J Soils Sediments
DOI 10.1007/s11368-014-0991-4

SOILS AND SEDIMENTS IN URBAN AND MINING AREAS

Soil condition and pollution in urban soils: evaluation of the soil quality in a Hungarian town

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Received: 13 January 2014 / Accepted: 21 September 2014

Abstract
Purpose In the course of our investigation, we analyzed physical and chemical parameters as well as heavy metal contents in the urban soils of Sopron, Hungary. Our aim was to identify the main feedback effects between the town and its environment.
Materials and methods Altogether, 208 samples were collected at 104 sites at depths of 0–10 and 10–20 cm in a standard network. The results have been represented in a GIS system, providing a useful basis for the research. We measured the following chemical and physical parameters: soil pH ($pH_{(H2O)}$, $pH_{(KCl)}$), calcium carbonate content, particle size distribution, humus content, ethylenediaminetetraacetic acid (EDTA) or diethylenetriaminepentaacetic acid (DTPA) soluble Mn, Cu, Zn, and Fe contents. In addition, 24 heavy metals, including Co, Cd, Cu, Pb, Zn, and Ni, were also measured following the method of Lakanen-Erviö. Relationships between these elements were evaluated in both soil layers.
Results and discussion In the downtown, most of the soils we investigated were alkaline. Therefore, the pollution of these soils has not yet leached into deeper layers. The Pb content was very high in both layers throughout the whole area of the town. Urban soils with high Cu content have been found mostly from garden and viticulture areas. Cd contents were the highest in the traffic zones, confirmed by the literature, reaching 3 mg Cd/kg soil. The Co and Zn results were below the Hungarian background and pollution limits (discussed below).
Conclusions According to the results, we have found the highest average values of heavy metals in the soils of parks, possibly originating from traffic contamination, binding in the soil of urban green spaces, thus possibly affecting human health. In the future, a detailed analysis of these polluted green areas will be carried out.

Keywords Heavy metals · Soil condition · Sopron · Topsoil · Urban soils

1 Introduction

Urban soil science is a relatively young field compared to the traditional soil sciences which originally dealt with agricultural and forest environments. Usually, we can talk about technogenic soils (Billwitz and Breuste 1980), when the human effects on the structure of the soils are stronger than the natural processes (Runge 1975). This is why the examination of original disturbance-free soil layers can be carried out only in very few places in residential areas. Soils in urban areas have several roles and populated areas have become increasingly important in ecosystems (Morel and Heinrich 2008). According to Lehmann (2007, 2010), urban soils can be evaluated similarly to natural soils, but specific properties, e.g., soil pH or bulk density, also have to be considered. The first significant book in this field was published by Bullock and Gregory (ed. 1991), discussing disturbed urban soils in the UK. Another important handbook originated from Craul (1992), evaluating the soils of cities in the USA from an anthropogenic point of view. Since the 1990s, numerous books (e.g., Hiller and Meuser 1998; Kollender-Szych et al. 2008; Meuser 2010; Hazelton and Murphy 2011) and well-established articles (e.g. Burghardt 1994; Scharenbroch et al. 2005) have been published on urban soil pollution all over the world. In these studies, soil scientists tried to find answers for

Responsible Editor: Richard K. Shaw

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Published online: 07 October 2014

the causes of the enrichment of toxic elements in soils of different cities, e.g., Isle of Skye in Scotland (Entwistle et al. 1998), in Stockholm (Bergbäck et al. 2001), in Hong Kong (Li et al. 2004), or in Lubbock city (Brown et al. 2008). Norra and Stüben (2003) presented the distribution of trace metals in urban soils of Karlsruhe with contour maps. Jim (1998) reported on the investigation of an urban park in Hong Kong; Farsang and Jóri (1999) researched the topsoils of 44 urban parks in Szeged where the soils were heavily affected by human activity. Nowadays, this field has also become extraordinarily ramified. In Hungarian scientific literature, there are few works in this field which are also scientifically based. Regarding the soils of Hungarian cities, heavy metal content has only been measured in Budapest (Kovács and Nyári 1984) and in Debrecen (Szegedi 1999a; Sándor et al. 2013). Puskás and colleagues performed the measurement and classification of urban soils in Szeged (Puskás and Farsang 2007; Puskás et al. 2008; Puskás and Farsang 2009), where the accumulation of metals in urban garden soils has been also found (Szolnoki et al. 2013). In Sopron, Varga et al. (1999) analyzed the topsoil (0–5 cm) next to urban trees several years ago, but a city-wide investigation has not been carried out since then.

The objective of the present work was to assess the condition of the soil of the city by measuring its physical and chemical properties and toxic elements (Co, Cd, Cu, Pb, Zn, and Ni), as these metals are especially detrimental to human health. There is abundant literature about pollution limits of heavy metals in soils and plants (Blume 1992), even for complete ecosystems (Zöttl 1987). In recent years, several studies have been carried out in Hungary on the heavy metal pollution of soils next to public roads, as a function of distance and time (Kovács and Nyári 1984; Szolnoki et al. 2013). The different heavy metals released by urban traffic first spread in the air, then reach the soil and the plants (Fiedler 1990). The largest proportion of these toxic heavy metals originate from fuels (Pb), corrosion of vehicle chassis (Zn, Cu), and from tire wear (Cd). Some of the metals have no substantially detrimental effects; in fact, Cu, Co, Zn, and Ni are even essential for living organisms but only in low amounts and are only toxic at high levels. However, Cd and Pb accumulate in organs thus are highly poisonous (Blume 1992; Szabó 1996). The mobility of metals in soils depends on the pH; thus, their accumulation can be observed most frequently in the upper layers in the form of complexes (Zöttl 1987). The hydrogen ions of acidic compounds can replace the metal ions from these metal-humus complex molecules and also from the surface of clay minerals (McEldowney et al. 1993; Szegedi 1999a). Complex stability usually decreases with the acidification of the soil, influencing the migration of the metals into the deeper layers and into the soil solution, making these pollutants available to urban plants. The pH of urban soils is mostly in the alkaline range (Lehmann 2007), which has also been confirmed by the present research. Under these circumstances, Co and Cd are moderately mobile, while Pb, Zn, Ni, and Cu are weakly mobile (McEldowney et al. 1993). With the increase of the metal content of the soils, species diversity and biological activity decrease (emerging of metal-bearing plant species). This can lead to increased levels of organic matter which are also accompanied by high $CaCO_3$ contents in urban soils. The connection between the condition of soils and land use was also evaluated. By drawing informative maps, specific local problems can be revealed, and the condition of urban soils could be improved.

