Characteristics and Classification of Three Urban Soils in the Sisak City, Croatia

Stjepan HUSNJAK [1](✉)
Vedran RUBINIĆ [1]
Josip HALAMIĆ [2]
Ajka ŠORŠA [2]
Boris VRBEK [3]

Summary

Many soil classification systems (including Croatian Soil Classification - CSC) do not treat urban (technogenic) soils adequately. Moreover, in different parts the world, different names for similar urban soils are often used. All this hampers effective management of these increasingly important soils. The main aim was to classify three typical Sisak City soils according to CSC and international WRB system. Additional aim was to assess soil contamination by heavy metals. In two soil profiles pedogenetic A horizon was formed. Hence, according to CSC, we classified these soils as Rendzinas and not Technogenic soils. Given that CSC does not include a subtype of Rendzina on deposited land material, it was proposed. In one profile, topsoil organic matter accumulated mainly due to human activity, so it was classified according to CSC as a Deposol on land material. Since CSC offers no criteria for further systematization of Deposols, we proposed some. According to WRB, two soils were systemized as Technosols, but one was not. Namely, since one soil did not contain enough artefacts to qualify as a Technosol, it was classified as a complex (buried) soil (Regosol over Retisol). However, qualifier *Relocatic* could be used to indicate dominant human influence on this profile. Compared with CSC, WRB was more suitable for classifying these soils. Accordingly, CSC should be updated. According to the reference threshold for parks and recreational areas, heavy metals contents were below maximum allowed values in each soil. However, contents of some metals were over the threshold for agricultural soils.

Key words

Technosols, Croatian soil classification system, WRB, Soil heavy metals

[1] University of Zagreb, Faculty of Agriculture, Svetošimunska 25, 10000 Zagreb, Croatia
✉ e-mail: shusnjak@agr.hr
[2] Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croati
[3] Croatian Forest Research Institute, Cvjetno naselje 41, 10450 Jastrebarsko, Croatia

Received: March 7, 2018 · Accepted: April 10, 2018

Introduction

City of Sisak is located in the central part of the Republic of Croatia, having almost 50000 inhabitants. It is characterized by continuity of urban living for more than 2000 years, as witnessed by numerous archaeological sites. Significant portion of the urban area of Sisak, in addition to residential, industrial and infrastructural areas, is occupied by land used for parks, playgrounds, smaller agricultural plots, etc. With respect to their origin and present location, soils of the above-described area can be systemized as urban soils.

Urban soils are found in urbanized areas and are, at least slightly, affected by human actions. More precisely, urban soils are the soils occurring in urbanized, industrial, traffic and mining areas (Burghardt, 1994; according to Sobocka, 2008). Such soils are increasingly recognized as a value of vital importance. Still, in many soil classification systems of the world, these soils do not get the attention they deserve, i.e., they are not covered with enough detail and/or they are named using different terms or systemized into very different categories. Such situation often results with lack of information and confusion, disabling effective management of urban soils. Although most authors regard urban soils as anthropogenic soils, they designate those using special names, thus creating a large number of different terms (Resulović and Čustović, 2007). Further on, we provide some examples of different terms and categories used for urban soils across different classification systems: class of Technogenic soils – Croatia (Škorić, 1986; Husnjak 2014), class of Reduktosols – Germany (Sponagel, 2005; according to Lehmann and Stahr, 2007), subclasses of Artificial Anthroposols and Reconstituted Anthroposols – France (Baize and Girard, 1998; according to Lehmann and Stahr, 2007), separate section of Technogenic Superficial Formations – Russia (Shishov et al., 2001; according to Lehmann and Stahr). Resulović et al. (2008) recommend systemization of urban soils in different subclasses of the Technosols class, such as Urbisols, Garbisols and Necrosols. Lehmann and Stahr (2007) proposed the categories of Anthropogenic inner-urban soils, Anthropogenic extra-urban soils and Natural urban soils for descriptive purposes, and the terms Man-influenced soils, Man-changed soils and Man-made soils for taxonomic purposes.

The main aim of this paper is to present the characteristics of three typical urban soils in Sisak, as well as their classification according to the Croatian Soil Classification (Husnjak, 2014) (CSC) and the World Reference Base for Soil Resources classification system (IUSS Working Group WRB, 2014) (WRB). The additional aim was to assess soil contamination by heavy metals on the three sites.

