

Technogenic

edited by

P. Charzyński M. Markiewicz M. Świtoniak

soils atlas



**technogenic soils
atlas**

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edited by

**Przemysław Charzyński
Maciej Markiewicz
Marcin Świtoniak**

Polish Society Of Soil Science
Toruń 2013

Editors

Przemysław Charzyński, Nicolaus Copernicus University, Toruń, Poland

Maciej Markiewicz, Nicolaus Copernicus University, Toruń, Poland

Marcin Świtoniak, Nicolaus Copernicus University, Toruń, Poland

Reviewers:

Radim Vácha, Research Institute for Soil and Water Conservation, Prague, Czech Republic

Piotr Hulisz, Nicolaus Copernicus University, Toruń, Poland

Language editing

Ewa Kaźmierczak

Cover design

Marcin Świtoniak

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P. Charzyński, M. Markiewicz, M. Świtoniak (Editors)

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Graphics design:

Beata Króliczak-Zajko

White Plum

87-100 Toruń,

ul. Szosa Bydgoska 50

tel. +48 56 651 97 87

Press:

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tel. +48 56 651 97 87

www.machinadruku.pl

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Technological development and rapid growth of the human population in the world increasingly affect the transformation of the natural environment. One of the main ecosystem components, which undergoes irreversible changes is the soil cover in urban and industrial areas. The extent and type of changes in the soil depend on many factors: duration, intensity and the land use, properties of primary soils or reclamation techniques. Urban or industrial soils are dominated or strongly affected by human-made material and exhibit a high spatial heterogeneity. Their properties and pedogenesis are mainly related to technical origin. These soils are more likely to be contaminated than soils from other groups. Even when the environment of urban or industrial areas is essentially changed, the technically transformed soils can still fulfill the same ecological functions as natural soils. Advancing our knowledge about these soils is essential for spatial planning, optimal use of resources and can bring considerable benefits resulting in the improvement of life quality in the cities. This book provides an extensive database on urban and industrial soils from the following countries: Hungary, Poland, Romania and Slovakia. The main objective of this study was to present a great diversity of transformations in the investigated soils. Most of the presented examples meet the criteria of Technosols – one of the Reference Soil Groups in the WRB classification system. The above-mentioned RSG includes only pedons with a very high degree of technogenic disturbances. For this reason, a broader term is proposed – 'technogenic soils' – to describe all urban and industrial soils. The collected data will allow greater understanding of processes taking place in human-made ecosystems and will be a useful tool in soil-science teaching.

Przemysław Charzyński
Maciej Markiewicz
Marcin Świtoniak

LIST OF SYMBOLS WITH EXPLANATIONS

- Ca_t** – total calcium
CEC – cation exchange capacity
EC_{1:2} – electrical conductivity of a 1:2 soil-water extract
EC_e – electrical conductivity of the soil saturation extract
K_a – available potassium
K_t – total potassium
LoI – loss on ignition
Mg_a – available magnesium
Mg_t – total magnesium
N_t – total nitrogen
Na_t – total sodium
n.d. – not determined
NEL – non-polar extractable substances
OC – organic carbon
P_a – available phosphorus
P_{ca} – phosphorus soluble in 1% citric acid solution
P_t – total phosphorus
PAH – polycyclic aromatic hydrocarbons
PCB – polychlorinated biphenyl

RENATA BEDNAREK

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND
bednarek@umk.pl

PRZEMYSŁAW CHARZYŃSKI

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND
pecha@umk.pl

ANDRZEJ GREINERT

DEPARTMENT OF LAND PROTECTION AND RECLAMATION
INSTITUTE OF ENVIRONMENTAL ENGINEERING
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
UNIVERSITY OF ZIELONA GÓRA, POLAND
A.Greinert@iis.uz.zgora.pl

MARCIN KUBUS

DEPARTMENT OF DENDROLOGY AND LANDSCAPE ARCHITECTURE
WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN, POLAND
marcin.kubus@zut.edu.pl

KATARZYNA MALINOWSKA

DEPARTMENT OF PLANT PHYSIOLOGY
FACULTY OF ENVIRONMENTAL MANAGEMENT AND AGRICULTURE
WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN, POLAND
katarzyna.malinowska@zut.edu.pl

RYSZARD MALINOWSKI

DEPARTMENT OF PEDOLOGY
FACULTY OF ENVIRONMENTAL MANAGEMENT AND AGRICULTURE
WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN, POLAND
ryszard.malinowski@zut.edu.pl

MACIEJ MARKIEWICZ

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND
mawicz@umk.pl

EDWARD MELLER

DEPARTMENT OF PEDOLOGY
FACULTY OF ENVIRONMENTAL MANAGEMENT AND AGRICULTURE
WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN, POLAND
edward.meller@zut.edu.pl

ŁUKASZ MENDYK

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND
mendyk.geo@gmail.com

TIBOR JÓZSEF NOVÁK

DEPARTMENT OF LANDSCAPE PROTECTION AND ENVIRONMENTAL GEOGRAPHY,
UNIVERSITY OF DEBRECEN, HUNGARY
novak.tibor@science.unideb.hu

GÁBOR SÁNDOR

DEPARTMENT OF LANDSCAPE PROTECTION AND ENVIRONMENTAL GEOGRAPHY,
UNIVERSITY OF DEBRECEN, HUNGARY
sandorgabor87@gmail.com

JAROSLAVA SOBOCKÁ

SOIL SCIENCE AND CONSERVATION RESEARCH INSTITUTE,
BRATISLAVA, SLOVAKIA
j.sobocka@vupop.sk

GYÖRGY SZABÓ

DEPARTMENT OF LANDSCAPE PROTECTION AND ENVIRONMENTAL GEOGRAPHY,
UNIVERSITY OF DEBRECEN, HUNGARY
szabo.gyorgy@science.unideb.hu

EMILIA SZYNKOWSKA

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND

MARCIN ŚWITONIAK

DEPARTMENT OF SOIL SCIENCE AND LANDSCAPE MANAGEMENT
FACULTY OF EARTH SCIENCES
NICOLAUS COPERNICUS UNIVERSITY, TORUŃ, POLAND
swit@umk.pl

1

TECHNOGENIC SOILS IN CLUJ-NAPOCA

Przemysław Charzyński
Maciej Markiewicz
Renata Bednarek
Marcin Świtoniak

Cluj-Napoca is the second most populous city in Romania after the national capital Bucharest, and is the seat of Cluj County located in the northwestern part of the country (Fig. 1). The city is situated in the Someșul Mic River valley, and is considered to be an unofficial capital of the historical province of Transylvania. The Cluj-Napoca metropolitan area has a population of 411 379 people and 324 576 inhabitants live within the city limits (2011). The boundaries of the municipality contain an area of 179.52 square kilometres.

Today, Cluj-Napoca is one of the most important academic, cultural, industrial and business centres in Romania. At the site of the present-day city, there was a pre-Roman settlement called Napoca. After the Roman conquest of the area in 106 AD, the place was known as Municipium Aelium Hadrianum Napoca (Dragos et al. 2007).

Cluj-Napoca is located within the Someșul Mic corridor at the intersection of three major geographical units: the Transylvanian Plain, the Someș Plateau and the Apuseni Mountains, at an average altitude of 360 m and is intersected by the parallel of 46°46' north latitude and the meridian of 23°36' east longitude. It extends over the valleys of Someșul Mic and Nadăș. The southern part of the city covers the upper terrace of the northern slope of Feleac Hill, and is surrounded along three sides by hills or mountains with an altitude between 500 m and 700 m. The Someș plateau is situated to the east, while the northern part of the city includes Dealurile Clujului ('the Hills of Cluj'), with

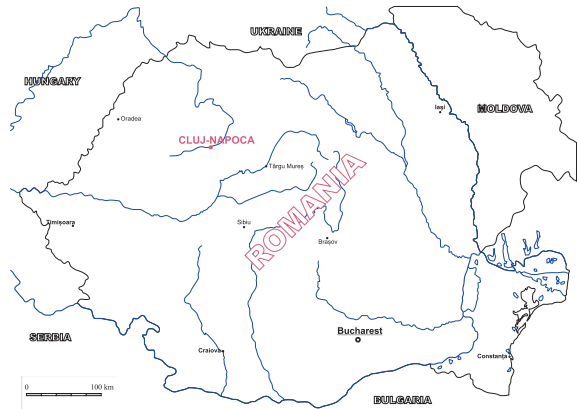


Fig. 1. Location of Cluj-Napoca

the following peaks: Lombului (684 m), Dealul Melcului (617 m), Techintău (633 m), Hoia (506 m) and Gârbău (570 m). Other hills are located in the western districts, and the hills of Calvaria and Cetățuia (Belvedere) are located near the centre of the city.

The natural dominant soils in the surroundings of the city are Eutric Cambisols, Haplic Luvisols and most fertile Haplic Phaeozems. In the river valleys, Eutric Gleyic Fluvisols predominate (Soil Atlas of Europe 2005).

The research on the urban soil cover was carried out in the city. Information on the lead contamination in Cluj-Napoca soils can be found in the paper by Rusu and Bartok (2002). The soils in the industrial zone Somes-Nord of Cluj-Napoca were described by Micle et al. (2005). The effects of a waste platform on soil pollution near the city of Cluj-Napoca was investigated by Cacovean et al. (2007). Studies of bacterial communities and enzymatic activities in the polluted soils of the traffic, industrial and household waste dumping ground in Cluj-Napoca was carried out by Simule and Bularda (2009a, b). Ekranosols in the Cluj-Napoca city centre was investigated by Charzyński et al. (2011a).

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We are grateful to Marcin Chmurzyński and Jolanta Błaszczewicz for support in the field and laboratory.

Site 1 – Ekranic Technosol (Calcaric, Skeletic)



Location:

Tipografiei 10 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'39.7" N 23°35'40.4" E

Altitude:

341 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

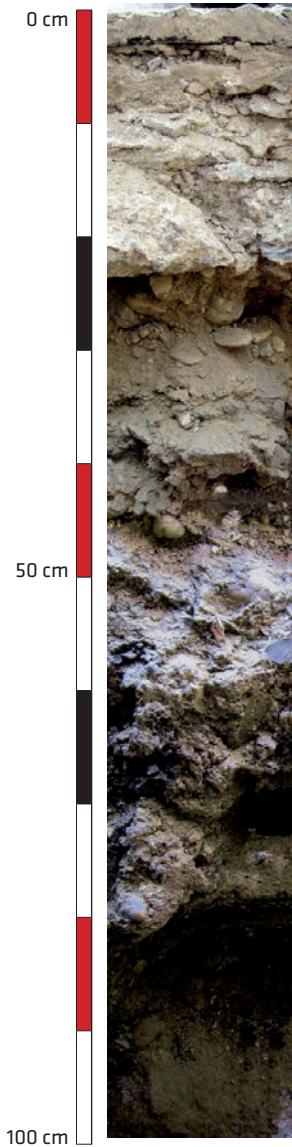
594 mm

Land-use: side-street

Vegetation: none



Site 1 – Ekranic Technosol (Calcaric, Skeletic)



Morphology:

0–20 cm: *technic hard rock* (asphalt).

Bu1 – 20–73 cm: sand, white, granular structure, dry, few artefacts (tile fragment; about 5%), clear boundary.

Bu2 – 73–97 cm: sandy loam, very pale brown, granular structure, slightly moist, few artefacts (grout; 5%).

Site 1 – Ekranic Technosol (Calcaric, Skeletic)

Selected soil properties

HORIZON		Bu1	Bu2
DEPTH [cm]		20–73	73–97
PARTICLE SIZE DISTRIBUTION			
ø [mm]		[%]	
>2.0		40	6
2.0–1.0		24	1
1.0–0.5		26	1
0.5–0.25		22	2
0.25–0.1		15	23
0.1–0.05		4	37
0.05–0.02		2	23
0.02–0.002		5	6
<0.002		2	8
TEXTURE CLASS (USDA)		sand	sandy loam
SOIL MATRIX COLOUR	dry	10YR 8/1	10YR 8/2
	wet	10YR 5/1	10YR 7/3
OC [%]		0.22	0.16
N _t [%]		0.006	0.008
C:N		37	20
P _t [mg·kg ⁻¹]		268	331
pH	H ₂ O	8.0	9.3
	1M KCl	7.4	8.0
CaCO ₃ [%]		3.1	1.6

Site 2 – Linic Technosol (Paracalcaric, Parahumic)



Location:

Cardinal Luliu Hossu 37 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'11.8" N 23°34'15.0" E

Altitude:

343 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:
594 mm

Position:

bridge over rain channel

Vegetation:

grass (*Poaceae* sp.)



Site 2 – Linc Technosol (Paracalcaric, Parahumic)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0–(1–3)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		4
2.0–1.0		7
1.0–0.5		13
0.5–0.25		18
0.25–0.1		16
0.1–0.05		30
0.05–0.02		9
0.02–0.002		7
<0.002		0
TEXTURE CLASS (USDA)		loamy sand
SOIL MATRIX	dry	10YR 5/3
COLOUR	wet	10YR 5/1
OC [%]		7.03
N_t [%]		0.281
C:N		25
pH	H ₂ O	7.3
	1M KCl	7.1
CaCO₃ [%]		3.2
P_{ca} [mg·kg⁻¹]		198
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		<16
Zn		297
Cu		84
Cd		<5

Site 3 – Linic Technosol (Paracalcaric, Parahumic)



Location:

Cardinal Luliu Hossu 37 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'11.8" N 23°34'15.0" E

Altitude:

343 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

594 mm

Position:

bridge over rain channel

Vegetation:

ruderal species (e.g. *Plantago* sp.,
Taraxacum sp., *Poaceae* sp.)



Site 3 – Linc Technosol (Paracalcaric, Parahumic)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0–(1–4)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		6
2.0–1.0		12
1.0–0.5		20
0.5–0.25		26
0.25–0.1		15
0.1–0.05		11
0.05–0.02		11
0.02–0.002		4
<0.002		1
TEXTURE CLASS (USDA)		loamy sand
SOIL MATRIX	dry	10YR 4/2
COLOUR	wet	10YR 2/2
OC [%]		4.84
N_t [%]		0.279
C:N		17
pH	H ₂ O	7.4
	1M KCl	7.2
CaCO₃ [%]		3.2
P_{ca} [mg·kg⁻¹]		210
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		365
Zn		569
Cu	[mg·kg ⁻¹]	48
Cd		<5

Site 4 – Linic Technosol (Paracalcaric, Parahumic)



Location:

Prahovei 5 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'10.6" N 23°35'25.6" E

Altitude:

350 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:
594 mm

Position:

Top of brick wall at a height of 2.5 m

Vegetation:

Chelidonium maius L.



Site 4 – Linic Technosol (Paracalcaric, Parahumic)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0–(2–3)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		13
2.0–1.0		9
1.0–0.5		21
0.5–0.25		31
0.25–0.1		22
0.1–0.05		5
0.05–0.02		5
0.02–0.002		5
<0.002		2
TEXTURE CLASS (USDA)		sand
SOIL MATRIX	dry	10YR 8/1
COLOUR	wet	10YR 7/2
OC [%]		10.4
N_t [%]		0.068
C:N		152
pH	H ₂ O	8.2
	1M KCl	8.0
CaCO₃ [%]		9.5
P_{ca} [mg·kg⁻¹]		161
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		<16
Zn		87
Cu	[mg·kg ⁻¹]	91
Cd		<5

Site 5 – Linc Technosol (Paracalcaric)



Location:

Prahovei 5 st., Cluj-Napoca,
Romania

Coordinates:

46°46'10.6" N 23°35'25.6" E

Altitude:

350 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

594 mm

Position:

Foundation of partly ruined
building at a height of 0.4 m

Vegetation:

grass (*Poaceae* sp.)



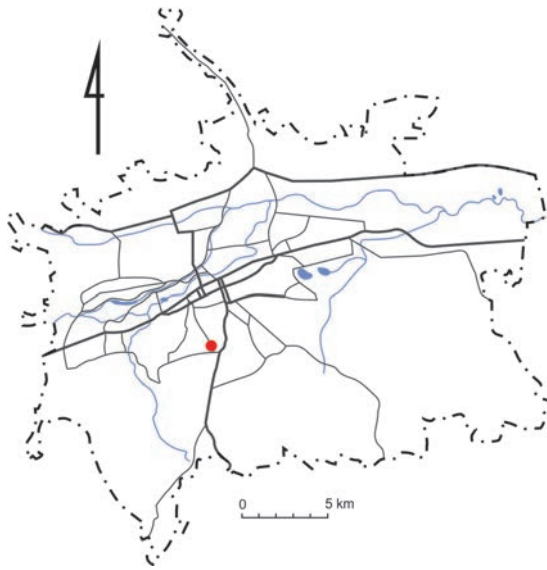
Site 5 – Linc Technosol (Paracalcaric)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0-(3-5)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		12
2.0-1.0		8
1.0-0.5		17
0.5-0.25		25
0.25-0.1		24
0.1-0.05		5
0.05-0.02		6
0.02-0.002		9
<0.002		6
TEXTURE CLASS (USDA)		loamy sand
SOIL MATRIX	dry	7.5YR 8/1
COLOUR	wet	7.5YR 4/4
OC [%]		0.45
N_t [%]		0.187
C:N		2
pH	H ₂ O	7.8
	1M KCl	7.7
CaCO₃ [%]		8.3
P_{ca} [mg·kg⁻¹]		216
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		<16
Zn		70
Cu	[mg·kg ⁻¹]	17
Cd		<5

Site 6 – Linic Technosol (Paracalcic, Parahumic)



Location:

Avram Iancu 23 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'00.2" N 23°35'33.5" E

Altitude:

354 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

594 mm

Position:

Top of the wall at a height of 3.0 m

Vegetation:

Chelidonium maius L.,

Chenopodium bonus-henricus L.



Site 6 – Linic Technosol (Paracalcaric, Parahumic)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0-(3-7)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		10
2.0-1.0		5
1.0-0.5		8
0.5-0.25		12
0.25-0.1		17
0.1-0.05		12
0.05-0.02		10
0.02-0.002		21
<0.002		15
TEXTURE CLASS (USDA)		sandy loam
SOIL MATRIX	dry	7.5YR 8/1
COLOUR	wet	7.5YR 4/4
OC [%]		1.88
N_t [%]		0.178
C:N		11
pH	H ₂ O	8.3
	1M KCl	7.4
CaCO₃ [%]		8.3
P_{ca} [mg·kg⁻¹]		78,2
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		256
Zn		96
Cu		60
Cr		<5

Site 7 – Protofolic Linic Technosol



Location:

Avram Iancu 23 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'00.8" N 23°35'37.1" E

Altitude:

354 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

594 mm

Position:

roof of the outbuilding at a height
of 3.0 m

Vegetation:

Chelidonium maius L.



Site 7 – Protofolic Linic Technosol



Selected soil properties

HORIZON		Ou
DEPTH [cm]		0–(5–7)
SOIL MATRIX	dry	7.5YR 3/2
COLOUR	wet	7.5YR 3/1
OC [%]		25.8
N _t [%]		2.05
C:N		13
pH	H ₂ O	7.2
	1M KCl	6.8
CaCO ₃ [%]		–
P _{ca} [mg·kg ⁻¹]		267
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO ₃		
Pb		67
Zn	[mg·kg ⁻¹]	124
Cu		17
Cr		<5

Site 8 – Linic Technosol (Paracalcaric, Parahumic, Paraskeletic)



Location:

Uzinei Electrica / Stadion,
Cluj-Napoca, Romania

Coordinates:

N 46°45'58.3" E 23°34'12.7"

Altitude:

343 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

594 mm

Position:

Roof of transformer substation at
a height of 5.0 m

Vegetation:

Acer negundo L.



Site 8 – Linic Technosol (Paracalcaric, Parahumic, Paraskeletic)

Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0-(1-4)
PARTICLE SIZE DISTRIBUTION		
ϕ [mm]		[%]
>2.0		29
2.0-1.0		10
1.0-0.5		18
0.5-0.25		16
0.25-0.1		19
0.1-0.05		9
0.05-0.02		12
0.02-0.002		13
<0.002		3
TEXTURE CLASS (USDA)		sandy loam
SOIL MATRIX COLOUR	dry	10YR 8/1
	wet	10YR 5/2
OC [%]		1.52
N _t [%]		0.101
C:N		15
pH	H ₂ O	7.9
	1M KCl	7.6
CaCO ₃ [%]		4.7
P _{ca} [mg·kg ⁻¹]		1115
BASE CATIONS		
Ca ²⁺		21.5
Mg ²⁺	[cmol·kg ⁻¹]	0.5
K ⁺		0.6
Na ⁺		0.3
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO ₃		
Pb		<16
Zn	[mg·kg ⁻¹]	128
Cu		22
Cr		<5

Site 9 – Linic Technosol (Paracalcaric, Parahumic)



Location:

Uzinei Electric/Stadion,
Cluj-Napoca, Romania

Coordinates:

46°45'58.3" N 23°34'12.7" E

Altitude:

343 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:
594 mm

Position:

Roof of transformer substation at
a height of 5.0 m

Vegetation:

Populus L.



Site 9 – Linic Technosol (Paracalcaric, Parahumic)



Selected soil properties

HORIZON		AuCu
DEPTH [cm]		0-(3-5)
PARTICLE SIZE DISTRIBUTION		
ø [mm]		[%]
>2.0		30
2.0-1.0		11
1.0-0.5		31
0.5-0.25		28
0.25-0.1		14
0.1-0.05		4
0.05-0.02		3
0.02-0.002		5
<0.002		4
TEXTURE CLASS (USDA)		sand
SOIL MATRIX	dry	10YR 2/2
COLOUR	wet	10YR 2/1
OC [%]		9.58
N_t [%]		0.238
C:N		40
pH	H ₂ O	8.1
	1M KCl	7.7
CaCO₃	[%]	4.7
P_{ca} [mg·kg⁻¹]		151
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃		
Pb		<16
Zn		143
Cu	[mg·kg ⁻¹]	110
Cr		<5

Site 10 – Urbic Ekranic Technosol (Calcaric)



Location:

Tipografiei 12 st.,
Cluj-Napoca, Romania

Coordinates:

46°46'39.7" N 23°35'40.6" E

Altitude:

341 m a.s.l.

Climate:

Average annual temperature: 8.3°C

Average annual precipitation:

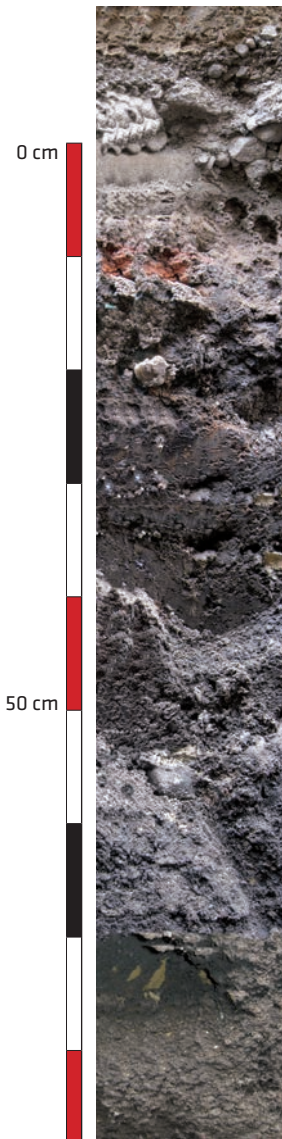
594 mm

Land-use: pavement

Vegetation: none



Site 10 – Urbic Ekranic Technosol (Calcaric)



Morphology:

0–5 cm: *technic hard rock* (asphalt).

Bu1 – 5–20 cm: sand, grey, granular structure, dry, clear boundary; common artefacts: (brick pieces, charcoals 30%).

Bu2 – 20–45 cm: loam, light grey, angular structure, slightly moist, common artefacts: (bones, charcoals, wood, metal elements; 10%), clear boundary.

Bu3 – 45–95 cm: loam, light brownish grey, angular structure, moist.

Site 10 – Urbic Ekranic Technosol (Calcaric)

Selected soil properties

HORIZON		Bu1	Bu2	Bu3
DEPTH [cm]		5–20	20–45	45–95
PARTICLE SIZE DISTRIBUTION				
ø [mm]		[%]		
>2.0		50	0	19
2.0–1.0		10	4	4
1.0–0.5		35	5	7
0.5–0.25		24	8	10
0.25–0.1		16	20	16
0.1–0.05		5	11	11
0.05–0.02		5	13	10
0.02–0.002		4	27	28
<0.002		1	12	14
TEXTURE CLASS (USDA)		sand	loam	loam
SOIL COLOUR MATRIX	dry	5Y 5/1	5Y 7/1	2.5Y 6/2
	wet	5Y 3/1	5Y 4/2	2.5Y 3/4
OC [%]		0.53	–	1.53
N_t [%]		0.012	0.119	0.138
C:N		44	–	11
P_t [mg·kg⁻¹]		519	2 559	636
pH	H ₂ O	9.3	8.6	8.3
	1M KCl	8.0	7.3	7.2
CaCO₃ [%]		10.4	21.4	6.8

2

TECHNOGENIC SOILS IN DEBRECEN

GÁBOR SÁNDOR
GYÖRGY SZABÓ
PRZEMYSŁAW CHARZYŃSKI
EMILIA SZYŃKOWSKA
TIBOR JÓZSEF NOVÁK
MARCIN ŚWITONIAK

Debrecen, the seat of Hajdú-Bihar, is situated in the eastern part of Hungary, at a distance of 230 km from the capital and 35 km from the Romanian border – 21°38' E and 47°31' N. With an area of 461.65 km² and a population of about 200 000, Debrecen is the second largest and most populated city of the country. It is commonly known as the 'Calvinist Rome' or the 'Civis city'. It is a cultural, economic, tourism and transport centre and one of the most dynamically developing city of Eastern Hungary. Debrecen environs

were inhabited since the Ancient Ages. Before Hungarians, who were leading a nomadic lifestyle until about the year 800, more ethnical groups (Vandals, Goths, Avars, and Bulgarians) lived in the Carpathian Basin. The name of the city was first mentioned in 1235 in a church document and it earned the *oppidum* status in 1361. A 4–5 m deep trench was found around the settlement which served defensive purposes. Trading was booming in the 16th century and most of the trade relations were established with the northern and western European countries. That was the time when the city converted to Protestantism.

