Researches Reviews of the Department of Geography, Tourism and Hotel Management
43-1/2014

Review article UDC 504.05:631.43

SOILS IN THE CITIES: STATE, PROBLEMS AND REMEDIATION TEHNIQUES

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Received: October 7, 2013 | Accepted: March 15, 2014

ABSTRACT: *Historically, urban soils were ignored for a long period in scientific research because their significance for urban population was not recognized. In time, theirs importance was recognized and scientific research of urban soils characteristics, functions, etc. has started.*

Urban soil classification has long history and it was in many cases different from one country to another. Based on a new classification system from World Reference Base for Soil Resources, urban soils are classified into Technosols reference soil group because theirs functions and characteristics are dominated by technical human activity. Because of this, urban soils have substantial presence of artefacts (glass, metal, etc.), physically are disturbed, theirs temperature and humidity are changed, they have less organic matter compared to rural soils, often they are polluted, the intensity of self-purification is reduced, etc. Covering of soils due to construction is marked as one of the key indicators of denaturalization and ecological destruction of ecosystem services in cities.

In this work is explained what are urban soils, problems with their clasiffication and their state in the cities in the world and in Serbia was poined out. Beside this, main pollutants of urban soils and strategies for their mitigation are listed and explained.

Key words: *urban soils, soil clasiffication, soil contamination, soil remediation, Republic of Serbia*

INTRODUCTION

Cities ar often called „concrete jungles" due to a constructed urban area and replacement of natural ground and vegetation with antropogenic objects. Due to anthropogenic impacts are disturbed the structure and content of nutrients in the soils, but also a system of soil wildlife leading to a reduced ability of self-purification of soil. Adverse anthropogenic effects are not limited only to the fertile land, but also are expanding to the geological environment and groundwater due to the depth construction wortks (Nagy, 2008).

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Covering the area is marked as one of the key indicators of denaturalization and destruction of ecosystem services in cities (Breuste, 2010). Below the concrete, however, there is a soil as a complex mixture of minerals, water, air and organic matter which perform important ecosystem functions (Bartens et al., 2012).

Soil research in the cities is important both from the scientific as well as in terms of sustainable development aspect. Since 2008 more than half of the world's population lives in cities, and this trend of urban population growth will continue in the coming decades. According to the UN predictions (United Nations, 2007) it is expected that in the 2050, 70% of the world population will live in urban areas and the soil in the cities will come under even greater anthropogenic pressure. Therefore it is necessary to inform the political representatives of cities, city bureaus, institutions and citizens about the importance of the protection and proper use of soils in cities in order to plan sustainable urban development and the functional life of the urban population.

Numerous authors have dealt with this issue in the world (Craul, 1985; Craul, 1992; Schleuss et al., 1996; Evans et al., 2000; Dudal et al., 2002; Golubiewski, 2006; Kachenko and Singh, 2006; Lehmann and Stahr, 2007; Wieland et al., 2010; Hagan et al., 2012) and in the Republic of Serbia (Miljković, 1996; Sekulić et al., 2005; Brankov et al., 2006; Nagy, 2008).

The aim of this paper is to present the state and problems of urban soils in the world and in the Republic of Serbia. Moreover, the main factors of load and pollution of urban soil are specified, as well as their place in the taxonomy of soil. Emphasis is placed also on techniques for soil remediation in relation to their accessibility, cost, timeframe, efficiency and environmental impact. In this paper was used scientific literature presented in the form of scientific papers published in reputable international and national scientific journals, as well as numerous reports and analysis of international and domestic associations and agencies involved in the assessment of the soil and environmental protection.

SOILS IN THE CITIES

Craul (1992) defines urban soils as material that has nonagricultural, artificial top layer at least 50 cm thick, which is created by mixing, filling and contamination of surface soils in urban and suburban areas. However, the potential soil fertility in cities was indicated by Soil Survey Staff (1975) with remark that urban soils are the collection of natural bodies on the earth's surface in areas altered or even created by man and they containe organic matter and can faciliate the development of plants which was pointed out in scientific studies (Schleuss et al., 1998; Golubiewski, 2006).

A longer period the discussion about the characteristics of soils in the cities and their place in the taxonomy of soils was avoided, but in this segment has been progress. Urban soils have been ranked in the broader context of physically disturbed land, ie. "Anthropogenic soils" (Evans et al., 2000; Dudal et al., 2002). Soils that are not physically disturbed, but theirs temperature and humidity are changed due to urbanization are also urban soils (Lehmann and Stahr, 2007).

Table 1. Scheme of soil division changed and created under antropization influence

I group: Cultisols	
Positive influence	Negative influence
1. Hortisols (garden soil)	1. Toxisols
2. Rigosols (rigolated soil)	a) Oleotoksisols (liquid pollutant)
3. Terasosols (at eroded slope)	b) Imitotoksisol (solid pollutant)
4. Plagosols	2. Barosols (compact soil without vegetation)
II subgroup: Anthroposols	
Positive influence	Negative influence
1. Homosols (fine natural materials)	1. Urbisols
2. Deposols (natural materials with different granulation + skeleton)	a) without vegetation - under buildings and other construction objects
3. Technosols (inorganic municipal and industrial classified eco-waste)	b) with vegetation - free area (urban parks)
4. Reductosols (organic waste material with the development of methane)	

Source: Miljković, 1996 (translated from Serbian)

Miljković (1996) pointed out that the name "anthropogenic soil" is incorrect because the Greek word "Anthropogenesis" means the origin and development of the human species, and not the soil. Therefore, he stands out, within a single classification system, a special group that includes soil formations whose properties are modified under the direct and indirect impact of human activity (anthropisation) with positive and negative consequences. Soils in cities he calls Urbisoli and puts them in a subgroup Anthroposols (table 1).