Materials and methods

Features of urban soils in Sisak are presented on the basis of three soil profiles, which we consider typical for the area. Field research, including soil sampling, was carried out in late 2010 (Šorša, 2014; Šorša and Halamić, 2014), in line with FAO (2006).

Laboratory research was done in early 2011. Soil particle size distribution was analyzed according to HRN ISO 11277 (2004), while soil texture was interpreted according to FAO (2006). Soil pH was determined according to HRN ISO 10390 (2005), and soil carbonate content according to HRN ISO 10693 (2004). Total nitrogen content was measured according to HRN ISO 13878 (2004) and soil cation exchange capacity (CEC) according to HRN ISO 11260 (2004). Base saturation was calculated as follows: sum of basic cations (Ca, Mg, Na, K) / CEC) x 100. Humus content was determined after Tjurin (Škorić, 1985).

The content of heavy metals in soil was analyzed after Šorša et al. (2017). Assessment of soil contamination by heavy metals was done on the basis of the following: a) „Ordinance on the protection of agricultural land against pollution" (Official Gazette, 2010), b) revised intervention values for soils and intervention values for soil remediation (New Dutch List, 2009) in the Republic of Croatia, c) thresholds for parks and recreational area (AZO, 2008), and d) thresholds for children playgrounds (AZO, 2008).

Results and discussion

Profile No. 1

The first location, on which the Profile No. 1 (Fig. 1) was excavated, was in the northern part of the City, on a playground near a kindergarten (GPS coordinates X=5607693, Y=5039790, Gauss-Krüger's projection). A meadow, surrounded by deciduous trees and buildings, was found on the site. Land surface is nearly level. Natural drainage is good. Parent material comprises anthropogenic deposits of soil material with abundant artefacts, containing mostly (> 50%) pieces of bricks, but also (< 50%) pieces of bones, iron, glass, limestone, etc.

The profile is black (10YR 2/1) when moist throughout to the depth of 120 cm, implying a high content of soil organic matter (SOM) (Fig. 1). Soil has a silt loam texture in the surface layer, and loam texture in all other layers, with no lithic discontinuities (LDs) observed (Table 1). Usually, LDs represent differences in lithology or in age within a soil (IUSS Working Group WRB, 2014). Therefore, this material may be regarded as relatively homogeneous. Coarse fragments (almost exclusively artefacts) content varies along the profile depth from 14.9% to 71.3% (Table 1).

Soil is calcareous, with pH in 1M KCl being neutral in the surface layer and slightly alkaline in the deeper layers (Table 2). Humus content varies from low to high, showing no clear decreasing trend with soil depth (Table 2). However, due to biological activity, it is notably higher in the surface horizon, compared with the remaining ones (Table 2). In Table 2, cation exchange capacity (CEC) and base saturation (BS) values are given. The former corresponds to the distribution of clay and humus along soil depth (Tables 1 and 2), whereas the latter corresponds to soil pH (Table 2).

Heavy metals concentrations and threshold values are shown in Table 3. According to the threshold for agricultural soils, Cu and Pb contents are above the maximum allowed values in all horizons, while contents of all other metals remain below the maximum allowed values. According to the intervention values for soils and the threshold for parks and recreational area, content of all metals is well below the maximum allowed values. However, Cu and Pb concentrations are too high in all horizons, according to the thresholds for children playgrounds (AZO, 2008).

In the Basic Soil Map of Croatia at scale 1:50000, urban soils of Sisak were previously systemized within the division of Automorphic soils, into the class of Technogenic soils, as a soil type called Deposol. However, today it is possible, on the basis of new field and analytical data, to detect evidence of pedogenetic processes in this soil. These processes (most notably – humification) contributed to further soil development (most notably - in terms of the formation of

Figure 1.
Landscape at the Sisak site No.1 with the corresponding Profile No. 1

Table 1. Soil horizons designations and particle size distribution of the Profile No. 1

Soil depth (cm)	Horizon [1]		Diameter (mm) and content (%) of fractions						Soil texture
	CSC	FAO	2–0.2	0.2–0.063	0.063–0.02	0.02–0.002	<0.002	>2.0 [2]	
0 – 12	A	Au	22.5	12.3	27.3	26.8	11.1	14.9	Silt loam
12 – 29	I	Cu1	28.1	12.8	24.5	23.5	11.1	36.1	Loam
29 – 50	II	Cu2	33.4	14.6	19.2	20.9	11.9	33.4	Loam
50 – 70	III	Cu3	33.7	14.1	21.4	22.2	8.6	71.3	Loam
70 – 100	IV	Cu4	32.5	10.8	25.9	21.2	9.6	41.0	Loam
100 – 120	V	Cu5	35.8	11.9	22.1	20.8	9.4	61.7	Loam

