardens (Tab. 2). Average content of pseudototal Co was 9.7 ± 2.4 and 11.3 ± 2.7 mg/kg in urban garden and field plots, respectively. Content of Co is statistically higher in field plot soils than in the garden soils (Tab. 2). Average content of pseudototal Pb in urban garden soil was 58.0 ± 180.8, while in field plots it was 24.0 ± 3.6 mg/kg. There is no significant difference between these two groups. Pb content was elevated in one garden soil sample in extremely high concentrations of 1382.5 mg/kg (Tab. 2). Average content of pseudototal Cd in urban garden soil was 1.11 ± 0.41, and in field plots 0.86 ± 0.64 mg/kg. Content of Cd is statistically higher in the soils of gardens (Tab. 2). Average content of pseudototal Ni in urban garden soil was 32.5 ± 21.3, and in field plots 37.7 ± 5.0 mg/kg. There is no significant difference between contents of Ni in garden and field soils. Out of 56 analysed garden soil samples, 9 had Ni content above MAC. In the soil for field vegetable production, one of 40 tested samples exceeded MAC (Tab. 2). Average content of pseudototal Cr in urban garden soil was 20.0 ± 9.5, while in field plots it was 28.6 ± 7.5 mg/kg. The content of Cr is significantly higher in the soil of field vegetable production than in urban garden soil (Tab. 2).

Table 2. Statistical summary and difference of heavy metals in soil between urban garden and field soil for vegetable production

[mg/kg]	Cu	Zn	Co	Pb	Cd	Ni	Cr
Garden soil – Average	68.0^{a}	115.4^{a}	9.7^{b}	58.0^{a}	1.11^{a}	32.5^{a}	20.0^{b}
Garden soil – Minimum	18.0	54.3	5.5	16.0	0.23	2.0	5.0
Garden soil – Maximum	422.0	214.7	15.7	1382.5	2.05	92.3	41.5
Garden soil – St. dev.	70.75	39.05	2.39	180.79	0.41	21.13	9.55
Garden soil – CV [%]	104.11	33.83	24.72	311.85	36.91	65.07	47.81
Garden soil – St. Error	9.46	5.22	0.32	24.16	0.05	2.82	1.28
Field plots – Average	23.3^{b}	66.4^{b}	11.3^{a}	24.0^{a}	0.86^{b}	37.7^{a}	28.6^{a}
Field plots – Minimum	12.9	43.3	7.1	17.4	0.18	28.2	15.1
Field plots – Maximum	64.6	90.5	17.4	33.5	1.70	53.8	44.3
Field plots – St. dev.	7.97	12.03	2.68	3.60	0.64	5.01	7.52
Field plots – CV [%]	34.26	18.12	23.73	14.97	74.83	13.28	26.28
Field plots – St. Error	1.26	1.90	0.42	0.57	0.10	0.79	1.19
MAC	100.0	300.0	/	100.0	3.00	50.0	100.0

Values that are marked with same letter do not differ statistical significance (according to the Duncan multiple range test, p≤0.05)