In the framework of the International Union of Soil Sciences (IUSS), Working Group of the World reference base for soil resources (WRB) has classified urban and industrial soils into a new reference group named Technosols (IUSS, 2006; IUSS, 2007). This group is characterized by altered soil properties and functions arising under the influence of the dominant technical activities of man: the presence of a number of artefacts in the soil (material created or significantly altered under the influence of human activities, e.g. brick, glass, garbage, etc.), soil covered with technical material (e.g. asphalt), etc.

When writing about the classification of soils in the cities, CORINE land cover classification is very important. CORINE land cover nomenclature distinguishes artificial surfaces, agricultural areas, forest and semi-forest areas, wetlands and water bodies (Nestorov i Protić, 2006). Within the artificial surfaces are urban areas with suitable soil.

However we define urban soils, into account must be taken that their properties and fauna can be significantly changed in urban areas due to which it is unrealistic to define a typical urban soil. Moreover, urban soils have a surprising capacity to support the development of plants and fauna in the soil, thereby providing people in urban areas with a number of ecosystem services. As a result, it is expected that the interest in the study of soils in cities will increase in the new field, called "Anthropopedology" (Richter et al., 2011).

POTENTIAL FACTORS OF LOADING AND POLLUTION OF SOILS IN THE CITIES

There are two groups of potential soil pollutants in cities based on their location - some of them have been widely deployed in urban environments, while others are specific to certain industrial and commercial areas.

Contaminants that may be widely deployed in the city environment are:

- **Lead** which has historically been used widely in paint formulations and as a gasoline additive,
- **Arsenic** which was widely used in wood preservatives, fertilizers, pesticides, and weed-killers,
- **Cadmium**, which has entered the environment through the uncontrolled burning of coal and garbage and
- **Polyaromatic hydrocarbons (PAH's)**, which are formed during the incomplete combustion of organic matter. They are found in vehicle emissions as well as soot and ash from wood burning stoves and backyard fires (Wieland et al., 2010).

Some of the contaminants that may be found near industrial or commercial sites include:

- **Benzene, toluene, ethyl benzene and xylene** associated with leaks and spills at gas stations,
- **Stoddard solvent and tetrachloroethene** associated with dry cleaners and

Table 2. Maximum allowed concentrations (MAC) of hazardous and harmful substances in soil according to Yugoslav legislation (mg/kg of air-dry soil)

Element	Official Gazette of the Republic of Serbia 23/1994	The Council of Europe regulations 2092/91	Ordinance on the methods of organic plant production, Official Gazette of the Republic of Serbia, 51/2002
Cadmium	3	2	0.8
Lead	100	100	50
Mercury	2	1	0.8
Arsenic	25	-	10
Chromium	100	160	50
Nickel	50	50	30
Fluorine	300	-	-
Copper	100	50	50
Zinc	300	150	150
Boron	50	-	-
Molybdenum	-	-	10
Cobalt	-	-	30

Source: Kastori et al., 2003

- **Metals and cyanides** associated with metal finishing operations (Wieland et al., 2010).

Lead, arsenic, cadmium and PAH's may also be found in higher than usual concentrations around industrial locations. In Table 2 are presented the maximum allowable concentration (MAC) of dangerous and harmful substances according to the regulations of the Federal Republic of Yugoslavia, which remains valid for the Republic of Serbia. Also are given the MAC according to the Council of Europe regulations. It may be noted that for most elements MAC of hazardous and harmful substances in the soils in Serbia are higher than the European standards.

STATE OF THE SOILS IN THE CITIES IN THE WORLD

Many researchers study the problem of soil pollution in urban areas and publish their research in the renowned scientific journals.

Research of the amount of metals in urban soils and dust across the UK was performed by Culbard et al. (1988). Increased levels of lead, cadmium, copper and zinc in urban soils and dust were observed. Mean levels of lead in urban soils within more than 4.000 locations examined is 298 mg/kg-1 which exceeds the MAC in the soil.

Urban soils in Bangkok have increased concentration of cadmium (up to 2.5 mg/kg^{-1}), copper (283 mg/kg^{-1}), lead (269 mg/kg^{-1}) and zinc (813 mg/kg^{-1}) as a result of anthropogenic activities in the city (Wilcke et al., 1998).

Pollution of soil in Brazilian city of Uberlandia was investigated by Wilcke et al. (2000). Levels of cadmium, manganese, copper, lead, zinc and certain PAH's in the analyzed samples of urban soils were higher than in the samples of agricultural soils near the city.

Manta et al. (2002) investigated soil quality in Palermo. The results suggest that the median values of lead (202 mg/kg^{-1}), zinc (138 mg/kg^{-1}), copper (63 mg/kg^{-1}) and mercury (0.68 mg/kg^{-1}) in urban soils had higher values than the amount of these elements in uncontaminated soils in Sicily. Increased amounts of lead, zinc, copper and mercury in the soil are associated with anthropogenic activities in the city.

