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Ekranic Technosols and Urbic Technosols of Toruń Necropolis

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Excavations for graves lead to development of specific soils, which could be named Necrosols. Soils of graveyards occur throughout the world. Cemeteries could be found in every town or city and in most villages. Many of such soils could be classified as Ekranic Technosols, other as Urbic Technosols.

Sobocka (2003) has defined a new anthropogenic soil type included in the latest supplement of the Slovak anthropogenic soil classification. Necrosols are thus defined as soils formed by special human activity in cemeteries and burial grounds with specific soil horizons (layers) sequence, specific physical, chemical and biological properties. One and only published paper representing genetic approach to investigation of cemetery soils was also written by Sobocka (2004).

The aim of this paper is to investigate morphological, chemical and physical properties of Necrosols in Toruń and to discuss their position in the WRB Classification System. This is a part of larger studies on urban soils of Toruń town in Northern Poland.

Key words: Ekranic Technosols, Urbic Technosols, Necrosols, cemeteries, Necropolis

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INTRODUCTION

Necrosols are defined as soils resulting from excavations for graves. Soils of graveyards are occurring throughout the world. Cemeteries could be found in every town or city and in most villages. In Poland the post-mortem changes in human corpses usually take place in the earth, cremation is much less common. Ideally, decomposition leads to the entire skeletalisation of corpses, which is usually achieved within the regular resting time: 15–25 years (Fiedler and Graw, 2003). Soil researches on cemeteries are very rare. First scientific researches dealing with Necrosols were published in Czechoslovakia by Smolik (1957), and Svec and Hlina (1978). For the first time Necrosols were included in the classification of urban soils in the system proposed by Burghardt (1994). Also, in Russia there was elaborated the Systematics for urban surface formations (Stroganova et al., 1998; Gerasimova, Stroganova and Prokofieva, 2003). In this system Necrosols were defined as soils of cemeteries in towns with about two meters depth of pedoturbation. In Poland, the issue of graveyard soils was mentioned only in one paper (Bednarek et al., 2004), but in the context of pedo-archeology.

There was just only one published paper representing genetic approach to investigation of Necrosols (Sobocka, 2004). Sobocka (2003) has defined a new anthropogenic soil type included in the latest proposal of the anthropogenic soil classification in

Slovakia. Necrosols are defined as soils formed by special human activity in cemeteries and burial grounds with specific soil horizons sequence, specific physical, chemical and biological properties.

Aims of his paper are as follows:

– to investigate morphological, chemical and physical properties of Necrosols and compare them with reference profiles located on the verge of cemeteries, which was not disturbed by burial techniques;