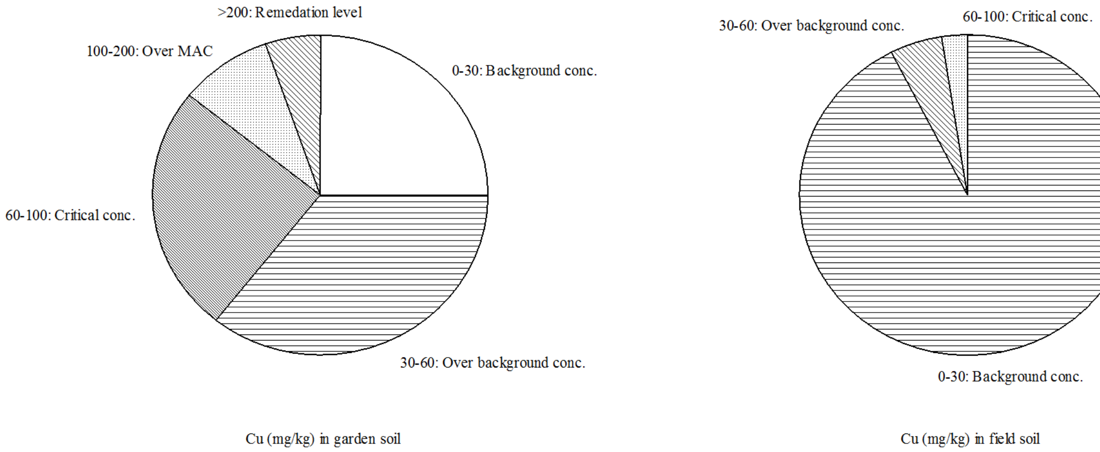

Figure 4 Distribution of soil samples by copper content

Discussion

pH value of the soil is an important parameter that reflects the course of other physical and chemical reactions in the soil. pH value is initially conditioned by pedogenetic 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. According to previous studies (Sekulić et al., 2011), the soils of broader studied area (Vojvodina Province) are neutral to slightly alkaline. Due to the aridity of the climate and geological substrates rich in bases (usually sedimentary rocks - loess), the soils of Vojvodina dominantly belong to the class alkali soils. Slightly alkaline reaction of soils is desirable because it implies lower availability of heavy metals. Contrary to the expected, there is no significant difference in the content of organic matter OM between urban garden and field plot soil. Compost application is the most common input of OM to urban gardens (Murray et al., 2011). According to De Bon et al. (2010), in developing countries the use of organic matter, although very frequent, is not so widespread in urban agriculture. The use of solid waste in urban agriculture is common in cities of developing countries. In studies of vacant urban land, it was confirmed that adding organic matter increases quality and productivity of soil (Beniston et al., 2016). Comparison of organic matter content in urban allotments to soils from the surrounding agricultural region, and in a typical UK city showed that urban soils were more quality in these parameters (Edmondson et al., 2014). In the study of quality of urban lawns depending on three management programs, proved that professional and do-it-yourself programs nagatively affect microbial biomass and soil organic matter in compare with no-input program (Cheng et al., 2008). Research 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. In study of Murray et al. (2011), compost amendment increased the accumulation of metals in the vegetables. Since two different soil types have been compared in this study: fluvisol as an urban garden soil and prevalently chernozem in field soil, stated differences are most probably the consequence of physical and chemical properties characteristic for the type of soil, but not for an antopogenic effect of land use. In future studies, it is necessary to choose locations with the same type of soil in order to determine the changes of pH, CaCO3, organic matter and total N content depending on the use of land. 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). Based on the share of individual soil samples per content categories (Fig. 2 and 3), 89% of garden soil areas was excessively fertilized with phosphorus and 82% with potassium, since these areas have higher content of nutrients than the optimum. In the soils of field plots, 31% and 56% of areas have higher P and K content than the optimum, respectively. Based on previous study (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 specified 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 (Abdulkadir et al., 2013; Gregory et al., 2016; 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 (Pfeifer & Bennett, 2011; Cheng et al., 2014). Analyses indicate that city soils are more polluted that those in rural areas (De Bon et al., 2010). 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 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 share of soil samples in specific classes by pseudototal copper content, strong anthropogenic effect was proved in gardens of small areas. In summary, based on shown distribution of tested soil samples from gardens of Novi Sad in classes by the content of pseudototal copper (Fig. 4), 39% of samples belong to the zone of critical concentration and/or above MAC. Risk assessment, soil monitoring and complete reduction of copper-based fungicide application should be performed on 39% of tested areas under garden vegetable production. Obtained results comply with studies where limit of Cu contamination was 40% of the urban soil samples in Hungary (Horváth et al., 2015). In addition, according to previous extensive study (Joimel et al., 2016), Cu content in orchards, vineyards and urban vegetable gardens was significantly higher compared to other manners of use. Share of soil samples in specific categories from areas under field vegetable production (Fig. 4) shows that these areas are not threatened by excessive use of copper. A total of 92% of tested samples are at the level of background Cu concentration (< 30 mg/kg). Cu content below critical concentration and above the background (30-60 mg/kg) was recorded with the share of 5%. One tested sample exceeded critical concentration, but it is still below MAC. This kind of distribution complies with previous soil studies under field vegetable production. In studies total of 1200 ha, none out of total 199 analysed samples exceeded the MAC. Average content of pseudototal Cu was 21.0 mg/kg and ranged from 15.5 to 78.6 mg/kg (Ralev et al., 2003). In studies at the same site (City of Novi Sad), Cu origin from anthropogenic sources was proved (Mihailović et al., 2015). Anthropogenic