2 Materials and methods

The studied area was the township of Sopron, located in the north-western part of Hungary at the western border of the country. The area of the city has been inhabited since the prehistoric age. In the Roman age, the city was called Scarbantia. In 1277, the city was named Suprun, and it became a free royal city. During the times of Turkish occupation, the city was the center of the unoccupied part of the country. In 1676, a conflagration destroyed most of Sopron. During World War II, the city survived many air raids (Tóth 2011). Most of the city is located in the Sopron-Basin, which is situated between the Fertőside Hills and the Sopron Hills. The city is covered by Neogene deposits (Dövényi 2010). The Sopron Hills were formed 580–520 Ma ago during the Cambrian period and probably consist of the oldest rocks in Hungary (gneiss and mica-schist). Tertiary deposits (e.g., Badenian clay) still cover a significant area of the city, but they are often overlain by a good water-bearing gravel cover, many meters thick of the predecessor of the Ikva creek, and also by glacial loam, as well as by washover loess sediment with recent (Holocene) alluvium. Luvisols typically evolved in the Sopron Hills and in the suburb. In the Sopron Basin, where most of the city is located, the characteristic type of soils is Fluvisols, but in the downtown, they turn to Technosols (calcic) (Charzyński et al. 2013; Sándor et al. 2013; IUSS Working Group WRB 2007). The climate of the city is temperate cold with an annual precipitation of 500–600 mm. In the Sopron Hills, the amount of annual precipitation exceeds 750 mm (Dövényi 2010). The present research may provide a useful basis for studying the future development of the quality of urban soils and for the implementation of suitable treatment and protection strategies. Nowadays, the largest anthropogenic effects appear in the areas of city construction and in the soils of the city center. In order to investigate soil properties, samples from a large number of sites were collected as indicated in Fig. 1. Sample collection was carried out during the spring of 2011.

The soil samples were taken on 104 points, from depths of 0–10 and 10–20 cm, in a standard network also including industrial zones. Altogether, 208 samples were analyzed,

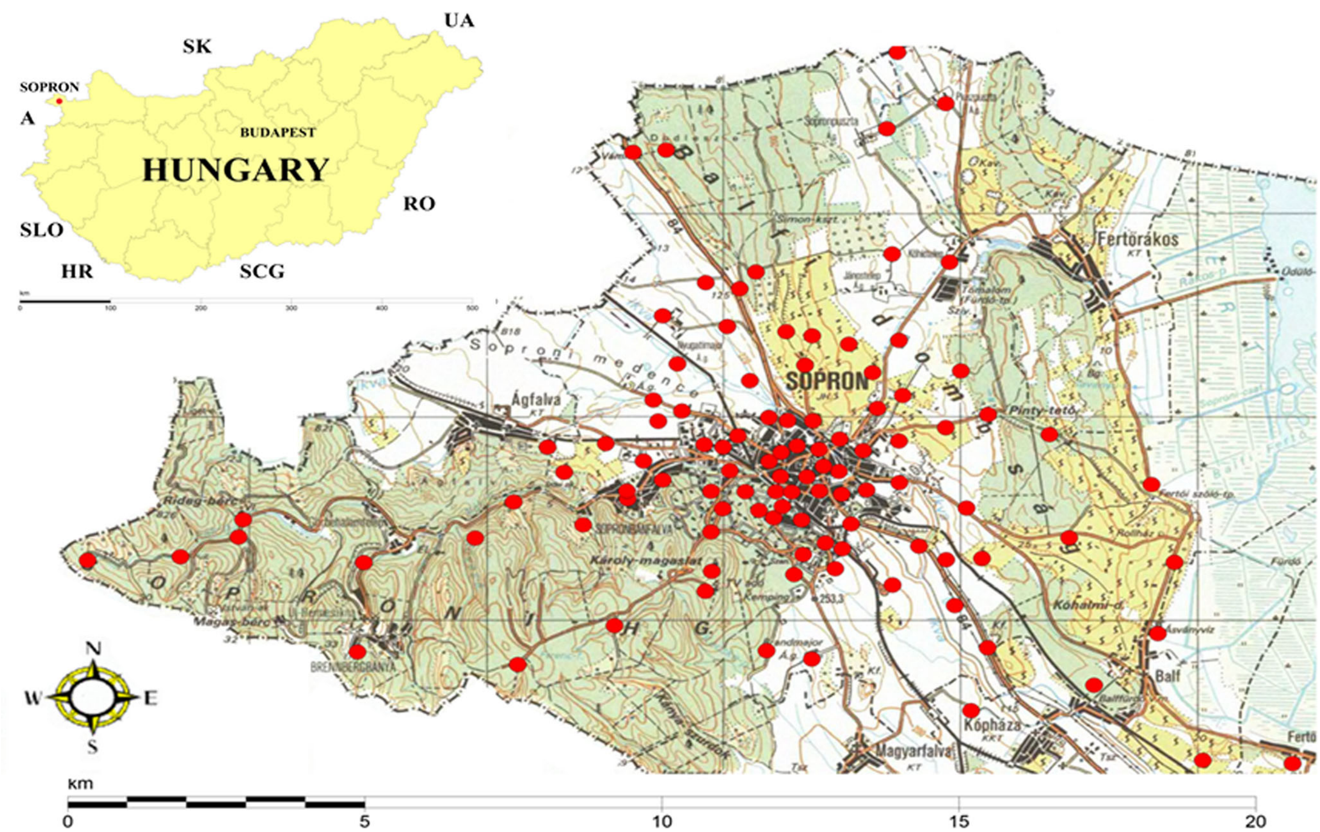

Fig. 1 Sampling points and the investigated area

originating from 104 sampling points. The distance between the points was generally 1 km in the suburban area and 0.5 km in the downtown. GPS coordinates, elevation above sea level, date of collection, type of urban area, information about land usage, vegetation, plant species, type of covering, and origin of soil were recorded for the sites. The following soil characteristics were recorded: boundary between two layers, amount of humus, structure, compactness, root system, skeletal percent, Munsell color. In the laboratory, we measured soil pH (potentiometrically in water); the texture of soils was determined by particle size distribution (Van Reeuwijk 2002) and the values of the compactness (based on the yarn test of Arany, which amount of water in cm^3 added to a 100-g soil sample to obtain a yarn) (MSZ-08-0205 1978; Stefanovits et al. 1999) together. We determined calcium carbonate content (Scheibler calcimeter) and soil organic matter content (FAO 1990). In addition, the total nitrogen content, ammonium lactate/acetic acid extractable (AL) potassium and phosphorus content, KCl extractable magnesium and calcium, ethylenediaminetetraacetic acid (EDTA) and diethylenetriaminepentaacetic acid (DTPA) extractable Mn, Cu, Zn, and Fe were determined (Bellér 1997) but will not be discussed. The results of the field and laboratory measurements were represented in a GIS system (Digiterra Map, ArcGIS). The categorization of the soil samples was carried out as reviewed by Baranyai et al. (1987), Bellér (1997), Stefanovits et al. (1999), and Juhász (ed. 2006). Heavy metal contents were determined by the method of Lakanen-Erviö (MSZ 21470–50 2006 – 0.5 mol/dm^3 $NH_4C_2H_3O_2$+ 0.5 mol/dm^3 CH_3COOH+0.02 mol/dm^3 EDTA added for 5 g soil) using ICP technique. The study area is full of urban gardens and green areas which belong to the character of the city and its surroundings. This method had been used because we will continue our work with analysis of urban plants (indicators). The statistical processing of the results was made with STATISTICA 11 (ANOVA, Basic Statistic). Conclusions were drawn from the results and the construction characteristics of the city and on earlier findings (Horváth et al. 2013).