Debrecen is located on the border of Hajdúság and Nyírség landscapes. The first one represents a loess plateau landscape, whereas Nyírség is a lowland covered with sand dunes. This sandy region occupies an area north of the city and it is the highest part of

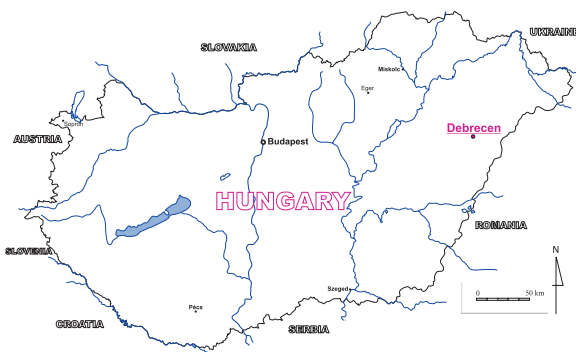


Fig. 1. Location of Debrecen

the Great Hungarian Plain. The landscape limit can be found along the Böszörményi road - Nyugati street - Train Station line, however, at a depth of 5–10 m, it is difficult to establish a sharp boundary since the sand of Nyírség was deposited in multiple places onto the loess of Hajdúság during the last glaciation, and it appears that the sand is also covered with a thin loess film. The various landscape features affect also the soil conditions, therefore in the sand areas of Nyírség mostly Arenosols can be found on the surface. On the loess plains, including Hajdúság, Chernozem is the most frequent soil type (Martonné 2008).

In the past, four different villages (almost completely vanished now) were located in the present-day city centre. In the place of the hub of the city centre, the present-day Kossuth Square, there was a wet dune within a depression where planks were used to make the traffic possible. Through the centuries, the natural deposits have been overlain by younger anthropogenic sediments, and today the original soil surface can be found at a depth of 2–3 m (Csorba 2008). The area has the highest ratio of soil sealing – 75%. The structure of the road network in the city centre is mostly radial. The area is built up mainly with 2–4 storey blocks and houses with a closed facade facing the street. The areas surrounding the city centre are higher, therefore the cultural layer is usually thinner. Recently in the eastern part of Debrecen, family houses have become a characteristic feature, and sealed areas represent less than 50%. Whereas in the western part of the city, 4–14 storey housing estates dominate and the sealed soils cover 50–75% (Szegeci 1999, 2003).

From the aspect of air quality, Debrecen is a moderately polluted city, however, in the city centre, the pollution coming from the transportation is a major issue as the emission rate of nitrogen-oxide and volatile organic compounds is increasing. The industrial companies – the main sources of the polluting agents – are located in four industrial parks. In the industrial structure of the city, apart from the pharmaceutical, light, bearing and plastic industry, medical device manufacturing and electronics, also traditional, mainly food industry companies are significant. The Tiszántúl Environmental Protection, Nature Conservation and Water Management Inspectorate in a survey performed in 2009 registered 184 objects where operations are dangerous to the waters and the geological environment. Among others, dangerous pollution was detected in the area of TEVA pharmaceutical, the airport, the MÁV service station, the old communal dump site, the power plant and the petrol stations (The Environment Protection Program of Debrecen 2009).

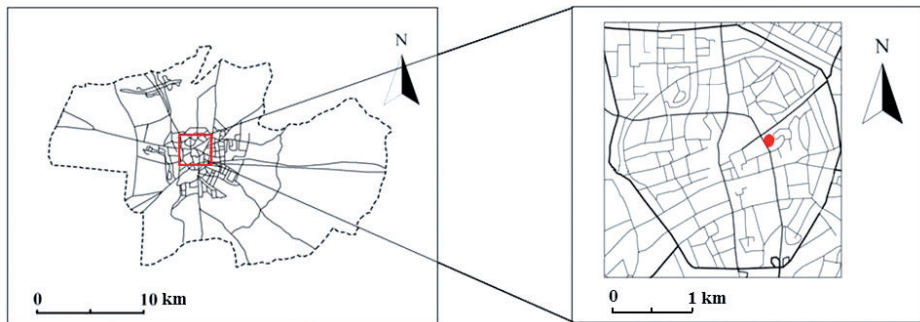
Regarding the soils of Debrecen, so far one research was carried out which deals with the distribution pattern of heavy metals coming from the transportation and its urban ecological effects. Szegeci (1999) established that the lead content in the soils is the highest in the city centre, near the roads with heavy traffic (at present or in the past) and in the industrial areas. The lowest heavy metal content was measured within the green areas. Based on the results of the research, it can be established that soils of playgrounds, recreational areas, small gardens and meadows near the roads are most

sensitive in terms of exposure to heavy metals, because the latter can easily get into the human body from there.

The study of Sándor and Szabó (IUSS Working Group WRB 2007) examines soil features modified by technogenic factors, the vertical distribution of the toxic heavy metals and classification of the soils according to the WRB system (2007). It can be said that soils of the centre of Debrecen are under strong technogenic influence, because of the accumulation of cultural layers and strong modifications in the majority of sections where the original soil structure cannot be recognized. In all of the examined sections, we found artefacts which were mostly building waste materials. The soils reaction was slightly alkaline. Higher pH is mainly caused by the occurrence of artefacts containing CaCO_3 , therefore the technogenic origin is evident. The vertical distribution of the humus content also indicates a strong technogenic effect; alternating layers of humus-rich and humus-poor soil layers were found towards the deeper levels. In the city centre, the ratio of the covered surfaces is very high, therefore almost exclusively Ekranic Technosols occur here; the most widely used qualifiers are Calcaric, Ruptic and Arenic.

Soil pits 7-12 were dug during LiFES workshop supported by grant 2012-2-PL1-ERA10-28971 awarded by Polish Foundation for the Development of the Education System.

Site 1 – Ekranic Technosol (Calcaric, Toxic, Epiarenic)



Location: Csapó Street, Debrecen, East Hungary

Coordinates: 47°31'56.22" N 21°37'52.26" E

Altitude: 122 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: fallow, disused

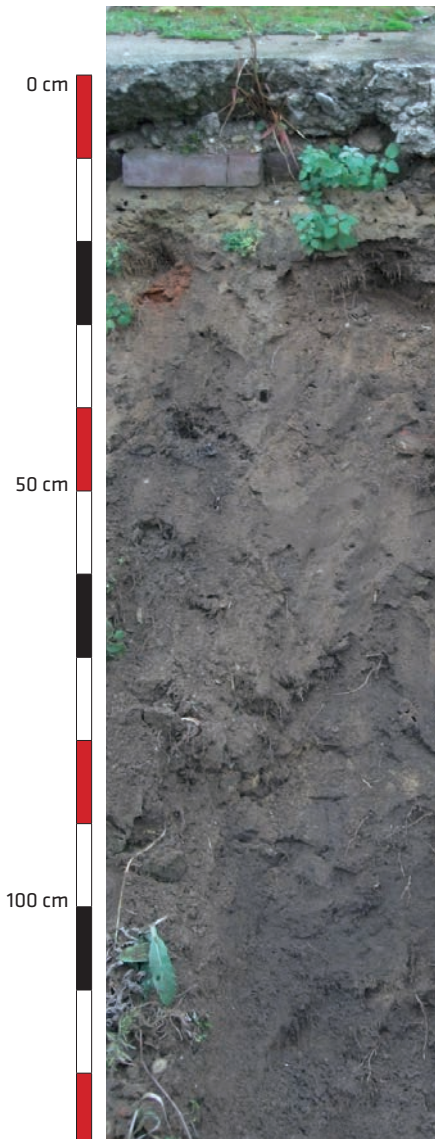
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: lawn grass, weed

Site 1 – Ekranic Technosol (Calcaric, Toxic, Epiarenic)



Morphology:

0–15 cm: *technic hard rock* – flagstone and gravel.

HTM – 15–20 cm: human-transported material, sand, pale yellow, single grain structure, dry, abrupt boundary, common artefacts.

Cu1 – 20–45 cm: loamy sand, brown, single grain structure, dry, gradual boundary, common artefacts.

Cu2 – 45–80 cm: loamy sand, dark greyish brown, single grain, dry, gradual boundary, few artefacts.

Ab – below 80 cm: sandy loam, brown, weak granular structure, slightly moist, gradual boundary, very few artefacts.

Comments:

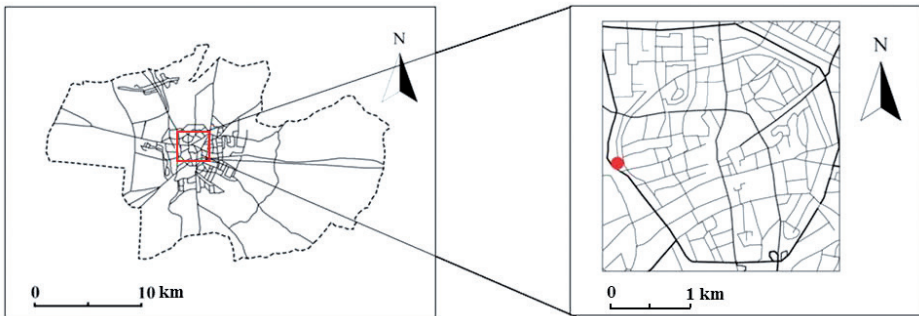
Site 1 was located in Csapó Street in downtown of Debrecen. Presently, the area is fallow. Periodically it is used as the parking place.

Site 1 – Ekranic Technosol (Calcaric, Toxic, Epiarenic)

Selected soil properties

HORIZON	HTM	Cu1	Cu2	Ab	
DEPTH [cm]	15-20	25-45	45-80	> 80	
PARTICLE SIZE DISTRIBUTION					
ϕ [mm]	[%]				
Artefact content	7	7	3	1	
2.0-0.2	14	14	13	11	
0.2-0.1	61	56	59	52	
0.1-0.05	11	10	12	11	
0.05-0.02	4	5	5	9	
0.02-0.01	2	4	3	5	
0.01-0.005	2	3	3	4	
0.005-0.002	2	3	2	3	
<0.002	4	5	3	5	
TEXTURE CLASS (USDA)	loamy sand	loamy sand	loamy sand	sandy loam	
SOIL MATRIX COLOUR	dry	2.5Y 8/4	10YR 6/3	10YR 5/2	10YR 4/1
	wet	2.5Y 8/6	10YR 5/3	10YR 4/2	10YR 4/3
LoI [%]	0.82	0.79	0.69	1.46	
OC [%]	0.48	0.46	0.4	0.85	
P_{ca} [mg·kg⁻¹]	6	9	11	6	
pH	H ₂ O	8.3	8.2	8.1	7.9
	1M KCl	8.2	8.2	8.1	7.9
CaCO₃ [%]	4.5	5.9	5.2	4.5	
HEAVY METALS SOLUBLE IN 2M HNO₃					
Zn	48.5	62.0	58.8	65.5	
Pb	29.5	43.5	55.7	105	
Cd	<1	<1	<1	<1	
Cu	[mg·kg ⁻¹]	18.5	49.7	81.3	25.7
Cr		9.0	17.5	10.3	12.5
Ni		7.22	8.13	6.68	7.31
Co		7.07	5.22	6.52	5.95

Site 2 – Ekranic Technosol (Calcaric, Ruptic, Toxic, Arenic)



Location: Segner Square, Debrecen, East Hungary

Coordinates: 47°31'45.59" N 21°36'43.75" E

Altitude: 119 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: pathway and cycle path

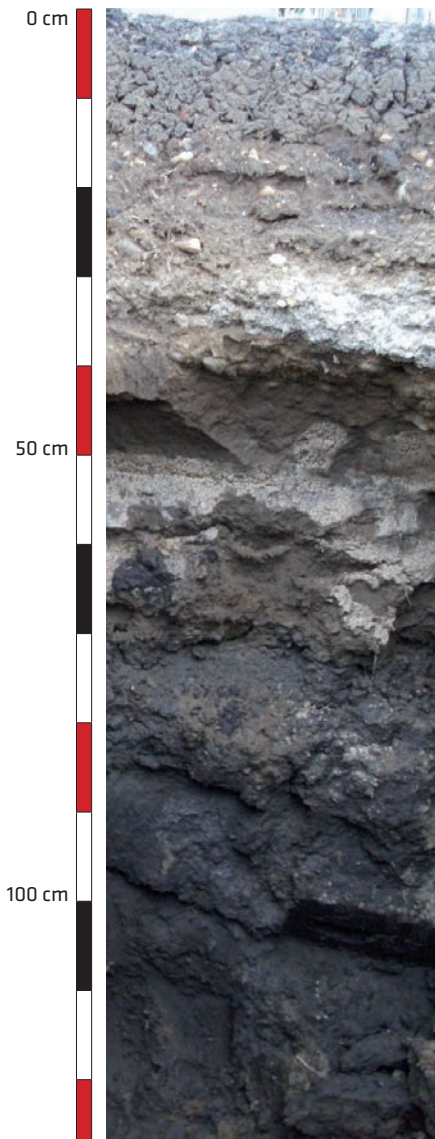
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene drift of sands

Vegetation: none

Site 2 – Ekranic Technosol (Calcaric, Ruptic, Toxic, Arenic)



Morphology:

0–15 cm: *technic hard rock* – flagstone and gravel.

HTM – 15–60 cm: human-transported material, sand, grey colour, single grain structure, dry, clear boundary, common artefacts.

Au – 60–115 cm: sandy loam, very dark greyish brown, weak structure, slightly moist, clear boundary, very few artefacts.

B – 115–130 cm: loam, very dark greyish brown, weak structure, moist, very few artefacts.

Comments:

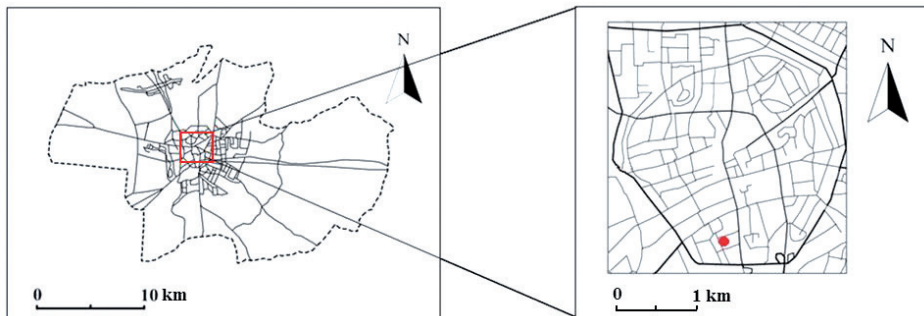
Site 2 is located on the Segner Square. Here is located one of main bus terminals of Debrecen. This part of Debrecen is quite busy. Nearby is the Kenézy Gyula Hospital and a lot of supermarkets.

Site 2 – Ekranic Technosol (Calcaric, Ruptic, Toxic, Arenic)

Selected soil properties

HORIZON		HTM	Au	B
DEPTH [cm]		15-60	60-115	115-130
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]		[%]		
Artefact content		8	2	0
2.0-0.2		25	8	1
0.2-0.1		56	36	18
0.1-0.05		12	18	12
0.05-0.02		1	22	22
0.02-0.01		1	6	11
0.01-0.005		1	3	9
0.005-0.002		1	4	10
<0.002		3	3	17
TEXTURE CLASS (USDA)		sand	sandy loam	silt loam
SOIL MATRIX COLOUR	dry	10YR 5/1	10YR 3/1	10YR 3/2
	wet	10YR 4/2	10YR 3/2	10YR 3/2
LoI [%]		0.51	2.45	2.75
OC [%]		0.30	1.42	1.60
P_{ca} [mg·kg⁻¹]		6	4	3
pH	H ₂ O	8.8	8.2	8.2
	1M KCl	8.3	7.9	7.8
CaCO₃ [%]		2.9	7.0	10.6
HEAVY METALS SOLUBLE IN 2M HNO₃				
Zn		20.5	67.7	73.5
Pb		10.3	59.7	104
Cd		<1	<1	<1
Cu	[mg·kg ⁻¹]	7.1	28.9	29.9
Cr		8.0	25.8	47.0
Ni		4.58	10.3	12.3
Co		7.41	4.71	3.64

Site 3 – Ekranic Technosol (Calcaric, Ruptic, Arenic)



Location: Vörösmarty Mihály Street, Debrecen, East Hungary

Coordinates: 47°31'20.52" N 21°37'30.12" E

Altitude: 120 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: surfaced road, sidewalk

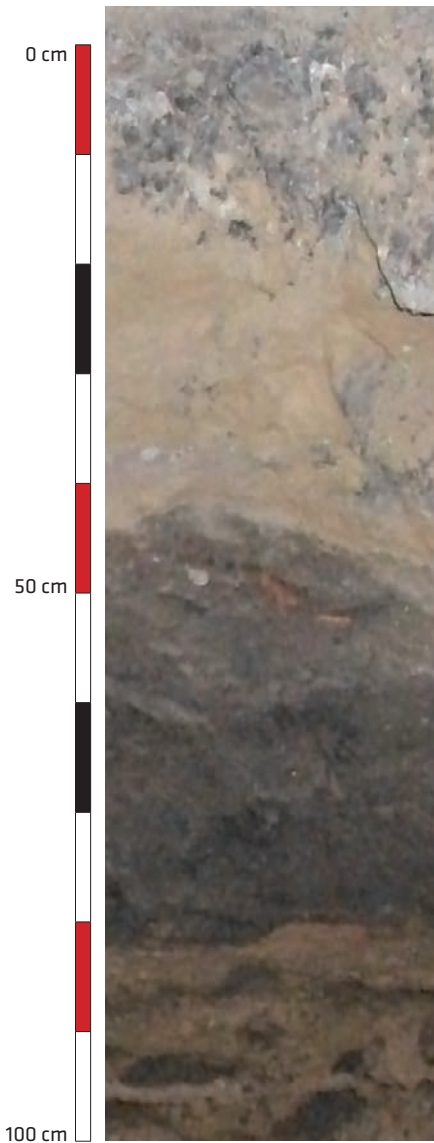
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene drift of sands

Vegetation: none

Site 3 – Ekranic Technosol (Calcaric, Ruptic, Arenic)



Morphology:

0–20 cm: *technic hard rock* – flagstone and gravel.

HTM – 20–45 cm: human-transported material, sand, brownish yellow, single grain structure, dry, abrupt boundary, common artefacts.

Abu1 – 45–85 cm: sandy loam, brown, granular structure, moist, abrupt boundary, common artefacts.

Au/C – 85–100 cm: mixed horizon, sandy loam, yellowish brown, single grain structure, moist, abrupt boundary, few artefacts.

Comments:

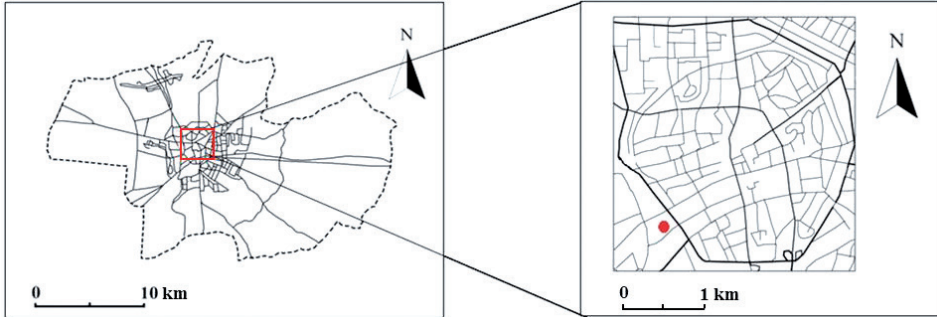
Site 3 was located in Vörösmarty Mihály street in downtown of Debrecen. Nearby the main train station is located. The traffic is low and the houses are four-storey.

Site 3 – Ekranic Technosol (Calcaric, Ruptic, Arenic)

Selected soil properties

HORIZON		HTM	Abu1	Au/C
DEPTH [cm]		20–45	45–85	85–100
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]		[%]		
Artefact content		13	9	4
2.0–0.2		13	10	6
0.2–0.1		65	35	36
0.1–0.05		15	16	14
0.05–0.02		2	13	15
0.02–0.01		1	7	8
0.01–0.005		1	5	5
0.005–0.002		1	5	7
<0.002		2	9	9
TEXTURE CLASS (USDA)		sand	sandy loam	sandy loam
SOIL MATRIX COLOUR	dry	10YR 6/6	10YR 5/3	10YR 5/4
	wet	10YR 5/4	10YR 4/3	10YR 4/4
LoI [%]		0.47	1.21	1.41
OC [%]		0.27	0.71	0.82
P_{ca} [mg·kg⁻¹]		5	2	5
pH	H ₂ O	8.4	8.5	8.5
	1M KCl	8.3	8.2	8.2
CaCO₃ [%]		3.6	10.6	8.9
HEAVY METALS SOLUBLE IN 2M HNO₃				
Zn		29.5	76.8	62.5
Pb		32.5	43.3	72.5
Cd		<1	<1	<1
Cu	[mg·kg ⁻¹]	6.0	23.1	24.5
Cr		7.5	21.8	29.0
Ni		2.4	9.7	9.8
Co		7.5	4.8	4.0

Site 4 – Ekranic Thaptomollic Luvic Technosol (Calcaric, Toxic, Humic)



Location: Krúdy Street, Debrecen, East Hungary

Coordinates: 47°31'18.89" N 21°36'47.28" E

Altitude: 123 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: garden

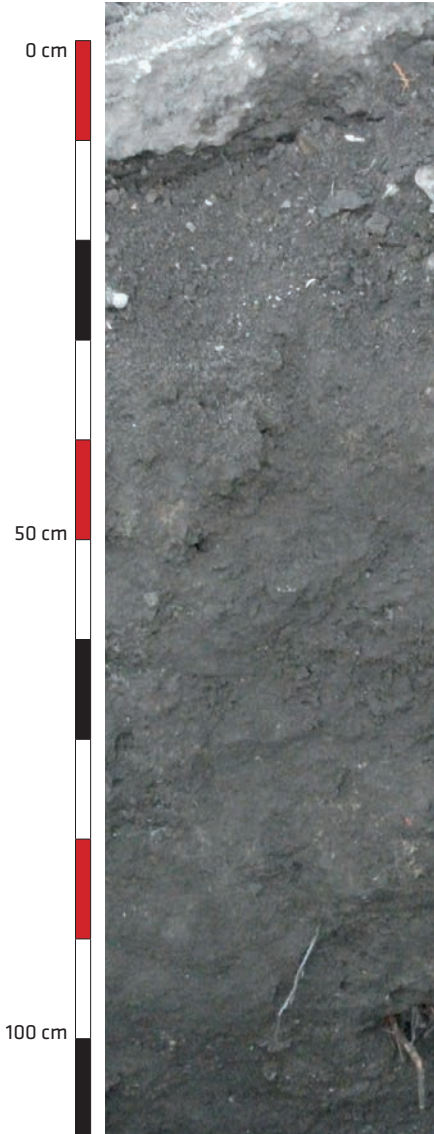
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: weeds

Site 4 – Ekranic Thaptomollic Luvic Technosol (Calcaric, Toxic, Humic)



Morphology:

0–15 cm: *technic hard rock* – flagstone and gravel.

Au1/Au2 – 15–30 cm: mixed horizon, sandy loam, dark grey, granular structure, dry, clear boundary, common artefacts.

Au1 – 30–60 cm: sandy loam, dark grey, granular structure, dry, gradual boundary, common artefacts.

Au2 – 60–80 cm: sandy loam, dark grey, granular structure, slightly moist, gradual boundary, common artefacts.

Au3– 80–115 cm: loam, very dark greyish brown, weak structure, moist, gradual boundary, few artefacts.

Comments:

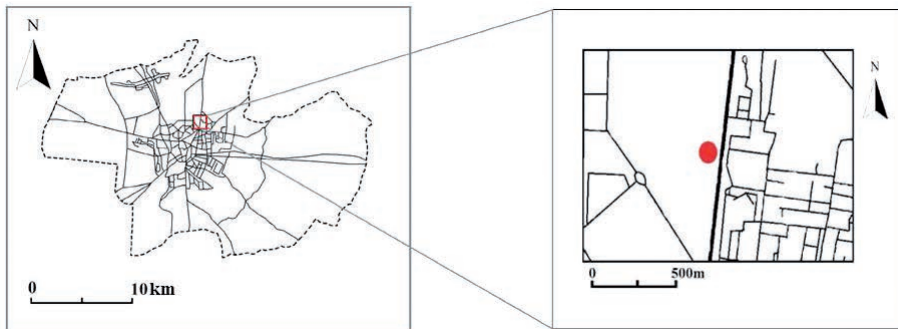
Site 4 was located in Krúdy Gyula Street in Debrecen. This area of the city belongs to 'Family Houses with garden' zone.

Site 4 – Ekranic Thaptomollic Luvic Technosol (Calcaric, Toxic, Humic)

Selected soil properties

HORIZON	Au1/Au2	Au1	Au2	Au3
DEPTH [cm]	15–30 cm	30–60	60–80	80–115
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]	[%]			
Artefact content	9	9	9	2
2.0–0.2	11	12	8	6
0.2–0.1	43	45	37	27
0.1–0.05	14	14	14	12
0.05–0.02	15	13	20	18
0.02–0.01	6	5	8	10
0.01–0.005	4	4	5	8
0.005–0.002	4	4	4	8
<0.002	3	3	4	11
TEXTURE CLASS (USDA)	sandy loam	sandy loam	sandy loam	loam
SOIL MATRIX COLOUR	dry	10YR 4/1	10YR 4/1	10YR 4/1
	wet	10YR 3/1	10YR 3/1	10YR 3/1
LoI [%]	2.06	2.07	2.04	2.35
OC [%]	1.12	1.20	1.18	1.36
P_{ca} [mg·kg⁻¹]	9	10	3	5
pH	H ₂ O	8.1	8.0	8.3
	1M KCl	8.0	7.9	8.1
CaCO₃ [%]	8.6	7.0	11.8	11.6
HEAVY METALS SOLUBLE IN 2M HNO₃				
Zn	108	111	102	102
Pb	85.7	92.0	73.0	120
Cd	<1	<1	<1	<1
Cu	[mg·kg ⁻¹]	39.0	38.9	39.2
Cr		24.7	21.5	31.0
Ni		9.00	8.22	10.6
Co		4.34	4.61	3.79

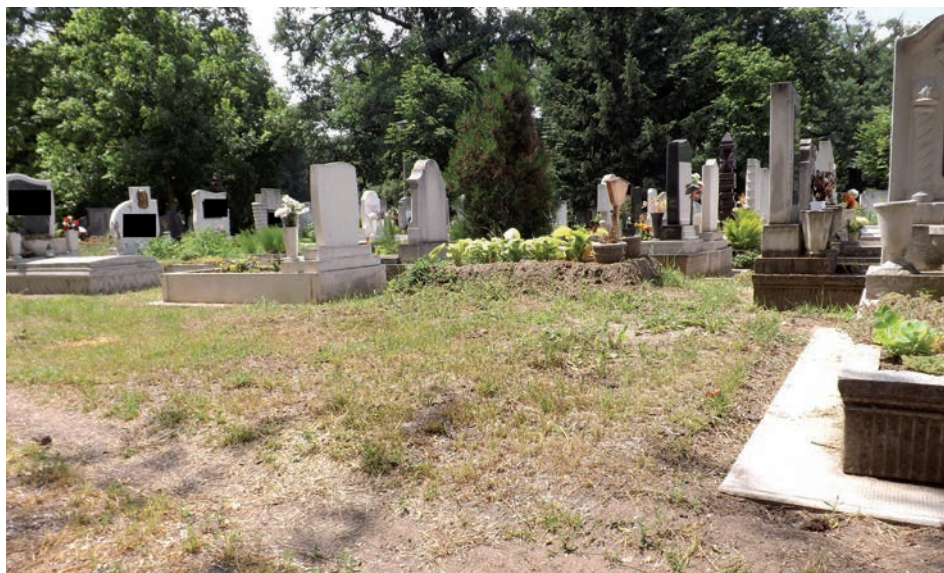
Site 5 – Ekranic Thapptomollic Luvic Technosol (Calcaric, Toxic, Humic)



Location: The public cemetery, Debrecen, East Hungary

Coordinates: 47°33'30.49" N 21°39'00.67" E

Altitude: 124 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: cemetery

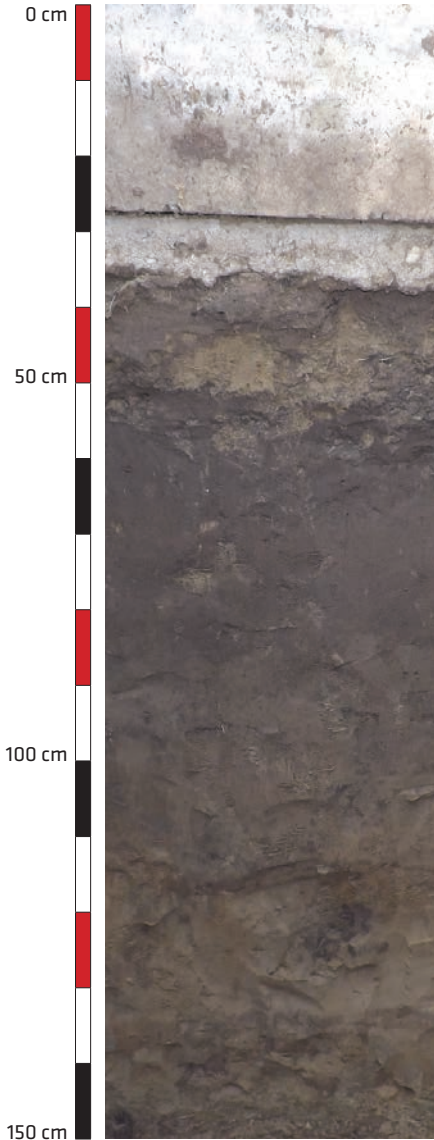
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene drift of sands

Vegetation: deciduous trees, pine trees, flowers

Site 5 – Ekranic Thaptomollic Luvic Technosol (Calcaric, Toxic, Humic)



Morphology:

0–35 cm: *technic hard rock* – concrete layer.