effect is indicative based on high value of standard deviation and wide range of results in garden soil. Since tested gardens are small, beside long application, high copper content in tested soil is a consequence of use of larger quantities of copper-based fungicides than the recommended. Due to low cost of copper preparation, individual producers who aim at higher yields often apply the content of one sprayer on much smaller area than recommended. Contamination is also stated as the major challenge in urban garden as a consequence of inappropriate use of pesticides (Karanja et al., 2010). Contamination of soils under vineyards due to excessive use of copper-based fungicides was widely studied (Besnard et al., 2001; Komarek et al., 2010). Copper accumulation in the soil negatively affects soil biota primarily (Paoletti et al., 1998; Merrington et al., 2002). In addition, it can be phytotoxic and it can negatively affect vine quality and yield (Ninkov et al., 2012). Recent studies indicated paradox that soils in organic production contain more Cu than soils under conventional production, which is a consequence of exclusive application of copper-based protective agents (Vavoulidou et al., 2005; Bjorn et al., 2008; Coll et al., 2011). Since Cu is very persistent in soil and accumulates in short period, the attention should be directed toward preventive measures of its application. Significant preventive measure is education of producers about the fact that application of copper-based pesticides is not completely safe, as it is widely considered to be nowadays. In addition, a significant preventive measure would be the development of science studies in the direction of possibility of copper-based fungicides application in lower concentrations than currently recommended. Statistically higher content of Zn in the soils of gardens can also be the consequence of copper-based fungicide application, since $CuSO_4$, as raw material used for making copper-based fungicides, contains high concentrations of other heavy metals, especially Zn and Pb (Mirlean et al., 2005; 2007). 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 & Đurišić-Mladenović, 2013; Joimel et al., 2016), Zn 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). Cobalt pseudototal 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 & Montanarella, 2006). Although the Co content was higher in field plot soils than in the garden soils, very close values were obtained in a narrow interval with relatively narrow result range. According to previous studies at the same site (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 & Đurišić-Mladenović, 2013), while in rural soil it was 15.7 mg/kg (Škrbić & Đurišić-Mladenović, 2013), at 0-10 cm soil depth. Lead content at one site with extremely high concentrations (1382.5 mg/kg) represents a limitation for primary plant production, especially vegetable. Although average Pb value is higher in garden soil than in field, there is no significant difference between these two groups. Lead is one of the most common contaminants in urban areas with its origin in vehicle exhaust gases (Davies, 1995). Tendency of lowering Pb 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 (City of Novi Sad), Pb content was higher in urban soil than in rural (Škrbić & Đurišić-Mladenović, 2013), while it was confirmed that Pb 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 Pb 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). Cadmium content was below limit MAC value in the whole study. Generally, the analysed soils are not at risk of environmental pollution with Cd, which is good news since it is extremely toxic metal. Average value of Cd in garden soil is significantly higher than in field production, which indicates both potential anthropogenic effect and the importance of further monitoring of urban garden soils. According to previous studies at the same site (City of Novi Sad), the mean value of Cd in urban soil was 1.59, and in rural 1.73 mg/kg (Škrbić & Đurišić-Mladenović, 2013), at the 0-10 cm soil depth. The results of pseudototal Ni content had wider range in urban garden soil than in field soil, which indicatively shows that increased Ni content can originate from anthropogenic sources. 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 & Đurišić-Mladenović, 2013) mg/kg, and in rural soil it was 29.8 mg/kg (Škrbić & Đurišić-Mladenović, 2013), at 0-10 cm soil depth. Since Cr content was below MAC value in the whole study, none of these two categories (garden and field vegetable soils) is quality limited by this element. When calculating the concentration of risk for Cr, it is suggested that difference from Cr^{III} and Cr^{VI} (which is much more toxic) should be made (Boim et al., 2016). Results obtained in this study are very similar to extensive study of Joimel et al. (2016), where soil characteristics were compared by the manner of usage: forest, grassland, cultivated, orchards and vineyards, urban vegetable gardens and industrial land uses. It was confirmed that human activities increase metal contamination along an anthropization gradient in the abovementioned study.