[1] CSC = Croatian soil classification (Husnjak, 2014), FAO = Guidelines for soil description (FAO, 2006), [2] Coarse fragments – mainly artefacts

Table 2. Soil chemical properties of the Profile No. 1

Soil depth (cm)	pH			$CaCO_3$ %	Humus %	Nitrogen %	CEC [1] cmol+/kg	BS [2] %
	H_20	1M KCl	$CaCl_2$					
0 – 12	7.85	7.12	6.18	6.3	8.1	0.50	30.41	100
12 – 29	7.98	7.34	6.97	8.0	4.5	0.24	28.87	100
29 – 50	7.97	7.34	7.46	2.1	5.2	0.31	31.81	100
50 – 70	7.94	7.33	7.44	6.7	2.7	0.15	30.34	100
70 – 100	7.93	7.30	7.46	6.7	3.6	0.20	33.63	100
100 – 120	7.94	7.29	7.44	7.1	3.5	0.18	22.55	100

[1] CEC = Cation exchange capacity, [2] BS = base saturation

Table 3. Heavy metals concentrations (mg/kg dry soil) in the Profile No. 1

Soil depth (cm)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
0 – 12	0.54	23	93.7	26.1	129.4	123.9
12 – 29	0.54	22	128.4	26.7	198.6	141.3
29 – 50	0.58	21	141.1	23.4	180.4	143.6
50 – 70	0.60	21	146.2	24.6	181.8	134.3
70 – 100	0.57	23	155.7	24.1	272.9	148.2
100 – 120	0.55	21	148.5	22.8	190.5	134.0
Tv [1]	0.5 – 1.0	40 – 80	60 – 90	30 – 50	50 – 100	60 – 150
Tv [2]	13	258	190	100	530	720
Tv [3]	30	500	300	200	500	700
Tv [4]	5	100	60	50	100	200

Tv = Threshold value, Tv[1] = Threshold for agricultural loam soils (Offical Gazette, 2010), Tv [2] = Revised intervention values for soils and intervention values for soil remediation (New Dutch List, 2009), Tv [3] = Thresholds for parks and recreational area (AZO, 2008), Tv [4] = Thresholds for children playgrounds (AZO, 2008) a humus-rich A horizon). Because of this, as well as because no specific attention has been given to urban soils in CSC, we suggest that this particular soil profile should be systemized into the class of Humus-accumulative soils, as Rendzina (soil type) on deposited land material (subtype), calcareous (variety), loamy (form). Given that the structure of the existing CSC does not include a subtype of Rendzina on deposited land material, its inclusion into this classification system is here proposed.

According to WRB, the analyzed soil profile showed neither diagnostic horizons, nor diagnostic properties. Since, on average, more than 20% artefacts were determined in the upper 100 cm from the soil surface (Table 1), the soil was systemized into the Reference Soil Group (RSG) of Technosols. This group combines soils whose properties and pedogenesis are dominated by their technical origin (IUSS Working Group WRB, 2014).

IUSS Working Group WRB (2014) defines *artefacts* (bricks, pottery, glass, crushed stone, waste and garbage, mine spoil, crude oil, etc.) as solid or liquid substances that:

1. are created or substantially modified by humans as part of an industrial or artisanal manufacturing process; and/or are brought to surface by human activity from a depth where they were not influenced by surface processes, with properties substantially different from the environment where they are placed; and
2. have substantially same properties as when first manufactured/modified/excavated.

Since the artefacts in the studied profile contained more than 35% of rubble and refuse of human settlements, the Urbic Principal qualifier (PQ) was attributed to the RSG name. Also, four Supplementary qualifiers (SQs) were added: Loamic, Calcaric, Grossartefactic, Humic. *Loamic* indicates loamy texture in a layer ≥ 30 cm thick within ≤ 100 cm from the soil surface (Table 1). *Calcaric* stands for *Calcaric material* (≥ 2% $CaCO_3$) throughout between 20 and 100 cm from the soil surface (Table 2), while *Humic* stands for the humus content of 1% or more to the depth of 50 cm from the soil surface (Table 2). *Grossartefactic* implies 40% or more coarse fragments (artefacts) averaged over a depth of 100 cm from the soil surface (Table 1). Finally, this profile is named Urbic Technosol (Loamic, Calcaric, Grossartefactic, Humic).