A/C – 35–54 cm: mixed horizon, sandy loam, light yellowish brown and dark greyish brown, abundant mottles, weak structure, very dry, abrupt boundary, no artefacts.

A1 – 54–85 cm: humus horizon, loamy sand, dark greyish brown, weak structure, dry, clear boundary, no artefacts.

A2 – 85–104 cm: humus horizon, sand, greyish brown, single grain, dry, clear boundary, no artefacts.

C1 – 104–130 cm: loamy sand, brown, single grain, slightly moist, gradual boundary, no artefacts.

C2 – 130–155 cm: sandy loam, brownish yellow, single grain, slightly moist, gradual boundary, no artefacts.

Comments:

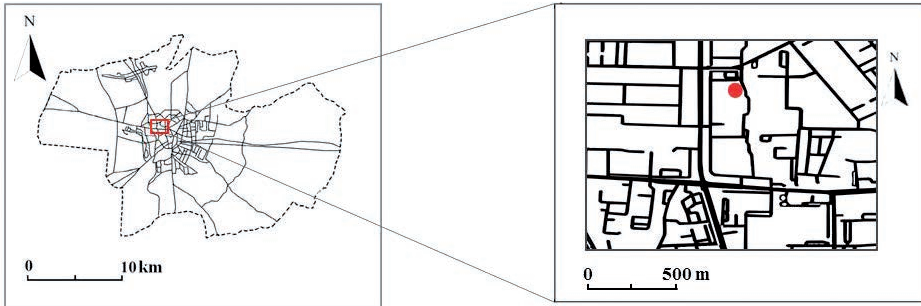
Site 5 was located in the public cemetery, established in 1932 (northern part of Debrecen). The national main road '4' is next to it.

Site 5 – Ekranic Thapptomollic Luvic Technosol (Calcaric, Toxic, Humic)

Selected soil properties

HORIZON	A/C	A1b	A2	C1	C2	
DEPTH [cm]	35–54	54–85	85–104	104–130	130–155	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
Artefact content	0	0	0	0	0	
2.0–0.2	7	14	11	11	7	
0.2–0.1	41	49	58	56	37	
0.1–0.05	25	15	16	17	22	
0.05–0.02	10	6	5	5	11	
0.02–0.01	4	4	2	2	4	
0.01–0.005	2	3	2	2	3	
0.005–0.002	3	3	2	2	3	
<0.002	8	6	4	5	13	
TEXTURE CLASS (USDA)	sandy loam	loamy sand	sand	loamy sand	sandy loam	
SOIL MATRIX COLOUR	dry	10YR 6/4;4/2	10YR 4/2	10YR 5/2	10YR 6/3	10YR 6/4
	wet	10YR 6/8;3/2	10YR 3/2	10YR 4/2	10YR 5/3	10YR 6/8
LoI [%]	0.86	1.47	0.57	0.26	0.43	
OC [%]	0.50	0.85	0.33	0.15	0.25	
P_{ca} [mg·kg ⁻¹]	86	180	79	80	97	
pH	H ₂ O	7.6	7.7	7.7	7.7	7.7
	1M KCl	7.5	7.4	7.2	7.0	6.8
CaCO ₃ [%]	3.9	2.5	2.3	3.2	2.8	
HEAVY METALS SOLUBLE IN 2M HNO₃						
Zn	38.0	49.0	19.3	17.2	28.8	
Pb	38.1	32.8	17.6	16.0	22.5	
Cd	<1	<1	<1	<1	<1	
Cu	[mg·kg ⁻¹]	19.0	17.1	10.8	9.45	14.1
Cr	15.6	14.8	8.78	9.14	24.5	
Ni	<2	<2	<2	<2	<2	
Co	4.08	4.08	4.52	4.51	3.85	

Site 6 – Urbic Technosol (Calcaric, Ruptic, Arenic)



Location: Jerikó Street, Debrecen, East Hungary

Coordinates: 47°32'49.30" N 21°36'42.12" E

Altitude: 121 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: lawn (recreational)

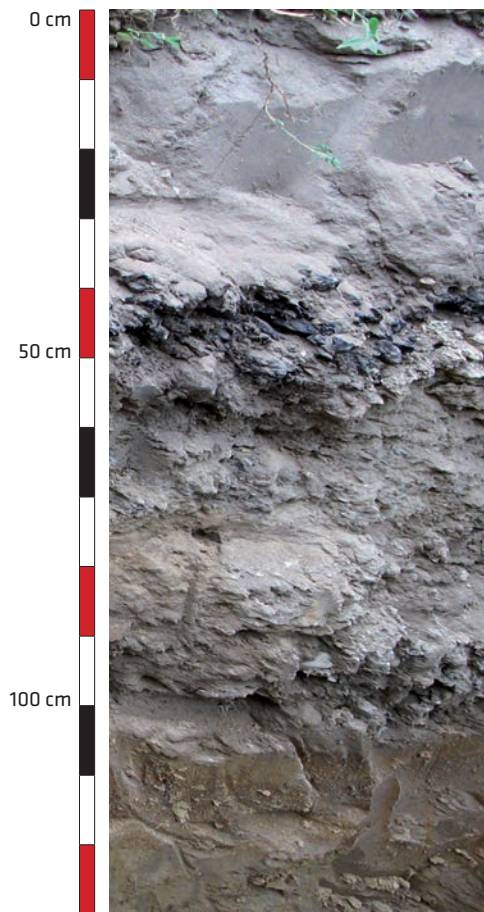
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene drift of sands

Vegetation: lawn grass

Site - 6 Urbic Technosol (Calcaric, Ruptic, Arenic)



Morphology:

Au - 0-32 cm: humus horizon, sand, light grey, single grain structure, very dry, abrupt boundary, numerous artefacts.

32-47 cm: *technic hard rock* -asphalt mixture, weakly permeable.

Cu - 47-90 cm: loamy sand, light brownish grey, single grain structure, very dry, abrupt boundary, many artefacts.

C - 90-115 cm: loam, yellowish brown, weak structure, slightly moist, abrupt boundary, no artefacts.

Comments:

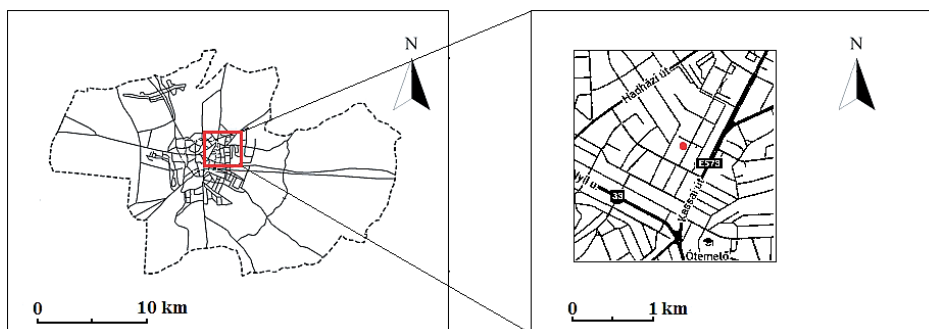
Site 6 was located in 'Newgarden' in north part of Debrecen. Residential district with 4-14 floors apartment houses with small parks and playgrounds.

Site - 6 Urbic Technosol (Calcaric, Ruptic, Arenic)

Selected soil properties

HORIZON		Au	Cu	C
DEPTH [cm]		0-32	47-90	90-115
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]		[%]		
Artefact content		16	16	0
2.0-0.2		17	16	1
0.2-0.1		62	56	25
0.1-0.05		9	11	16
0.05-0.02		3	4	26
0.02-0.01		2	3	9
0.01-0.005		2	2	5
0.005-0.002		2	3	4
<0.002		3	5	14
TEXTURE CLASS (USDA)		sand	loamy sand	loam
SOIL MATRIX COLOUR	dry	10YR 7/2	10YR 6/2	10YR 7/6
	wet	10YR 4/2	10YR 4/2	10YR 5/6
LoI [%]		0.61	0.15	0.30
OC [%]		0.35	0.09	0.17
P _{ca} [mg·kg ⁻¹]		126	92.5	74.5
pH	H ₂ O	7.6	8.3	7.5
	1M KCl	7.2	7.9	6.2
CaCO ₃ [%]		2.2	3.4	2.7
HEAVY METALS SOLUBLE IN 2M HNO₃				
Zn		26.6	27.8	44.2
Pb		33.7	36.6	41.8
Cd		<1	<1	<1
Cu [mg·kg ⁻¹]		24.8	13.4	26.4
Cr		9.74	15.5	41.7
Ni		<2	<2	<2
Co		4.30	3.44	2.92

Site 7 – Urbic Ekranic Technosol (Arenic)



Location: Kassai Campus, Laktanya utca 1, Debrecen

Coordinates: 47°32'29.4" N 21°38'20.7" E

Altitude: 130 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: university campus,
former Soviet army barracks area

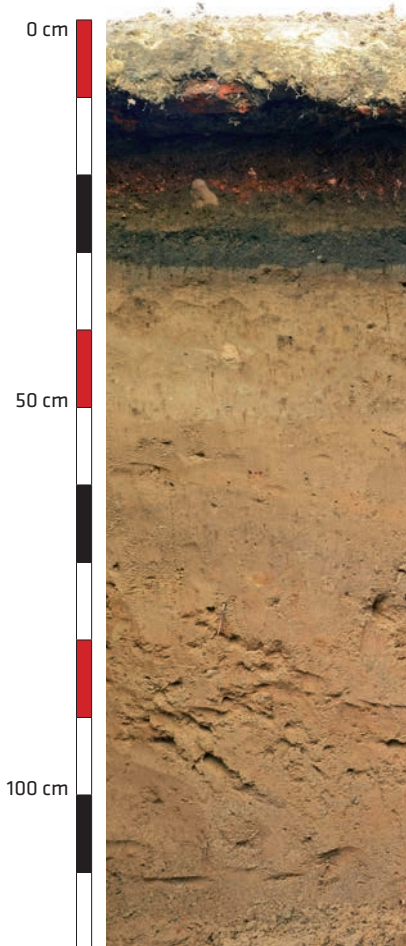
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: lawn grass, weeds

Site 7 – Urbic Ekranic Technosol (Arenic)



Morphology:

0–20 cm: *technic hard rock* – concrete slab.

Au1 – 20–23 cm: loamy sand, single grain structure, brown, clear and smooth boundary, few artefacts (construction materials; 3%).

Au2 – 23–28 cm: loamy sand, single grain structure, brown, clear and smooth boundary, dominant artefacts (construction materials, e.g. brick pieces; 85%).

Au3 – 28–32 cm: loamy sand, single grain structure, brown, clear and smooth boundary, few artefacts (construction materials; 4%).

Bu1 – 32–38 cm: loamy sand, medium granular structure, dark grey, clear and smooth boundary, few artefacts (construction materials; 3%).

Bu2 – 38–41 cm: loamy sand, single grain structure, greyish brown, gradual and smooth boundary, few artefacts (construction materials; 4%).

Bu3 – 41–57 cm: loamy sand, single grain structure, light yellowish brown, gradual and smooth boundary, few artefacts (construction materials; 3%).

Bu4 – 57–93 cm: loamy sand, single grain structure, pale brown, gradual and smooth boundary, few artefacts (construction materials; 4%).

Bu5 – >93 cm: loamy sand, single grain structure, light yellowish brown, few artefacts (construction materials; 3%).

Comments:

Site 7 was located in Laktanya 1 street in Debrecen; former Soviet military area. Nowadays used as a parking place.

Site 7 – Urbic Ekranic Technosol (Arenic)

Selected soil properties

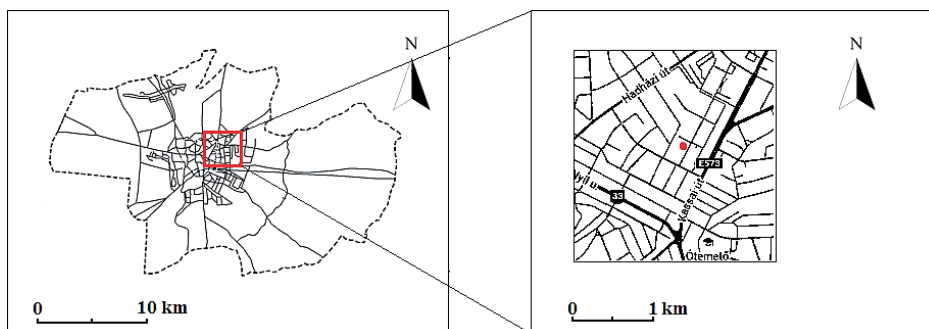
HORIZON	Au1	Au2	Au3	Bu1	Bu2	Bp3	Bp3	Bp5
DEPTH [cm]	20-23	23-28	28-32	32-38	38-41	41-57	57-93	>93
PARTICLE SIZE DISTRIBUTION								
ø [mm]								
2.0-1.0	7	11	5	14	8	1	1	1
1.0-0.5	9	13	4	17	6	2	1	3
0.5-0.25	18	16	15	20	21	19	12	20
0.25-0.1	51	43	65	40	57	69	79	68
0.1-0.05	11	10	9	4	6	8	7	4
<0.05	4	7	2	5	2	1	0	4
TEXTURE CLASS (USDA) loamy sand loamy sand loamy sand loamy sand loamy sand loamy sand loamy sand loamy sand								
SOIL MATRIX	dry	7,5YR 5/2	7,5YR 5/3	10YR 4/1	10YR 5/2	10YR 6/4	10YR 6/3	10YR 6/4
COLOUR	wet	7,5YR 3/2	7,5YR 3/3	10YR 2/1	10YR 4/2	10YR 4/3	10YR 3/3	10YR 4/4
OC [%]	1.23	1.03	0.96	2.76	0.58	0.15	0.21	0.14
N _t [%]	0.074	0.050	0.042	0.092	0.045	0.01	0.02	0.01
C:N [%]	17	21	23	30	13	15	11	12
P _{ca} [mg·kg ⁻¹]	115	84	100	128	235	305	378	138
pH	H ₂ O	8.3	8.6	8.3	8.5	8.7	8.3	8.3
	1M KCl	7.7	7.8	7.4	7.9	8.0	8.0	8.0
CaCO ₃ [%]		0.3	0.0	0.1	0.3	0.2	0.7	0.1

Site 7 – Urbic Ekranic Technosol (Arenic)

Selected soil properties cont.

HORIZON	Au1	Au2	Au3	Bu1	Bu2	Bu3	Bu4	Bu5
DEPTH [cm]	20-23	23-28	28-32	32-38	38-41	41-57	57-93	>93
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃								
Zn	75	68	48	92	45	17	19	19
Pb	66	52	51	80	63	63	66	33
Cd	<5	<5	<5	<5	<5	<5	<5	<5
Cu	41	36	27	54	25	21	21	19

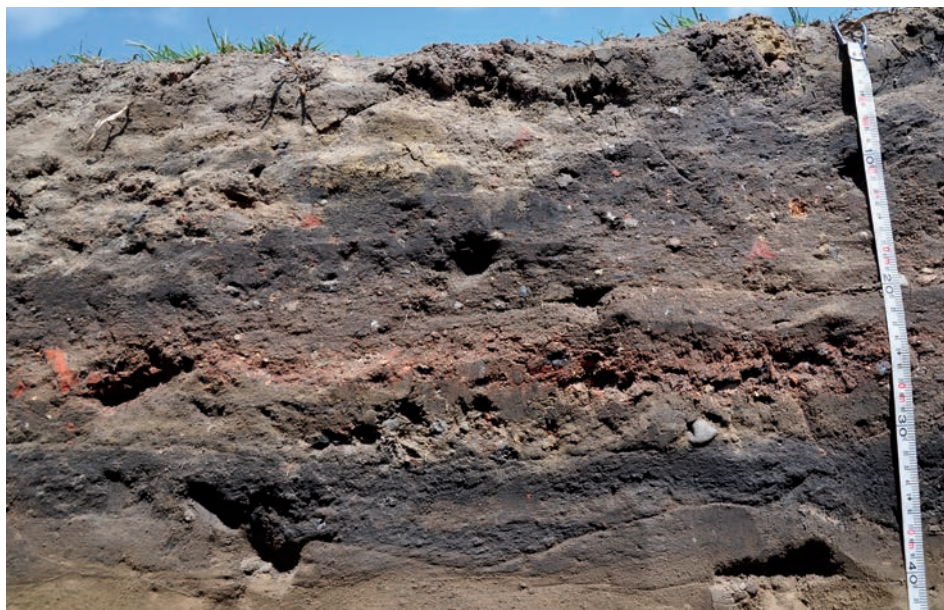
Site 8 – Urbic Technosol (Arenic)



Location: Kassai Campus, Laktanya utca 1, Debrecen, Hungary

Coordinates: 47°32'29.4" N 21°38'20.7" E

Altitude: 130 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: fallow, disused

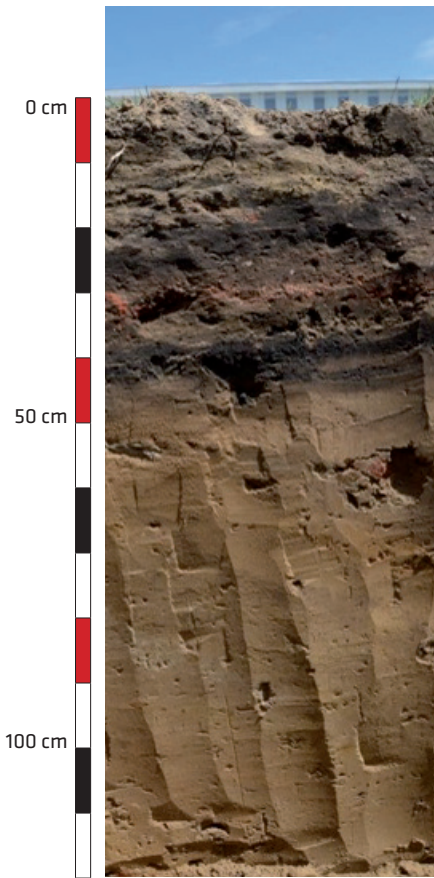
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: lawn grass, weed

Site 8 – Urbic Technosol (Arenic)



Morphology:

Ap – 0–20 cm: fine sand, single grain structure, dark greyish brown, few roots, few artefacts (construction materials; 4%), clear and smooth boundary.

Au – 20–30 cm: fine sand, single grain structure, brown, very few roots, dominant artefacts, 50% (construction materials), clear and smooth boundary.

Bp1 – 30–36 cm: fine sand, single grain texture, dark grey, few artefacts (construction materials; 3%), clear and smooth boundary.

Bp2 – 36–42 cm: fine sand, very fine granular structure, rock fragments, brown, few artefacts (construction materials: 3%), clear and smooth boundary.

Bp3 – 42–127 cm: fine sand, weak, very fine granular structure, light yellowish brown, few artefacts (construction materials; 3%).

Comments:

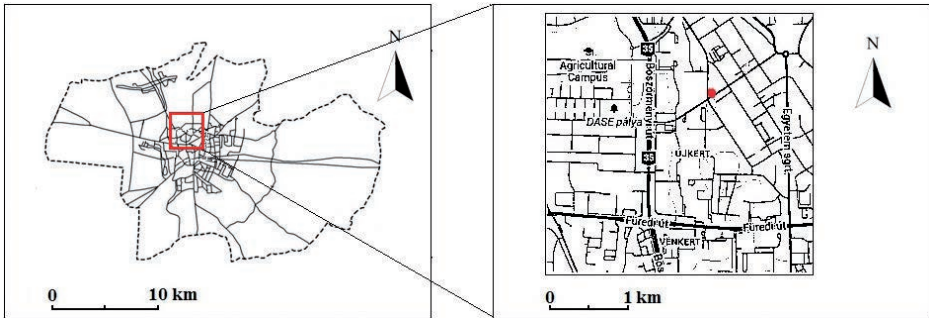
Site 8 was located in Laktanya 1 street in Debrecen; former Soviet military area. Nowadays a lawn.

Site 8 – Urbic Technosol (Arenic)

Selected soil properties

HORIZON	Ap	Au	Bp1	Bp2	Bp3	
DEPTH [cm]	0–20	20–30	30–36	36–42	42–107	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
2.0–1.0	9	13	12	4	1	
1.0–0.5	8	14	12	7	1	
0.5–0.25	19	15	18	21	10	
0.25–0.1	50	44	43	59	80	
0.1–0.05	8	8	10	8	7	
<0.05	6	6	5	1	1	
TEXTURE CLASS (USDA)	fine sand	fine sand	fine sand	fine sand	fine sand	
SOIL MATRIX COLOUR	dry	10YR 4/2	7,5YR 5/3	10YR 4/1	10YR 5/3	10YR 6/4
	wet	10YR 2/2	7,5YR 3/3	10YR 2/1	10YR 3/2	10YR 4/4
OC [%]	1.91	1.13	2.03	0.41	0.18	
N _t [%]	0.091	0.053	0.070	0.038	0.019	
C:N [%]	21	21	29	11	10	
P _{ca} [mg·kg ⁻¹]	160	109	194	401	271	
pH	H ₂ O	8.3	8.2	7.5	8.1	8.4
	1M KCl	7.8	7.9	7.1	7.6	7.8
CaCO ₃ [%]	1.4	0.8	0.2	0.2	0.0	
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃						
Zn	70	62	48	32	36	
Pb	[mg·kg ⁻¹]	26	35	38	37	36
Cd		<5	<5	<5	<5	<5
Cu		31	37	36	22	20

Site 9 – Urbic Technosol (Arenic)



Location: Bolyai utca 27, Debrecen, Hungary

Coordinates: 47°32'58" N 21°36'57" E

Altitude: 126 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: residential use

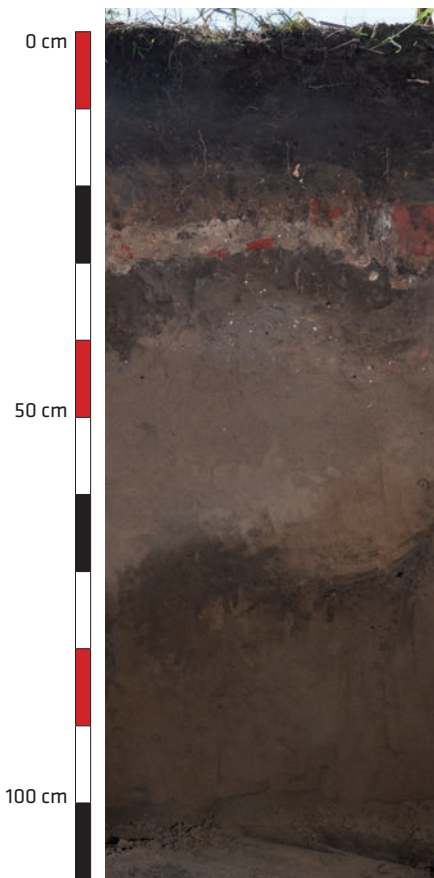
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: lawn grasses, weeds

Site 9 – Urbic Technosol (Arenic)



Morphology:

A – 0–20 cm: fine sand, single grain structure, clear and smooth boundary, roots, few artefacts (construction materials; 3%).

ABu – 20–28 cm: fine sand, single grain structure, clear and smooth boundary, roots, dominant artefacts (construction materials, glass; 10%).

Bu – 28–35 cm: fine sand, single grain structure, clear and smooth boundary, roots, dominant artefacts (construction materials, glass, bricks; 85%).

ABu – 35–48 cm: fine sand, single grain structure, clear and smooth boundary, very few roots, dominant artefacts (construction materials, glass, bricks, aluminium foil, plastic bottle; 90%).

B – 48–105 cm: fine sand, single grain structure, clear and smooth boundary, very few roots, few artefacts.

Comments:

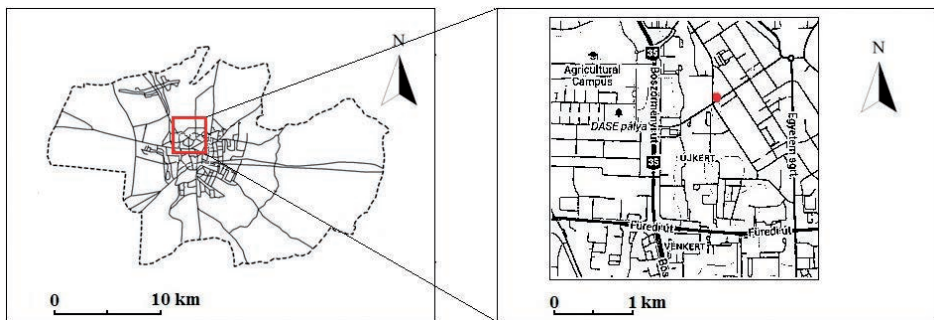
Site 9 was located in Bolyai utca 27 of Debrecen. Narrow strip of lawn (3 m wide) along the street.