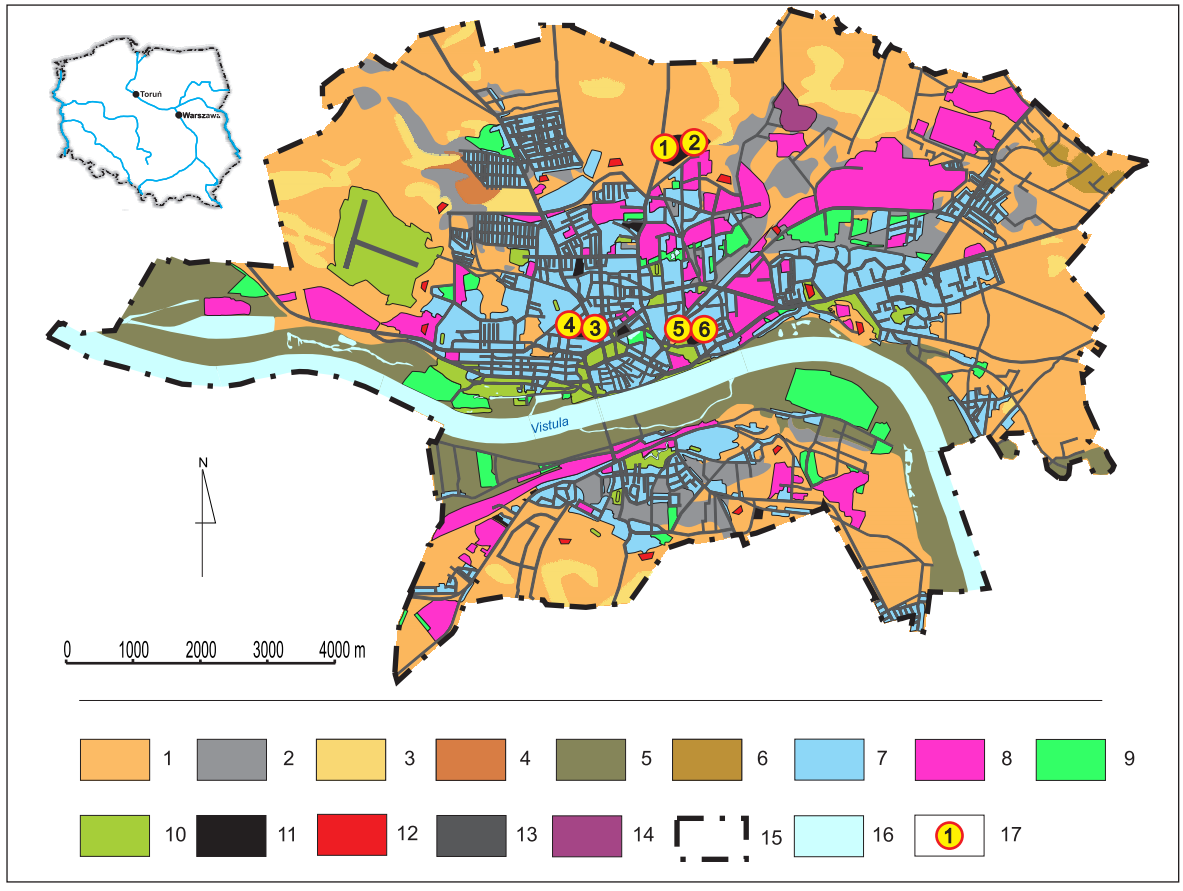

Fig. 1. The map of soils within Toruń Urban Area with localization of soil profiles (reproduced from Bednarek, Charzyński, Zawadzka, 2003; Bednarek, Jankowski, 2006; modified):
1 – Brunic Arenosols, *2* – Mollic Gleysols, Umbric Gleysols, *3* – Albic Podzols, Haplic Podzols, *4* – Gleyic Podzols, *5* – Haplic Fluvisols, *6* – Luvisols, *7* – Urbic Technosols, Technic Regosols and residential areas, *8* – industrial soils and industrial areas, *9* – Hortic Anthrosols, *10* – soils of urban parks and lawns, *11* – Necropolis (Ekranic Technosols and Urbic Technosols), *12* – Linic Technosols, *13* – Ekranic Technosols, *14* – waste dumps, *15* – administrative boundaries of Torun, *16* – surface waters, *17* – study soil profiles (*1* and *2* – Central Communal Cemetery; *3* and *4* – St. George Cemetery; *4* and *5* – St. Jacob the Apostle Parish Cemetery)

1 pav. Torūnės urbanizuotos teritorijos gruntų žemėlapio tirti profiliai (modifikuota pagal Bednarek, Charzyński, Zawadzka, 2003; Bednarek, Jankowski, 2006):
1 – bruniko smėlingas dirvožemis, *2* – moliko glėjinis dirvožemis, umbro glėjinis dirvožemis, *3* – albio jaurinis dirvožemis, *4* – glėjinis dirvožemis, *5* – haplio fliuvialinis dirvožemis, *6* – išplautžemio dirvožemis, *7* – urbanistinis dirvožemis, *8* – pramoninis dirvožemis ir pramoninės teritorijos, *9* – horčio trąšažemio gruntas, *10* – miesto parkų ir pievų dirvožemis, *11* – nekropolis (izoliuojantis technogeninis dirvožemis ir miesto dirvožemis), *12* – linikinis dirvožemis, *13* – izoliuojantis dirvožemis, *14* – šiukšlynas, *15* – Torūnės miesto administracinės ribos, *16* – paviršinis vanduo, *17* – tirti profiliai (*1* ir *2* – centrinės kapinės, *3* ir *4* – Šv. Jurgio kapinės, *4* ir *5* – Šv. Jokūbo kapinės)

– to discuss their taxonomic position in the WRB Classification System (IUSS Working Group WRB, 2006).