Möller et al. (2005) studied the quality of the soil in Damascus and its immediate surroundings. Research results indicated elevated levels of lead, copper and zinc in the soil surface. The main cause are traffic and other anthropogenic activities. Large amounts of chromium in the soil (up to 1800 mg/kg-1) were found in the vicinity of industrial plants and tanneries and may pose a problem for public health.

The quality of the soil in three Romanian cities: Bucharest, Iasi and Baia Mare was investigated by Lacatusu et al. (2008). Soil samples were taken from city parks, from the vicinity of busy roads and urban soils on which are grown vegetables. The highest contamination is present in the soils located near roads and in industrial zones with the content of heavy metals exceeding 3-4 times the MAC.

Research performed in Marrakesh indicate an increase of soil pollution from the periphery of the city to its historic centre due to strengthening of anthropogenic activities.

This trend is particularly pronounced for cadmium, copper and zinc and lower for nickel (Khalil et al., 2008).

On the territory of Szeged soil quality was investigated at 15 locations distributed from the city center towards its periphery. A large amount of debris, small and variable amounts of humus and nitrogen, a small value of quality topsoil, high and variable amounts of carbonate and simultaneous variance of pH and modified mechanical properties of the soil indicates that the soil is altered under the influence of anthropogenic activities (Puskas and Farsang, 2009).

Hagan et al. (2012) have studied the impact of different human activities on the properties of urban soil in subtropical, coastal city of Tampa, Florida. Some chemical properties of the soil (pH, content of phosphorus, calcium, sodium and copper) varies considerably according to the purpose and area covered, while changes in population density does not show a connection to the properties of the soil. The amount of phosphorus and sodium in soil coincides with the years since urbanization began with higher values as urbanization began earlier.

STATE OF THE SOILS IN THE CITIES IN THE REPUBLIC OF SERBIA

The Provincial Secretariat for Environmental Protection and Sustainable Development of the Autonomous Province of Vojvodina funded the monitoring of the quality of non-agricultural soil in the province in the period 2002-2005. Among other, non-agricultural soil was sampled in the industrial areas of major cities of Vojvodina in Novi Sad, Pančevo, Subotica, Zrenjanin, Sombor and Vrbas (seven samples per year). The analysis of basic chemical soil properties (pH,% CaCO3, content of humus, etc.), the content of trace elements and heavy metals (arsenic, cadmium, cobalt, chromium, copper, manganese, nickel, lead and zinc), PAH's content and number of certain groups of microorganisms (Sekulić et al., 2005).

The results showed the toxic content of available phosphorus (> 100 mg P_2O_5 per 100 g soil) in the industrial zone in Subotica (Chemical industry "Zorka") as a result of the production of phosphorous fertilizers. Elevated phosphorus content in the soil was also recorded in the industrial area of Pančevo. The lead content in the industrial area of Sombor is extremely high with maximum recorded value of 18888.22 ppm which is 188 times the value of the MAC. This significant soil contamination is the result of production of batteries and requires urgent recovery and remedation measures. The amounts of PAH's that were recorded in the industrial zones of the investigated cities are 10 to 100 times higher than those in rural areas, but do not exceed the MAC (Sekulić et al., 2005).

Brankov i sar. (2006) studied the content of trace elements and heavy metals in agricultural and non-agricultural soil in the Serbian part of Banat. Within non-agricultural soil, 13 samples were taken from 13 locations including the industrial zone of Pančevo and Zrenjanin (sampling depth of 0-30 cm). The content of copper, zinc, manganese, cobalt, lead, nickel, chromium and cadmium in soils of industrial zones was studied and only the content of nickel in Pančevo (50.38 mg/kg) was slightly above the MAC (50 mg/kg).

In a report on the status of the soil in the Republic of Serbia prepared by the Ministry of Environment and Spatial Planning (2009), among others, soil quality of urban areas was studied. Data was analyzed for the period 2006-2008 for four cities: Belgrade, Novi Sad, Kragujevac and Sevojno.

On the territory of Belgrade were determined certain concentrations of hazardous and harmful substances in the soil of different urban zones: narrow zones of sanitary protection of the Belgrade waterworks, near busy roads, within the communal environment, near the industrial buildings and in city parks (Figure 1).

In the period 2006-2008 soil was sampled at 93 locations in the city of Belgrade at depths of 10 and 50 cm and 184 soil samples were analyzed. Based on the obtained results it can be concluded that in a number of locations, there are discrepancies regarding the presence of hazardous and harmful substances in the soil in relation to domestic and international regulations (Figure 2). Increased presence of lead in most soil samples from the border zone of the city parks along major roads was noted as a result of emissions from cars. In most of the samples was observed positive deviation of nickel from MAC, but it is a consequence of the presence of nickel in the surface soil in the city (geological origin) (Министарство животне средине и просторног планирања Републике Србије, 2009).