Site 9 – Urbic Technosol (Arenic)

Selected soil properties

HORIZON	A	ABu	Bu	ABu	B	
DEPTH [cm]	0–20	20–28	28–35	35–48	48–105	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
2.0–1.0	36	14	5	3	0	
1.0–0.5	17	8	6	5	0	
0.5–0.25	14	17	18	13	15	
0.25–0.1	20	48	61	64	79	
0.1–0.05	9	6	7	10	5	
<0.05	4	7	3	5	1	
TEXTURE CLASS (USDA)	fine sand	fine sand	fine sand	fine sand	fine sand	
SOIL MATRIX	dry	10YR 4/2	10YR 5/3	10YR 7/2	10YR 5/2	10YR 6/3
COLOUR	wet	10YR 2/2	10YR 3/3	10YR 5/3	10YR 3/2	10YR 4/3
OC [%]	1.90	0.69	1.42	1.09	0.13	
N _t [%]	0.177	0.043	0.028	0.087	0.009	
C:N [%]	11	16	51	12	13	
P _{ca} [mg·kg ⁻¹]	176	213	164	116	82	
pH	H ₂ O	7.7	8.4	8.8	8.2	8.2
	1M KCl	7.1	7.9	8.2	7.8	7.5
CaCO ₃ [%]	0.2	1.2	8.4	1.2	0.1	
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃						
Zn	41	34	13	31	8	
Pb	65	62	68	92	46	
Cd	<5	<5	<5	<5	<5	
Cu	27	33	33	39	19	

Site 10 – Ekranic Technosol (Arenic)



Location: Bolyai utca 27, Debrecen, Hungary

Coordinates: 47°32'58" N 21°36'57" E

Altitude: 126 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: traffic area, bus stop

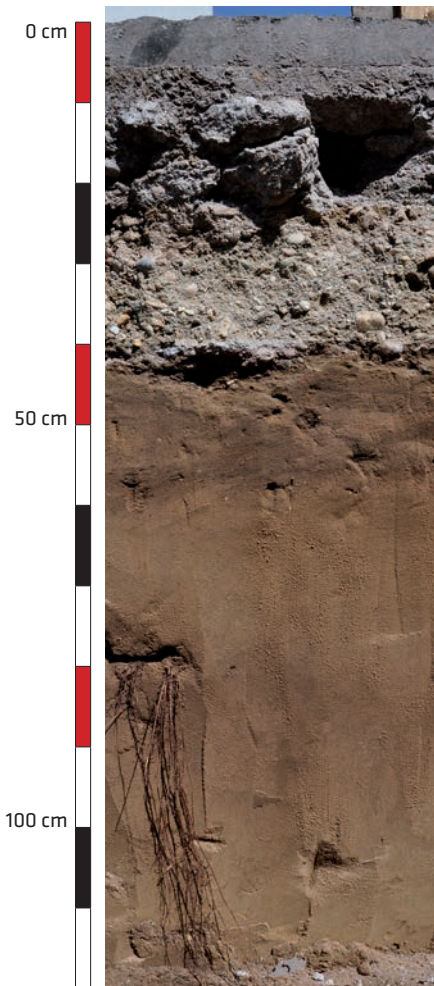
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: none

Site 10 – Ekranic Technosol (Arenic)



Morphology:

0–6 cm: *technic hard rock* – flagstone and gravel.

HTM – 6–40 cm: human-transported material, fine sand, single grain structure, clear and smooth boundary, few artefacts (construction materials, bricks; 4%).

ABu – 40–58 cm: fine sand, single grain structure, clear and smooth boundary, few artefacts (construction materials; 3%).

B – 58–120 cm: fine sand, single grain structure, clear and smooth boundary, few artefacts (construction materials; 4%), roots.

Comments:

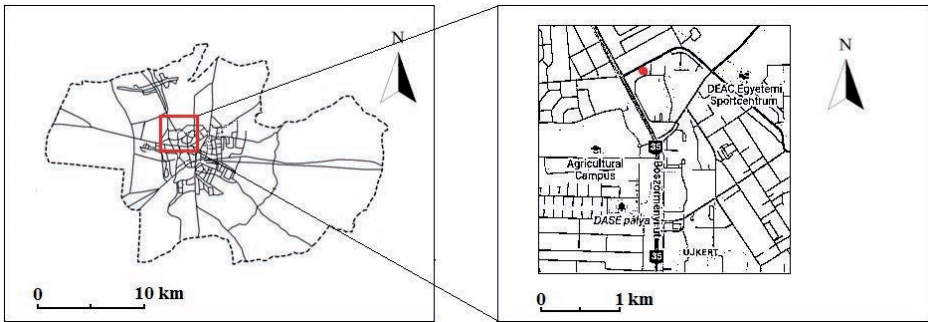
Site 10 was located in front of Regional Committee of Hungarian Academy of Sciences in Debrecen; Bolyai utca 27.

Site 10 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON		HTM	ABu	B
DEPTH [cm]		6–40	40–58	58–120
PARTICLE SIZE DISTRIBUTION				
ø [mm]				
2.0–1.0		33	7	0
1.0–0.5		35	2	1
0.5–0.25		24	21	28
0.25–0.1		6	63	63
0.1–0.05		1	4	5
>0.05		1	3	3
TEXTURE CLASS (USDA)		fine sand	fine sand	fine sand
SOIL MATRIX COLOUR	dry	10YR 6/3	10YR 6/3	10YR 5/3
	wet	10YR 5/3	10YR 3/3	10YR 3/3
OC [%]		0.10	0.27	0.13
N_t [%]		0.008	0.021	0.017
C:N [%]		12	13	7
P_{ca} [mg·kg⁻¹]		110	126	109
pH	H ₂ O	9.0	8.7	7.9
	1M KCl	8.5	8.3	7.0
CaCO₃ [%]		0.2	0.4	0.1
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃				
Zn		13	21	7
Pb		<16	24	24
Cd		<5	<5	<5
Cu		20	44	18

Site 11 – Urbic Ekranic Technosol



Location: Doberdó Street, Debrecen, Hungary

Coordinates: 47°33'23" N 21°36'31" E

Altitude: 126 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: residential area, soil under pedestrian alley

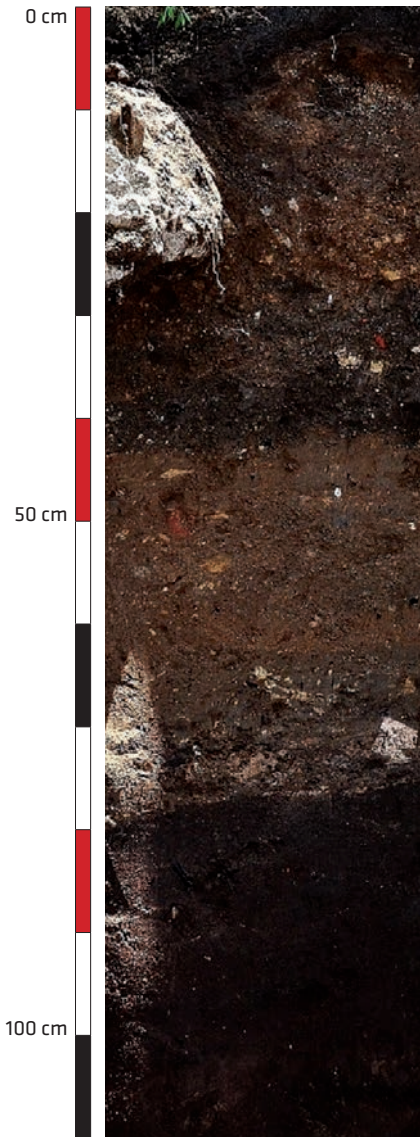
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: none

Site 11 – Urbic Ekranic Technosol



Morphology:

0–12 cm: *technic hard rock* – flagstone and gravel.

HTM 12–24 cm: human-transpored material – loamy sand, single grain structure, very pale brown, roots, abrupt boundary, dominant artefacts (construction materials, bricks; 90%).

A– 24–32 cm: loamy sand, single grain structure, roots, abrupt boundary, few artefacts (bricks).

Bu – 32–70 cm: loamy sand, single grain structure, abrupt boundary, dominant artefacts (construction materials, stone, bricks, cinder; 85%).

Bu2 – 70–92 cm: loamy sand, single grain structure, abrupt boundary, dominant artefacts (construction materials, stone, brick, cinder, plastic bottle, metal nails; 85%).

Bu3 – 92–104 cm: loamy sand, single grain structure, abrupt boundary, dominant artefacts (construction materials, stone, bricks, cinder; 85%).

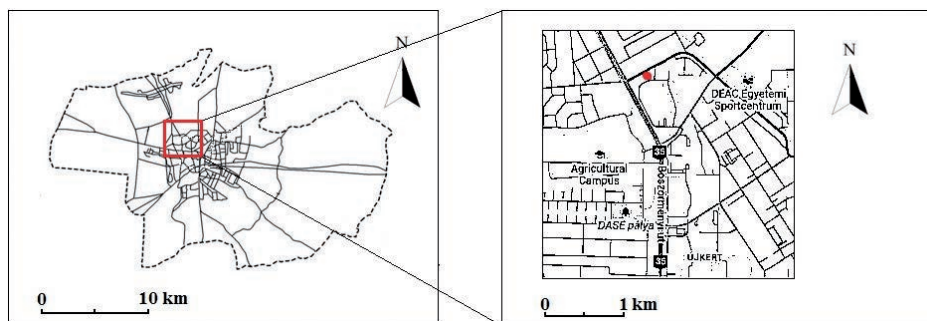
Ab – 104–160 cm: loamy sand (gleyic properties), single grain structure, few artefacts.

Site 11 – Urbic Ekranic Technosol

Selected soil properties

HORIZON	HTM	A	Bu	Bu2	Bu3	Ab	
DEPTH [cm]	12–24	24–32	32–70	70–92	92–104	104–160	
PARTICLE SIZE DISTRIBUTION							
ϕ [mm]	[%]						
2.0–1.0	34	46	11	14	15	9	
1.0–0.5	35	18	11	8	13	8	
0.5–0.25	26	12	22	20	16	29	
0.25–0.1	4	17	47	48	43	47	
0.1–0.05	1	4	6	7	7	5	
<0.05	0	3	3	3	6	2	
TEXTURE CLASS (USDA)	loamy sand	loamy sand	loamy sand	sandy loam	sandy loam	sandy loam	
SOIL MATRIX COLOUR	dry	10YR 7/3	10YR 3/2	10YR 6/2	10YR 6/3	10YR 5/3	10YR 5/2
	wet	10YR 4/3	10YR 2/2	10YR 3/2	10YR 4/2	10YR 3/2	10YR 2/2
OC [%]	0.07	1.13	0.63	0.41	0.51	0.44	
N_t [%]	0.006	0.121	0.036	0.029	0.039	0.044	
C:N [%]	12	9	17	14	13	10	
P_{ca} [mg·kg⁻¹]	130	541	60	35	91	61	
pH	H ₂ O	8.4	7.5	8.5	8.6	8.4	8.2
	1M KCl	7.7	6.2	7.9	8.0	7.9	7.3
CaCO₃ [%]	0.1	0	1.3	1.2	1.2	0.1	
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃							
Zn	12	67	38	23	23	20	
Pb	40	68	66	73	78	78	
Cd	<5	<5	<5	<5	<5	<5	
Cu	19	32	27	56	22	22	

Site 12 – Urbic Technosol



Location: Doberdó Street, Debrecen, Hungary

Coordinates: 47°33'22" N 21°36'28 E

Altitude: 126 m a.s.l.



Climate:

Average annual temperature: 9.6–9.9°C

Average annual precipitation: 540 mm

Land-use: residential area, lawn area between street and apartment houses

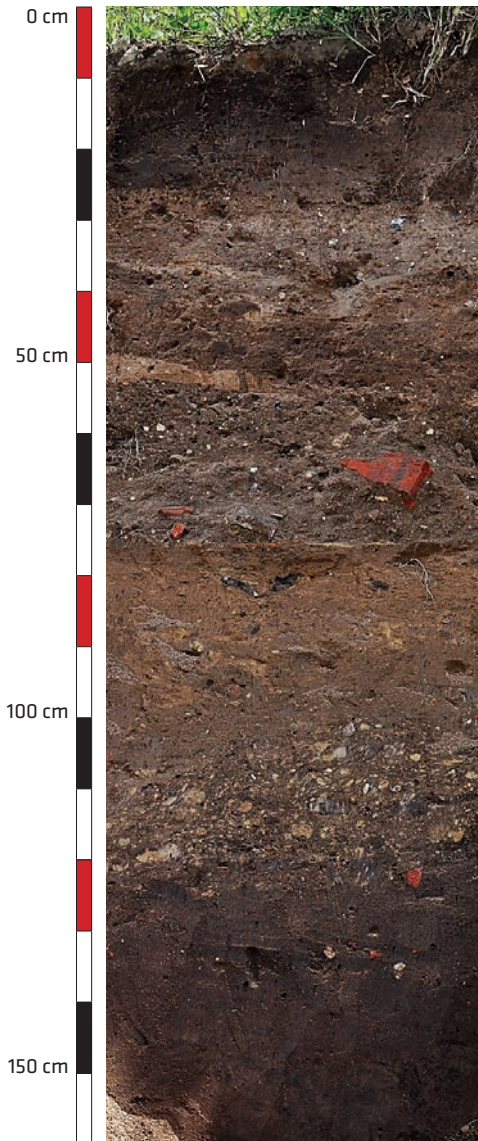
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene blown-sand

Vegetation: lawn grasses, weeds

Site 12 – Urbic Technosol



Morphology:

A – 0–24 cm: loamy sand, single grain structure, few roots, clear and smooth boundary.

Bu1 – 24–40 cm: loamy sand, single grain structure, few roots, clear and smooth boundary, few artefacts (construction materials, cinder, charcoals; 4%).

Bu2 – 40–74 cm: loamy sand, single grain structure, few roots, clear and smooth boundary, dominant artefacts (construction materials, cinder, bricks; 90%).

Bu3 – 74–98 cm: loamy sand (gleyic properties), single grain structure, few roots, clear and smooth boundary, dominant artefacts (construction materials, glass, cinder, bricks; 85%).

Bu4 – 98–116 cm: loamy sand (gleyic properties), single grain structure, clear and smooth boundary, few artefacts (charcoals, bricks, stones; 4%).

Ab – 116–147 cm: loamy sand texture, single grain structure, clear and smooth boundary, few artefacts (construction materials, glass, nails; 3%).

Site 12 – Urbic Technosol

Selected soil properties

HORIZON		A	Bu1	Bu2	Bu3	Bu4	Ab
DEPTH [cm]		0–24	24–40	40–74	74–98	98–116	116–147
PARTICLE SIZE DISTRIBUTION							
ø [mm]		[%]					
2.0–1.0		24	11	11	12	21	10
1.0–0.5		15	6	15	7	12	7
0.5–0.25		18	15	19	14	15	26
0.25–0.1		26	54	44	56	38	49
0.1–0.05		14	12	9	6	7	5
<0.05		3	2	2	5	7	3
TEXTURE CLASS (USDA)		loamy sand	loamy sand	loamy sand	loamy sand	loamy sand	loamy sand
SOIL MATRIX COLOUR	dry	10YR 4/2	10YR 5/3	10YR 6/2	10YR 6/3	10YR 5/2	10YR 3/2
	wet	10YR 2/2	10YR 2/3	10YR 3/2	10YR 3/3	10YR 3/2	10YR 2/2
OC [%]		2.16	0.83	1.76	0.41	0.56	0.48
N _t [%]		0.208	0.057	0.064	0.024	0.046	0.053
C:N [%]		10	15	27	17	12	9
P _{ca} [mg·kg ⁻¹]		123	88	115	131	82	42
pH	H ₂ O	6.8	8.4	8.5	8.7	8.5	7.5
	1M KCl	6.1	7.8	7.9	8.0	7.8	8.1
CaCO ₃ [%]		0.1	0.5	5.7	1.2	1.2	0.2
HEAVY METALS EXTRACTED IN MIXTURE OF ACIDS HF AND HClO₃							
Zn		48	29	41	20	25	38
Pb		96	104	40.2	25	40	39
Cd		<5	<5	<5	6	6	<5
Cu		31	27	29	40	24	23

3

TECHNOGENIC SOILS IN SLOVAKIA

JAROSLAVA SOBOCKÁ

Bratislava is one of the youngest capitals in Europe with two thousand years of rich history. Location in the heart of Central Europe on the banks of the Danube River (Fig. 1), and thus at the intersection of trade routes, determined the multicultural character of the city. Bratislava - the capital of the independent Slovak Republic since early 1993 - is situated between two orographic units: the Danube Basin and the Záhorská Basin in the foothills of the Little Carpathians, at the confluence of the Danube and Morava rivers.

In the south and west, it is adjacent to the state borders of Hungary and Austria. The area of the city is 367.9 km² with a population of 432,800 (2010). It is located at 17°7' east longitude and 48°9' north latitude, at an altitude of 126–514 m above sea level (top point Devínska Kobyla), the average altitude is 140 m above sea level. Besides the Danube, which flows through the city from west to south-east, the north-western boundary of the city is delineated by the

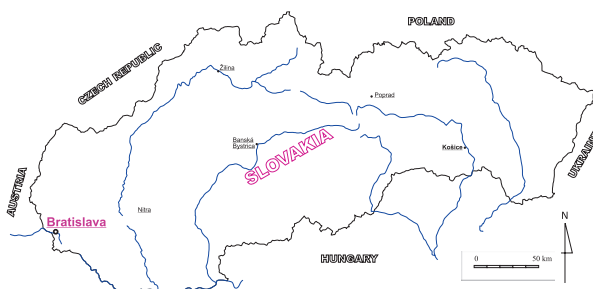


Fig. 1. Location of Bratislava

Morava River, which flows into the Danube in Devin. Climate conditions are very mild with mean annual temperature of 9.6°C, with the maximum of 20°C in July and minimum of -1.6°C in January. The total annual precipitation is 650–670 mm. The first traces of a permanent settlement are linked to the Neolithic Age (Celts, Romans and Slavs later).

Three geomorphologic units can be distinguished in Bratislava: 1) Little Carpathians, 2) Záhorská Lowland (as part of the Vienna Basin) and 3) Danube Lowland (as part of the Little Danube Basin). The Little Carpathians are built of crystalline and Mesozoic rocks, lined by low-lying Neogene and Quaternary sediments. Záhorská lowland depressions in the foothills are filled by the Neogene Vienna Basin materials covered with

debris and alluvial cones. Soils of sandy texture are also quite common. The Danube Lowland is a flat plane built mostly of the Holocene sandy-gravel and loamy sediments. Elevation differences in low-lying terraces are insignificant. The foothills of the Little Carpathians represent a narrow strip of higher, deforested area, which consists of Pleistocene alluvial cones and footslope debris.

Anthropogenic soils dominate in Bratislava (33.5%; Sobocká et al. 2007), represented by Antrozems and Kultizems according to the taxonomy of the Morphogenetic Soil Classification System of Slovakia (Collective 2000). The second (26%) significant group consists of Fluvizems – soils developed in alluvial deposits. The next group of soils represents pedons with the mollic horizon (21%) (Phaeozems, Chernozems) associated with the Danube Lowland and the group of brown soils (Kambizems) occurring in the Little Carpathians (16%). The group of Rendzinas soils (2%) is represented in a single area of Devínska Kobyla.

The built-up area in Bratislava is affected by strong technogenic activity. Soil in the urban area is present on the ground surface in the form of green exposures, mostly ornamental gardens, street alleys, recreation areas, children's playgrounds and schoolyards, cemeteries, city parks etc. Soil of these areas was classified as Kultizems or Antrozems – highly dominant types in urban areas. Ornamental parks, orchards, gardens represent the soil type of Kultizems, which form the core of the Castle Hill. Kultizems are soils with a deep, transformed top horizon (more than 35 cm), while the origin of the soil can be determined based on the diagnostic remains of subsoil. The newly built residential areas, historic and commercial centres, and industrial zones are mapped and classified as Antrozems – artificial soils with antrozemic Ad-horizon formed from human-transported anthropogenic materials of different origin. The anthropogenic substrate is defined as human-transported material (HTM) of natural or natural-technogenic or technogenic origin. Such soils are not associated with specific ecological environment; they are significantly azonal and are a product of human, or civil-engineering activities. Technogenic material, formed during industrial processing, construction or mining and military activities is less safe for handling and difficult to diagnose. In Bratislava, we can recognize all subtypes of Antrozems but Initial Antrozems dominate, with an initial Adi-horizon having a thickness of 1–10 cm and containing at least 0.3% of organic carbon. Reclaimed Antrozems are soils with significantly improved fertility after reclamation treatments. An Antrozem's covering subtype can be found on artificial surfaces consisting of soil improvers such as peat, humolit, compost, humic earth. It should be emphasized that soils in built-up areas, especially Antrozems, possess highly diverse as a consequence of entropically developed environment. This means that soil is without any horizontal internal structure, instead developed chaotic arrangement (Sobocká 2003, 2004, 2005, 2008a, 2008b, 2008c, 2010; Sobocká et al 2000; Sobocká, Poltárska 2004; Sobocká, Burghardt 2005; Sobocká, Fulajtár 2009). Soil types listed as Nekrozems, Ekranozems or Industrizems will be defined in the upcoming version of the Slovak Soil Classification System and will be referred to the soil type Technozem.

Site 1 – Spolic Technosol (Toxic, Skeletic)



Location:

Bratislava – Vrakuna, Danube lowland, chemical waste dump site from the chemical industry, south-western Slovakia

Coordinates:

48.16° N 17.186° E

Altitude:

134 m a.s.l.

Climate:

Average annual temperature: 10.3°C

Average annual precipitation: 580 mm

Relief and lithology:

Major landform: lowland, alluvial flood plain

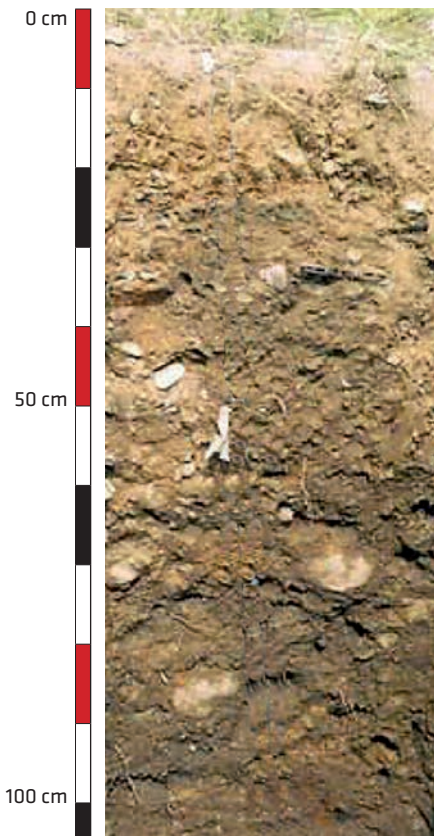
Lithology: quaternary (Würm), land fill-up age 45 years

Land-use: abandoned area

Vegetation: ruderal green and trees



Site 1 – Spolic Technosol (Toxic, Skeletic)



Morphology:

Au – 0–2 cm: sandy loam, pale red, dry, slightly hard, friable, weak subangular blocky, mediate rooting, calcareous, 15% presence of mixed anthro-gravels clear boundary.

Bu1 – 2–18 cm: sandy loam, light red, moderate moist, firm, weak subangular blocky to no structure, rarely rooting, calcareous, 30% tiny gravel, abundant artefacts: (brick, glass, plastic, wood, rarely coarse gravel; 50%), clear boundary.

Bu2 – 18–66 cm: sandy loam, olive brown, moderate moist, firm, no structure, few roots, calcareous, 60–70% of gravel, 30% of artefacts, clear boundary.

Bu3 – 66–94 cm: sandy loam, olive brown, moist, firm, loam to sandy loam, no structure, few roots, calcareous, 10% of boulders, 40–50% medium coarse gravels, presence of artefacts as building material, clear boundary.

Bu4 – below 94 cm: sandy loam, brownish yellow, moist, firm, no structure, redoximorphic mottles >25%, few roots, calcareous, artefacts presence (bricks, wire).

Comments:

Site 1 was located on abandoned area, partly building activities chemical waste dump (at present finished).

Artefacts – 60% building and toxic material, chemical waste material from chemical industry.

Site 1 – Spolic Technosol (Toxic, Skeletic)

Selected soil properties

HORIZON	Au	Bu1	Bu2	Bu3	Bu4	
DEPTH [cm]	0–2	2–18	18–66	66–94	>94	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
2.0–0.05	67	57	63	68	71	
0.05–0.002	22	27	23	18	17	
<0.002	11	16	14	14	12	
TEXTURE CLASS (USDA)	sandy loam	sandy loam	sandy loam	sandy loam	sandy loam	
OC [%]	1.91	1.22	0.80	0.47	0.64	
N _t [%]	1.343	–	–	–	–	
pH	H ₂ O	8.0	8.2	8.4	8.4	8.5
	1M CaCl ₂	7.2	7.2	7.6	7.6	7.8
ORGANIC COMPOUNDS						
Content PAH 1*	***38.8	***8.0	***21.1	***3.3	***3.3	
Content PAH 2**	***38.8	***8.0	***20.8	***3.3	***3.3	
Content PCB	0.02	***2.11	–	–	–	
Content of NEL	***130	***860	***110	***100	***290	

* Content PAH 1 = sum of 16 compounds: naphthalene, acetophthalene, acenaphthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, chryzene.

** Content PAH 2 = sum of 12 compounds according to Soil Protection Act 220/2004 [Slovak Republic]: naphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, benzo(g,h,i)perylene.

According to the Act. No. 220/2004 (Slovakia) on the protection and use of agricultural land limits are:

- limit value of PAH = 1 mg·kg⁻¹
- limit value of PCB = 0.05 mg·kg⁻¹
- limit value of NEL = 100 mg·kg⁻¹

*** These values exceed limits for organic risk elements. This site represents environmental risk [hot spot area] which served as sink for sewage dilution from Dynamite Nobel factory in the past. Groundwater and soil is contaminated because no preventive protection measures were made.

Site 2 – Urbic Technosol (Calcaric, Skeletic)



Location:

Bratislava – Dubravka, Little Carpathians, Devinska Kobyla, south-western Slovakia

Coordinates:

48.199° N 17.032° E

Altitude:

220 m a.s.l.