METHODS

In the city of Torun there are located 15 old cemeteries (some no longer prevail), and 11 contemporary cemeteries, still in use.

For soil researches there were selected 3 cemeteries. Two are old ones established nearly 2 centuries ago. The last one is the newest and biggest (59 ha) Torun Necropolis. Six soil profiles were described and analyzed in 2006 (Fig. 1):

- 2 profiles were located in Central Communal Cemetery established in 1975;
- 2 profiles were located in St. George Cemetery existing since 1811;
- 2 profiles were located in St. Jacob the Apostle Parish Cemetery established in 1817.

In each cemetery there were located two soil pits – one in the grave sealed before with a tombstone (Figs. 2, 3, 4 and 5) and a reference one, beyond the burial area, near the fence at the cemetery border.

Soil samples were submitted by standard physical and chemical analyses: relative moisture content (%); bulk density (g/cm^{-3}); hygroscopic moisture (%); soil colour according to Munsell; texture (by the Bouyoucose method modified by Casagrande and Prószyński); pH in water and in 1M KCl (1 : 2.5); $CaCO_3$ by the Scheibler

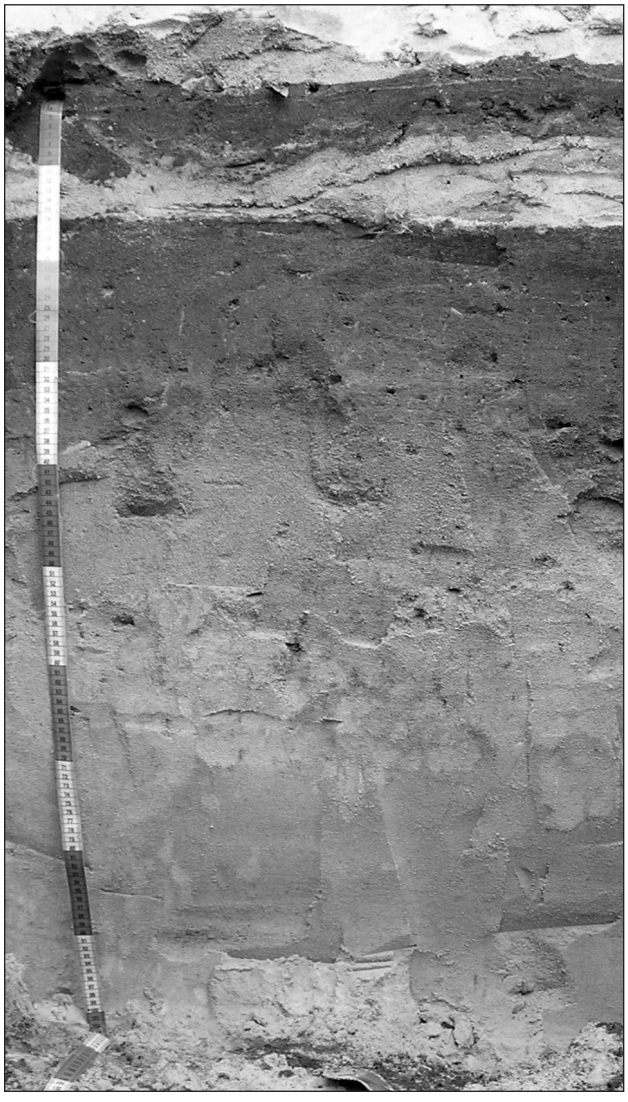

Fig. 2. Soil profile No. 2
2 pav. Grunto profilis Nr. 2

Fig. 3. Soil profile No. 4
3 pav. Grunto profilis Nr. 4

Fig. 4. Soil profile No. 4, from the opposite side
4 pav. Grunto profilis Nr. 4 iš priešingos pusės

Fig. 5. Soil profile No. 6
5 pav. Grunto profilis Nr. 6

method; organic carbon (OC) by the Tyurin method; total nitrogen by the Kjeldahl method; total phosphorus by the Bleck method, modified by Gebhardt; NA and K by the ES method, Ca and Mg by the AAS method (Bednarek et al., 2004).