In Novi Sad was examined the quality of agricultural soil near roads and industrial facilities (depth of 30 cm) and non-agricultural soil in the area of kindergartens and public parks (depth of 0-5 cm) (Figure 3). Only at a few locations were recorded

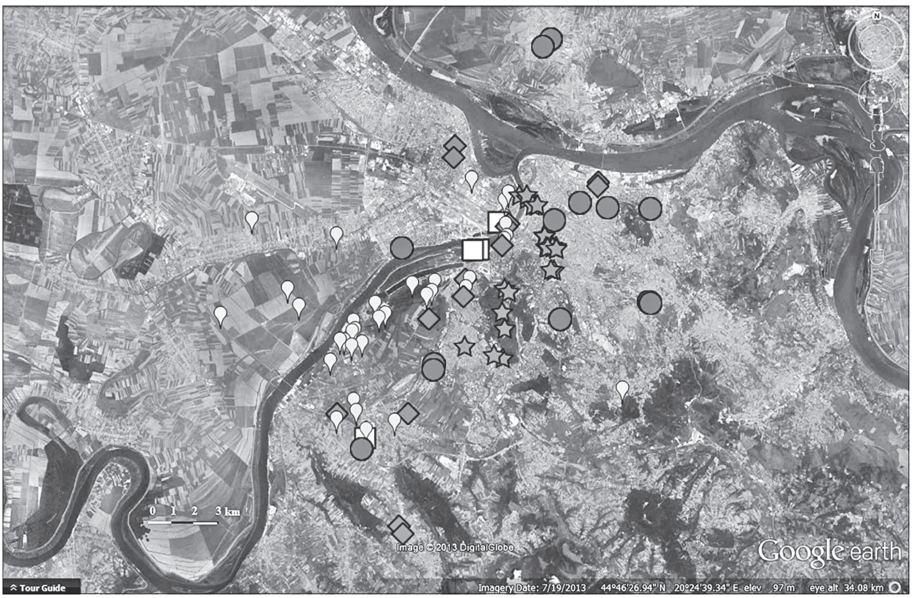

Figure 1. Location of soil sampling in the period 2006-2008 in Belgrade; circle- communal area, square- industrial area, romb- zone near traffic roads, location mark- zone of sanitary protection and star- parks

Source of the base map: Министарство животне средине и просторног планирања Републике Србије, 2009

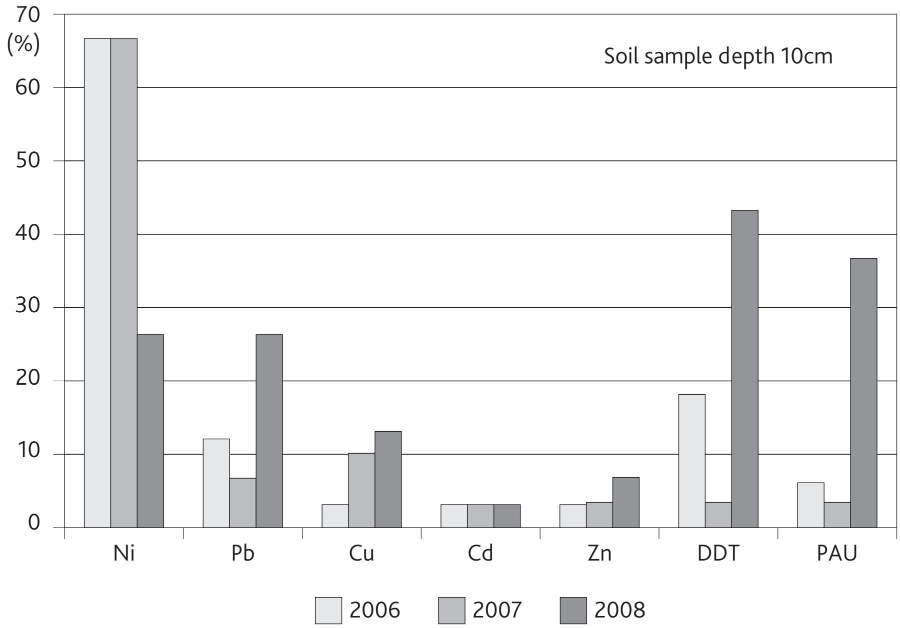

Figure 2. Percentage of deviation from MAC in the period 2006-2008 for investigated elements at the depth of 10 cm in Belgrade

Source: Министарство животне средине и просторног планирања Републике Србије, 2009

increased concentrations of lead (98.78 mg/kg^{-1} in Sremska Kamenica), which is close to the MAC, and the amount of copper (273.90 mg/kg^{-1} in Petrovaradin) and nickel (84.11 mg/kg^{-1} in the park in Sremska Kamenica) that exceed the MAC (Министарство животне средине и просторног планирања Републике Србије, 2009).

Soil sampling was conducted in 2008 at 30 playgrounds that are located within the facilities of preschools “Radosno destinjstvo” in Novi Sad, in order to determine the presence of hazardous and harmful substances. In some kindergartens are detected disturbingly high copper content (300.68 mg/kg^{-1} in kindergarten “Pčelica” and 257.30 mg/kg^{-1} in kindergarten “Vidovdanski zvončić”) and lead (908.8 mg/kg^{-1} in kindergarten “Švrća”) (Министарство животне средине и просторног планирања Републике Србије, 2009).

In Kragujevac, soil quality was tested at 14 locations, twice a year in the period 2007-2008. The results indicate an increased concentration of nickel (up to 125.5 mg/kg^{-1} in March 2007 at site Morava-Brzan), chromium (up to 115.32 mg/kg^{-1} in March 2007 near Goršničko lake dam) and lead (up to 193.86 mg/kg^{-1} in March 2007 at city landfill) that exceed MAC at some locations (Министарство животне средине и просторног планирања Републике Србије, 2009).