Climate:

Average annual temperature: 10.3°C

Average annual precipitation: 580 mm

Relief and lithology

Major landform: mountains foot slope

Slope position: undulated plain

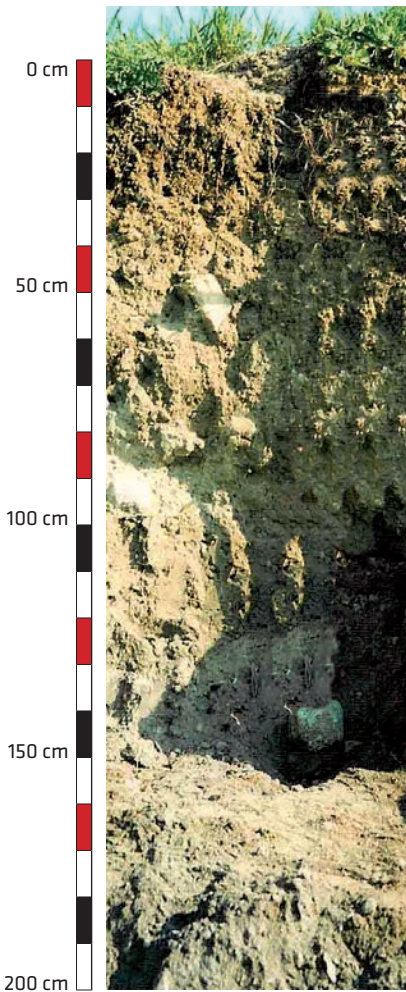
Lithology: Mesozoic (middle Triassic), building rubble 30 years

Land-use: abandoned urban area ready for recultivation activities

Vegetation: ruderal green and some trees



Site 2 – Urbic Technosol (Calcaric, Skeletic)



Morphology:

Au – 0–20 cm: sandy loam, dark yellowish brown, dry, friable, calcareous, human-transported material with admixture of 60% gravel and sharp stoniness (granite), no structure, presence of artefacts (20%), weak or moderate rooting, abrupt boundary.

Bu1 – 20–30 cm: sandy loam, dark yellowish brown, dry, friable, calcareous, with admixture of >60% gravel, and weathered rock (granite, sandstone, slate), no structure, very weak rooting, fragments of artefacts: brick, plastic, iron-concrete, clear boundary.

Bu2 – 30–90 cm: sandy loam, pale brown, moist, friable, 10–15% sharp granite weathered rock, rarely boulders, no structure, no rooting, clear boundary.

Bu3 – 90–150 cm: sandy loam, light grey, moist, friable, more than 50% gravel (dominantly sharp weathered rock – granite, sandstone, slate), abundant artefacts (iron-concrete, plastic, mortar, brick, no structure, no rooting; 50%).

Comments:

Artefacts – 50% urban building rubble.

Site 2 – Urbic Technosol (Calcaric, Skeletic)

Selected soil properties

HORIZON	Au	Bu2	Bu3
DEPTH [cm]	0–20	50–70	130–150
PARTICLE SIZE DISTRIBUTION			
ϕ [mm]	[%]		
2.0–0.05	60	65	66
0.05–0.002	28	24	26
<0.002	12	11	8
TEXTURE CLASS (USDA)	sandy loam	sandy loam	sandy loam
OC [%]	0.96	0.56	1.16
N _t [%]	–	–	–
C:N	–	–	–
P _a [mg·kg ⁻¹]	21.5	23.3	13.3
K _a [mg·kg ⁻¹]	135	90.0	95.6
EC _e [μS·cm ⁻¹]	365	120	1370
pH	H ₂ O	8.3	8.1
	1M KCl	7.4	7.9
INORGANIC ELEMENTS			
As*	1.10	1.04	1.36
Cd	0.32	0.03	0.14
Co	5.39	1.07	1.19
Cr	9.38	1.54	3.86
Cu	14.70	3.00	6.30
Mn	139	101	179
Ni	7.50	0.90	2.20
Pb	62.50	4.40	45.80
Zn	80.70	7.40	27.10
Hg**	0.05	0.03	0.06

Extraction with 2M HNO₃, As* – extraction with 2M HCl, Hg** – total content

Site 3 – Spolic Technosol (Siltic)



Location: Sered (town), Danube lowland, industrial waste spoil heap near to abandoned nickel smelter, southern Slovakia

Coordinates: 48.278° N 17.733° E

Altitude: 118 m a.s.l.



Climate:

Average annual temperature: 9.6°C

Average annual precipitation: 529 mm

Land-use: controlled dump

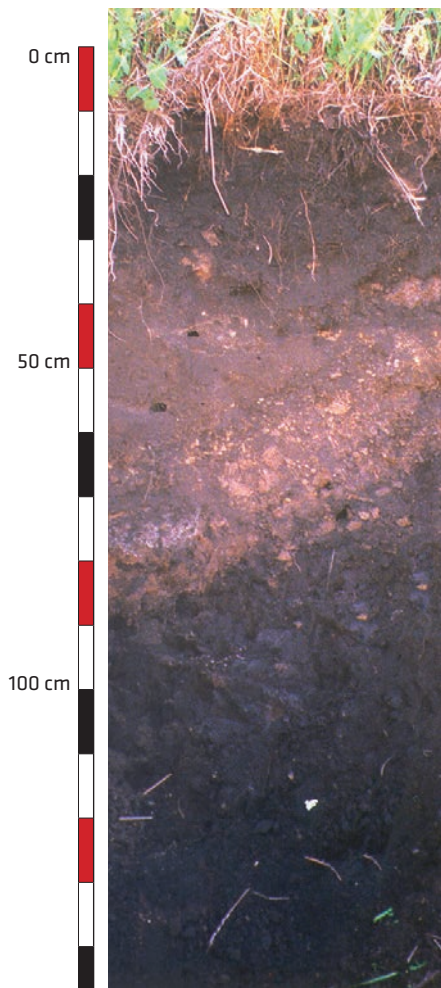
Relief and lithology:

Major landform: lowland, foot slope of spoil heap on alluvial plain

Lithology: alkaline industrial waste from nickel metallurgy

Vegetation: ruderal green, partially seeded

Site 3 – Spolic Technosol (Siltic)



Morphology:

Ap – 0–20 cm: silt, black, dry, very friable, crumbly structure, moderate rooting, partly accumulated, clear boundary.

Bp1 – 20–90 cm: silt, light reddish brown, dry, compacted, angular blocky, alkaline, efflorescence and accumulation of carbonates, wave clear boundary.

Bp2 – >90 cm: silt, black, dry, friable, no structure, dominant artefacts (alkaline industrial material with 49% of iron; 100%).

Site 3 – Spolic Technosol (Siltic)

Selected soil properties

HORIZON	Ap	Bp1	Bp2
DEPTH [cm]	0–20	50–70	90–110
PARTICLE SIZE DISTRIBUTION			
ϕ [mm]		[%]	
2.0–0.05	74	79	77
0.05–0.002	24	20	22
<0.002	2	1	1
TEXTURE CLASS (USDA)	loamy sand	loamy sand	loamy sand
BULK DENSITY [$\text{g}\cdot\text{cm}^{-3}$]		1.21	1.42
ACTUAL MOISTURE [% v/v]		20.4	29.7
OC [%]		0.99	0.87
P_a [$\text{mg}\cdot\text{kg}^{-1}$]		<0.56	0.56
K_a [$\text{mg}\cdot\text{kg}^{-1}$]		37.0	45.5
pH	H ₂ O	8.1	8.5
	1M KCl	8.0	8.1

Chemical composition of spoil bank material [%]

Fe	49–52	CaO	3–4.5	K ₂ O	0.08–0.10
Fe ₂ O ₃	42–43	MgO	2–3	Ni	0.27–0.29
FeO	27–28	Cr ₂ O ₃	3–3	Cu	0.01–0.02
Fe metamorph.	0.25–0.35	P ₂ O ₅	0.06–0.8	TiO ₂	0.10–0.12
SiO ₂	8–10	SO ₃	0.08–0.10	Na ₂ O	0.20–0.21
Al ₂ O ₃	4–6	MnO	0.3–0.4	H ₂ O	15–18

Sieve analysis of spoil bank material

Fractions	Percentage	Fractions	Percentage
>200 μm	1.60	40–30 μm	11.75
200–90 μm	10.90	30–20 μm	10.95
90–70 μm	13.80	20–10 μm	7.60
70–60 μm	4.70	10–5 μm	17.05
60–50 μm	10.95		

Site 4 – Ekranic Spolic Technosol (Skeletal)



Location: Hacava, Slovak Ore Mountains, surroundings of the magnesite factory, Central Slovakia

Coordinates: 48.747° N 20.777° E

Altitude: 402 m a.s.l.



Climate:

Average annual temperature: 8.0°C

Average annual precipitation: 630 mm

Land-use: abandoned and partly recultivated area surrounding industrial plant (smelter)

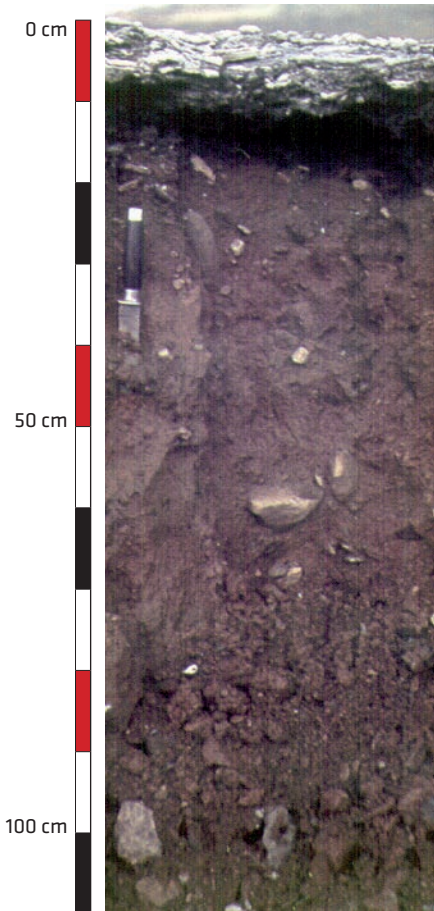
Relief and lithology:

Major landform: mountains

Lithology: weathering rock of phyllites

Vegetation: very rarely ruderal green, significantly reduced vegetation

Site 4 – Ekranic Spolic Technosol (Skeletal)



Morphology:

0–10 cm: *technic hard rock* – MgCO_3 hard crust from longterm emission fallout of magnesite work, with cracs 1–2 cm thick, clear boundary.

AB – 10–25 cm: silty clay loam, dark yellowish brown, dry, compact, platy, 30% stoniness, distinct boundary.

Bw – 25–45 cm: clay loam, yellowish brown, dry, compact, angular blocky, 35% stoniness, gradual boundary.

BC – >45 cm: clay loam, yellowish brown, dry, hard, massive, more than 60% stoniness.

Comments:

Artefacts – 50% industrial waste (on the topsoil occurrence of MgCO_3 crust, 10 cm thick).

Site 4 – Ekranic Spolic Technosol (Skeletal)

Selected soil properties

HORIZON	AB	Bw	BC	
DEPTH [cm]	10–25	25–45	>45	
PARTICLE SIZE DISTRIBUTION*				
ø [mm]	[%]			
2.0–0.25	2	5	10	
0.25–0.05	17	16	12	
0.05–0.01	22	20	20	
0.01–0.001	24	22	20	
<0.001	35	37	38	
OC [%]	5.76	0.64	0.34	
P _a [mg·kg ⁻¹]	1.7	1.2	1.25	
K _a [mg·kg ⁻¹]	87	34	31	
pH**	H ₂ O	8.6	8.4	8.3
	1M KCl	8.5	7.8	7.7
CaCO ₃ [%]	–	–		

* Soil texture in site 4

** pH – was altered by visible technogenic emission [MgCO₃ crust] of former non-calcareous acid soil

Chemical elements composition of emission from the magnesite rotary kiln [in ppm]

Mg	Ca	Fe	Mn	Cu	Pb	Zn
221 300	3 200	20 200	1 460	60	159	20
Co	Cr	Ni	As	Hg	Cd	Sb
45	140	79	3	2	3	126

Site 5 – Garbic Gleyic Technosol (Reductic, Skeletic)



Location: Horné Prsany, Kremnica Mountains, municipal waste dump, Central Slovakia

Coordinates: 48.695° N 17.032° E

Altitude: 635 m a.s.l.



Climate:

Average annual temperature: 8.0°C

Average annual precipitation: 653 mm

Land-use: regulated waste dump
(at present finished)

Relief and lithology:

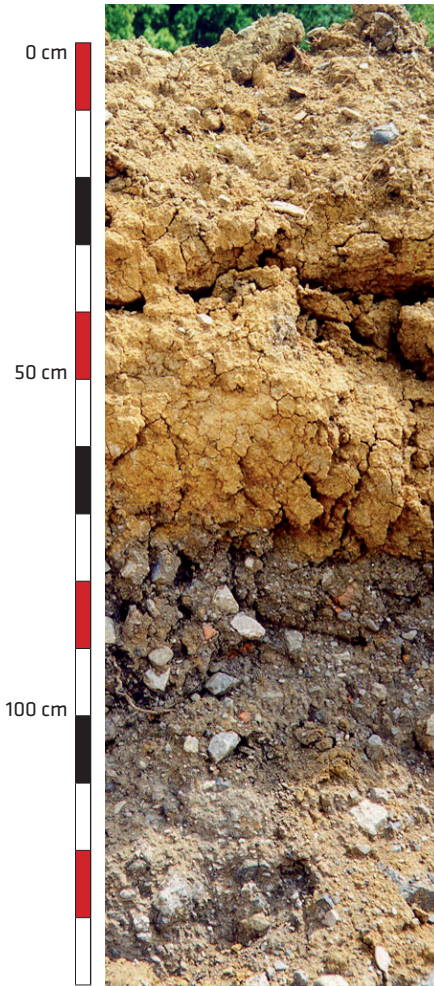
Major landform: mountains, fill up terrain

Slope position: gently sloping plain

Lithology: weathering rock of silicate dolomites

Vegetation: ruderal green (grassland)

Site 5 – Garbic Gleyic Technosol (Reductic, Skeletic)



Morphology:

Ap – 0–28 cm: sandy loam, top horizon, dark yellowish brown, dry, loose, sub-angular blocky structure, 30% stoniness, weak rooting, fragments of asphalt, clear boundary.

Bp1 – 28–70 cm: human-transported protective clay material, with 1–2 cm thick cracks, light yellowish brown, dry, compacted, strong mottling, clear boundary.

Bp2 – > 70 cm: burned municipal waste material with metagenesis possibility, greyish brown, 60% stoniness, presence of artefacts: plastic cables, bricks, cinder blocks, hard plastic.

Comments:

Artefacts – 40% municipal waste (incinerated) overlaid by recultivation material.

Site 5 – Garbic Gleyic Technosol (Reductic, Skeletic)

Selected soil properties

HORIZON		Ap	Bp2
DEPTH [cm]		0–20	70–90
SOIL COLOUR (MATRIX)	dry	–	–
	wet	10YR 4/4	10YR 6/4
BULK DENSITY [$\text{g}\cdot\text{cm}^{-3}$]		1.11	1.46
ACTUAL MOISTURE [% v/v]		27.8	34.6
OC [%]		0.95	2.20*
P_a [$\text{mg}\cdot\text{kg}^{-1}$]		24.5	0.63
K_a [$\text{mg}\cdot\text{kg}^{-1}$]		220	185
pH	H ₂ O	7.7	7.2
	1M KCl	6.8	6.2
CaCO ₃ [%]		–	–

*evidence of ignition of the municipal waste, the landfill is used for afforestation, and excluded from agricultural use

4

TECHNOGENIC SOILS IN SZCZECIN

EDWARD MELLER
RYSZARD MALINOWSKI
EDWARD NIEDŹWIECKI
KATARZYNA MALINOWSKA
MARCIN KUBUS

Szczecin, the largest city and the capital of the West Pomeranian Province (Fig. 1), is located on the Oder River and Lake Dąbie. It covers an area of 300.55 km²; almost 24% are lands under water. The report on the state of Szczecin (2004) shows that the city is divided into four administrative districts: Downtown (with Międzyodrze), North, West and Right-Bank. In 2011, the population of Szczecin was 410 000 (Demographic Yearbook 2012).

Kollender-Szych et al. (2008) provide a historical overview of the Szczecin city. In the area of present Szczecin, there was a settlement dated back to the period of the Lusatian culture, i.e. the 7th–6th century BC. In the 9th century, the Dukes of Slavic tribes built a castle surrounded by a moat, in the foothills of which a fishing settlement developed. In 967, Pomerania and Szczecin were annexed to Poland by Mieszko I. Szczecin consisted then of three parts: the castle, borough and the port.

In 1181, the city with West Pomerania became a vassal of the emperor of the Holy Roman Empire. In 1243, Duke Barnim I granted Szczecin the town privileges. The town was occupied by the Swedes in 1630, and in 1713, the city was annexed to Prussia. The Russians besieged Szczecin during the Seven Years' War. In the years 1806–1813, Szczecin was under French occupation. The French dominion ended in December 1813 and was followed by

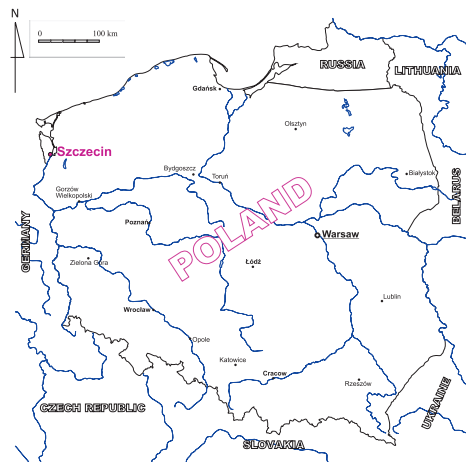


Fig. 1. Location of Szczecin

Prussian and German rule. In 1873, the then Mayor of the city, Hermann Haken made the decision to pull down the walls and expand the city. During the Second World War, Szczecin was liberated on 26 April 1945, and the official transfer of the city to the Polish authorities took place on 5 July 1945.

The time when Szczecin was surrounded by new walls (brick and stone) corresponds with the town privileges granted. Disposal of old wood and earthen embankments, and construction of a new defence system required major land levelling (Kotla 2001). They were carried out mainly in the Odra valley and on the island Łasztownia. These wetlands required significant superstructuring of soil banks for the development (Adamczak et al. 1999). The period of building the powerful fortress in Szczecin (by the Swedes and the Prussians) was also associated with a large-scale land levelling. Old moats were filled up, new excavations were created, old fortifications were surfaced and new earth ramparts and bastions were erected (Turek-Kwiatkowska and Białecki 1991; Kotla 2001).

A huge amount of artefacts introduced into the soil, covered with natural levelling material, creates a cultural layer, which results in an increased thickness of the urban soil layer and a raised land surface (Chudecka 2009). After 1873, during the removal of fortifications, the ground defensive structures constructed in the earlier periods were levelled on a large scale. Consequently, the ground surface in the city is almost flat (Baranowska 2001). The late 19th and the early 20th century was a period of intensive development and industrialization of the city (Adamczak et al. 1999; Baranowska 2001). During the Second World War Szczecin was destroyed in 60–70% and turned into a pile of rubble. The city was covered with another cultural layer – the technogenic one. Reconstruction of Szczecin has resulted in new embankments consisted of debris and earth, as well as ground mixing for laying pipelines, drains and new power lines (Chudecka 2009).

The study of technogenic soils of north-west Szczecin in areas along the roads with heavy traffic (Bohaterów Warszawy Av., Mieszka I st., Sprzymierzonych and Odrodzenia Sq. and Giedroycia Rbt.) and streets with little traffic (Chopina, Braniborska and Słowackiego sts.) was conducted by Niedźwiecki et al. (2009). The obtained results indicate that these soils consisted of thick layers of highly transformed silt loamy sand with admixtures of substrates of technical origin and in the upper layer – the fertilizing organic materials.

The studies of technogenic soils in the oldest part of Szczecin (which dates back to the Roman times) were conducted by Chudecka (2009). The author showed that the thickness of man-made sediments reaches 6.2 m and is diverse in terms of particle size.

Several scientific studies focused on heavy metal contamination in Szczecin soils, including: Piasecki et al. (1995), Wojcieszczuk and Niedźwiecki (2003), Niedźwiecki et al. (2004), Wojcieszczuk et al. (2006), Malinowska (2012).

Site 1 – Mollic Urbic Technosol



Location:

Mierzyn, Waniliowa st.,
northern Poland

Coordinates:

53°26'15.2" N 14°27'14.7" E

Altitude:

37 m a.s.l.

Climate:

Average annual temperature: 8.6°C

Average annual precipitation:
538 mm

Relief and lithology:

Major landform:

plain (Gumieniecka Plain)

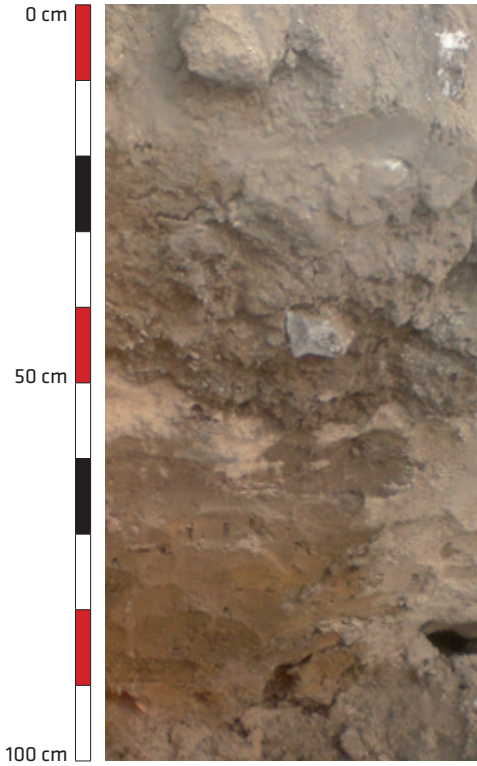
Lithology: glacial tills

Land-use: wasteland

Vegetation: lawn grass, bushes



Site 1 – Mollic Urbic Technosol



Morphology:

Au1– 0–35 cm: loamy sand with large amount of rubble, pieces of bricks and gravel (50%), dark yellowish brown.

Au2 – 35–40 cm: sandy loam with slag (60%).

2A – 40–55 cm: sandy clay loam, reddish brown.

2C1 – 55–90 cm: sandy clay loam, yellowish brown, massive structure.

2C2 – 90–150 cm: sandy clay loam, yellowish brown.

Site 1 – Mollic Urbic Technosol

Selected soil properties

HORIZON	Au1	Au2	2A	2C1	2C2	
DEPTH [cm]	0–35	35–40	40–55	55–90	90–150	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
>2.0	25	90	6	4	49	
2.0–0.05	74	68	51	51	52	
0.05–0.002	18	23	26	25	24	
<0.002	8	9	23	24	24	
TEXTURE CLASS (USDA)	loamy sand	sandy loam	sandy clay loam	sandy clay loam	sandy clay loam	
LoI [%]	1.95	8.00	3.06	2.52	2.61	
OC [%]	1.07	3.83	1.53	0.49	0.28	
N _t [%]	0.05	0.09	0.11	0.06	0.03	
C:N	21	43	14	8	9	
pH	H ₂ O	7.7	7.6	7.4	7.1	7.4
	1M KCl	7.6	7.5	7.4	6.7	7.0
P _a [*]	3.21	9.59	4.71	1.10	0.66	
K _a [*]	[mg·100 g ⁻¹]	9.4	21.4	22.6	20.6	15.8
Mg _a ^{**}	14.7	9.04	9.65	13.7	19.5	
P _t	484	1 056	605	264	253	
K _t	3 080	2 310	3 600	19 280	18 330	
Mg _t	[mg·kg ⁻¹]	3 050	2 540	2 200	4 690	5 070
Ca _t	14 070	16 940	4 850	2 890	3 540	
Na _t	245	1 483	200	207	223	

* content of available forms of P and K – by the method of Egner-Riehm

** content of available forms of Mg – by the method of Schachtschabel

Site 1 – Mollic Urbic Technosol

Selected soil properties cont.

HORIZON	Au1	Au2	2A	2C1	2C2
DEPTH [cm]	0–35	35–40	40–55	55–90	90–150
HEAVY METALS SOLUBLE IN 1M HCl					
Cd	0.04	0.42	0.16	0.03	0.04
Co	1.47	1.83	1.49	1.39	2.93
Cu	4.49	17.1	6.61	3.52	2.41
Zn	37.7	137	30.4	6.30	14.6
Pb	13.6	61.3	21.9	7.50	5.6
Ni	1.80	5.67	3.39	2.50	1.72
Mn	134	143	112	51.8	28.7
Fe	1 910	2 810	3 250	1 890	2 150
HEAVY METALS SOLUBLE IN MIXTURE OF ACIDS HNO₃ + HClO₄					
Cd	0.04	0.42	0.27	0.18	0.13
Co	5.4	13.0	5.4	7.0	10.2
Cu	12.4	40.3	13.0	11.3	10.9
Zn	75.5	276	54.0	40.0	40.2
Pb	19.2	58.0	88.9	19.4	19.7
Ni	12.7	36.8	13.7	25.7	25.7
Mn	214	229	132	114	101
Fe	16 370	17 330	14 200	27 910	30 210

Site 2 – Urbic Ekranic Technosol



Location:

Mierzyn, Milenijna-Długa street,
northern Poland

Coordinates:

53°25'40.4" N 14°27'49.7" E

Altitude:

26 m a.s.l.

Climate:

Average annual temperature: 8.6°C

Average annual precipitation:

538 mm

Relief and lithology:

Major landform: plain (Gumieniecka
Plain)

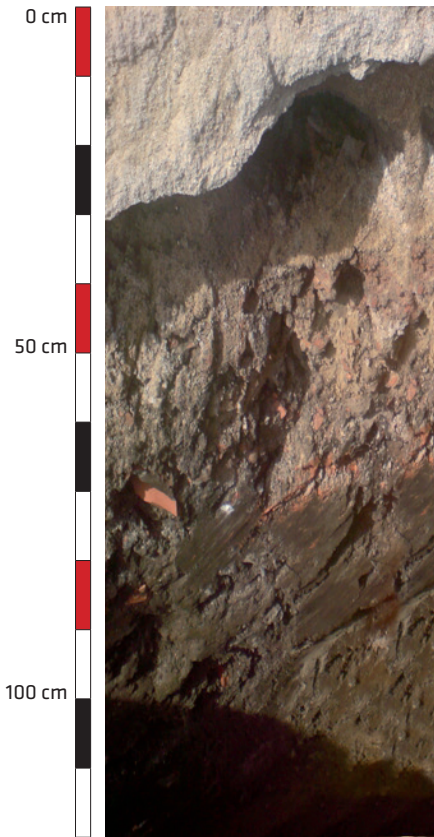
Lithology: glacial tills

Land-use: residential area, square
surrounded by buildings

Vegetation: lawn grasses, bushes



Site 2 – Urbic Ekranic Technosol



Morphology:

0–25 cm: *technic hard rock* – cobblestones with foundation and gravel ballast.

Au1 – 25–50 cm: layer created of great amount of sand with great addition of rubble, pieces of bricks and gravel, yellowish brown colour (10YR 5/4).

Au2 – 50–70 cm: loamy sand with addition of rubble and gravel, very dark grey (5Y 3/1), mottles of oximorphic colours.