3 Results and discussion

Soil samples were first classified by land use type. About the quarter of the samples originated from forested areas, which are characteristic of the city and its surroundings. About 42 % of the samples were collected in residential areas, traffic zones, and industrial areas where human activity is the highest. Figure 2 indicates that the proportion of seminatural areas is still balanced compared to the degree of human presence.

Soil pH is one of the most important soil parameters, because it serves as a basis for the rest of the examinations.

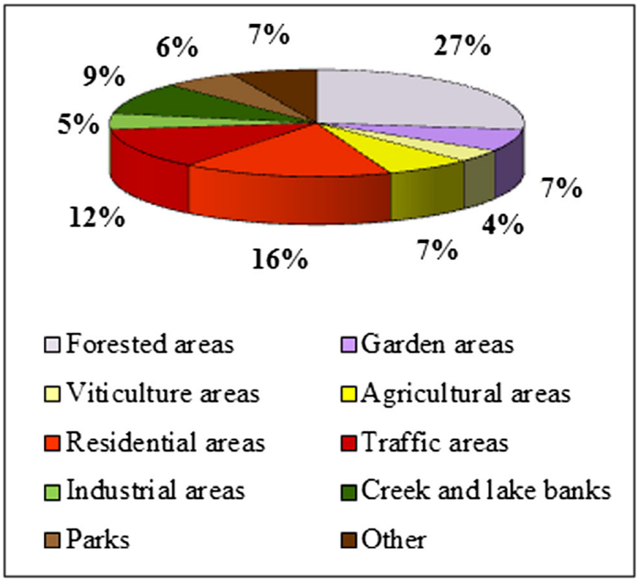

Fig. 2 Distribution of the samples according to land use type

The city is surrounded by the forests of the Sopron Hills, where the soil is mostly acidic (pH=4.9 on average) determined significantly by the metamorphic bedrock. The city area is covered with calcareous sediment, which is derived from the geologic circumstances and from anthropogenic effects. Therefore, most of the samples originating from this area were alkaline or weakly alkaline in both layers (pH=7.3–8.0). In 78 % of the soil samples, the $pH_{(H20)}$ was higher in the lower layers. This can be regarded as a positive feature, because technogenic pollutants can be absorbed better in urban soils with slightly alkaline pH, and thus, they will become immobilized. The contamination of the acidic soils in forest areas surrounding the town might become a significant problem in the future due to the increasing traffic. Toxic elements from traffic become mobilized in acidic media and can be leached into deeper layers of the soil causing significant contamination of the soil solution. Average values of the physical and chemical properties are summarized in Table 1 by land use.

The $CaCO_3$ content of the soils was 10–11 % in both layers on average and showed a strong connection with soil pH. Because of the presence of calcareous sediments, high contents were measured in the whole area especially in the soils of the old town (14 % $CaCO_3$). One third of the samples of the suburban area show the same result. In the city center, a significant proportion of the $CaCO_3$ may originate from artefacts and from the waste of previous building operations. Since this area has been inhabited since the prehistoric age, undisturbed soils without any artefacts are rarely found.

The determination of the texture based on the results of the particle size distribution by Van Reeuwijk (2002) and the values of the yarn test of Arany (MSZ-08-0205 1978). According to the particle size distribution, the samples belong to silt fraction (0.05–0.002 mm). In addition, the values of the yarn test of Arany (K_A) showed that the samples were clayey loam (K_A=42–50—30 % of the samples), clay (K_A=50–60—27 % of the samples), or heavy clay (K_A>60—15 % of the samples), but there were loam (K_A=38–42—13 % of the samples) also. In summary, the samples were predominantly clayey. These types of soils can be characterized with good absorbing capacity; although they can store water quite well, this water is hardly available to the vegetation (Stefanovits 1992). On the south-western part of Sopron, compactness values of the soils were often high in both levels. For many samples, the joint analysis of the soil properties shows that the high compactness values occur together with high amounts of humus and high nitrogen. This phenomenon has been established in all of the soil samples in the suburban forests. The possible reason for this is that in these forest soils, the substantial litter layer and the moisture content are seldom affected by human disturbance; so, decomposition processes are quick, which results in well-fertilized soils. Another explanation could be that the humus content increases the water storage capacity of the soils, which in turn increases the compactness index (Bidló et al. 2012).

In the upper layers (0–10 cm), the highest average soil organic matter content has been determined for forest lands (8.08 %) and traffic zones (7.07 %). Lower values have been measured in soils of the “other” category (4.19 %) and garden areas (4.77 %). In the 10–20-cm layers, the highest organic matter contents were determined at the banks of creeks and lake shores (5.63 %) as well as in the soils of public parks (5.21 %). The lowest values were measured in garden areas (3.43 %) and residential zones (3.8 %). There was a radial increase with the distance from the city center, which can be attributed to the increasing proportion of forests in the outskirts. These results also confirm previous results on the high carbon storage capacity of forested areas, especially in topsoils (Juhász et al. 2008).

For evaluating heavy metal concentrations, the orders of the Ministry of Rural Development (6/2009. (IV. 14.) KvVM-EüM-FVM) and 10/2000. (VI. 2) KöM-EüM-FVM-KHVM) were considered, which specify pollution limits for heavy metals in soils and water. In addition, we took into consideration the suggested temporary pollution limits by Kádár (1998), who used the method of Lakanen-Erviö also. Results and evaluation for the six toxic heavy metals are summarized in Table 2.

Background concentrations give representative values for the natural or close to natural levels for each of the metals. After comparison with the background concentrations, the correlation between layers was analyzed, presupposing that there is a relationship between the data of upper and lower layers. It has been established that there is a strong correlation between the concentrations in the upper and lower layers of single sampling points, as demonstrated in the amounts of Cu (Fig. 3).

Table 1 Properties of the investigated soils — average values of particle size analysis, soil pH, $CaCO_3$ content, soil organic matter, and compactness (the yarn number of Arany) in soils categorized by land use types and soil layer depth, *n* number of samples

Land use category	Sampling depth	*n*	Percentage of fractions (%)			pH (H_2O)		Soil organic matter	Yarn number of Arany
		qty	2.0–0.05 mm	0.05–0.002 mm	<0.002 mm		%	%	%
Forested areas	0–10 cm	28	63.21	21.01	15.78	5.5	7	8.08	55
	10–20 cm	28	62.23	21.35	16.42	5.3	6	4.63	46
Garden areas	0–10 cm	7	55.57	22.57	21.86	7.5	13	4.77	47
	10–20 cm	7	54.15	21.14	24.71	7.6	12	3.43	43
Viticulture areas	0–10 cm	4	49.98	19.98	30.04	7.5	11	6.46	53
	10–20 cm	4	50.00	19.00	31.00	7.0	10	4.90	53
Agricultural areas	0–10 cm	7	51.86	21.14	27.00	7.3	8	5.74	52
	10–20 cm	7	49.00	22.57	28.43	7.5	7	4.39	47
Residential areas	0–10 cm	17	58.53	19.88	21.59	7.6	13	5.72	49
	10–20 cm	17	56.64	20.71	22.65	7.8	13	3.80	44
Traffic areas	0–10 cm	13	58.07	20.62	21.31	7.7	16	7.07	52
	10–20 cm	13	58.23	19.69	22.08	7.9	16	4.11	45
Industrial areas	0–10 cm	5	67.00	16.80	16.20	7.8	19	5.55	46
	10–20 cm	5	65.40	17.20	17.40	8.0	18	3.85	43
Creek and lake banks	0–10 cm	10	58.80	19.80	21.40	7.7	14	6.64	57
	10–20 cm	10	58.60	19.80	21.60	7.8	14	5.63	51
Parks	0–10 cm	6	55.34	21.33	23.33	7.7	14	6.79	56
	10–20 cm	6	56.01	19.33	24.66	7.9	13	5.21	50
Other	0–10 cm	7	51.57	26.00	22.43	7.5	20	4.19	55
	10–20 cm	7	50.71	24.00	25.29	7.7	20	4.23	50