Soil quality was investigated in Sevojno during 2007. The samples were taken from the depth of 0-10 cm, 10-30 cm and 30-60 cm. Based on the results of laboratory tests increased content of copper and zinc in the vicinity of the industrial zone, but also in other parts of the settlement was observed. The content of other potential contaminants such

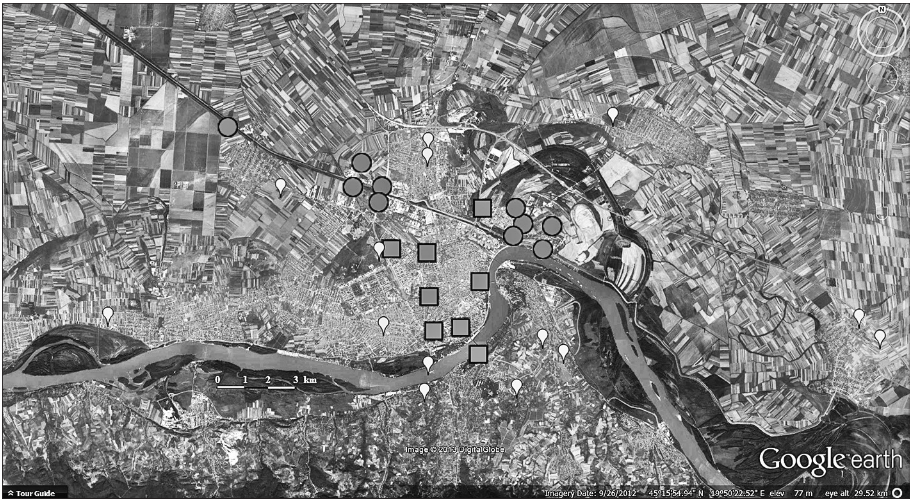

Figure 3. Locations of soil sampling in the period 2006-2008. in Novi Sad; circle- industrial area, square- kindergartens and parks and location mark- zone near traffic roads

Source of the base map: Министарство животне средине и просторног планирања Републике Србије, 2009

as chromium, lead, nickel, arsenic and cadmium is below the MAC (Министарство животне средине и просторног планирања Републике Србије, 2009).

Agency for Environmental Protection of the Ministry of Energy, Development and Environmental Protection of the Republic of Serbia (2012) issued a “Report on the status of the soil in the Republic of Serbia for year 2011”. Among other, the degree of vulnerability of soil in urban areas was investigated at 175 sites, with 258 samples analyzed in seven cities. Tests were conducted in Belgrade, Novi Sad, Kragujevac, Kruševac, Užice, Subotica and Požarevac.

The program included analysis of soil at 40 locations in the city of Belgrade in 2011. Samples were taken from a depth of 10 cm and 50 cm within the urban environment, near roads, water facilities and at agricultural areas, and the results of laboratory tests indicate that the highest deviations were recorded for nickel, dichloro-diphenyl-trichloroethane (DDT), PAH’s, cadmium, zinc, copper and lead (Министарство енергетике, развоја и заштите животне средине Републике Србије, 2012).

In Novi Sad were analyzed soil samples at eight locations on agricultural land next to the industrial zone and on agricultural land near busy roads at a depth of 0-30 cm. Soil samples were taken from non-agricultural areas like urban parks at a depth 0-10 cm. Results indicate exceeding MAC’s for parameters: cobalt (about 60% exceeded MAC), nickel (about 20% exceeded MAC) and copper (about 10% exceeded MAC) (Министарство енергетике, развоја и заштите животне средине Републике Србије, 2012).

In Kragujevac was conducted soil sampling at 14 locations at depths of 10 cm and 50 cm in the zone of the water supply source, urban environment, industrial zones and urban landfills. Noticed are the exceedings of MAC for nickel and mercury in the tested soil samples.

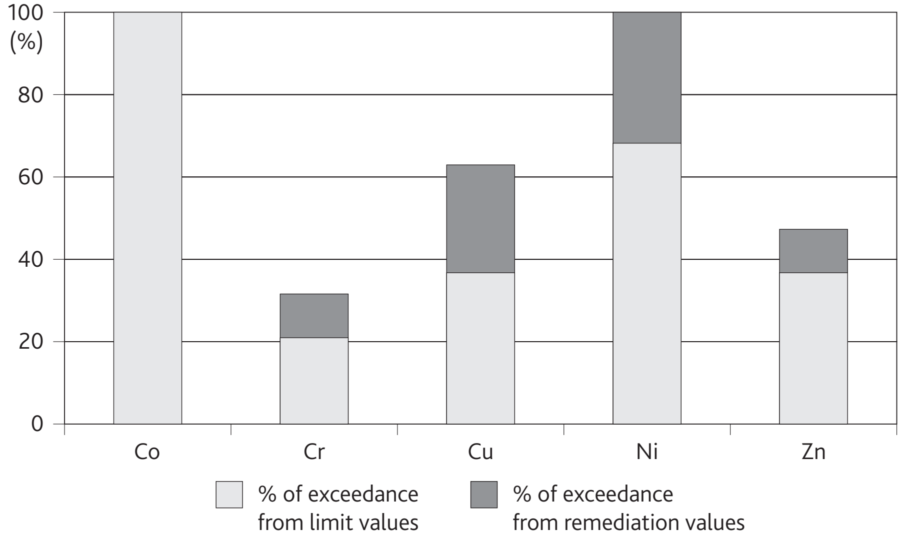

Figure 4. Percentage of deviation from MAC for investigated elements in Užice
Source: Министарство енергетике, развоја и заштите животне средине Републике Србије, 2012

During 2011 soil sampling was conducted at 39 locations in the city of Kruševac, and the largest exceeding of MAC's were observed for atrazine and nickel.