A3 – 70–120 cm: humus layer, sandy loam, very dark greyish brown (10YR 3/2), mottles of oximorphic colours.

A4 – 120–150 cm: humus layer, clay loam, olive color (5Y 5/4), gleyic colour pattern.

Site 2 – Urbic Ekranic Technosol

Selected soil properties

HORIZON	Au1	Au2	A3	2A4
DEPTH [cm]	25–50	50–70	70–120	120–150
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]	[%]			
>2.0	14	12	1	83
2.0–0.05	87	79	74	27
0.05–0.002	9	15	17	42
<0.002	4	6	9	31
TEXTURE CLASS (USDA)	sand	loamy sand	sandy loam	clay loam
LoI [%]	1.72	3.04	3.48	3.86
OC [%]	1.23	2.00	1.74	0.90
N _t [%]	0.04	0.09	0.13	0.08
C:N	31	22	13	11
pH	H ₂ O	8.4	7.8	7.7
	1M KCl	8.3	7.6	7.5
P _a *	2.99	3.52	5.89	3.30
K _a *	[mg·100 g ⁻¹]	40.0	16.8	29.2
Mg _a **	3.70	7.07	8.16	11.62
P _t	429	275	440	506
K _t	2 010	2 140	3 190	30 800
Mg _t	[mg·kg ⁻¹]	2 010	1 510	1 970
Ca _t	36 470	11 670	8 990	10 390
Na _t	238	125	140	342

* content of available forms of P and K – by the method of Egner-Riehm

** content of available forms of Mg – by the method of Schachtschabel

Site 2 – Urbic Ekranic Technosol

Selected soil properties cont.

HORIZON	Au1	Au2	A3	2A4
DEPTH [cm]	25–50	50–70	70–120	120–150
HEAVY METALS SOLUBLE IN 1M HCl				
Cd	0.09	0.18	0.19	0.18
Co	0.66	1.04	1.08	2.38
Cu	5.3	24.3	13.2	4.9
Zn	26.9	74.2	55.1	9.5
Pb	6.4	13.1	15.0	11.7
Ni	3.2	9.9	9.3	6.8
Mn	83.1	58.9	76.8	85.5
Fe	1402	16.8	1700	1750
HEAVY METALS SOLUBLE IN MIXTURE OF ACIDS HNO₃ + HClO₄				
Cd	0.29	0.43	0.28	0.27
Co	2.6	3.6	4.2	11.0
Cu	8.07	27.6	16.2	16.1
Zn	28.8	128	101	118
Pb	18.0	25.0	25.5	27.6
Ni	8.17	19.1	19.4	39.6
Mn	153	116	145	179
Fe	7 180	7 960	21 420	34 320

Site 3 – Technic Phaeozem (Arenic)



Location:

Szczecin, Przestrzenna street,
northern Poland

Coordinates:

53°23'48.8" N 14°39'26.8" E

Altitude:

1 m a.s.l

Climate

Average annual temperature: 8.6°C

Average annual precipitation:

538 mm

Relief and lithology

Major landform: plain (Odra
Floodplain)

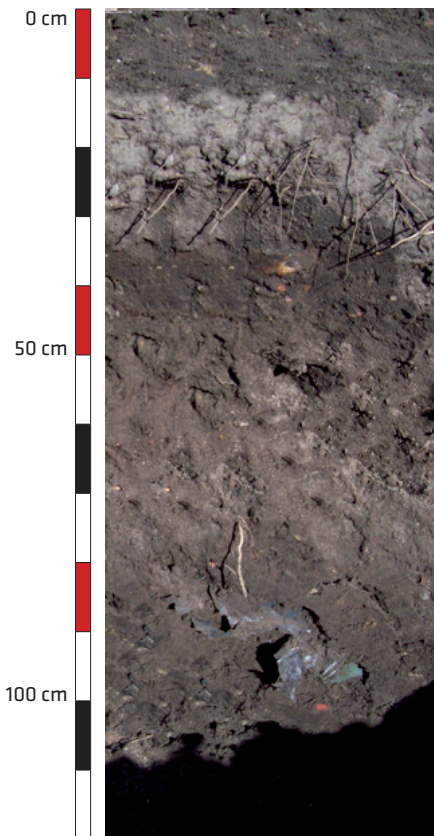
Lithology: late Pleistocene fluvial
sands

Land-use: wasteland

Vegetation: bushes, single trees



Site 3 – Technic Phaeozem (Arenic)



Morphology:

A1 – 0-30 cm: sand, black (10YR 2/1), many artefacts: rubbles, pieces of bricks, textiles, plastic, metals, rubber.

A2 – 30-150 cm: sand with addition of rubbles, black (10YR 2/1), artificial materials, rubber.

Site 3 – Technic Phaeozem (Arenic)

Selected soil properties

HORIZON		A1	A2
DEPTH [cm]		0–30	30–150
PARTICLE SIZE DISTRIBUTION			
ø [mm]		[%]	
>2.0		5	1
2.0–0.05		91	91
0.05–0.002		7	7
<0.002		2	2
TEXTURE CLASS (USDA)		sand	sand
LoI [%]		8.82	5.50
OC [%]		4.49	2.90
N _t [%]		0.28	0.18
C:N		16	16
pH	in H ₂ O	7.5	7.3
	in 1M KCl	7.4	7.1
P _a *		7.70	4.80
K _a * [mg·100 g ⁻¹]		4.20	4.00
Mg _a **		8.93	7.49
P _t		506	374
K _t		1 350	881
Mg _t [mg·kg ⁻¹]		842	879
Ca _t		9 850	12 020
Na _t		123	127

* content of available forms of P and K – by the method of Egner-Riehm

** content of available forms of Mg – by the method of Schachtschabel

Site 3 – Technic Phaeozem (Arenic)

Selected soil properties cont.

HORIZON	A1	A2
DEPTH [cm]	0–30	30–150
HEAVY METALS SOLUBLE IN 1M HCl		
Cd	0.11	0.18
Co	0.72	0.77
Cu	7.64	14.3
Zn	88.8	163
Pb	37.9	45.7
Ni	2.44	2.41
Mn	48.6	46.1
Fe	1 540	1 920
HEAVY METALS SOLUBLE IN MIXTURE OF ACIDS HNO₃ + HClO₄		
Cd	0.46	0.71
Co	2.68	2.89
Cu	13.9	19.3
Zn	115	341
Pb	38.4	55.1
Ni	6.38	5.95
Mn	245	236
Fe	6 240	6 670

Site 4 – Technic Arenosol



Location:

Szczecin, Sąsiedzka st.,
northern Poland

Coordinates:

53°21'37.9" N 14°36'32.1" E

Altitude:

68 m a.s.l.

Climate

Average annual temperature: 8.6°C

Average annual precipitation:

538 mm

Relief and lithology

Major landform: terminal moraine
(Bukowe Hills)

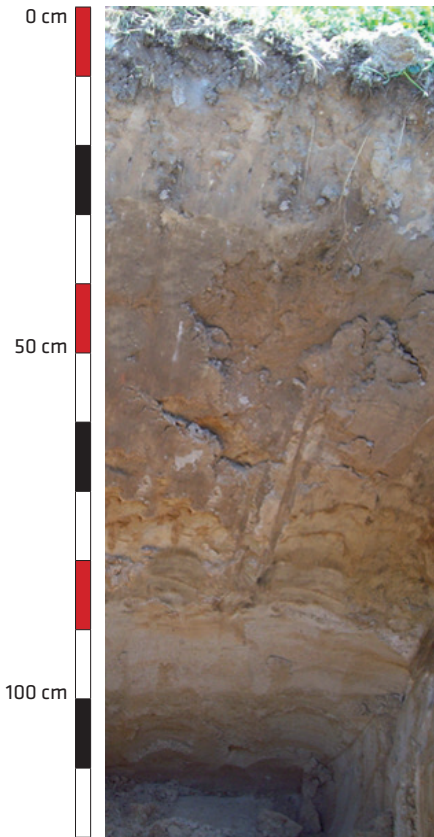
Lithology: glacial loamy sands

Land-use: lawn

Vegetation: lawn grasses



Site 4 – Technic Arenosol



Morphology:

A1 – 0–15 cm: loamy sand with small amount of artefacts, light olive brown (2.5Y 5/4).

A2 – 15–30 cm: loamy sand, light yellowish brown (2.5Y 6/4), visible artefacts (man-made materials).

C1 – 30–55 cm: layer of sandy texture, yellow (10YR 7/6), many artefacts in the form of artificial materials and textiles.

C2 – 55–110 cm: layer composed of many narrow layers with texture of sand, very pale brown (10YR 8/4), many rust-colored mottles.

C3 – 110–150 cm: sand, pale brown (2.5Y 8/4).

Site 4 – Technic Arenosol

Selected soil properties

HORIZON	Au1	Au2	Cu1	C2	C3	
DEPTH [cm]	0–15	15–30	30–55	55–110	110–150	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
>2.0	7	12	5	0	0	
2.0–0.05	83	81	93	95	98	
0.05–0.002	12	14	4	5	1	
<0.002	5	5	3	0	1	
TEXTURE CLASS (USDA)	loamy sand	loamy sand	sand	sand	sand	
LoI [%]	2.70	1.78	0.80	0.46	0.24	
OC [%]	1.48	0.85	0.18	0.01	0.05	
N _t [%]	0.118	0.059	0.014	0.010	0.005	
C:N	13	14	13	1	10	
pH	H ₂ O	7.4	7.5	7.4	7.2	7.9
	1M KCl	7.5	7.5	7.4	7.1	7.9
P _a *	4.4	2.8	2.7	1.7	2.2	
K _a *	[mg·100 g ⁻¹]	39.2	11.4	6.0	3.8	3.6
Mg _a **	2.61	1.67	1.32	1.09	0.52	
P _t	297	253	209	143	143	
K _t	1 590	1 590	943	935	856	
Mg _t	[mg·kg ⁻¹]	847	972	525	443	318
Ca _t	5 500	5 940	1 000	715	2 070	
Na _t	72	75	53	43	42	

* content of available forms of P and K – by the method of Egner-Riehm

** content of available forms of Mg – by the method of Schachtschabel

Site 4 – Technic Arenosol

Selected soil properties cont.

HORIZON	Au1	Au2	Cu1	C2	C3
DEPTH [cm]	0–15	15–30	30–55	55–110	110–150
HEAVY METALS SOLUBLE IN 1M HCl					
Cd	0.17	0.06	0.01	0.22	0.26
Co	0.68	1.04	0.41	0.23	0.23
Cu	4.30	3.79	1.41	1.16	1.08
Zn	56.7	43.8	10.7	28.6	9.37
Pb	7.75	6.59	2.59	2.36	1.85
Ni	1.29	1.34	0.67	0.31	0.44
Mn	35.6	33.6	18.3	6.56	10.0
Fe	433	584	330	380	314
HEAVY METALS SOLUBLE IN MIXTURE OF ACIDS HNO₃ + HClO₄					
Cd	0.77	1.99	2.03	1.99	2.01
Co	2.78	3.97	2.55	2.25	1.88
Cu	6.06	6.68	3.09	3.08	2.83
Zn	93.6	58.4	28.4	24.5	26.6
Pb	26.2	5.55	4.35	5.09	4.92
Ni	6.69	5.89	3.40	2.80	1.68
Mn	232	275	172	125	158
Fe	7 350	14 500	5 840	5 650	3 990

5

TECHNOGENIC SOILS IN TORUŃ

Przemysław Charzyński
Maciej Markiewicz
Renata Bednarek
Łukasz Mendyk

Toruń is one of the oldest cities in Poland. The history of Toruń as an urban centre began on 18 December 1233 when the city rights were granted. In the Middle Ages, it was a prominent trade centre as a member of the Hanseatic League. Nowadays, because of the famous Gothic urban complex, the city is one of the most important and crowded tourist centres in Poland. The population of the city as of January 1st 2013 was 198 383 inhabitants. Toruń covers an area of 116 km². It is located on the Vistula river, in the eastern part of the Toruń Basin (part of the Vistula ice marginal valley) in North Poland – 18°36' E and 53°01' N

(Fig. 1). The genesis of the Toruń Basin is associated with erosion and accumulation processes induced by meltwaters during the recession of the Weichselian ice sheet. There is a set of eleven river terraces in the described area, built of thick sand series. Within the terraces, vast dune complexes occur. The origin of surface feature transformation in the area of Toruń goes back to the 13th century with the highest intensity in the 19th and 20th centuries. Nowadays the largest areas in Toruń are represented by flat lands, which have developed as a result of filling of primary or secondary depressions and levelling of natural convex forms (e.g. dunes). Human activity generates the development of negative and positive land forms, which contribute to specific technogenic relief within the city limits (Podgórski 1996). Destructive morphological activity of man was present, among others, in the construction of roads, streets, channels and drainage ditches, and levelling surfaces, etc. The impact of human activity led to a gradual transformation

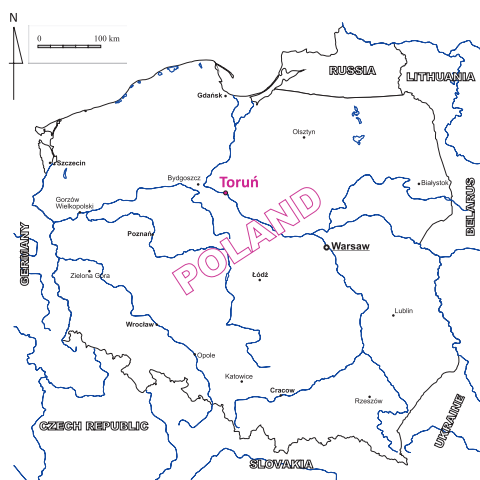


Fig. 1. Location of Toruń

of negative and positive land forms, which contribute to specific technogenic relief within the city limits (Podgórski 1996). Destructive morphological activity of man was present, among others, in the construction of roads, streets, channels and drainage ditches, and levelling surfaces, etc. The impact of human activity led to a gradual transformation

of aeolian forms and to the total elimination of small dunes. The thickness of surface embankments within the administrative boundaries of the city varies depending on their age. In the medieval area of the city and in the left-bank Podgórz district, there are 2.5–4.0 m thick embankments. On the outskirts of the Old Town, their thickness increases to about 7 m. The embankments with a thickness of 1.0–2.5 m occur within the boundaries of the 19th century city (Fedorowicz 1993).

The present state of urban soils in Toruń is a result of over 750-years of spatial development and an effect of human economic activity. The variety of technogenic soils can be found in Toruń: undisturbed and weakly transformed soils, urbisols, industrisols, garden soils, soils of parks and lawns, necrosols, ekranosols, constructosols and edifisols (Charzyński et al. 2013a). Urban forest soils (Podzols and Arenosols) cover about 23% of the city area. Changes in their morphology and properties are often relatively minor. Therefore, locally these soils can be classified even as natural. A large part of this area in the left-bank part of the city are military training grounds and locally soils are strongly transformed (Jankowski, Sewerniak 2013). The urban agricultural soils (mainly Fluvisols) are used as meadows, pastures and arable lands. They cover ca. 25% of the city area, but this value constantly decreases. Urbisols formed in the urban built-up area are characterised by varying degrees of morphological transformation. The soils occurring in the Old Town and downtown were formed on a well-developed cultural layer with the urbic horizon of a large thickness and high content of artefacts. The areas of relatively new housing estates are covered with incompletely developed urbisols. Toruń industry, and thus industrisols are concentrated in three parts of the city – western, north-eastern and southern. Allotment gardens in Toruń cover ca. 349 ha (3% of the total city area). The largest complex occurs in left-bank Toruń, in the Rudak quarter. Garden soils in Toruń cover a slightly larger area, because such soils can also be found in districts of detached houses. The soils of parks and grass plots cover 1.95% of the city area. Lawn soils are described by Charzyński et al. (2013b). There are 11 contemporary cemeteries in Toruń. Their soils – necrosols – were researched by Charzyński et al. (2011b). The largest homogeneous area of ekranosols in the city is located under the runway and taxiways of Toruń Aerodrome. Furthermore, ekranosols also occur under all asphalted or cemented streets, sidewalks and alleys in the city parks (Charzyński et al. 2011a, 2013d). Constructosols in Toruń are mainly represented by soils developed on forts (Jankowski et al. 2013) or some medieval walls, and soils of older sport grounds. Locally, edifisols can be found on some medieval structures and on ruined or badly maintained buildings (Charzyński et al. 2010, 2013c).

Acknowledgments

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Site 1 – Ekranic Technosol (Arenic)



Location: Central Communal Cemetery established in 1975, Toruń, northern Poland

Coordinates: 53°2'43.85" N 18°37'6.71" E

Altitude: 71.5 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: cemetery

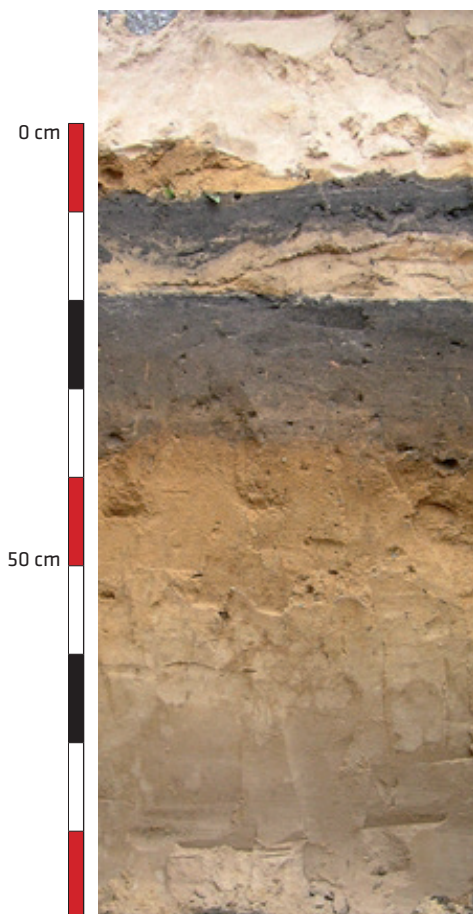
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 1 – Ekranic Technosol (Arenic)



Morphology:

Au – 0–11 cm: sand, dark grey, single grain structure, slightly moist, clear boundary.

Bu – 11–15 cm: sand, light yellowish brown, single grain structure, slightly moist, abrupt boundary, common soft concretions of iron.

Ab – 15–36 cm: sand, greyish brown, granular structure, slightly moist, gradual boundary.

Bw – 36–60 cm: sand, greyish brown, single grain structure, slightly moist, diffuse boundary.

C – below 60 cm: sand, very pale brown, single structure, slightly moist.

Comments:

25 years old grave.

Site 1 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON	Au	Bu	Ab	Bw	C	
DEPTH [cm]	0–11	11–15	15–36	36–60	>60	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
>2	1	2	5	2	0	
2.0–1.0	1	2	3	2	0	
1.0–0.5	9	15	14	15	4	
0.5–0.25	43	48	48	68	17	
0.25–0.1	44	28	25	13	76	
0.1–0.05	2	2	6	1	0	
0.05–0.02	1	2	2	1	1	
0.02–0.002	0	2	2	0	2	
<0.002	0	1	0	0	0	
TEXTURE CLASS (USDA)	sand	sand	sand	sand	sand	
SOIL MATRIX COLOUR	dry	10YR 4/1	10YR 6/4	10YR 5/2	10YR 6/6	10YR 8/3
	wet	10YR 2/4	10YR 4/4	10YR 3/2	10YR 4/6	10YR 6/3
BULK DENSITY [g·cm⁻³]	1.57	1.57	1.63	1.67	1.51	
ACTUAL MOISTURE	[% v/v]	2.7	6.4	7.8	2.8	3.2
	[% w/w]	4.3	10.1	12.7	4.7	4.9
OC [%]	0.98	–	0.50	–	–	
N_t [%]	0.070	–	0.035	–	–	
C:N	14	–	14	–	–	
P_t [mg·kg⁻¹]	382	121	347	137	80	
pH	H ₂ O	8.1	7.9	7.6	7.4	7.2
	1M KCl	7.6	7.0	6.6	6.1	6.0
CaCO₃ [%]	0.3	–	–	–	–	

Site 2 – Urbic Technosol (Humic, Arenic)



Location: Sienkiewicza St., Toruń, northern Poland

Coordinates: 53°00'54" N 18°34'54" E

Altitude: 52 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: fallow.

Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: grasses, weeds

Site 2 – Urbic Technosol (Humic, Arenic)



Morphology:

Au – 0–30 cm: sand, dark greyish brown, granular structure, slightly moist, clear boundary, common roots, artefacts: charcoals, grout, pieces of bricks, glasses.

Au2 – 30–95 cm: sand, weak red, granular structure, slightly moist, common roots, dominant artefacts (pieces of bricks, glasses, plastic, metal, bones etc.; 80%), clear boundary.

C – 95–130 cm: sand, light brown, single grain structure, dry.

Comments:

Site 2 was located in former Nicolaus Copernicus University botanical garden.

Site 2 – Urbic Technosol (Humic, Arenic)

Selected soil properties – site 2

HORIZON	Au	Au2	C
DEPTH [cm]	0–30	30–95	95–130
PARTICLE SIZE DISTRIBUTION			
ϕ [mm]	[%]		
>2	7	11	0
2.0–1.0	3	7	3
1.0–0.5	12	24	17
0.5–0.25	54	47	59
0.25–0.1	18	13	18
0.1–0.05	7	4	1
0.05–0.02	0	1	0
0.02–0.002	3	2	0
<0.002	3	2	2
TEXTURE CLASS (USDA)	sand	sand	sand
SOIL MATRIX	dry	2.5Y 4/2	2.5Y 4/2
COLOUR	wet	2.5Y 3/1	2.5Y 3/1
BULK DENSITY [g·cm ⁻³]	1.41	–	1.65
ACTUAL MOISTURE	[% v/v]	9.5	–
	[% w/w]	13.1	–
OC [%]	1.49	2.64	0.20
N _t [%]	0.103	0.128	–
C:N	14	21	–
P _{ca} [mg·kg ⁻¹]	34	51	14
pH	H ₂ O	7.6	7.7
	1M KCl	7.2	7.1
CaCO ₃ [%]	0.5	0.8	
HEAVY METALS SOLUBLE IN MIXTURE OF HF AND HClO₄			
Zn	[mg·kg ⁻¹]	142	577
Pb		<3	148
Cu		<7	22

Site 2 – Urbic Technosol (Humic, Arenic)

Site 3 – Ekranic Technosol (Arenic)



Location: St. George Cemetery, Toruń, northern Poland

Coordinates: 53°0'58.79" N 18°35'40.35" E

Altitude: 53.5 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: cemetery

Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 3 – Ekranic Technosol (Arenic)



Morphology:

Au – 0–53 cm: sand, dark grey, granular structure, slightly moist, common roots, gradual boundary.

AC – 53–65 cm: sand, brown, single grain structure, slightly moist, gradual boundary.

C – 65–110 cm: sand, very pale brown, single grain structure, slightly moist.

AC (inclusion) – left side of C horizon: sand, mixed with humus material, greyish brown, single grain structure, common roots.

Comments:

Site 3 was located in oldest Toruń cemetery (St. George Cemetery) existing since 1811.

Site 3 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON		Au	AC	C	AC (incl.)
DEPTH [cm]		0–53	53–65	65–110	65–110
PARTICLE SIZE DISTRIBUTION					
ø [mm]		[%]			
>2		4	0	0	0
2.0–1.0		2	1	1	1
1.0–0.5		17	12	6	16
0.5–0.25		57	61	63	60
0.25–0.1		19	23	27	19
0.1–0.05		1	0	3	3
0.05–0.02		2	1	0	0
0.02–0.002		2	2	0	1
<0.002		0	0	0	0
TEXTURE CLASS (USDA)		sand	sand	sand	sand
SOIL MATRIX COLOUR	dry	10YR 4.5/1	10YR 5/3	10YR 7/4	10YR 5/2
	wet	10YR 2.5/1	10YR 3/3	10YR 5/4	10YR 4/1
BULK DENSITY [g·cm⁻³]		1.46	1.66	1.60	1.52
ACTUAL MOISTURE	[% v/v]	5.5	2.4	2.4	3.3
	[% w/w]	8.0	4.1	3.9	5.0
OC [%]		0.69	–	–	0.50
N_t [%]		0.049	–	–	0.035
C:N		14	–	–	14
P_t [mg·kg⁻¹]		472	126	115	292
pH	H ₂ O	8.1	8.6	8.0	7.8
	1M KCl	7.6	8.3	7.3	7.4
CaCO₃ [%]		0.5	0.4	0.2	0.4

Site 4 – Ekranic Technosol (Arenic)



Location: St. Jacob the Apostle Parish Cemetery established in 1817 Toruń, northern Poland

Coordinates: 53°59'32" N 18°37'35.31" E

Altitude: 62.5 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: cemetery

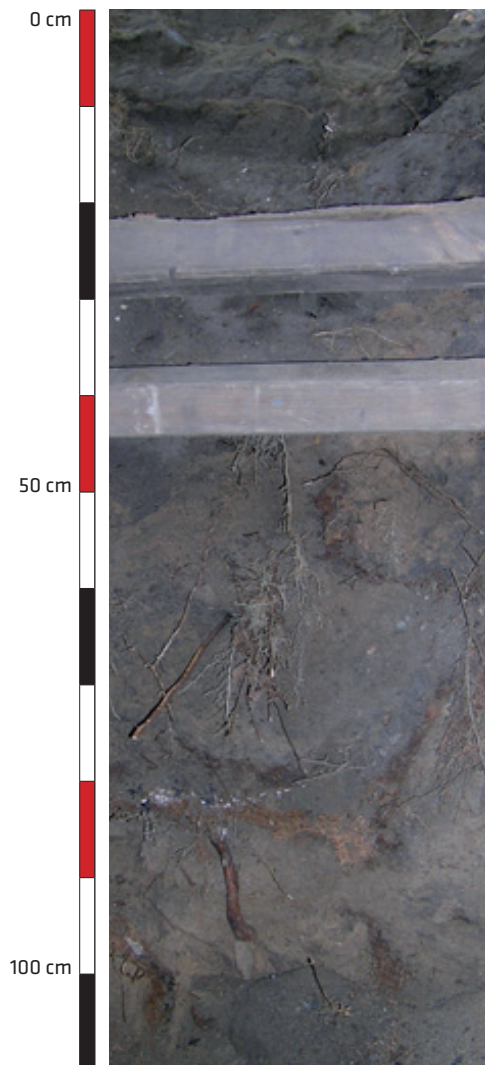
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 4 – Ekranic Technosol (Arenic)



Morphology:

Au – 0–60 cm: sand, dark grey, single grain structure, slightly moist, very few roots, gradual boundary.

AC – 60–85 cm: sand, greyish brown, single grain structure, slightly moist, clear boundary.

Bu – 85–90 cm: sand, very pale brown, single grain structure, slightly moist, common artefacts (remains of coffin, part of chain, nails, bones etc. 5–15%), abrupt boundary.

C – 90–100: sand, brown, single grain structure, slightly moist.