Profile No. 2

Profile No. 2 (Fig. 2) was opened near the center of Sisak, close to the Kupa river (GPS coordinates X=5607638, Y=5038581, Gauss-Krüger's projection). The land on the site is used as a park, and features a meadow with deciduous and evergreen ornamental trees and shrubs. Natural drainage is good. Parent material is made dominantly of anthropogenic deposits (deposited successively over a longer period of time) and sporadically of alluvial sediments. Nylon film found at the depth of 15 cm (Fig. 2) probably originates from the flower plants event held at the site in 2009.

Soil color is dominantly dark brown (10YR 3/3) when moist in darker layers and dark yellowish brown (10YR 3/6) when moist in lighter layers (Fig. 2). Presence of lighter soil layers sandwiched between the darker ones (Fig. 2) indicated an unusual distribution of SOM along the profile, presumably due to human activities (e.g., soil material relocations and enrichments with organic materials). The surface soil layer was probably created by significant enrichment with organic matter during the preparation of the site for the previously-mentioned flower plants event. Since this layer did not develop by natural pedogenesis, it is not designated as an A horizon in CSC, although ongoing pedogenesis clearly pushes this horizon towards an A horizon (Table 4).

Soil texture varies from sand loam, over silt loam to silty clay loam (Table 4). In line with IUSS Working Group WRB (2014), LDs due to the highly variable contents of sand particles were determined at the depths of 15 cm, 33 cm and 60 cm (Table 4). These discontinuities reflect episodes of erosion and/or deposition due to human and/or fluvial activities in the past. They are also the reason why the increase in clay content with soil depth (Table 4) should not be readily attributed (without further evidence) to clay illuviation (see IUSS Working Group WRB, 2014). Anyhow, vertical distribution of clay content clearly affected the values of CEC along soil depth (Tables 4 and 5).

All horizons are calcareous, but the content of calcium carbonate is much lower in the two bottom layers, compared to the overlying layers (Table 5). Accordingly, only the lowest layer may be regarded as neutral, whereas all others are alkaline (Table 5). Humus content is high in the surface layer and decreases with depth, only to increase again in the deepest layer (Table 5). These results agree with the initial morphological observation and explain why the lowest layer was designated according to FAO (2006) using the number 5 instead of the number 4, although no discontinuity in particle size distribution was determined between the two bottom layers (Table 4).

The concentrations of heavy metals and threshold values are given in Table 6. According to the threshold for agricultural soils, only the Zn concentration in the surface layer is above the maximum allowed value, while concentrations of all other displayed metals, and of Zn in the deeper horizons, remain below the maximum allowed values. According to the intervention values for soils and the threshold for parks and recreational area, content of all metals is well below the maximum allowed values (AZO, 2008).

Regarding its formation (land material deposition within the park area), this soil profile is classified, according to CSC, into the class of Technogenic soils - soil type Deposol. As in the case of the Profile No. 1, here also CSC shows some limitations regarding the detailed classification of technogenic soils. Since within the structure of the existing CSC the criteria for the division of this soil type into subtypes, varieties and forms are not given, we think it is necessary to introduce them. Namely, we suggest that the criterion for the division of types into subtypes could be the species of technogenic deposit, for the division of subtypes into varieties - presence of $CaCO_3$, and for the division of varieties into forms - texture of technogenic deposits. Thus, we suggest that this soil should be systemized as Deposol on land material, calcareous, loamy.

According to WRB, the Profile No. 2 was classified as a Technosol. This was due to the presence of a highly diagnostic artefact, i.e., a nylon film at the depth of 15 cm (Fig. 2). Since it was regarded as a continuous, very slowly permeable to impermeable constructed geomembrane found within 100 cm of the soil surface, the PQ *Linic* was added to the RSG name. Further, two SQs were added: *Calcaric* and *Ruptic*. The first one indicates presence of *Calcaric material*, and the second one indicates presence of LD within 100 cm of the soil surface. Therefore, this soil is named as follows: Linic Technosol (Calcaric, Ruptic).