On the territory of the city of Užice soil sampling was conducted at 19 locations in the agricultural and non-agricultural land and the lake accumulation zone at a depth of 30 cm. In Figure 4 is presented the exceedance of limit and remediation values for certain parameters. Especially large excess amounts of nickel, cobalt, copper, zinc and chromium in the city were reported.

In the city of Subotica soil sampling was performed at 25 locations from agricultural areas, parks and in the surrounding of water supplies zones. The biggest overruns were recorded for copper, chromium and zinc.

The analysis of the quality of soils from 30 sites within the urban area, near roads, around water facilities and in the surrounding mines at depths of 10 and 50 cm was carried out in Požarevac. Positive deviations of nickel (geochemical origin) and atrazine from MAC are registeered in sampled soils.

In the report on the quality of soil in the Republic of Serbia for 2011 was not given an explanation of the causes of soil contamination by hazardous and noxious substances. However, it can be assumed that the increased amount of nickel in soils have geochemical origin, while increased amounts of cobalt, copper, chromium, zinc, lead, mercury, atrazine and DDT have anthropogenic origin.

REMEDIATION TEHNIQUES FOR SOILS IN THE CITIES

Remediation process involves taking measures to stop the pollution of the environment to a level that is safe for the future use of the site. There are numerous techniques to reduce the level of pollution of soil some of which are more practical than others. When selecting the most efficient techniques for remediation of the soil, following five factors have to be considered:

1. **Accessibility** – whether the selected techniques are available for use or is still in the development stage,
2. **Cost** – cheaper techniques for soil quality improvement are preferred and frequently used,
3. **Timeframe** – some techniques are implemented and completed over the course of a few days, while others may take years to be effective,
4. **Efficiency of techniques for different human activities** – the use of urban soils for agricultural purposes refers to the ability of the techniques to bring the soil up to agricultural standards and
5. **Environmental effects** – some techniques do not adversely affect the environment, while others leave byproducts after their application or require putting materials into the soil that are not biodegradable (Turner, 2009).

In accordance with the above factors, selection of the remediation technique that best suits the needs is performed. Remediation techniques are divided into *physical* and *biological*.

Physical remediation techniques require the use of techniques for soil remediation. They include:

- **Excavation** refers to physically removing contaminated soil and dispose it at a landfill. It is accomplished with heavy machinery, at a relatively high cost. However, it can take place quickly, while new soil is needed after the excavation, at extra cost.
- **Geotextiles** are a synthetic blanket-like material. They can be used after the excavation process to provide a protective barrier, impermeable to any remaining contaminants which may otherwise migrate into the new soil after excavation. They are relatively low-cost, but must be combined with excavation. One concern with geotextiles is that the fabric can tear, allowing contaminants to pass through into the new soil.
- **Soil washing** involves the physical removal of the contaminated soil and its treatment at a plant. After the contamination is removed through the treatment process, the soil is put back into the ground. This technique is generally high-cost, and the disposal of the removed contaminants must be addressed after the process is complete.
- **Soil vapor extraction** involves the installation of wells and pipes in the soil, through which soil contaminants are extracted. This is the most costly procedure of the physical remediation techniques listed here, but is effective at removing the contaminants (Turner, 2009).

Table 3. Main characteristics of physical remediation techniques

Factors	Excavation	Geotextiles	Soil washing	Soil vapor extraction
Access	yes	Yes	yes	yes
Cost	low	Low	moderate	high
Timeframe	short < 1season	short < 1season	short < 1season	short < 1season
Effectiveness for urban agriculture	1	2	1	1
Environmental effects	- energy use - air pollution - disposal	- energy use - air pollution - disposal	- energy use - air pollution - disposal	- energy use - air pollution - disposal

Source: Heinegg et al., 2000

In general, physical remediation techniques are relatively fast to implement and effective at remediating soil. However, they can be very costly, and have environmental drawbacks such as disposal of contaminants/contaminated soil and air pollution from machinery. Excavation, with or without geotextiles, is considered the most useful physical remediation technique for small-scale urban agriculture (Heinegg et al., 2000). The main benefits of these techniques are relative low cost and fast and effective remediation of contamination. Using the five factors discussed above, Table 3 illustrates these techniques and uses a scale of 1 – 3 where 1 is unconditionally effective, 2 is conditionally effective, and 3 is ineffective.

Biological techniques are generally performed directly on-site, unlike physical remediation techniques. They include:

- **Microbial remediation** refers to the use of microbes in degrading contaminants into a less toxic form. This technique can be very effective in the treatment of hydrocarbons, PAH's, pesticides, and polychlorinated biphenyls (PCB's). Cost is relatively low, and timeframe is short.
- **Phytoremediation** is the process of using plants to extract contaminants or to degrade them in the soil. The cost is low, however the timeframe can be longer than several years. Effectiveness in remediation of soil varies, as one species of plant is generally used on one type of contaminant, potentially leaving a range of contaminants behind. As well, the contaminated plants used for extraction must be disposed of properly.
- **Fungal remediation** refers to the use of certain species of fungus to degrade contaminants in the soil. This technique is still in the development phase and is not commercially available as of now.
- **Compost remediation** involves the addition of compost to the soil. This technique is cheap and time effective. However, it is not a true remediation technique, as the contaminants generally remain intact in the soil. The addition of compost can, however, is used to create a raised bed, in which the plant roots may not reach the contaminated soil (Turner, 2009).