No significant differences have been found between the two layers, regarding the order of magnitude of the levels of Cd, Co, Cu, Ni, Pb, and Zn. Comparing the two layers, it clearly cannot be said that the upper layer is more polluted than the lower layer. Many samples could be characterized with heavy metal contents exceeding the permissible limits, mostly in the upper layers, but the deeper layers contained even higher levels of the metals in some of the samples. This could possibly be explained mainly by the soil pH, although metal mobility is also determined by several other factors or soil properties (organic matter content and its quality, and clay content) (Szabó 1996). These properties influence the mobility of metals, as well as the location of these sampling points and their daily rate of load. The mobility and plant availability

Table 2 Heavy metal concentrations in the soil samples; *n* number of samples

Sampling depth		*n*	Cd	Co	Cu	Ni	Pb	Zn
		qty	mg/kg					
0–10 cm	Mean	104	1.62	20.63	118.39	25.74	124.55	132.95
	Min.	104	0.37	3.58	11.46	5.51	27.57	26.78
	Max.	104	6.74	64.16	1221.00	98.71	558.70	606.50
	Std. deviation	104	0.84	11.23	203.65	14.14	84.41	111.14
10–20 cm	Mean	104	1.52	21.13	121.39	25.31	120.49	101.58
	Min.	104	0.17	5.39	10.88	4.11	25.41	16.38
	Max.	104	6.14	55.86	1,449	70.99	586.7	578.6
	Std. deviation	104	0.85	11.35	233.55	14.32	98.82	98.06
	Background concentration	104	0.5	15	30	25	25	100
	Pollution limit	104	1	30	75	40	100	200

Background concentration and pollution limit values based on decrees of Ministry of Rural Development (6/2009. (IV.14.) KvVM-EüM-FVM and 10/2000. (VI. 2) KöM-EüM-FVM-KHVM). All concentrations are in indicated in mg/kg

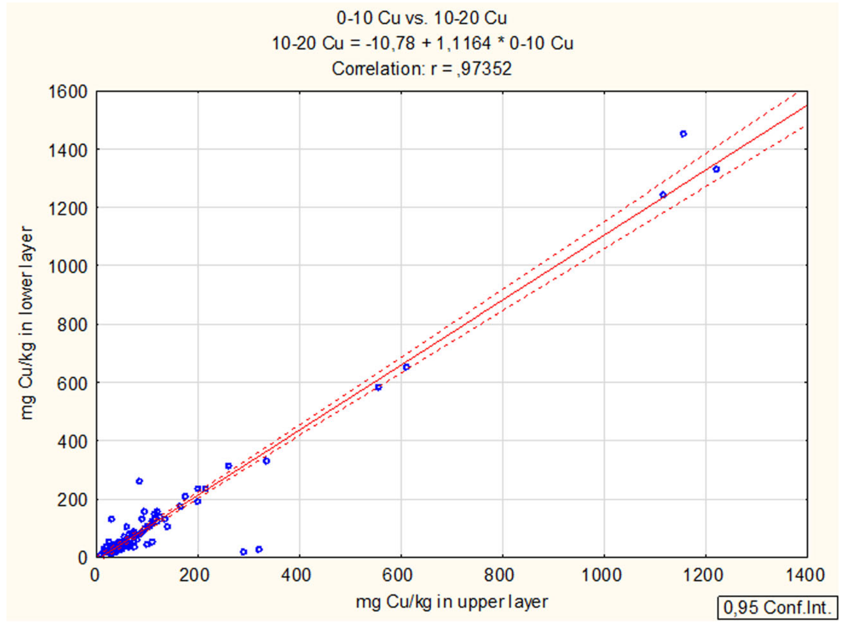

Fig. 3 Relationship between the copper content of the upper and lower layers of single sampling points

of heavy metals depend on their origin. Anthropogenic metals are mostly very mobile and readily accessible by plants (Kabata-Pendias 1993; Szolnoki et al. 2013). Fekete (1989) used the method of Lakanen-Erviö to investigate topsoil samples on the area of Hungary. He found low average values, which were close to the natural background limits, but since then, we have changed our environment. Figures 4 and 5 depict the levels of the Pb in both soil layers. It was found that in the downtown areas, both layers are polluted with Pb, as these places are subjected to a continuous load. The soils of the suburbs contain lower levels of Pb, possibly because the intermittent traffic allows the metal to bind to the humus and to accumulate in the topsoil layer (Figs. 4 and 5).

The Pb levels are generally high in the soils of the city in spite of the fact that the use of leaded fuel was officially prohibited in the beginning of the 1990s. Accumulation is characteristic to the upper layers, although intense and high amounts of precipitation are supposed to render Pb mobile even in alkaline media. The concentrations of Pb far exceed the Hungarian pollution limit (100 mg Pb/kg), established in 6/2009 joint decree (Table 2). According to the suggested natural background level (10 mg Pb/kg), the pollution limit (25 mg Pb/kg) and intervention pollution limits (C_1 75–150, C_2 150–300, C_3 >300 mg Pb/kg—depending on the sensitivity of the area) for Pb by Kádár, our values can be characterized predominantly in C_2 intervention pollution limit. The concentration of Pb decreases slightly in the topmost soil layers while moving from the traffic affected downtown toward the suburban areas of the city. Nevertheless, the suburban soils are more acidic; so, even low traffic can increase the mobility of Pb in an acidic media. A weak linear relationship was established between Pb and Zn contents of the upper soil layers. In 40 % of the upper and in 34 % of the lower soil layer samples, Zn levels were higher than the specified background contamination level (100 mg/kg). Overall, 30 out of the 208 samples exceeded allowable pollution limits. In 8 sampling sites, both of the soil layers (16 samples) were heavily contaminated with Zn (concentration levels exceeding 200 mg/kg). However, only a fraction of the Zn occurring in the soils originates from traffic itself (Szolnoki et al. 2013), as Zn and its compounds are also present in household appliances and are also widely used for industrial and agricultural purposes. Considering the whole area of the city, Zn levels are predominantly lower than prescribed limit values; thus, the local increase in the concentrations cannot be related directly to the intensity of the traffic. Kádár (1993) has already measured accumulation in traffic and industrial zones with the method of Lakanen-Erviö (Csathó 1994). According to the suggested natural background level (5 mg Zn/kg), the pollution limit (20 mg Zn/kg), and intervention pollution limits (C_1 40–80, C_2 80–160, C_3 >160 mg Zn/kg—depending on the sensitivity of the area) for Zn by Kádár (1998), our results were mostly higher than these limits.