RESULTS

In all horizons and layers of investigated soils sand is a dominant texture fraction (83–98%), silt fraction is from 1 to 8% and the fraction of clay has the lowest percentage share (0–4%). Investigated Necropolis soils are well aerated and characterized by high permeability but low water-holding and soil-absorbing capacity. Such soils are suitable for cemeteries because of a relatively short time of complete human body decomposition (up to 20 years).

The main features of the morphology of Necrosols (Gerasimova et al., 2003) are the following: absence of natural horizons, presence of urban layers with sharp transitions and occurrence of anthroskeleton (e. g. fragments of bricks, glass, nails). This was also observed in soils of Torun cemeteries.

Samples taken from St. George Cemetery and St. Jacob the Apostle Parish Cemetery, two oldest ones in the town, consisted of large quantities of human-made materials and artefacts. An example

of the sorts of artefacts found in Profile 3 are shown in Table 1 and those found in Profile 6 are presented in Figures 6, 7 and 8.

Distribution of the bulk density values was different from the natural soils, where it is usually rising with depth. In Profiles 1 and 3 the highest values of the bulk density can be found in the uppermost horizons / layers. In Profiles 2 and 4 the lowest values of the bulk density were noted in C horizons (Table 2).

In all investigated soils the OC content was rather low (0.17–1.62%). The pH values in most soils were neutral or slightly alkaline, which can be connected with some amounts of $CaCO_3$ to be found in most of the profiles (No. 2, 3, 4 and 5). Only one soil profile (1) was characterized by acidic reaction. It was the soil in nearly natural state (Brunic Arenosol according to WRB, 2006) located in the youngest of the cemeteries, earlier used as military training ground. Background value for total phosphorus in sandy soils of Central and North Poland is about 250 mg/kg. In all investigated soils phosphorus had higher values, especially in urbic layers (up to 524 mg/kg) and horizons / layers enriched in organic matter (up to 580 mg/kg). The highest value of P (984 mg/kg) can be found in the A horizon of Profile 3. This soil was used as a garden for many years, and organic fertilizers could be the source of phosphorus in that case.

Table 1. **Types of artefacts in skeleton in Profile 3 (St. George Cemetery)**

1 lentelė. **Artefaktų tipai profilyje Nr. 3 (Šv. Jurgio kapinės)**

Horizon / layer	Type of artefacts	% of skeleton
W1	Gravel	37
	Loam	31
	Concrete and bricks	13
	Cinder	9
	Metals	7.5
	Ceramics	1.3
	Plastic	0.5
	Bones	0.1
A	Concrete and bricks	72
	Gravel	25
	Cinder	2
	Glass	0.8
	Charcoals	0.6
	Bones	0.2
AC	Gravel	81
	Charcoals	14
	Bones	4.3
	Plastic	1

Fig. 6. Artefacts from Profile 6 – bones and clothing pieces (nylon stockings)
6 pav. Profilio Nr. 6 artefaktai – kaulai ir drabužių skiautės (nailoninės kojinės)

Fig. 7. Layer with coffin remnants in Profile 6
7 pav. Sluoksnis su karsto liekanomis, profilis Nr. 6