Site 4 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON		Au	AC	C
DEPTH [cm]		0–60	60–85	90–100
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]		[%]		
>2		5	2	4
2.0–1.0		4	2	4
1.0–0.5		8	9	7
0.5–0.25		47	50	46
0.25–0.1		31	32	35
0.1–0.05		3	3	3
0.05–0.02		4	3	1
0.02–0.002		1	1	4
<0.002		2	0	0
TEXTURE CLASS (USDA)		sand	sand	sand
SOIL MATRIX COLOUR	dry	10YR 4/1	10YR 5/2	10YR 5/3
	wet	10YR 2/1	10YR 3/1	10YR 3/2
BULK DENSITY [g·cm⁻³]		1.38	1.49	1.49
ACTUAL MOISTURE	[% v/v]	5.2	3.0	4.4
	[% w/w]	7.2	2.4	3.5
OC [%]		0.93	0.78	0.48
N_t [%]		0.068	0.053	0.038
C:N		14	15	13
P_t [mg·kg⁻¹]		580	372	352
pH	H ₂ O	7.2	7.1	7.3
	1M KCl	6.8	6.5	6.7
CaCO₃ [%]		–	–	–

Site 5 – Urbic Ekranic Technosol



Location: Gałczyńskiego st., Toruń, northern Poland

Coordinates: 53°00'59.25" N 18°35'59.99" E

Altitude: 53 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: former parking

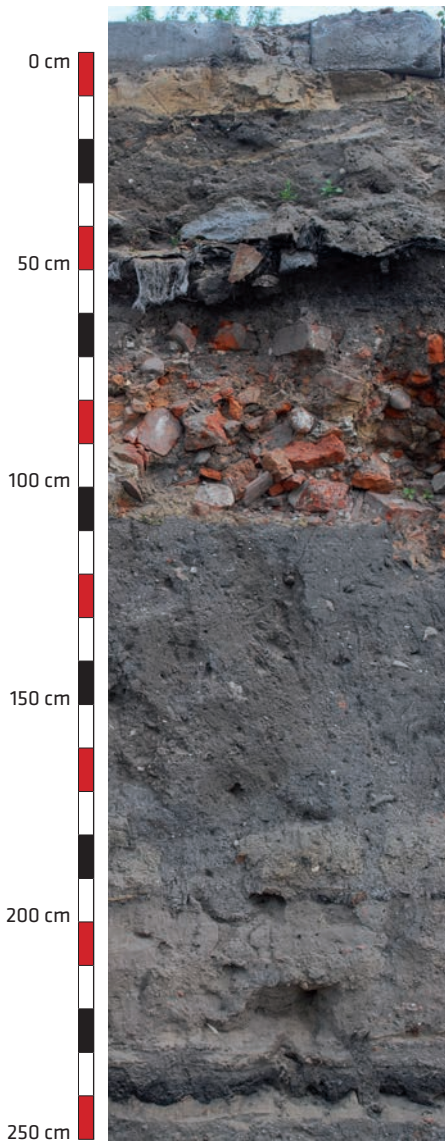
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 5 – Urbic Ekranic Technosol



Morphology:

Bu1 – 0–15 cm: sand, light grey, single grain structure, slightly moist, dated for 20th century, abrupt boundary.

Bu2 – 15–45 cm: sand, light brownish grey, single grain structure, slightly moist, dated for 20th century, abrupt boundary.

Bu3 – 45–55 cm: layer consisting of rubbish: pieces of glass, polystyrene, bitumen etc., dated for 20th century, abrupt boundary.

Bu4 – 55–65 cm: sand, dark grey, single grain structure, slightly moist, dated for 20th century, abrupt boundary.

Bu5 – 65–115 cm: layer consisting of bricks fragments, dated for 19th/20th century, abrupt boundary.

Bu6 – 115–180 cm: loamy sand, greyish brown, granular structure, slightly moist, dated for 19th/20th century, clear boundary.

Bu7 – 180–235 cm: sand, light grey, single grain structure, slightly moist, dated for 19th/20th century, clear boundary.

Bu8 – 235–245 cm: sand, dark grey, single grain structure, slightly moist.

Site 5 – Urbic Ekranic Technosol

Selected soil properties

HORIZON	Bu1	Bu2	Bu4	Bu6	Bu7	Bu8	
DEPTH [cm]	0–15	15–45	55–65	115–180	180–235	235–245	
PARTICLE SIZE DISTRIBUTION							
ϕ [mm]	[%]						
>2	4	9	6	8	1	18	
2.0–1.0	2	4	4	3	1	10	
1.0–0.5	6	15	12	17	20	22	
0.5–0.25	12	32	42	35	54	29	
0.25–0.1	59	36	24	20	15	15	
0.1–0.05	18	6	5	8	1	3	
0.05–0.02	2	2	6	7	2	8	
0.02–0.002	1	3	5	9	4	13	
<0.002	0	2	3	1	3	0	
TEXTURE CLASS (USDA)	sand	sand	sand	loamy sand	sand	loamy sand	
SOIL MATRIX	dry	2.5Y 7/2	2.5Y 6/2	5Y 4/1	2.5Y 5/2	10YR 7/1	2.5Y 4/1
COLOUR	wet	2.5Y 4/4	2.5Y 4/2	5Y 1/1	2.5Y 3/2	10YR 7/2	2.5Y 2/2
OC [%]	0.14	0.52	4.21	1.39	2.64	0.75	
N _t [%]	0.005	0.020	0.278	0.097	0.083	0.025	
C:N	28	26	15	14	32	30	
P _t [mg·kg ⁻¹]	200	541	2 590	4 180	1 880	2 060	
pH	H ₂ O	8.0	8.2	7.7	8.1	8.0	8.1
	1M KCl	7.4	7.7	7.4	7.7	7.6	7.7
CaCO ₃ [%]	0.2	3.2	2.2	7.3	0.7	22.7	
HEAVY METALS SOLUBLE IN MIXTURE OF HF AND HClO₄							
Pb	65	109	228	206	208	n.d.	
Cd	5	5	6	6	6	n.d.	
Zn	17	36	102	88	54	n.d.	
Cu	19	28	61	124	92	n.d.	

Site 6 –Urbic Ekranic Technosol



Location: Szosa Chełmińska st., Toruń, northern Poland

Coordinates: 53°00'59.33 N 18°35'05.55" E

Altitude: 53 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: pavement

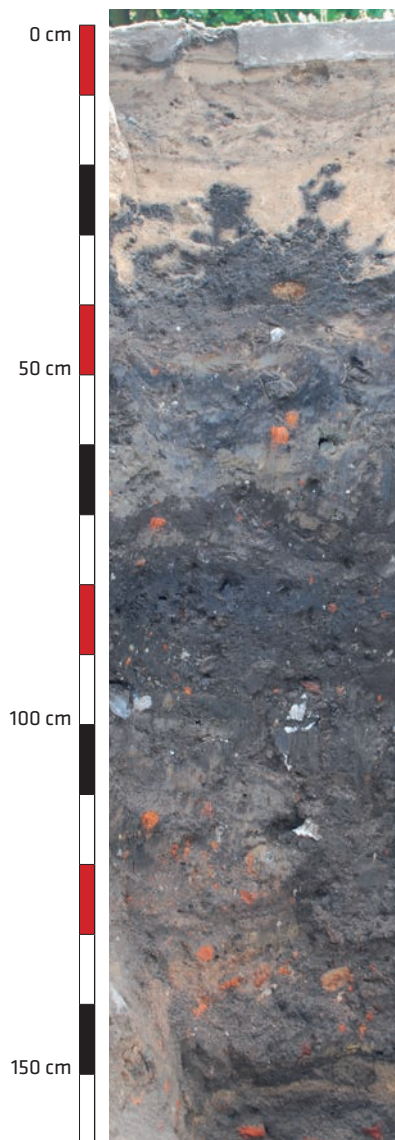
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 6 – Urbic Ekranic Technosol



Morphology:

Bu1 – 0–15 cm: sand, light grey, single grain structure, slightly moist, gradual boundary, dated for the end of 20th century.

Bu2 – 15–30 cm: sand, light brownish grey, slightly moist, clear boundary, dated for 19th/20th century.

Au1 – 30–39 cm: sandy loam, light yellowish brown, granular structure, moist, gradual boundary, dated for 19th/20th century.

Buh1 – 39–65 cm: sandy loam, granular structure, light olive brown, slightly moist, gradual boundary, dated for 19th/20th century.

Buh2 – 65–90 cm: loamy sand, subangular structure, black, slightly moist, artefacts: pieces of bricks, gradual boundary, dated for 19th/20th century.

Buh3 – 90–140 cm: loamy sand, grey, subangular structure, slightly moist, artefacts: pieces of glass, polystyrene, bricks, gradual boundary, dated for 19th/20th century.

Buh4 – 140–150 cm: sandy loam, light brownish grey, granular structure, slightly moist, artefacts: pieces of bricks, dated for 19th/20th century.

Comments:

Soil under the concrete pavement.

Site 6 – Urbic Ekranic Technosol

Selected soil properties

HORIZON	Bu1	Bu2	Au1	Buh1	Buh2	Buh3	
DEPTH [cm]	0–15	15–30	30–39	39–65	65–90	90–140	
PARTICLE SIZE DISTRIBUTION							
ϕ [mm]	[%]						
>2	2	2	0	0	7	14	
2.0–1.0	1	2	4	2	1	2	
1.0–0.5	21	25	9	9	10	14	
0.5–0.25	58	53	27	26	36	33	
0.25–0.1	16	16	31	32	37	23	
0.1–0.05	2	2	3	7	5	7	
0.05–0.02	0	0	4	3	2	4	
0.02–0.002	1	1	10	11	7	13	
<0.002	1	1	12	10	2	4	
TEXTURE CLASS (USDA)	sand	sand	sandy loam	sandy loam	loamy sand	loamy sand	
SOIL MATRIX dry	10YR 7/2	2.5Y 6/2	2.5Y 6/3	2.5Y 5/4	5Y 2/1	5Y 5/1	
COLOUR wet	10YR 5/2	2.5Y 4/2	2.5Y 3/2	2.5Y 4/2	5Y 2/1	5Y 4/1	
OC [%]	0.13	0.06	1.54	0.57	1.85	1.22	
N_t [%]	0.002	0.000	0.055	0.030	0.098	0.042	
C:N	65	–	28	19	19	29	
P_t [mg·kg⁻¹]	249	165	1010	1830	784	1940	
pH	H ₂ O	8.5	8.4	8.0	8.2	7.7	8.1
	1M KCl	8.2	8.1	7.4	7.3	7.3	7.4
CaCO₃ [%]	0.4	–	3.1	3.5	2.3	0.5	
HEAVY METALS SOLUBLE IN MIXTURE OF HF AND HClO₄							
Pb	63	18	67	181	318	63	
Cd	6	8	6	6	6	6	
Zn	18	–	54	27	40	16	
Cu	21	18	59	36	135	66	

Site 7 – Urbic Ekranic Technosol (Calcaric)



Location: Szeroka st., Toruń, northern Poland

Coordinates: 53°00'37.67" N 18°35'26.12" E

Altitude: 49 m a.s.l.



photo J. Błaszkievicz

Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: sidewalk

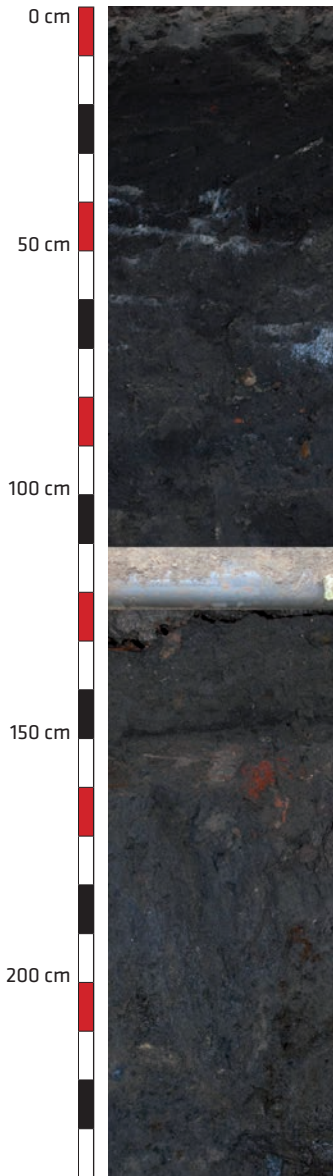
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 7 – Urbic Ekranic Technosol (Calcaric)



Morphology:

Buh1 – 0–18 cm: sand, light grey, single grain structure, slightly moist, gradual boundary.

Buh2 – 18–55 cm: sand, light grey, single grain structure, slightly moist, few artefacts, gradual boundary.

Buh3 – 55–110 cm: sand, light brownish grey, single grain structure, slightly moist, clear boundary.

Buh4 – 110–220 cm: sand, grey, single grain structure, moist, many artefacts: pieces of brick.

Comments:

Soil under the granite slabs on the main pedestrian street of Toruń Old Town.

Site 7 – Urbic Ekranic Technosol (Calcaric)

Selected soil properties

HORIZON	Buh1	Buh2	Buh3	Buh4	
DEPTH [cm]	0–18	18–55	55–110	110–220	
PARTICLE SIZE DISTRIBUTION					
ϕ [mm]	[%]				
>2	3	4	4	4	
2.0–1.0	7	6	4	3	
1.0–0.5	23	13	14	14	
0.5–0.25	37	41	40	41	
0.25–0.1	21	27	30	28	
0.1–0.05	3	4	5	4	
0.05–0.02	3	2	1	3	
0.02–0.002	5	5	6	6	
<0.002	1	2	0	1	
TEXTURE CLASS (USDA)	sand	sand	sand	sand	
SOIL MATRIX	dry	2.5Y 7/1	2.5Y 7/1	10YR 6/2	10YR 6/1
COLOUR	wet	2.5Y 3/4	2.5Y 3/4	10YR 3/4	10YR 3/4
OC [%]	0.44	0.04	0.84	0.60	
N_t [%]	0.016	0.015	0.034	0.021	
C:N	28	26	25	29	
P_t [mg·kg⁻¹]	1180	898	1780	1880	
pH	H ₂ O	9.0	8.1	8.1	8.1
	1M KCl	8.0	7.5	7.5	7.5
CaCO₃ [%]	2.4	2.1	1.3	1.0	

Site 8 – Ekranic Technosol (Arenic)



Location: Rybaki Street, Toruń, Northern Poland

Coordinates: 53°00.537' N 18°35.078' E

Altitude: 48 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: pavement

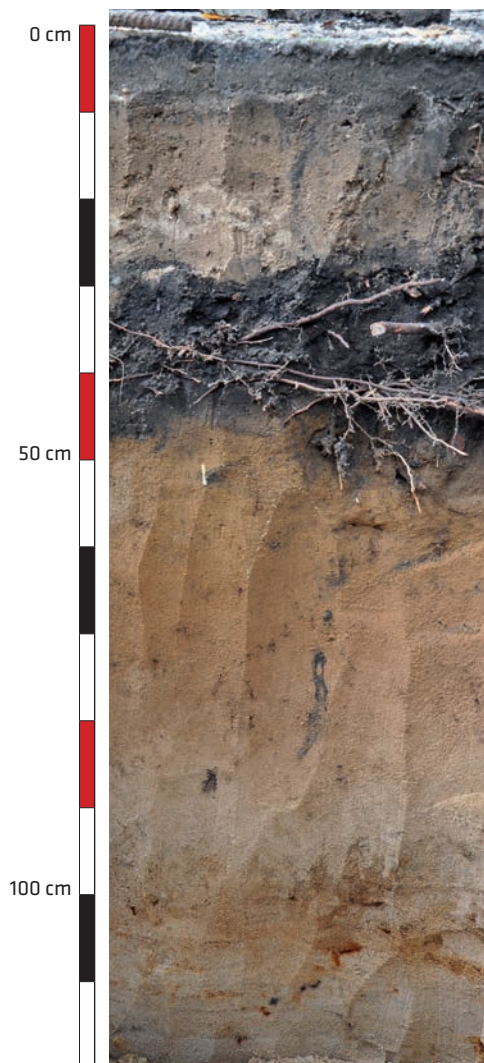
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 8 – Ekranic Technosol (Arenic)



Morphology:

0-5 – pavement tiles

B_{hu} – 5-20 cm: horizon enriched with organic matter, sand, yellowish brown, single grain structure, slightly moist, clear boundary, mixed material.

B_u – 20-21 cm: black bituminous layer.

A_b – 21-40 cm: buried humus horizon, sand, very dark grey, weak granular structure, slightly moist, clear boundary, common roots.

B_w – 40-80 cm: sand, very pale brown, single grain structure, slightly moist, few dead roots mottles, gradual boundary.

C_I – below 80 cm: sand, pale brown, single grain structure, slightly moist, common soft iron concretions.

Comments:

Site located at Rybaki Street. It was sealed with concrete pavement tiles (stairs to park alley).

Site 8 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON	Bhu	Bu	Ab	Bw	Cl	
DEPTH [cm]	5–20	20–21	21–40	40–80	80–120	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
>2	6	–	26	1	0	
2.0–1.0	6	–	8	1	1	
1.0–0.5	19	–	17	10	15	
0.5–0.25	33	–	46	51	56	
0.25–0.1	35	–	15	20	24	
0.1–0.05	5	–	2	9	2	
0.05–0.02	2	–	4	5	1	
0.02–0.002	0	–	7	3	1	
<0.002	0	–	1	1	0	
TEXTURE CLASS (USDA)	sand	–	sand	sand	sand	
SOIL MATRIX	dry	10YR 6/4	7.5YR 3/1	7.5YR 4/1	10YR 8/2	2.5YR 8/3
COLOUR	wet	10YR 4/4	7.5YR 2.5/1	7.5YR 2.5/1	10YR 6/4	10YR 6/3
BULK DENSITY [g·cm⁻³]	–	–	1.34	–	–	
ACTUAL MOISTURE	[% v/v]	–	–	15.9	–	–
	[% w/w]	–	–	11.9	–	–
OC [%]	0.43	12.5	7.50	0.19	0.04	
N_t [%]	0.010	0.269	0.163	0.004	0.004	
C:N	43	46	46	47	10	
P_t [mg·kg⁻¹]	122	134	86	109	97	
pH	H ₂ O	8.2	6.9	7.6	7.4	7.3
	1M KCl	7.8	6.4	7.0	6.5	6.8
CaCO₃ [%]	1.2	trace	0.7	0.5	0.4	
HEAVY METALS SOLUBLE IN MIXTURE OF HF AND HClO₄						
Zn	6	197	221	<3	11	
Pb	<16	<16	47	59	<16	
Cd	<5	<5	<5	<5	<5	
Cu	<7	55	34	<7	<7	

Site 9 – Ekranic Technosol (Arenic)



Location: Rybaki Street, Toruń, northern Poland

Coordinates: 53°00.537' N 18°35.078' E

Altitude: 48 m a.s.l.



Climate:

Average annual temperature: 7.5°C

Average annual precipitation: 600 mm

Land-use: asphalt alley

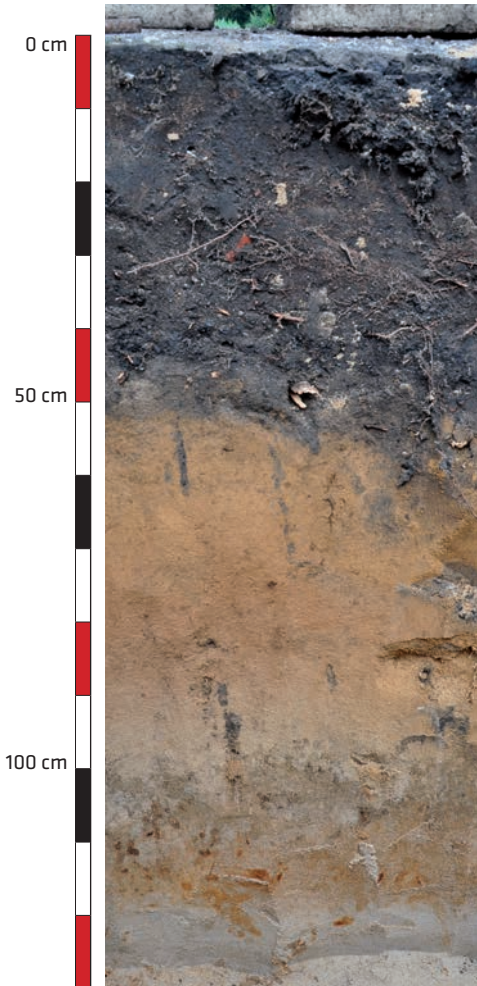
Relief and lithology:

Major landform: plain

Lithology: late Pleistocene fluvial sands

Vegetation: none

Site 9 – Ekranic Technosol (Arenic)



Morphology:

0–8 – asphalt (bituminous) alley

Bhu – 8–21 cm: sand mixed with bitumens, dark grey, weak granular structure, slightly moist, gradual boundary.

Ab – 21–40 cm: buried humus horizon, sand, dark greyish brown, weak granular structure, slightly moist, clear boundary, common roots.

Bw – 40–80 cm: sand, very pale brown, single grain structure, slightly moist, few dead roots mottles, gradual boundary.

Cl – below 80 cm: sand, pale brown, single grain structure, slightly moist, common soft iron concretions.

Comments:

Site located at Rybaki Street. It was sealed with hard bituminous layer (park alley).

Site 9 – Ekranic Technosol (Arenic)

Selected soil properties

HORIZON		Bhu	Ab	Bw	Cl
DEPTH [cm]		8–21	21–40	40–80	80–120
PARTICLE SIZE DISTRIBUTION					
ϕ [mm]		[%]			
>2		11	3	1	0
2.0–1.0		5	3	1	1
1.0–0.5		19	30	10	15
0.5–0.25		43	51	51	56
0.25–0.1		17	11	20	24
0.1–0.05		6	2	9	2
0.05–0.02		4	1	5	1
0.02–0.002		4	2	3	1
<0.002		2	0	1	0
TEXTURE CLASS (USDA)		sand	sand	sand	sand
SOIL MATRIX	dry	10YR 4/1	10YR 4/2	10YR 8/2	2.5YR 8/3
COLOUR	wet	10YR 2/1	10YR 3/2	10YR 6/4	10YR 6/3
BULK DENSITY [g·cm ⁻³]		–	1.49	–	–
ACTUAL MOISTURE	[% v/v]	–	15.4	–	–
	[% w/w]	–	10.3	–	–
OC [%]		4.54	1.30	0.19	0.04
N _t [%]		0.148	0.057	0.004	0.004
C:N		31	23	47	10
P _t [mg·kg ⁻¹]		247	344	109	97
pH	H ₂ O	6.9	7.9	7.4	7.3
	1M KCl	6.2	7.6	6.5	6.8
CaCO ₃ [%]		trace	0.8	0.3	0.4
HEAVY METALS SOLUBLE IN MIXTURE OF HF AND HClO₄					
Zn		78	20	<3	11
Pb		64	<16	59	<16
Cd	[mg·kg ⁻¹]	<5	<5	<5	<5
Cu		23	10	<7	<7

6

TECHNOGENIC SOILS IN ZIELONA GÓRA

ANDRZEJ GREINERT

Zielona Góra is a medium-sized city in the Polish-German border region (Fig. 1), located on the historical military route Berlin-Wrocław. The history of Zielona Góra as an urban area began probably in the 13th century. The first information about the city foundation comes from 1222 (Schmidt 1922, 1928), but the very first Slavic settlement was probably founded even in the 10th century (Garbacz 2003). The settlement was formed on the right bank of the Złota Łącza stream, near a hill, later called the Brick Height. The first document marked as ‘territorio Grunenbergense’ dates from 1302. The city rights were probably granted in 1312 (Schmidt 1922; Ribbeck 1929). During the Middle Ages, Zielona Góra was surrounded by a wall, first a wooden palisade, followed by a stone and brick wall. It was demolished in the 18th and 19th centuries (only small fragments of the brick wall are visible today). By the end of the 18th century, it was a typical small town (8 000 inhabitants), based on agriculture and craft. Intensive industrialization processes took place in the 19th and early 20th century. The main factories in the city were connected with food processing, textiles and metal industry. At the beginning of

World War II, Zielona Góra was populated by 30 000 inhabitants, living over a relative small area. A large increase in the area and the population size has been observed since the mid-20th century, especially in the late 20th century.

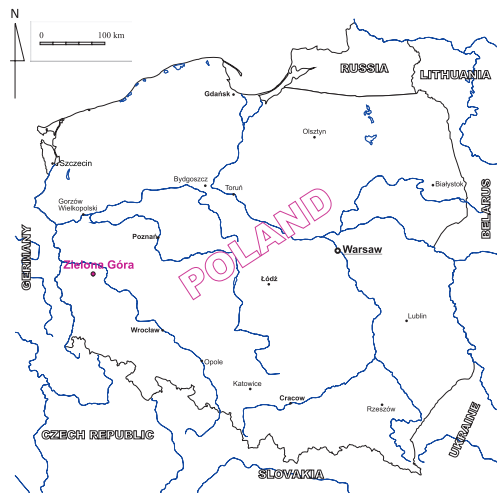


Fig. 1. Location of Zielona Góra

World War II, Zielona Góra was populated by 30 000 inhabitants, living over a relative small area. A large increase in the area and the population size has been observed since the mid-20th century, especially in the late 20th century.

In Polish, Czech and German, the city's name means a 'green mountain'. Vineyards were present in Zielona Góra almost throughout the entire history of the city – the first plantation was probably established in 1150 (Czyżniewski 2010). It is the only urban area in Poland based on the tradition of wine production. Nowadays, the city is known mostly for this tradition.

The population of the city, as of March 31st 2013, was 119 051 inhabitants. Zielona Góra covers an area of 5 864 ha. It is located on two geomorphological structures: glacier end-moraine (moraine belt) and moraine upland. The moraine belt in the southern part of the city is characterised by large differences in a relative height, exceeding 150 m (the highest point – Wilkanow Height – 221 m a.s.l.; 51°54'55.17" N 15°27'33.22" E). The northern part of the city is located within the moraine upland (70–100 m a.s.l.). The land cover in the city is not typical for modern agglomerations. A total area of 2 667 ha in Zielona Góra is covered by forests dominated by Scots pine (*Pinus sylvestris* L.). Climatic conditions are characterised by the following indices (2011): average annual air temperature 9.7°C, total annual precipitation 576 mm, average wind velocity 3.2 m·s⁻¹, insolation 1 937 h, average cloudiness in octants 4.7 (data source: Institute of Meteorology and Water Management 2012).

The origin of surface feature transformation in the area of Zielona Góra goes back to the 13th century with the highest intensity in the 19th and 20th centuries. Human activity generates huge changes in the types of area development. First of all, the vineyards and orchards have been transformed into the residential areas, first with multi-family housing, later with detached houses. The second, very important spatial factor consisted in surrounding the industrial ring (the historical one located outside the city) by the residential areas. Morphological changes in the city were caused by, among others, preparation of levelled surfaces for houses (making the 'platforms' on the moraine slopes), construction of roads, streets and channels etc. An interesting form of human activity in the city area consisted in channelling the streams into the pipes laid under the city.