Figure 2.
Landscape at the Sisak site No. 2 with the corresponding Profile No. 2

Table 4. Soil horizons designations and particle size distribution of the Profile No. 2

Soil depth (cm)	Horizon[1]		Diameter (mm) and content (%) of fractions					Soil texture
	CSC	FAO	2–0.2	0.2–0.063	0.063–0.02	0.02–0.002	<0.002	
0 – 15	I	Au	19.0	17.1	27.5	25.7	10.7	Silt loam
15 – 33	II	2C	34.3	16.2	24.3	19.1	6.1	Sand loam
33 – 60	III	3C	2.5	19.1	38.4	25.4	14.6	Silt loam
60 – 88	IV	4C	1.2	4.0	30.2	37.9	26.7	Silt loam
88 – 120	V	5C	1.3	4.3	26.5	37.8	30.1	Silty clay loam

[1] CSC = Croatian soil classification (Husnjak, 2014), FAO = Guidelines for soil description (FAO, 2006)

Table 5. Soil chemical properties of the Profile No. 2

Soil depth (cm)	pH			$CaCO_3$ %	Humus %	Nitrogen %	CEC[1] cmol+/kg	BS[2] %
	H_20	1M KCl	$CaCl_2$					
0 – 15	7.84	7.25	6.24	12.2	5.4	0.31	21.08	100
15 – 33	7.96	7.51	6.35	15.5	1.7	0.08	8.04	100
33 – 60	8.13	7.43	6.38	16.4	1.1	0.07	17.70	100
60 – 88	8.04	7.25	6.32	2.1	1.1	0.07	27.26	100
88 – 120	8.00	7.15	6.27	2.5	2.1	0.14	28.53	100

[1] CEC = Cation exchange capacity, [2] BS = base saturation

Table 6. Heavy metals concentrations (mg/kg dry soil) in the Profile No. 2

Soil depth (cm)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
0 – 15	0.63	41	38.8	28.2	76.5	180.0
15 – 33	0.29	17	25.6	18.7	36.1	68.9
33 – 60	0.28	22	17.5	29.1	17.9	58.6
60 – 88	0.44	37	30.3	43.2	32.6	94.2
88 – 120	0.57	38	31.5	45.6	33.5	92.8
Tv[1]	0.5 – 1.0	40 – 80	60 – 90	30 – 50	50 – 100	60 – 150
Tv[2]	13	258	190	100	530	720
Tv[3]	30	500	300	200	500	700

Tv = Threshold value, Tv[1] = Threshold for agricultural loam soils (Offical Gazette, 2010), Tv[2] = Revised intervention values for soils and intervention values for soil remediation (New Dutch List, 2009), Tv[3] = Thresholds for parks and recreational area (AZO, 2008)

Profile No. 3

Profile No. 3 (Fig. 3) is located in the part of Sisak called Caprag (GPS coordinates X=568767, Y=5035922, Gauss-Krüger's projection). Land surface at the site is nearly level. The land is currently used as a park, featuring a meadow with some deciduous and evergreen ornamental trees and shrubs. Natural drainage is good in the upper part, but poor in the lower part of the soil profile. Parent material is made of anthropogenic deposits of soil material, deposited successively over a period of time on top of Pleistocene loams (loess derivates), which occur at the site naturally. Not many artefacts were found in this soil (pieces of iron bars, bricks, glass, nylon, plastic, building waste, etc.).

Moist soil color alternates from brown (10YR 4/3) in the first and the third layer from the surface to various combinations of brown and yellowish brown in the remaining two layers (Fig. 3). Distinct inter-fingering of lighter-colored parts into the stronger-colored parts within the bottom layer is present (Fig. 3). Such morphology (i.e., *mottling*) is due to the abundance of redoximorphic features that were formed in response to the periodic stagnation of precipitation water and the corresponding alterations between reducing and oxidizing soil conditions. In agreement with IUSS Working Group WRB (2014), we infer that this horizon had developed a mottled appearance because oximorphic (stronger-colored) mottles/concretions precipitated inside soil aggregates, giving them colors with hue at least 2.5 units redder and chroma at least 1 unit higher than those of the surrounding soil found at/near the aggregate surfaces. Conversely, we recognize reductimorphic colors (lighter-colored soil, often representing *albic material*), with value at least 1 unit higher and chroma at least 1 unit lower than those of the soil inside the aggregates, as "fingers" penetrating through the lowest horizon along the surfaces of structural weakness (Fig. 3). Due to the above morphology, this horizon was given a designation comprising a suffix letter "g" (Table 7). We consider this horizon to represent a buried pseudogleyed loess derivate (Pleistocene loams). Pseudogleyed loess derivates, as the most widespread soil parent materials in continental Croatia, are described in detail in Rubinić et al. (in press).