Table 4. Main characteristics of biological remediation techniques

Factors	Microbal remediation	Phytoremediation	Fungal remediation	Compost remediation
Access	yes	Yes	no	yes
Cost	low	Low	not available	low
Timeframe	short			
< year	2-5 + years	not available	short	
< season				
Effectiveness for urban agriculture	2	2	3	2-3
Environmental effects	- potential metal toxicity	- disposal of toxic plants	- potential metal toxicity	- none

Source: Heinegg et al., 2000

In general, bioremediation techniques are conditionally effective in remediation of soil. Because the original soil remains intact, there may still be some contaminants that are unaffected by the technique used, resulting in a certain degree of uncertainty about the treatment of the contamination. Despite their extended time frame, these techniques are generally inexpensive, easy to implement, and environmental effects are low. In general, microbial remediation is thought to be the bioremediation technique most useful to urban agriculture (Heinegg et al., 2000). Using the five factors discussed above, Table 4 illustrates these techniques and uses a scale of 1 – 3 where 1 is unconditionally effective, 2 is conditionally effective, and 3 is ineffective.

It can be concluded that there are a number of techniques for soil remediation. The choice of technique will depend primarily on the specific needs of groups or individuals, their financial status, the desired timeframe and the availability of remediation techniques.

CONCLUSION

Soils in cities are exposed to numerous influences from their direct and indirect pollution to soil removal, construction of objects, disposal and mixing natural and artificial materials in them. As a result of intensive human activities on the territory of the city a number of natural soil properties are altered.

Sources of pollution in cities are numerous, however the soils highest pollution was caused as a result of industrial activities and transport. The most common contaminants of soils in cities are lead, arsenic, cadmium, PAH's and others.

The situation in the world and in Serbia is similar in terms of soil state in cities. In most of the studies conducted have been observed exceedings of the amounts of heavy metals from MAC. In Serbia, the situation is most critical in the industrial areas of some cities (Subotica, Pančevo, Sombor, Užice, etc.).

There are numerous techniques for soil remediation that can be implemented and save contaminated soil from further degradation. Selection of appropriate techniques will depend on many factors, but most often they are: price, timeframe and effectiveness of the techniques.

Monitoring of the soil quality in cities in Serbia is not at a high level. It is necessary to introduce regular monitoring of soil quality in major urban areas at the territory of the Republic of Serbia in order to assess their condition, protection and impact on the population. Also, it is necessary to make this information publicly available so that interested individuals and institutions would be able to make statistical processing and presentation of results.

Acknowledgments

This paper was supported by the research project no. 43002 funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

REFERENCES

Bartens, J., Basta, N., Brown, S., Cogger, C., Dvorak, B., Faucette, B., Groffman, P., Hettairachhchi, G., McIvor, K., Pouyat, R., Toor, G. and Urban, J. (2012). Soils in the city: A look at soils in urban areas. *CSA News*, 57-8, 4-13.

Breuste J. (2010). Challenges and problems of implementing landscape ecological knowledge in practice – the case of urban development. *The Problems of Landscape Ecology*, 13, 23-32.

Brankov, M., Ubavić, M., Sekulić, P. i Vasin, J. (2006). Sadržaj mikroelemenata i teških metala u poljoprivrednim i nepoljoprivrednim zemljištima Banata. Naučni institut za ratarstvo i povrtarstvo, Novi Sad. *Zbornik radova*, 42, 169-177 (in Serbian)

Craul, P. J. (1985). A description of urban soils and their desired characteristics. *Journal of Arboriculture* 11-11, 330-339.

Craul, P. J. (1992). *Urban soil in landscape design*. John Wiley & Sons, Inc., New York.

Culbard, E., Thornton, I., Watt, J., Wheatley, M., Moorcroft, S. and Thompson, M. (1988). Metal contamination in British urban dusts and soils. *Journal of Environmental Quality*, 17, 226-234.

Dudal, R., Nachtergaiel, F. and Purnell, M.F. (2002). The human factor of soil formation. Paper. 93. *In World Congress of Soil Science*, 17th, Bangkok, Thailand. 14–21 Aug. 2002.

Evans, C.V., Fanning, D.S. and Short, J.R. (2000). Human influenced soils, 33–67. In Brown, R.B., Anderson, J.L. and Huddleston, J.H. (ed.)- *Managing Soils in a Growing Urban Area*. Agronomy Monograph, 39. ASA, Madison, Wisconsin.

Golubiewski, N. E. (2006). Urbanization increases grassland carbon pools: Effects of landscaping in Colorado's front range. *Journal of Applied Ecology*, 16, 555–571.

Hagan, D., Dobbs, C., Timilsina, N., Escobedo, F., Toor, G. S. and Andreu, M. (2012). Anthropogenic effects on the physical and chemical properties of subtropical coastal urban soils. *Soil Use and Management*, 28, 78–88.

Heinegg, A., Maragos, P., Mason, E., Rabinowicz, J., Straccini, G. and Walsh, H. (2000). *Soil contamination and urban agriculture: A practical guide to soil contamination issues for individuals and groups*. Quebec, Canada: McGill University, McGill School of Environment.

IUSS Working Group WRB. (2006). *World reference base for Soil resources 2006.* World Soil Resources Report No. 103. FAO, Rome.