The Cd levels were high throughout the whole city. Accumulation was found in both of the soil layers. Altogether, 80 % of the samples (85 % of the upper layers and 75 % of the lower layers) were found to contain Cd in higher concentrations than the allowed limit (1 mg/kg). This contamination can originate from the combustion of wastes, waste waters, and traffic (tire wear). The levels of Cd can reach as high as 3 mg/kg in soils next to public roads. The levels of Cd that are absorbed can be significant in alkaline soils while in acidic forest sites, it can become more available to plants.

For copper, only 20 % of the samples exceeded the natural background level (30 mg Cu/kg), while the limit of

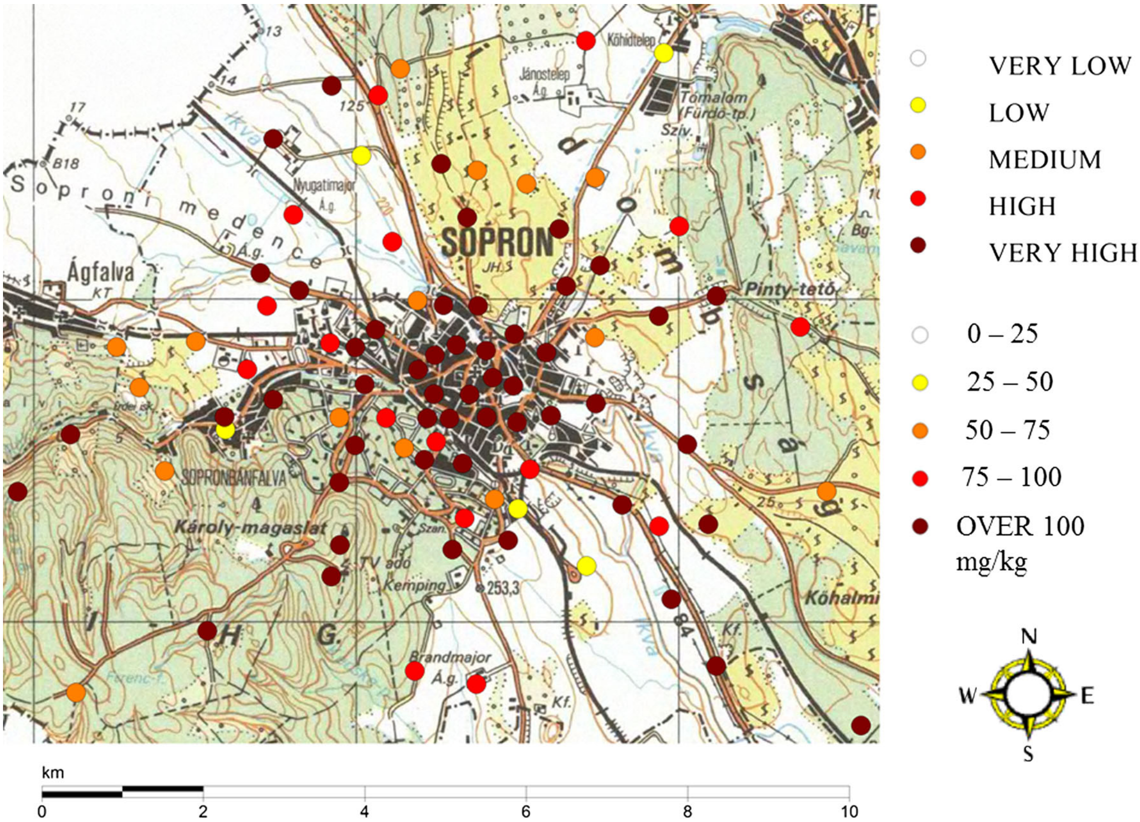

Fig. 4 Pb content in upper layer (0–10-cm depth)

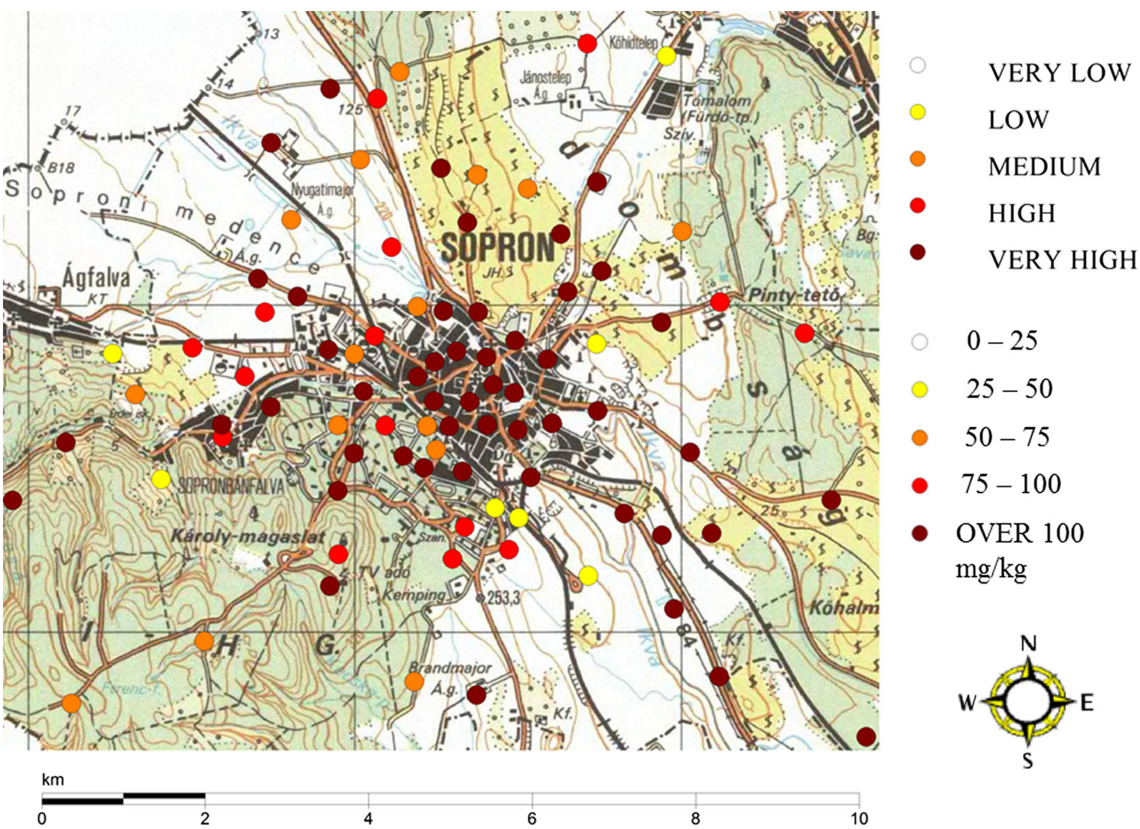

Fig. 5 Pb content in lower layer (10–20-cm depth)

contamination was surpassed by 40 % of the samples. Compared to the suggested natural background level (10 mg Cu/kg), the pollution limit (40 mg Cu/kg) and intervention pollution limits (C_1 90–140, C_2 140–190, C_3 >190 mg Cu/kg—depending on the sensitivity of the area) for Cu by Kádár (1998), the copper values were higher in every case than the pollution limit. The measurements have also confirmed previous results, determined in the soils of suburban vineyards and residential areas. Viticulture and agriculture (using a Bordeaux mixture) can be the reasonable sources of the elevated Cu levels. The high Cu levels determined in the lower soil layers in the downtown area can possibly originate from the corrosion of copper wires, as Cu accumulates in undisturbed soils typically in the topmost layers (Szegedi 1999b).