Soil texture is silt loam throughout the profile, albeit a steady increase in clay content is observed with the increase in soil depth (Table 7). Although vertical trends in the contents of coarse and fine sand particles do not point to any LDs, abrupt changes in soil morphology (color) between the adjacent layers do (Fig. 3, Table 7). This, together with the soil pH along the profile (Table 8), means that the increase in clay content with soil depth is not due to lessivage (see Sauer, 2009; Rubinić, 2015). However, the clay content of the bottom layer (the pseudogleyed loess derivate) is probably partly illuviated from the formerly-present overlying layers (see Rubinić et al., in press), which were removed and replaced (during the reconstruction of the site) by the land material now present up to the depth of 67 cm (Fig. 3, Table 7). Therefore, the designation of the lowermost soil layer comprises the suffix letter *t* (Table 7).

Table 8 shows a uniform soil pH (especially in H_2O) throughout the first three layers (7.56-7.65), followed with a sharp pH decrease in the bottom layer (5.49). Such trend confirms that the bottom layer is not the true parent material of the overlying soil, since the soils formed on pseudogleyed loess derivates normally show the opposite vertical trend in soil pH (e.g., Rubinić et al., 2015). Humus content is moderate in the surface layer and decreases towards the bottom layer (Table 8).

Heavy metals concentrations and threshold values are shown in Table 9. According to the threshold for agricultural soils, this profile, as well as Profile No. 2, has only the Zn content in the surface layer above the maximum allowed value. All other metal contents (Zn contents in the deeper horizons included) are below the maximum allowed values. According to the intervention values for soils and the threshold for parks and recreational area, contents of all metals are well below the maximum allowed values (AZO, 2008).

In this soil profile, as well as in the Profile No. 1, pedogenetic processes enabled the formation of the A horizon. Due to this, as well as due to insufficient criteria for systemizing similar soils in CSC, we suggest classifying this soil into the class of Humus-accumulative soils, as Rendzina (soil type) on deposited land material (subtype), calcareous (variety), loamy (form). According to Sobocka (2008), in many cases, man-made soils are classified according to a natural soil classification (as Regosols or Rendzinas, for example).

According to WRB, this soil was classified as a complex (buried) soil, with the bottom layer (4Ctg) considered to be buried. In the upper part of the soil profile (0-67 cm), no diagnostic horizons could be identified. However, this part of the profile did not qualify as a Technosol RSG, since pieces of artefacts found in it amounted nowhere near the required 20%. Also, the soil material of the upper 67 cm of the profile is not man-made, but only man-deposited natural soil with some artefacts. Rossiter (2007) gives an example of a fresh mine spoil, which is a Technosol (because the mine spoil does not occur naturally at the surface), and a freshly-dumped overburden, which is a Regosol or Arenosol (depending on its texture), in which the land material transport can be recognized by the Transportic qualifier - e.g. Arenosol (Transportic). Accordingly, the upper part of the Profile No. 3 is classified as a Regosol RSG.

The 4Ctg horizon, in spite the discontinuity at its upper boundary, is recognized as a buried *argic horizon* (it has a high enough clay content and adequate thickness) comprising *retic properties*, i.e., inter-fingering of the lighter colored albic material at least 0.5 cm wide into a finer-textured stronger-colored argic horizon. Hence, the 4Ctg horizon must have been a part of a Retisol´s subsoil.

Finally, the complete classification of the profile No. 3 resulted with the following soil name: Hypereutric Regosol (Siltic, Relocatic, Ruptic) over Hypereutric Relictistagnic Retisol (Siltic). The reasons for the use of the above-listed qualifiers are further explained. The *Hypereutric* PQ indicates a base saturation of 50% or more throughout between 20 and 100 cm from the soil surface and 80% or more in some layer within 100 cm from the soil surface (Table 8). *Relictistagnic* means there is a layer at least 25 cm thick that has *stagnic properties* in at least 25% of the total horizon area, but with *reducing conditions* no longer present. This PQ refers to the 4Ctg layer (Fig. 3). *Siltic* stands as a SQ for the silt loam texture present throughout the whole profile (Table 7). *Relocatic* indicates in situ remodeling of the profile by human activity, after which no significant horizon development occurred. Finally, *Ruptic* indicates presence of LDs within the profile.