IUSS Working Group WRB. (2007). *World reference base for Soil resources 2006, first update 2007.* World Soil Resources Report No. 103. FAO, Rome

Kastori, R., Sekulić, P., Petrović, N. i Arsenijević-Maksimović, I. (2003). Osvrt na granične vrednosti sadržaja teških metala u zemljištu u nas i u svetu. Naučni institut za ratarstvo i povrtarstvo, Novi Sad. *Zbornik radova*, 38, 49-58.

Kachenko, A. G. and Singh, B. (2006). Heavy Metals Contamination in Vegetables Grown in Urban and Metal Smelter Contaminated Sites in Australia. *Water, Air and Soil Pollution*, 169, 101–123.

Khalil, el H., Schwartz, C., Elhamiani, O., Kubiniok, J, Morel, J. L. and Boularbah, A. (2008). Contribution of Technic Materials to the Mobile Fraction of Metals in Urban Soils in Marrakech (Morocco). *Journal of Soil and Sediments*, 8-1, 17-22.

Lacatusu, R., Lacatusu, A-R., Lungu, M. and Breaban, J. A. (2008). Macro- and micorelements abundance in some urban soils from Romania. *Carpathian Journal of Earth and Environmental Sciences*, 3-1, 75-78.

Lehmann, A., and Stahr, K. (2007). Nature and significance of anthropogenic urban soils. *Journal of Soils and Sediment*s, 7: 247–260.

Manta, D. S., Angelone, M., Bellanca, A., Neri, R. and Sprovieri, M. (2002). Heavy metals in urban soils, a case study from the city of Palermo (Sicily), Italy. *The Science of the Total Environment*, 300, 229–243.

Министарство енергетике, развоја и заштите животне средине Републике Србије (2012). Извештај о стању земљишта у Републици Србији у 2011. години. Агенција за заштиту животне средине (in Serbian).

Министарство животне средине и просторног планирања Републике Србије (2009). Извештај о стању земљишта у Републици Србији. Агенција за заштиту животне средине (in Serbian).

Miljković, N. (1996). *Osnovi pedologije*. Prirodno-matematički fakultet, Institut za geografiju, Novi Sad (in Serbian).

Möller, A., Müller, H.W., Abdullah, A., Abdelgawad, G. and Utermann, J. (2005). Urban soil pollution in Damascus, Syria. Geoderma, 124, 63–71.

Nagy, I. (2008). *Városökológia (Urban Ecoology).* Dialog Campus, Budapest-Pécs. (In Hungarian).

Nestorov, I. i Protić, D. (2006). Implementacija CORINE Land Cover projekta u Srbiji i Crnoj Gori. *Geodetska služba*, 35 – 105, 25-29 (in Serbian).

Puskas, I. and Farsang, A. (2009). Diagnostic indicators for characterizing urban soils of Szeged, Hungary. *Geoderma*, 148, 267–281.

Richter, D. de B., Bacon, A.R., Megan, L.M., Richardson, C.J., Andrews, S.S., West, L., Wills, S., Billings, S., Cambardella, C. A., Cavallaro, N., DeMeester, J. E., Franzluebbers, A. J., Grandy, A. S., Grunwald, S., Gruver, J., Hartshorn, A. S., Janzen, H., Kramer, M. G., Ladha, J. K., Lajtha, K., Liles, G. C., Markewitz, D., Megonigal, P. J., Mermut, A. R., Rasmussen, C., Robinson, D. A., Smith, P., Stiles, C. A., Tate, R. L., Thompson, A., Tugel, A. J., Es, H. van, Yaalon, D. and Zobeck, T. M. (2011). Human–soil relations are changing rapidly: Proposals from SSSA's Cross-Divisional Soil Change Working Group. *Soil Science Society of America Journal*, 75, 2079–2084.

Schleuss, U., Wu, Q. L. and Blume, H. P. (1998). Variability of soils in urban and periurban areas in Northern Germany. *Catena*, 33, 255–270.

Sekulić, P., Hadžić, V., Lazić, N., Bogdanović, D., Vasin, J., Pucarević, M., Ralev, J. and Škorić-Zeremski, T. (2005). Monitornig nepoljoprivrednog zemljišta Vojvodine. Konferncija Životna sredina ka Evropi, Beograd, SCG, 5-8 Jun, *Zbornik radova sa EnE05*, 278-282 (in Serbian).

Soil Survey Staff (1975). *Soil taxonomy- a basic system of soil classification for making and interpreting soil surveys*. USDA Soil Conservation Service, Washington, DC.

Turner, A. H. (2009). *Urban Agriculture and Soil Contamination: An Introduction to Urban Gardening, Practice Guide* #25. Envorinmental Finance Center, EPA Region 4, University of Louisville, Kentucky.

United Nations (2007). *World Urbanization Prospects: The 2007 Revision.*

Wieland, B., Leith, A. and Rosen, C. (2010). *Urban Gardens and Soil Contaminants: A Gardener's Guide to Healthy Soil*. Minnesota Institute for Sustainable Agriculture, St. Paul, Minnesota.

Wilcke, W., Müller, S., Kanchanakool, N. and Zech, W. (1998). Urban soil contamination in Bangkok, heavy metal and aluminium partitioning in topsoils. *Geoderma*, 86, 211–228.

Wilcke, W., Lilienfein, J., Lima, S. de C. and Zech, W. (2000). Contamination of highly weathered urban soils in Uberlandia, Brazil. *Journal of Plant Nutrition and Soil Science*, 162, 529-548.