Figure 6 demonstrates strong linear relationships between Co and Ni contents in different depths of the soils. These metals are important in the formation of some rocks; their joint presence is evident. The main source of these metals is the natural bedrock, but due to technogenic factors (e.g., combustion), they have accumulated. The natural occurrence of Co and Ni is 18 and 25 mg/kg, respectively, and both metals are essential for living organisms in low concentrations. It has been established that neither of the metals accumulated in the 0–10-cm layer of the soil, but their concentrations increased in lower layers systematically. This proves that these metals are more mobile than Pb (as they do not form complexes with humic substances) and thus are leached into the deeper layers of the soil (Szegedi 1999b). Neither Ni nor Co reached pollution limit values (40 mg Co/kg; 50 mg Ni/kg), but near-limit levels were found next to agricultural areas and city parks. The Co and the Ni values were under the suggested intervention pollution limits of Kádár (1998).

While analyzing land use types (Table 3), it has been established that there are two categories which are subjected to high environmental load: In garden and viticulture areas, only one metal, namely, Cu, had elevated levels in the soils. This could be explained by the intensive use of Cu containing chemicals in these areas. The samplings were carried out during the spring, after the period of ground frosts at the beginning of sprouting when intense agricultural work had

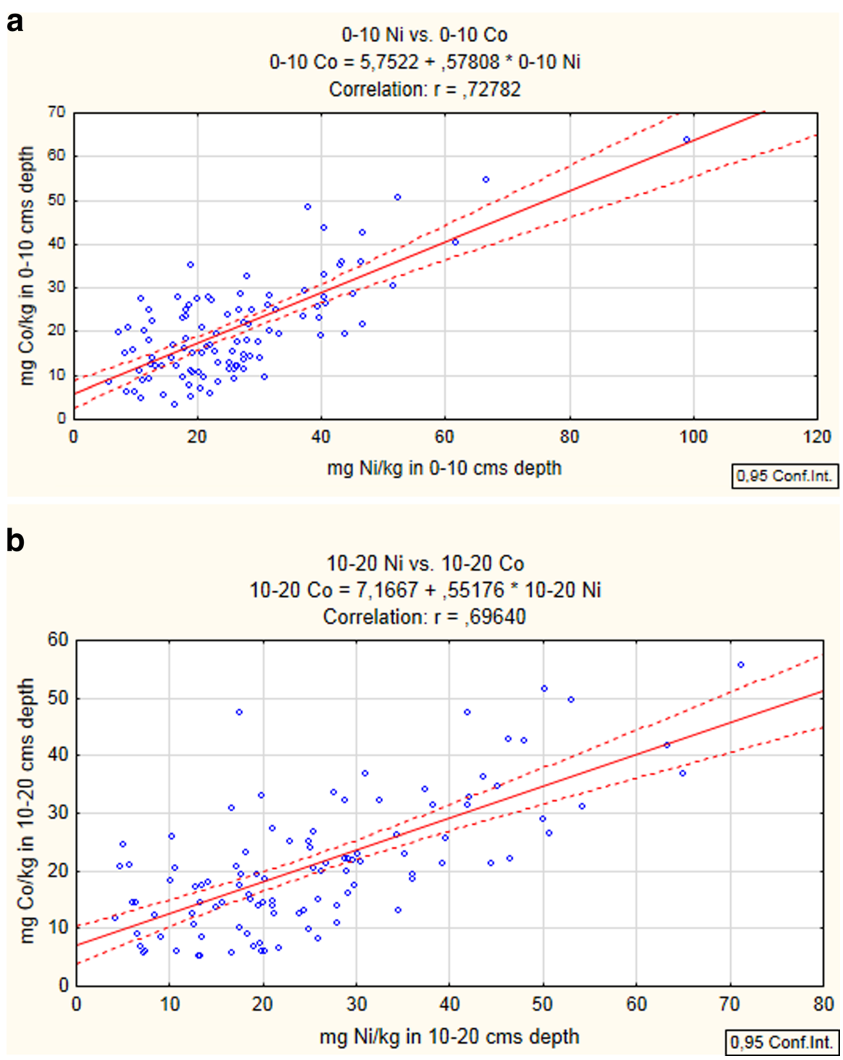

Fig. 6 Connection between Ni and Co contents in different depths

Table 3 Mean and standard deviation values of heavy metal in soils, categorized by land use types and soil layer depth, *n* number of samples

Land use category	Sampling depth	*n*	Cd	Co	Cu	Ni	Pb	Zn
		qty	mg/kg					
Forested areas	0–10 cm	28	1.2±0.6	22.0±10.9	42.2±56.6	20.7±17.0	123.1±61.8	111.7±117,7
	10–20 cm	28	0.9±0.6	19.7±7.9	27.1±15.7	15.8±10.7	89.5±43.7	59.9±42,4
Garden areas	0–10 cm	7	1.3±0.7	24.7±10.5	527.5±510.2	29.4±13.7	95.5±39.6	103.8±117.7
	10–20 cm	7	1.6±0.3	25.6±9.0	596.2±600.5	32.1±11.2	106.2±46.0	97.8±42.4
Viticulture areas	0–10 cm	4	1.4±0.9	28.2±13.9	453.1±455.6	24.7±12.5	95.3±33.2	130.7±58.3
	10–20 cm	4	1.6±0.7	28.7±14.2	413.1±573.2	26.2±11.8	326.1±40.4	111.2±70.2
Agricultural areas	0–10 cm	7	1.8±0.3	30.8±12.9	88.9±30.4	43.3±16.1	109.2±27.8	151.9±146.3
	10–20 cm	7	1.8±0.3	31.7±11.8	98.7±34.2	45.6±16.0	116.9±33.4	125.0±91.2
Residential areas	0–10 cm	17	1.8±0.7	20.2±13.4	101.1±57.9	26.6±13.0	163.2±128.0	159.1±104.1
	10–20 cm	17	1.7±0.8	23.9±14.7	100.1±74.2	27.8±16.2	134.4±106.6	111.7±80.6
Traffic areas	0–10 cm	13	2.3±1.7	18.2±7.1	86.0±46.4	26.3±8.2	134.4±106.1	155.6±167.3
	10–20 cm	13	2.1±1.6	18.3±9.3	88.6±56.7	25.7±10.6	143.6±146.1	133.8±167.2
Industrial areas	0–10 cm	5	1.7±0.4	16.1±11.6	54.9±14.1	23.7±12.8	104.1±40.6	121.0±50.2
	10–20 cm	5	1.4±0.7	15.1±15.8	47.9±24.7	21.4±15.8	93.7±48.4	84.7±59.8
Creek and lake banks	0–10 cm	10	1.7±0.6	15.5±5.8	89.7±46.1	27.4±8.3	113.0±61.4	151.4±94.5
	10–20 cm	10	1.9±0.6	15.7±6.2	108.1±67.6	27.8±7.1	131.9±82.8	158.1±158.8
Parks	0–10 cm	6	1.8±0.4	22.8±12.7	97.7±23.6	30.9±12.4	195.4±113.0	198.0±74.6
	10–20 cm	6	1.8±0.3	24.4±16.0	98.5±49.2	31.8±13.6	269.9±208.1	149.5±97.1
Other	0–10 cm	7	1.3±0.3	11.0±5.0	58.8±70.9	16.8±7.1	49.6±14.8	50.2±12.6
	10–20 cm	7	1.4±0.2	15.2±7.4	83.9±79.6	22.9±13.8	69.1±36.0	49.0±8.6
Background concentration			0.5	15	30	25	25	100
Pollution limit			1	30		40	100	200