Figure 3.
Landscape at the Sisak site No. 3 with the corresponding Profile No. 3

Table 7. Soil horizons designations and particle size distribution of the Profile No. 3

Soil depth (cm)	Horizon[1]		Diameter (mm) and content (%) of fractions					Soil texture
	CSC	FAO	2–0.2	0.2–0.063	0.063–0.02	0.02–0.002	<0.002	
0 – 14	A	A	5.6	3.8	40.6	38.1	11.9	Silt loam
14 – 28	I/II	2Ctg/3C	3.0	5.5	41.3	36.5	13.7	Silt loam
28 – 67	II	3C	1.6	3.7	44.7	33.7	16.3	Silt loam
67 – 130	Ctg	4Ctg	0.2	1.1	41.3	34.2	23.2	Silt loam

[1] CSC = Croatian soil classification (Husnjak, 2014), FAO = Guidelines for soil description (FAO, 2006)

Table 8. Soil chemical properties of the Profile No. 3

Soil depth (cm)	pH			$CaCO_3$ %	Humus %	Nitrogen %	CEC[1] cmol+/kg	BS[2] %
	H_20	1M KCl	$CaCl_2$					
0 – 14	7.56	6.66	5.89	1.3	3.8	0,23	16.57	100
14 – 28	7.65	6.55	5.94	0.8	1.4	0,08	14.70	100
28 – 67	7.65	6.10	5.80	0.8	1.0	0,07	9.48	100
67 – 130	5.49	4.08	4.92	0.0	0.5	0,03	12.50	100

[1] CEC = Cation exchange capacity, [2] BS = base saturation

Table 9. Heavy metals concentrations (mg/kg dry soil) in the Profile No. 3

Soil depth (cm)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
0 – 14	0.35	34	26.2	30.9	43.8	175.0
14 – 28	0.20	35	21.9	27.6	34.2	111.6
28 – 67	0.08	36	22.9	29.8	20.7	86.1
67 – 130	0.03	42	22.2	32.2	17.2	73.7
Tv[1]	0.5 – 1.0	40 – 80	60 – 90	30 – 50	50 – 100	60 – 150
Tv[2]	13	258	190	100	530	720
Tv[3]	30	500	300	200	500	700

Tv = Threshold value, Tv[1] = Threshold for agricultural loam soils (Offical Gazette, 2010), Tv[2] = Revised intervention values for soils and intervention values for soil remediation (New Dutch List, 2009), Tv[3] = Thresholds for parks and recreational area (AZO, 2008)

Conclusions

In the CSC system, insufficient attention has been given to the classification of urban and/or technogenic soils. Accordingly, Profile No. 1 and Profile No. 3 had to be systemized into the class of Humus-accumulative soils, as Rendzina soil types. Given that the structure of CSC does not include a subtype of Rendzina on deposited land material, its inclusion is proposed, along with the criteria for further dividing this subtype. In the Profile No. 2, the presence of a pedogenetic A horizon was not determined, so the soil could be systemized into the class of Technogenic soils, as a Deposol soil type. Since the CSC structure offers no criteria for detailed systematization of Deposols into lower categories, we proposed some.

According to the WRB system, Profile No. 1 and Profile No. 2 were systemized into the RSG of Technosols, and Profile No. 3 was not. Namely, Profile No. 3 did not contain enough artefacts to be considered as a Technosol. Instead, it was classified as a complex (buried) soil (Regosol over Retisol). However, it was possible to add the qualifier *Relocatic* to the name of the Profile No. 3 to indicate dominant human influence on soil formation and soil properties. Thus, it was shown that, in comparison with CSC, WRB represents a more suitable system for classifying urban soils. Accordingly, an updated (more detailed) classification of such soils is required in the CSC.

According to the threshold for parks and recreational areas, contents of heavy metals were below the maximum allowed values in each of the three soils. However, the contents of Cu and Pb in all layers of the Profile No. 1, as well as the content of Zn in the surface layer of profiles No. 2 and No. 3, were over the threshold for agricultural soils.

