Characteristics of the soils of Toruń cemeteries

Przemysław Charzyński[A], Renata Bednarek[B] and Beata Żołnowska[B]

[A]Department of Landscape Geography, Faculty of Biology and Earth Sciences, Nicolaus Copernicus University, Toruń, 87-100, Gagarina 9, Poland, Email pecha@umk.pl
[B]Department of Soil Science, Faculty of Biology and Earth Sciences, Nicolaus Copernicus University, Toruń, 87-100, Gagarina 9, Poland, Email bednarek@biol.uni.torun.pl

Abstract
Necrosols are defined as soils resulting from excavations for graves. Soils of graveyards occur throughout the world. Cemeteries could be found in every town or city and in most villages. There was just only one published paper representing a 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. 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 this paper are to investigate morphological, chemical and physical properties of necrosols in Toruń. This is part of a larger studies on urban soils of Toruń town in Northern Poland.

Key Words
Technosols, Necrosols, cemeteries.

Introduction
Necrosols are defined as soils resulting from excavations for graves. Soils of graveyards occur throughout the world. Cemeteries could be found in every town or city and in most villages. In central Europe, the post-mortem changes in human corpses usually take place in the earth. 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 was included in classification of urban soils in system proposed by Burghardt (1994). Also in Russia there was elaborated Systematics for urban surface formations (Stroganova *et al.* 1998; Gerasimova, Stroganova and Prokofieva 2003). In this system necrosols are defined as urban soils, depending on depth of burial and age of cemetery. In Poland the problem of graveyard soils was mentioned only in one paper (Bednarek *et al*. 2004).
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. Necrosols are defined as soils formed by special human activity in cemeteries and burial grounds with specific soil horizon sequences, specific physical, chemical and biological properties.
Aims of his paper are to investigate morphological, chemical and physical properties and compare them with reference soils located on the verge of cemeteries, which were not disturbed by burial.

Methods
Six soil profiles located on cemeteries of Toruń were described and analyzed in 2006:

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

In each cemetery there was located 2 soil pits – one in grave and reference one, out of the grave area, near the fence. Soil samples were submitted to standard physical and chemical analyses: relative moisture content [%]; Bulk density (g cm^{-3}); hygroscopic moisture [%]; Soil colour according to Munsell; texture (by Bouyoucose method modified by Casagrande and Prószyński; pH in water and in 1M KCl (1 : 2.5); $CaCO_3$ by Scheibler method; organic carbon (OC) by Tyurin method); total nitrogen by Kjeldahl method; total phosphorus by Bleck method, modified by Gebhardt; NA and K by ES method, Ca and Mg by AAS method (Bednarek *et al*. 2004).