Conclusion

Based on comparison of 96 soil samples (0-30 cm depth), out of which 56 belong to urban garden soil, and 40 to field plots for vegetable production, the following was determined: pH value and the content of $CaCO_3$ was significantly higher in urban garden soil. The content of organic matter ranged from slightly humic do highly humic soil, and there was no significant difference in the organic matter content between these two groups. In future studies it is necessary to choose locations with the same type of soil in order to determine the changes of pH, CaCO3, organic matter and total N content depending on the use of land. Readily available P_2O_5 in garden soils ranged from medium to toxic levels with mean value 115.5 mg/100 g, which is toxic. Readily available K_2O in garden soils ranged from medium to toxic levels with mean value 43.1 mg/100 g, which is high. The content of readily available P_2O_5 and K_2O was significantly higher in garden soil than in field plots for vegetable production. Based on share of individual soil samples by content categories, 89% of garden soil areas are excessively fertilized with phosphorus and 82% with potassium, since these areas have higher nutrient content than the optimum. The content of pseudototal Cu, Zn and Cd was significantly higher in garden than in field soil, while contents of Co and Cr were significantly higher in field soil than in garden plots. Based on the contents of Ni and Pb, there was no significant difference between these two soil categories. According to the criteria for MAC for agricultural land, eight samples of garden soil exceeded MAC for the content of Cu, one for Pb and nine for Ni. In field soil, only one sample exceeded MAC for the content of Ni. Based on the distribution of soil samples from urban gardens in categories by the content of pseudototal Cu, 39% of samples belonged to the zone of critical concentration and/or above MAC. In field plots for vegetable production, 92% of tested samples were at the level of background concentration. Obtained results confirm that contamination of small surface gardens comes from strong anthropogenic effects of excessive use of copper-based mineral fertilizers and fungicides. Aiming at higher yields, producers often apply much larger quantities of fertilizers and Cu fungicides than recommended due to lack of knowledge and mission of soil analyses. Obtained results indicate the necessity of broader education of urban vegetable producers.

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Zagađenje zemljišta u gradskim baštama prouzrokovano primenom đubriva i fungicida na bazi bakra

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Sažetak: Urbano baštovanstvo u gradskim zajednicama je aktivnost koja se intenzivno širi. Cilj ovog istraživanja bio je da ukaže na najčešće greške u proizvodnoj praksi u gradskim baštama i okućnicama malih površina. Uzorci zemljišta su prikupljeni sa ukupno 96 pojedinačnih parcela pod povrtarskim kulturama (56 iz gradskih bašta i okućnica na teritoriji grada Novog Sada i 40 iz njivske proizvodnje iz prigradskih naselja). Između dve grupe ispitivanih zemljišta nije bilo značajnih razlika u sadržaju organske materije. Sadržaj lakopristupačnog P_2O_5 i K_2O bio je značajno viši u zemljištima gradskih bašta i okućnica nego u zemljištima pod njivskom proizvodnjom povrća. Prema sadržaju pseudoukupnog bakra, 39% uzoraka u urbanim zemljištima svrstano je u kategoriju kritične koncentracije i/ili iznad MDK. Dobijeni rezultati ukazuju na zagađenje gradskih bašta i okućnica koje je prouzrokovano jakim antropogenim uticajem usled intenzivne primene mineralnih đubriva i fungicida na bazi bakra.

Ključne reči: bašte, đubrenje, zagađenje zemljišta

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