Fig. 8. Skull with denture
8 pav. Kaukolė su dantimis

Table 2. **Selected chemical properties**

2 lentelė. **Pasirinkti cheminiai rodikliai**

Horizon	Depth, cm	Bulk density, g/cm^3	Hygroscopic water, %	OC, %	Nt, %	C/N	P, mg/kg	$CaCO_3$, %	pH	
									H_2O	KCl
Profile 1										
A	0–4		0.59	0.80	0.056	14	307	–	5.3	4.4
Ap	4–25	1.60	0.51	0.51	0.030	17	245	–	4.8	4.4
A2	25–30	1.55	0.42	0.36	0.020	18	267	–	4.9	4.5
Bv	30–62	1.52	0.44	–	–	–	156	–	4.8	4.6
C	62–(118)	1.54	0.11	–	–	–	87	–	5.0	5.0
Profile 2										
WA	0–11	1.57	0.83	0.98	0.070	14	382	0.3	8.1	7.6
W	11–15	1.57	0.22	–	–	–	121	–	7.9	7.0
A	15–36	1.63	0.53	0.50	0.035	14	347	–	7.6	6.6
B	36–60	1.67	0.32	–	–	–	137	–	7.4	6.1
C	>60	1.51	0.14	–	–	–	80	–	7.2	6.0
Profile 3										
W1	0–14	1.62	0.29	0.34	0.021	16	339	0.4	8.1	7.8
A	20–50	1.19	1.17	1.62	0.124	13	984	0.4	7.6	7.1
AC	50–70	1.48	0.24	0.17	0.014	12	247	0.3	7.9	7.5
C	70–(160)	1.57	0.14	–	–	–	186	0.2	7.6	7.0
Profile 4										
An	0–53	1.46	0.61	0.69	0.049	14	472	0.5	8.1	7.6
AC	53–65	1.66	0.20	–	–	–	126	0.4	8.6	8.3
C	65–(110)	1.60	0.13	–	–	–	115	0.2	8.0	7.3
C (inclusion)	65–(110)	1.52	0.40	0.50	0.035	14	292	0.4	7.8	7.4
Profile 5										
A	0–20	1.35	0.70	0.84	0.060	14	468	0.8	7.7	7.4
W1	20–33	1.33	0.63	0.62	0.051	12	524	1.0	7.7	7.3
W2	33–70	1.38	0.63	0.43	0.039	11	361	0.9	7.9	7.4
W3	70–87	1.47	0.50	0.44	0.040	11	390	1.0	8.0	7.5
W4	87–(110)	1.54	0.58	0.47	0.044	11	372	0.7	7.9	7.3
Profile 6										
A	0–60	1.38	0.64	0.93	0.068	14	580	–	7.2	6.8
AC	60–85	1.49	0.53	0.78	0.053	15	372	–	7.1	6.5
C	90–(100)	1.49	0.44	0.48	0.038	13	352	–	7.3	6.7

CONCLUSIONS

Cemeteries soils are characterized by very variable morphological, physical and chemical properties, which depend on the age of cemetery and former land use (settlement areas, gardens, garbage dumps, industrial plants).

Specific features of Necrosols are:

- presence of mixed and disturbed horizons / layers;
- presence of large quantities of artefacts;
- raised amount of OC in lower layers as an effect of body decomposition and admixture of A horizons in effect of deep excavation;

- raised amount of phosphorus in comparison with background values;
- higher pH values.

Deep excavations (≥2 metres) performed on Necropolis areas and subsequently sealing of mixed soil with tombstones lead to formation of soils with specific properties.

In authors' opinion, it should be considered to add the qualifier Necric in 3rd edition of the World Reference Base for Soil Resources. Such addition would enable better characterization and mapping of soils in urban areas.

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EKRANINIAI TECHNOGENINIAI IR URBANISTINIAI GRUNTAI TORŪNĖS NEKROPOLYJE

S a n t r a u k a

Kapinėse formuojamas specifinės sudėties gruntas gali būti klasifikuojamas kaip nekrogruntas. Šio tipo gruntas paplitęs visame pasaulyje, nes kapinių yra visuose miestuose ar kaimuose. Dažnai toks gruntas tipizuojamas kaip ekraninis arba urbanistinis technogeninis gruntas.

Sobocka (2003) išskyrė naują antropogeninį gruntą – nekrogruntą ir pasiūlė jį įtraukti į Slovakijos antropogeninių gruntų klasifikaciją. Nekrogruntas tai – specifinės žmogaus veiklos suformuotas gruntas, turintis būdingus fizinius, cheminius ir biologinius rodiklius. Vienintelis straipsnis, kuriame apibūdintos šio tipo grunto savybės, Sobockos buvo publikuotas 2004 metais.

Pateikto straipsnio tikslas – aprašyti nekrogrunto Torūnės mieste morfologines, chemines, fizikines savybes ir aptarti galimą jų vietą klasifikacijos schemose. Tai yra stambesnės studijos, nagrinėjančios Torūnės miesto technogeninius gruntus Šiaurės Lenkijoje, dalis.

Raktažodžiai: ekraninis technogeninis gruntas, urbanistinis technogeninis gruntas, nekrogruntas, kapinės, nekropolis