Background concentration and pollution limit values based on decrees of Ministry of Rural Development (6/2009. (IV.14.) KvVM-EüM-FVM and 10/2000. (VI.2) KöM-EüM-FVM-KHVM). All concentrations are indicated in mg/mg

already commenced, possibly contributing to the high Cu levels.

On the other hand, the soils of parks could be characterized by the elevated levels of several of the heavy metals in both layers. Pollutants absorb on surface of the green areas of the city or are washed into the soils of parks as these locations provide a suitable surface for the infiltration of heavy metals.

4 Conclusions

There are relationships between polluting heavy metal concentrations and land use in the topsoils of the city of Sopron. Comparing the two investigated layers, it could not be said that the upper layer is more polluted than the lower layer. The acidic soil pH of the parental material can be observed in both layers on the southwest forest territories of the city, moreover the—so far insignificant—alkalizing of the city territories compared to the surroundings due to the land-shaping activities of mankind. The $CaCO_3$ content of soils is determined by the extent of disturbance and by the deposit of artefacts. The study area could be characterized by clayey loam and clay textures, and the upper layer contains more organic matter (more than 4 % by average by land use) than the lower layer on the whole investigated area. The Pb content was over the Hungarian pollution limit (>100 mg Pb/kg) in both layers for the entire Sopron area. Urban soils with the highest Cu content have been collected from garden and viticulture areas. That could be the result of the use of pesticides at the surrounding vineyards. Cd contents were also higher than Hungarian pollution limit (>1 mg Cd/kg), the highest values detected in traffic zones, where these values could be more than 3 mg Cd/kg according to the literature. The Co, Ni, and Zn results were under the pollution limits in most cases on sampling points (<30 mg Co/kg; <40 mg Ni/kg; <200 mg Zn/kg), but the average values were higher than limits based on land use categories. The highest average values of Zn and Pb were found in the soils of parks, but ultimately, this land use category is considered the most polluted. This contamination of Pb, Zn, and Cd, originating from traffic, is bound in the soils of urban green areas. In the future, a detailed investigation of these polluted green areas and analysis of urban plants will be carried out, which have effects on human health. Based on our experiments, the unique character of the city is fading away, the qualification of the peripheral areas is changing, the usage of the land is condensing, all of which lead to the declining quality of urban soil.

Acknowledgments The research was supported by the European Union by the TÁMOP 4.2.1.B-09/1/KONV-2010-0006 project. The authors wish to thank Anikó Horváth for her assistance with the statistical analyses.

References

Baranyai F, Fekete A, Kovács I (1987) Results of the Hungarian nutritional studies. Publishing House of Agriculture, Budapest. ISBN 963-232-294-0, p 189 (in Hungarian)

Bellér P (1997) Methods of soil analysis. University of Sopron, Faculty of Forestry, Department of Soil Site Survey, Sopron. p, 118; (in Hungarian)

Bergbäck B, Johansson K, Mohlander U (2001) Urban metal flows—a case study of stockholm. Review and Conclusions Water Air Soil Pollut: Focus 1(3–4):3–24

Bidló A, Horváth A, Kámán O, Németh E, Pődör A, Szűcs P (2012): Soil Investigation in cities of West Hungary. In: Neményi M, Heil B (eds) The impact of urbanization, industrial, agricultural and forest technologies on the natural environment. Publishing House of National Textbook, Budapest. ISBN 978-963-197352-5, pp 147–160

Billwitz K, Breuste J (1980) Anthropogene bodenveränderungen im stadtgebiet von halle/saale. In Wiss Zeitschrift Univ Halle, Halle 39(4):25–43

Blume HP (1992) Handbuch des Bodenschutzes. Ecomed Verlag. Germany, pp 277–303

Brown RW, Gonzales C, Hooper MJ, Bayat AC, Fornerette AM, McBride TJ, Longoria T, Mielke HW (2008) Soil lead (Pb) in residential transects through Lubbock, Texas: a preliminary assessment. Environ Geochem Health 30:541–547

Bullock P, Gregory PJ (ed) (1991) Soils in the urban environment. Blackwell, Oxford. ISBN 978-0-63202-988-4, p 174

Burghardt W (1994) Soils in urban and industrial environment. Plant Nutr Soil Sci 157(3):205–214

Charzyński P, Bednarek R, Greinert A, Hulisz P, Uzarowicz Ł (2013) Classification of technogenic soils according to WRB system in the light of Polish experiences. Soil Science Annual 64(4):145–150

Craul PJ (1992) Urban soils (applications and practices). John Wiley & Sons Inc., New York. ISBN 0-471-18903-0, p 366

Csathó P (1994) Contamination of the environment with heavy metals and its consequences on agricultural production. Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences. ISBN: 963-04-4857-2, pp 175 (in Hungarian)

Dövényi Z (ed) (2010) Hungarian microregions. Geographical Institute, Research Centre for Astronomy and Earth Sciences of the Hungarian Academy of Sciences. Budapest. ISBN 978-963-9545-29-8, p 876

Entwistle JA, Abrahams PW, Dodgshon RA (1998) Multi-element analysis of soils from Scottish historical sites interpreting land-use history trough the physical and geochemical analysis of soil. J Archaeol Sci 25:53–68

FAO (1990) Guidelines for soil description. 3rd Ed. (revised). Soil Resources, Management and Conservation Service, Land and Water Development Division. FAO, Rome. 70 pp

Farsang A, Jóri Z (1999) The heavy metal load in soils of green areas of Szeged city In: Galbács Z (ed) Proceedings of the 5th Symposium on Analytical and Environmental Problems. Szeged, pp 47–54 (in Hungarian)

Fekete A (1989) Non-essential (toxic) micronutrient content of the Hungarian soils. Agrochemistry and Soil Sciences 38(1–2):174–176 (in Hungarian)

Fiedler HJ (1990) Bodennutzung und Bodenschutz: Jena. VEB Gustav Fischer Verlag, p 267