References

AZO (2008). Program trajnog motrenja tala Hrvatske. Projekt “Izrada programa trajnog motrenja tala Hrvatske s pilot projektom”. Agencija za zastitu okolisa. Zagreb

FAO (2006). Guidelines for soil description. 4th edition. Rome

Husnjak S. (2014). Sistematika tala Hrvatske. Sveučilišni udžbenik. Hrvatska sveučilišna naklada, Zagreb

HRN ISO 11277 (2004). Soil quality - determination of particle size distribution in mineral soil material - method by sieving and sedimentation. Croatian Standard Institute. Zagreb

HRN ISO 13878 (2004). Soil quality - Determination of total nitrogen content by dry combustion (elementary analysis). Croatian Standard Institute. Zagreb

HRN ISO 10693 (2004). Soil quality - Determination of carbonate content - volumetric method. Croatian Standard Institute. Zagreb

HRN ISO 11260 (2004). Soil quality - Determination of effective cation exchange capacity and base saturation level using barium chloride solution. Croatian Standard Institute. Zagreb

HRN ISO 10390 (2005). Soil quality – determination of pH. Croatian Standard Institute. Zagreb

IUSS Working Group WRB (2014). World reference base for soil resources 2014. World Soil Resources Reports No. 106. FAO. Rome

Lehmann A., Stahr K. (2007). Nature and Significance of Anthropogenic Urban Soils. Journal of Soils and Sediments 7 (4): 247-260

New Dutch List (2009). Soil and groundwater intervention values and target values. Soil Remediation Circular 2009. Ministry of Housing, Spatial Planning and Environment. Holland

Offical Gazette (2010). Ordinance on the protection of agricultural land against pollution. N.N. 32/2010. Government of the Republic of Croatia. Zagreb

Resulović H., Čustović H. (2007). Technosols – Development, Classification and Use. Agriculturae Concpectus Scientificus 72 (1): 13-16

Resulović H., Čustović H., Čengić I. (2008). Sistematika tla/zemljišta: nastanak, svojstva i plodnost. Poljoprivredno-prehrambeni fakultet univerziteta u Sarajevu. Sarajevo

Rossiter D.G. (2007). Classification of Urban and Industrial Soils in the World Reference Base for Soil Resources. Journal of Soils and Sediments 7 (2): 96-100

Rubinić V., Lazarević B., Husnjak S., Durn G. (2015). Climate and relief influence on particle size distribution and chemical properties of Pseudogley soils in Croatia. Catena 127: 340-348

Rubinić V., Galović L., Lazarević B., Husnjak S., Durn G. (in press). Pseudogleyed loess derivates – the most common soil parent materials in the Pannonian region of Croatia. Quaternary International. doi: 10.1016/j.quaint.2017.06.044

Sauer D., Schulli-Maurer I., Sperstad R., Sorensen R., Stahr K. (2009). Albeluvisol development with time in loamy marine sediments of southern Norway. Quaternary International 209: 31–43

Sobocka J. (2008). Position of Technosols in the Slovak Soil Classification System and their Correlation. Gruntoznalstvo 9 (3-4/13): 177-182

Škorić A. (1985). Prirucnik za pedoloska istraživanja. Sveuciliste u Zagrebu. Zagreb

Škorić A., Filipovski G., Ćirić M. (1985). Klasifikacija zemljista Jugoslavije. Akademija nauka i umjetnosti Bosne i Hercegovine. Sarajevo

Škorić A. (1986). Postanak, razvoj i sistematika tla. Fakultet poljoprivrednih znanosti Sveucilista u Zagrebu. Zagreb

Šorša A. (2014). Urban geochemistry of the potentially toxic elements in the soils of the Sisak city and its surroundings. PhD. University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb (in Croatian)

Šorša A., Halamić J. (2014). Geochemical Atlas of Sisak. Public Library Vlado Gotovac Sisak, City Museum Sisak and Croatian Geological Survey, Sisak, Zagreb

Šorša A., Durn G., Halamić J., Husnjak S., Garašić V., Mileusnić M. (2017). Urban geochemistry: Sisak in Croatia, a long – lasting historical, urban and industrial city. Geochemistry: Exploration, Environment, Analysis 17 (2): 159-163

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