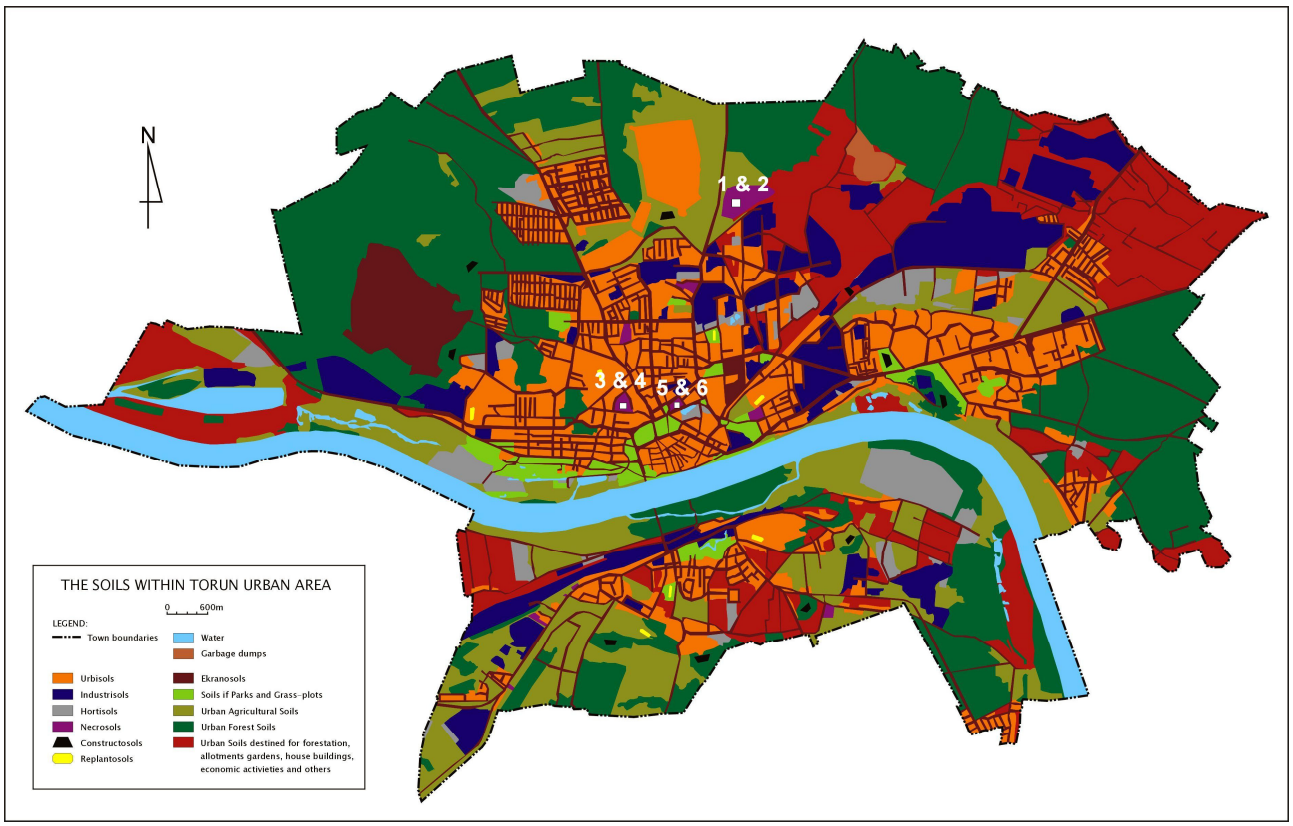

Figure 1. The map of soils within Toruń Urban Area with localization of soils profiles (reproduced from Bednarek, Charzynski, Zawadzka (2003); modified).

Results

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

The main features of morphology of necrosols are (Gerasimova *et al.* 2003*)* are: absence of natural horizons, presence of urban layers with sharp transitions and presence 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 town consisted large quantities of human-made materials and artifacts. Example of sorts of artifacts found in profile 3 and 6 are shown in Table 1 and on Figures 2 and 3. Distribution of the bulk density values was different from the natural soils, where is usually rising with depth. In profiles 1 and 3 highest values of bulk density can be found in uppermost horizons/layers. In profiles 2 and 4 the lowest values of bulk density was noted in C horizons.

In all investigated soils 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 youngest of the cemeteries, earlier used for military purposes. Background value for total phosphorus in sandy soils in central Poland is about 250 mg/kg. In investigated soils it had usually higher values, especially in urban layers (up to 524 mg/kg) and layers enriched in organic matter (up to 580 mg/kg). The highest value of P (984 mg/kg) can be found in A horizon of profile 3. This soil used to be a garden soil and organic fertilizers could be the source of phosphorus in that case.

Table 1. Sort of artefacts in skeleton in profile 3 (St. George cemetery).

Horizon/layer	Sort of artefacts	%
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

Table 2. Selected chemical properties.

Horizon	Depth (cm)	Bulk density (g/cm^3)	Hygro-scopic water (%)	OC (%)	N (%)	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

Figure 2. Artefacts from profile 6 – bones and clothing pieces (nylon stockings).

Figure 3. Layer with coffin remnants in profile 6.

Conclusion

Cemeteries soils are characterized by very variable morphological, physical and chemical properties, which depend on 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;
- presence of large quantities of artefacts;
- raised amount of OC in lower layers as a effect of body decomposition;
- raised amount of phosphorus in comparison with background values;
- higher pH values

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