Hazelton P, Murphy B (2011) Understanding soils in urban environments. Csiro Publishing, Collingwood, 160. ISBN 978-1-84971-237-8

Hiller DA, Meuser H (1998) Urbane Böden (Urban soils). Springer, Berlin, p 161

Horváth A, Szűcs P, Kámán O, Németh E, Bidló A (2013) Examination of topsoils in Sopron. Landsc Ecol 11(1):125–134 (in Hungarian)

IUSS Working Group WRB. 2007. World Reference Base for Soil Resources 2006. first update 2007. World Soil Resources Reports No. 103. FAO, Rome

Jim CY (1998) Soil characteristics and management in urban park in Hong Kong. Environ Manag 22(5):683–695

Juhász I (ed) (2006) Condition of hungarian soils. Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences. Budapest. pp 9117 (in Hungarian)

Juhász P, Bidló A, Heil B, Kovács G, Patocskai Z (2008) Bükkös állományok szénmegkötési potenciálja a Mátrában Beech forest Potential of carbon sequestration of beech forest satnds in Matra . In: Simon L (ed) Soil Protection Special Issue. 2008. Publishing House of Bessenyei György, Nyíregyháza. ISBN: 978-963-9909-03-8; ISSN: 1216–9560, pp 409–416 (in Hungarian)

Joint Decree No. 10/2000. (VI. 2) KöM-EüM-FVM-KHVM of the Ministers of Environmental Protection, Public Health, Agriculture and Regional Development, and of Traffic, Communication and Water Management on the Limit Values Necessary to Protect the Quality of Groundwater and the Geological Medium (in Hungarian)

Joint Decree No. 6/2009. (IV. 14) KvVM-EüM-FVM of the Ministers of Environmental Protection and Water Management, Public Health, Agriculture and Regional Development on the Limit Values Necessary to Protect the Quality of Geological Medium and the Groundwater and on Measurement of Pollution. (in Hungarian)

Kabata-Pendias A (1993) Behavioural properties of trace metals in soils. Appl Geochem 2:3–9

Kádár I (1993) Evaluation of the contaminated soils of traffic, settlement and industry. Crop Production 42(2):185–190. ISSN: 0546–8191 (in Hungarian)

Kádár I (1998) Remediation handbook 2. Investigation of contaminated soils. Ministry of Environment. p. 151. ISBN 963-04-5362-2 (in Hungarian)

Kollender-Szych A, Niedźwiecki E, Malinowski R (2008) Urban soils. Academia Rolnicza W. Szczecinie, Szczecin 61–100. (in Polish)

Kovács M, Nyári I (1984) The heavy metal contents of the public places of Budapest. Agrochemistry and Soil Sciences 33(3–4):501–510 (in Hungarian)

Lehmann A (2007) Nature and significance of anthropogenic urbansoils. J Soils Sediments 7(4):247–260

Lehmann A (2010) Evaluation and importance of soil functions in cities considering infiltration and climatic regulation. 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World 1–6 August 2010, Brisbane, Australia, pp 53–56

Li XD, Lee SL, Wong SC, Shi WZ, Thornton I (2004) The study of metal contamination in urban soils of Hong Kong using a GIS-based approach. Environ Pollut 129:113–124

McEldowney S, Hardman DJ, Waite S (1993) Treatment technologies. In: McEldowney S, Hardman J, Waite S (eds) Pollution ecology and biotreatment technologies. Longman, Singapore Publishers

Meuser H (2010) Contaminated urban soils. Springer Science-Business Media B.V., ISBN 978-90-481-9327-1, p 318

Morel JL, Heinrich AB (2008) SUITMA—soils in urban, industrial, traffic, mining and military areas; An interdisciplinary working group of the 'International Union of Soil Science' (IUSS) dedicated

to soils strongly modified by human activities. J Soils Sediments 8: 206–207
MSZ-08-0205 (1978) Determination of physical and hydrophysical properties of soils. Hungarian Standard Association, Budapest (in Hungarian)
MSZ 21470–50:2006 Environmental testing of soils. Determination of total and soluble toxic element, heavy metal and chromium(VI) content (in Hungarian)
Norra S, Stüben D (2003) Urban soils. J Soils Sediments 3(4):229–233
Puskás I, Farsang A (2007) The evaluation of the parameters indicating the level of anthropogenic effects in urban soils of Szeged. Landsc Ecol 5(2):371–379 (in Hungarian)
Puskás I, Prazsák I, Farsang A, Maróy P (2008) Physical, chemical and biological aspects of human impacts on urban soils of Szeged. Agrochemistry and Soil Sciences 57(2):261–280 (in Hungarian)
Puskás I, Farsang A (2009) Diagnostic indicators for characterizing urban soils of Szeged, Hungary. Geoderma 148(3–4):267–281
Runge M (1975) Westberliner Böden anthropogener Litho- oder Pedogenese. Dissertation an der Technischen Universität Berlin, p 237
Sándor G, Szabó Gy, Charzyński P, Szynkowska E, Novák TJ, Świtoniak M (eds) (2013) Technogenic soils atlas. Polish Society of Soil Science Toruń pp 35–74
Scharenbroch BC, Lloyd JE, Johnson-Maynard JL (2005) Distinguishing urban soils with physical, chemical, and biological properties. Pedobiologia 49:283–295
Stefanovits P (1992) Soil Sciences. Publishing House of Agriculture. Budapest. ISBN 963-81-6001-2, p 380 (in Hungarian)
Stefanovits P, Filep Gy, Füleky Gy (1999) Soil Sciences. Publishing House of Agriculture. Budapest. ISBN 963-286-178-7, p 470 (in Hungarian)
Szabó Gy (1996) Heavy metals in soils. Geogr Rev 120(4):253–266 (in Hungarian)
Szegedi S (1999a) Heavy metals in soils and plants of Debrecen of transportation origin, and its pedologic connections and city ecological effects. PhD dissertation. Kossuth Lajos University, Department of Applied Landscape Geography, Debrecen, p 138 (in Hungarian)
Szegedi S (1999b) The heavy metal pollution of the soil in Debrecen. Hungarian Sciences 106/66(10):1192–1200 (in Hungarian)
Szolnoki Zs, Farsang A, Puskás I (2013) Cumulative impacts of human activities on urban garden soils: origin and accumulation of metals. Environ Pollut 177:106–115
Tóth I (2011) History of Sopron. Scientific study. Museum of Sopron, Sopron, p 10 (in Hungarian)
Van Reeuwijk LP (ed) (2002) Procedures for soil analysis (6th ed.). Tech. Pap. 9. Wageningen, ISRIC, p 120
Varga G, Konkoly-Gyúró É, Kovács G, Schmidt G, Radó D, Baranyi K, Czimber K, Boros G, Héjj B, Krassay L, Rácz I, Szemerédy M and Varga T (1999) Information system describing the condition of urban trees and forests. Urban Greening and Landscape Architecture, Koppenhaga, 1999. június 23–25
Zöttl HW (1987) Responses of forest decline to experimental fertilization. In: Hutchinson TC and Meema KM: Effects of Atmospheric Pollutants on Forests, Wetlands and Agri-cultural Ecosystems. Springer Series G: Ecol Sci 16:255–265