The present state of urban soils is a result of different human activities: agricultural, urban and industrial. The areas covered with natural soils are still found within the city: (mainly Podzols and Brunic Arenosols, rarely Luvisols, Phaeozems, Gleysols and Histosols). Most of them are distinguished by major chemical transformations without changes in the morphology of soil Sites (Greinert 2003). Several different types of technogenic soils can be found in the city: urbisols, industrisols, garden soils, soils of parks and lawns, necrosols (relicts of several historical graveyards and cemeteries are to be found in the city centre), ekranosols and constructosols. The urban agricultural soils (mainly Phaeozems, Plaggic and Hortic Anthrosols) are used as allotment gardens. A large arable land (475 ha vs. residential area of 630 ha, industrial area of 236 ha) is a typical feature of Zielona Góra, next to a large forest area. Technosols are deeply transformed, including the enrichment with different construction and waste materials – a higher level of

enrichment in the subsoil compared to the topsoil is a typical situation (Greinert 2003; Greinert et al. 2013). Brick fragments, mortar, gravel and slag are most often found. Usually all the soil Sites are destroyed during the construction work. A low pH value of the topsoil (0–20 cm) – pH – 0.01M CaCl₂ of 3.2–4.5 – is a characteristic property of the forest soils outside the urban area. The analysis from Zielona Góra shows higher pH values in the forests – 4.3–5.3 (Greinert 2001) and significantly higher in the residential, traffic and industrial area – 6.4–8.3 (Greinert 2000, 2002, 2003). Considering the sandy texture and low content of organic carbon in the topsoil, the expected effect is a low content of elements in the soil, except for calcium (Greinert 2000, 2002, 2003; Greinert et al. 2013), and low EC values (0.1–0.3 mS·cm⁻¹) even on the roadsides (Greinert 2003, 2005; Greinert et al. 2013). A high concentration of Cu in several types of soil in the city is an interesting phenomenon connected with the presence of a vineyard in the past (the use of Bordeaux Mixture and slaked lime as a fungicide since 1882).

Site 1 – Horticultural Anthrosol



Location:

'Brick Height' Vineyard Park,
Zielona Góra,
western Poland

Coordinates:

51°56'15" N 15°30'43" E

Altitude: 142.5 m a.s.l.



Climate:

Average annual temperature: 9.2°C

Average annual precipitation: 591 mm

Relief and lithology:

Major landform: height's slope

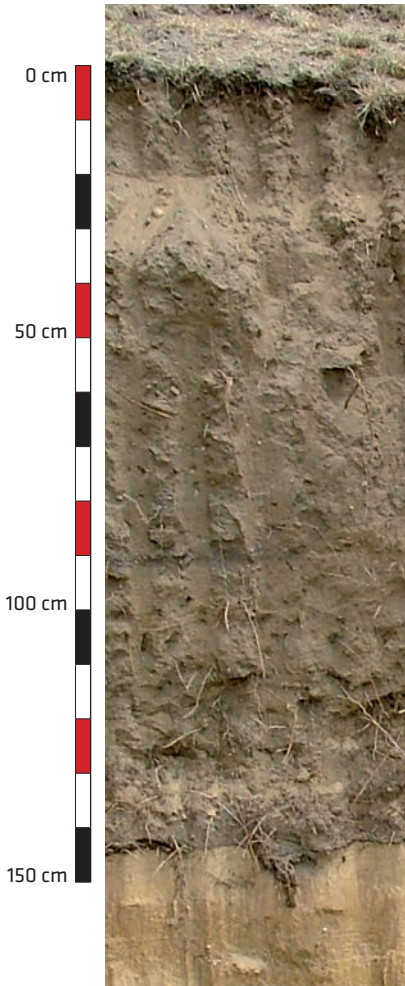
Slope position: the lower part of the slope,
elevation SW

Lithology: late Pleistocene (Vistulian,
Würm, Wisconsin) fluvio-glacial sands

Land-use: vineyard-park (recreational)

Vegetation: vineyard, grass as the intercrop

Site 1 – Hortic Anthrosol



Morphology:

A1 – 0–5 cm: sand, very dark greyish brown, granular structure, slightly moist, clear boundary, very few artefacts (plastics, municipal wastes, glass; < 1%);

A2 – 5–145 cm: sand, dark olive grey, granular structure, slightly moist, sharp boundary, few artefacts (stones; < 1%).

C – below 145 cm: sand, light yellow, loose, dry/slightly moist.

Comments:

Site 1 was located about 500 m from the Old Square, on the slope of the 'Brick Height' (part of the glacier end moraine), today developed as the Vineyard Park. It's a place probably close to the initial location of the town. From the 14th century till the end of the World War II productive vineyard.

Site 1 – Horticultural Anthrosol

Selected soil properties

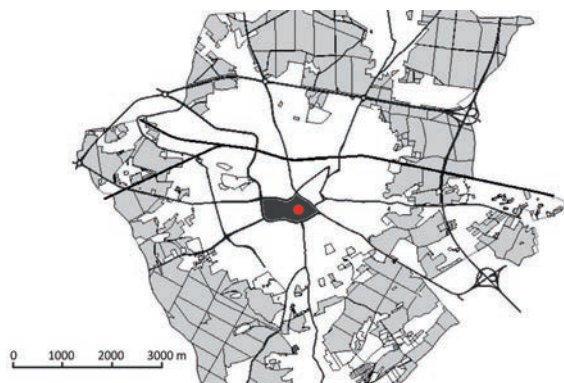
HORIZON	A1	A2	C	
DEPTH [cm]	0–5	5–145	> 145	
PARTICLE SIZE DISTRIBUTION				
ϕ [mm]		[%]		
>2	4.72	0.00	0.00	
2.0–1.0	18	21	35	
1.0–0.5	30	30	31	
0.5–0.25	27	27	17	
0.25–0.1	13	12	5	
0.1–0.05	7	3	7	
0.05–0.02	2	5	4	
0.02–0.002	3	2	1	
<0.002	0	0	0	
TEXTURE CLASS (USDA)	sand	sand	sand	
SOIL MATRIX	dry	5Y 4/1	5Y 5/1	2.5Y 8/3
COLOUR	wet	5Y 2.5/1	5Y 3/1	2.5Y 6/3
BULK DENSITY [g·cm⁻³]	1.42	1.51	1.62	
OC [%]	5.3	3.3	0.0	
N_t [%]	0.38	0.21	–	
C:N	14	16	–	
P_t [mg·kg⁻¹]	3 200	2 600	600	
pH	H ₂ O	6.5	6.8	6.8
	1M KCl	6.0	6.3	6.5
CaCO₃ [%]	0.5	0.3	0.0	
EC_{1:2} [mS·cm⁻¹]	0.28	0.24	0.06	
CEC [cmol·kg⁻¹]	22.8	20.6	2.0	
K_t [mg·kg⁻¹]	10 600	8 550	4 300	
Ca_t [mg·kg⁻¹]	26 000	22 000	2 800	

Site 1 – Hortic Anthrosol

Selected soil properties cont.

HORIZON	A1	A2	C
DEPTH [cm]	0-5	5-145	> 145
HEAVY METALS SOLUBLE IN AQUA REGIA			
Fe	9 430	8 400	5 760
Mn	341	290	187
Zn	143	123	46.4
Pb	57.0	43.0	17.5
Cd	0.52	0.30	0.20
Cu	192	138	29.4
Ni	10.0	8.7	6.4
Co	3.4	3.4	2.8
HEAVY METALS SOLUBLE IN 0.1M HCl			
Fe	219	617	878
Mn	237	232	166
Zn	53.6	50.1	12.9
Pb	23.2	21.5	15.8
Cd	0.32	0.18	0.09
Cu	94.4	80.2	19.5
Ni	3.0	2.6	1.7

Site 2 –Urbic Ekranic Technosol



Location:
Old Square,
Zielona Góra,
western Poland

Coordinates:
51°56'19" N 15°30'19" E

Altitude: 139.5 m a.s.l.

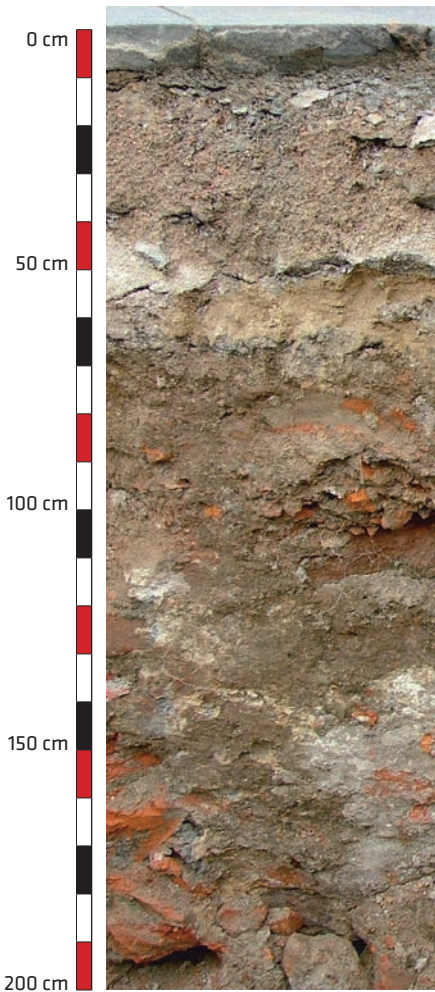


Climate:
Average annual temperature: 9.2°C
Average annual precipitation: 591 mm

Land-use: old town (commercial)

Relief and lithology:
Major landform: plain
Lithology: late Pleistocene (Vistulian,
Würm, Wisconsin) fluvio-glacial sands
Vegetation: few *Acer saccharinum* L. trees
in isolated places

Site 2 – Urbic Ekranic Technosol



Morphology:

0–12 cm: *technic hard rock* – concrete slabs, grey, links filled with cement mortar.

C –12–50 cm: sand, light yellowish brown, loose, slightly moist, clear boundary.

IIC – 50–80 cm: sand, pale yellow, slightly moist, clear boundary.

IIIC – 80–120 cm: loamy sand, dark olive brown, slightly moist, gradual boundary, few artefacts (pieces of bricks; 30%).

IVC – 120–195 cm: sandy loam, dark brown, slightly moist, gradual boundary, artefacts (mortar, brick fragments; 30%).

VC – below 195 cm: brick construction dated back to the late Middle Ages, loam.

Comments:

Site 2 was located on area of the Old Square, a few meters from the town hall's wall. Soil site with residues of medieval times about 150–200 cm below the present surface (i.a. the foundations of ancient buildings and the furnace bread were found). Until the end of the seventies of 20th century vehicular traffic permitted.

Site 2 – Urbic Ekranic Technosol

Selected soil properties

HORIZON	C	IIC	IIIC	IVC	VC	
DEPTH [cm]	12-50	50-80	80-120	120-195	> 195	
PARTICLE SIZE DISTRIBUTION						
ϕ [mm]	[%]					
>2	3	1	8	15	87	
2.0-1.0	12	15	12	7	6	
1.0-0.5	24	28	24	25	16	
0.5-0.25	34	32	25	24	16	
0.25-0.1	21	19	11	12	11	
0.1-0.05	5	4	4	5	6	
0.05-0.02	3	2	8	6	16	
0.02-0.002	1	1	12	11	16	
<0.002	0	0	4	10	13	
TEXTURE CLASS (USDA)	sand	sand	loamy sand	sandy loam	loam	
SOIL MATRIX COLOUR	dry	2.5Y 6/3	2.5Y 7/3 2.5Y 8/1	5YR 5/2	7.5YR 5/2	7.5YR 5/1
	wet	2.5 4/3	2.5 5/4	5YR 4/1	7.5YR 3.5/2	7.5YR 4/1
BULK DENSITY [g·cm⁻³]	1.42	1.53	1.66	1.72	–	
OC [%]	0.1	0.0	0.3	0.1	0.0	
P_t [mg·kg⁻¹]	600	200	1100	1500	900	
pH	H ₂ O	7.5	7.1	7.2	7.1	6.9
	1M KCl	7.1	6.8	6.9	6.8	6.7
CaCO₃ [%]	2.1	0.6	1.3	4.2	0.9	
EC_{1:2} [mS·cm⁻¹]	0.25	0.25	0.24	0.21	0.24	
CEC [cmol·kg⁻¹]	5.7	2.6	12.4	15.4	18.1	
K_t [mg·kg⁻¹]	2 460	2 650	3 780	4 200	4 290	
Ca_t [mg·kg⁻¹]	32 000	5 800	17 100	42 000	8 900	

Site 2 – Urbic Ekranic Technosol

Selected soil properties cont.

HORIZON	C	IIC	IIIC	IVC	VC
DEPTH [cm]	12–50	50–80	80–120	120–195	> 195
HEAVY METALS SOLUBLE IN AQUA REGIA					
Fe	10 970	11 720	10 570	8 870	12 670
Mn	164	445	459	309	81
Zn	293	181	135	53.8	49.8
Pb	85.2	127	75.4	13.6	10.2
Cd	0.58	0.58	0.52	0.32	0.28
Cu	33.0	61.7	63.4	40.6	20.1
Ni	9.7	14.1	11.1	10.1	21.0
Co	2.9	4.9	4.9	3.8	4.5
HEAVY METALS SOLUBLE IN 0.1M HCl					
Fe	1 410	1 390	1 330	736	1 410
Mn	112	386	403	292	44
Zn	61.9	57.1	51.6	15.5	6.3
Pb	17.9	51.3	45.0	11.3	5.7
Cd	0.39	0.36	0.21	0.09	0.08
Cu	7.3	30.5	37.7	31.9	6.9
Ni	2.1	3.7	3.6	3.4	3.0

Site 3 – Ekranic Episkeletic Technosol (Arenic)



Location:
Konstytucji 3 Maja Lane,
Zielona Góra,
western Poland

Coordinates:
51°56'12" N 15°30'33" E

Altitude:
118.0 m a.s.l.

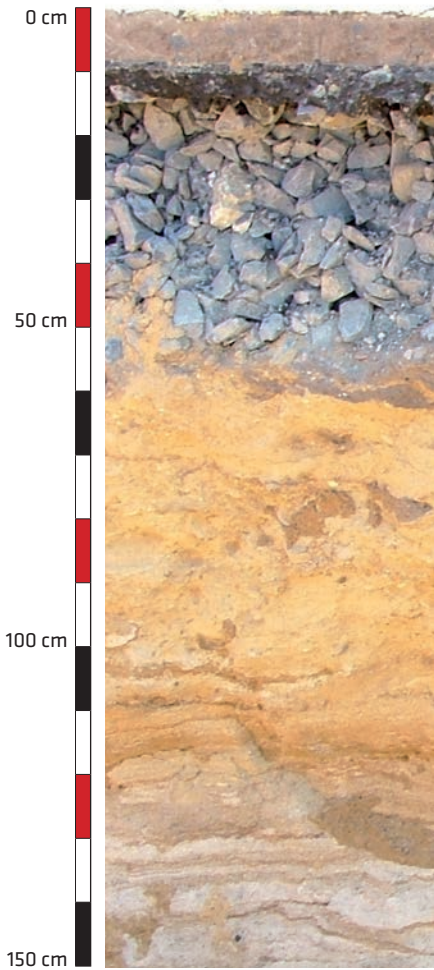


Climate:
Average annual temperature: 9.2°C
Average annual precipitation: 591 mm

Land-use: main city roadway

Relief and lithology:
Major landform: plain
Lithology: late Pleistocene (Vistulian,
Würm, Wisconsin) fluvio-glacial sands
Vegetation: lawn on median strip, single
trees about 50 m from the soil pit

Site 3 – Ekranic Technosol (Episkeletic, Arenic)



Morphology:

0–8 cm: *technic hard rock* – concrete slabs, grey, links filled with asphalt.

8–13 cm: *technic hard rock* – asphalt.

HTM1 – 13–38(55) cm: *technic hard rock* – road-material (breakstone); cement and silt admixtures (3%); greenish grey.

HTM2 – 38(55)–55(60) cm: human-transported material – sand with cement and silt (30%), greenish grey, gradual boundary..

C1 – 55(60)–120 cm: sand, yellow, loose, slightly moist, gradual boundary.

C2 – 120–150 cm: sand, white/pale yellow, loose, slightly moist.

Comments:

Site 3 was located within sidewalk along one of the most important roads of Zielona Góra (road from Wrocław). The road borders from the south historical center of Zielona Góra.

Site 3 – Ekranic Technosol (Episkeletic, Arenic)

Selected soil properties

HORIZON		HTM1	HTM2	C1	C2
DEPTH [cm]		13–38(55)	38(55)–55(60)	55(60)–120	120–150
PARTICLE SIZE DISTRIBUTION					
ϕ [mm]		[%]			
>2		96	73	< 1	< 1
2.0–1.0		47	39	13	15
1.0–0.5		35	38	24	28
0.5–0.25		11	16	34	32
0.25–0.1		7	7	21	19
0.1–0.05		6	6	5	4
0.05–0.02		1	2	3	1
0.02–0.002		2	1	0	1
<0.002		0	0	0	0
TEXTURE CLASS (USDA)		sand	sand	sand	sand
SOIL MATRIX COLOUR	dry	5G 6/1	5G 6/1	5Y 8/6	2.5Y 8/1 2.5Y 7/3
	wet	5G 4/1	5G 3/1	2.5Y 5/6	2.5Y 7/2 2.5Y 4/3
BULK DENSITY [g·cm ⁻³]		–	–	1.55	1.59
OC [%]		0.04	0.03	–	–
P _t [mg·kg ⁻¹]		800	800	300	200
pH	H ₂ O	7.8	7.6	7.3	7.3
	1M KCl	7.3	7.1	6.9	6.9
CaCO ₃ [%]		2.1	1.6	0.5	0.0
EC _{1:2} [mS·cm ⁻¹]		0.20	0.10	0.07	0.07
CEC [cmol·kg ⁻¹]		11.7	11.7	8.9	3.9
K _t [mg·kg ⁻¹]		0.68	0.63	0.55	0.37
Ca _t [mg·kg ⁻¹]		1.90	1.52	0.48	0.16

Site 3 – Ekranic Technosol (Episkeletic, Arenic)

Selected soil properties cont.

HORIZON	HTM1	HTM2	C1	C2
DEPTH [cm]	13–38(55)	38(55)–55(60)	55(60)–120	120–150
HEAVY METALS SOLUBLE IN AQUA REGIA				
Fe	4 480	2 870	1 030	1 790
Mn	165	123	152	132
Zn	85.0	16.4	11.6	7.0
Pb	35.8	7.2	1.9	1.0
Cd	0.4	0.2	0.1	0.2
Cu	15.4	8.1	23.1	15.1
Ni	4.8	3.2	10.2	2.4
Co	2.2	2.6	1.4	1.1
HEAVY METALS SOLUBLE IN 0.1M HCl				
Fe	1 580	1 050	571	510
Mn	129	70	77	78
Zn	6.9	7.0	3.2	2.5
Pb	11.3	1.6	0.7	0.7
Cd	0.1	0.1	n.d.	n.d.
Cu	4.4	4.4	10.9	2.8
Ni	2.2	2.2	1.8	1.1

Site 4 – Ekranic Technosol (Humic, Arenic)



Location:

Dąbrowskiego St.,
Zielona Góra,
western Poland

Coordinates:

51°56'53" N 15°29'35" E

Altitude:

118.0 m a.s.l.



Climate:

Average annual temperature: 9.2°C
Average annual precipitation: 591 mm

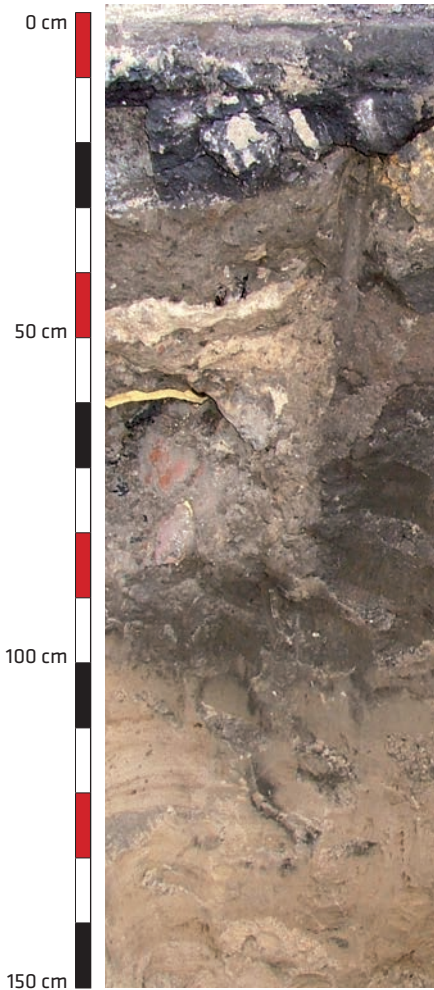
Land-use: local city roadway

Relief and lithology:

Major land form: plain
Lithology: late Pleistocene (Vistulian,
Würm, Wisconsin) fluvio-glacial sands

Vegetation: none

Site 4 – Ekranic Technosol (Humic, Arenic)



Morphology:

0-10 cm: *technic hard rock* – asphalt surface.

10-20(28) cm: *technic hard rock* – uneven layer made of asphalt and different construction wastes, clear boundary.

AuBu - 20(28)-55(85) cm: sand with different technogenic admixtures uneven filled (5-50%), greyish brown, slightly moist, unclear boundary.

Bu - 55(85)-100 cm: loamy sand, dark greyish brown, without technogenic admixtures, slightly moist, gradual boundary.

C - 100-150 cm: sand, light greenish grey, loose, moist.

Comments:

Site 4 was located under the sidewalk along the local roadway connecting city center with north-western city quarters. Primary road construction was made in early fifties of the 20th century; surface of the road was few times rebuild.

Site 4 – Ekranic Technosol (Humic, Arenic)

Selected soil properties

HORIZON	AuBu	Bu	C	
DEPTH [cm]	20(28)–55(85)	55(85)–100	100–150	
PARTICLE SIZE DISTRIBUTION				
ø [mm]	[%]			
>2	19	–	–	
2.0–1.0	34	19	17	
1.0–0.5	29	30	30	
0.5–0.25	17	28	32	
0.25–0.1	9	12	15	
0.1–0.05	8	9	5	
0.05–0.02	2	1	1	
0.02–0.002	1	1	0	
<0.002	0	0	0	
TEXTURE CLASS (USDA)	sand	sand	sand	
SOIL MATRIX	dry	2.5Y 5/2	2.5Y 4/2	5GY 8/1
COLOUR	wet	2.5Y 4/2	2.5Y 3/3	5Y 7/4
BULK DENSITY [g·cm⁻³]	1.48	1.59	1.63	
OC [%]	1.6	2.0	0.6	
N_t [%]	0.44	0.35	0.06	
C:N	27	17	10	
P_t [mg·kg⁻¹]	5 100	2 500	600	
pH	H ₂ O	8.6	7.6	7.4
	1M KCl	8.3	7.2	7.1
CaCO₃ [%]	2.5	1.4	0.4	
EC_{1:2} [mS·cm⁻¹]	0.45	0.17	0.20	
CEC [cmol·kg⁻¹]	12.6	15.8	5.5	
K_t [mg·kg⁻¹]	0.67	0.85	0.50	
Ca_t [mg·kg⁻¹]	3.0	1.8	0.3	

Site 4 – Ekranic Technosol (Humic, Arenic)

Selected soil properties cont.

HORIZON	AuBu	Bu	C
DEPTH [cm]	20(28)–55(85)	55(85)–100	100–150
HEAVY METALS SOLUBLE IN AQUA REGIA			
Fe	3 090	6 300	2 970
Mn	100	110	107
Zn	68	64	28
Pb	16	14	7
Cd	0.4	0.4	0.6
Cu	15.3	51.9	8.9
Ni	4.1	15.9	10.7
Co	1.7	2.9	0.9
HEAVY METALS SOLUBLE IN 0.1M HCl			
Fe	780	3940	815
Mn	11	89	14
Zn	31	28	12
Pb	1	2	5
Cd	0.1	0.1	0.1
Cu	9.8	32.3	4.8
Ni	4.1/	4.5	1.7

Site 5 – Technic Gleyic Podzol (Novic)



Location:

Pod Topolami st.,
Zielona Góra,
western Poland

Coordinates:

51°56'29" N 15°30'25" E

Altitude:

135.5 m a.s.l.



Climate:

Average annual temperature: 9.2°C
Average annual precipitation: 591 mm

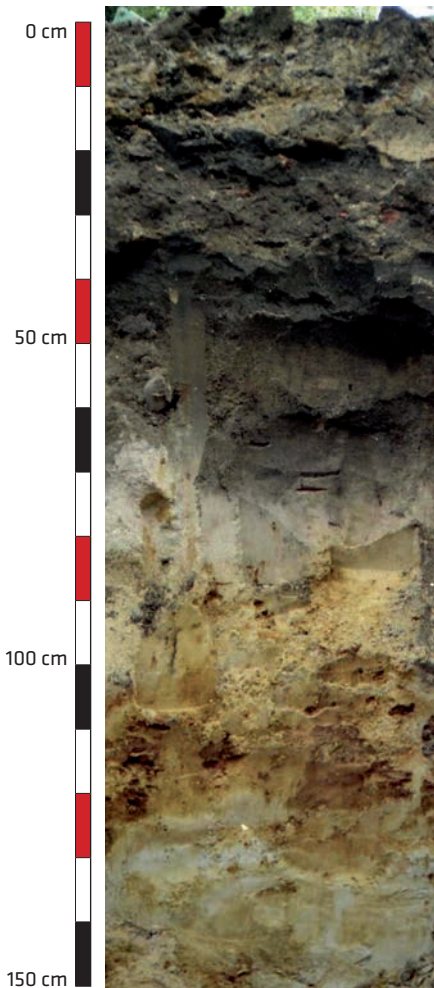
Land-use: wasteland in the city center

Relief and lithology:

Major landform: plain
Lithology: late Pleistocene (Vistulian,
Würm, Wisconsin) fluvio-glacial sands

Vegetation: herbaceous vegetation typical
for urban wasteland

Site 5 – Technic Gleyic Podzol (Novic)



Morphology:

Auh1 – 0–15 cm: humus and sand mixed with municipal wastes (40%), reddish brown, slightly moist, clear boundary.

Auh2 – 15–32 cm: dark brown, slightly moist, artefacts (mortar, stones, concrete elements, plastics, glass; 10%), clear boundary.

Auh3 – 32–48 cm: very dark brown, slightly moist, clear boundary.

Au – 48–68 cm: sand, few artefacts (stones, brick elements, < 1%), slightly moist, gradual boundary.

Es – 68–84 cm: sand, white, loose, slightly moist, gradual boundary.

Bs – 84–125 cm: sand, yellow, humic and ferrous deposits, slightly moist, gradual boundary.

CG – 125–150 cm: sand, pale yellow/light greenish grey, loose, moist.

Comments:

Site 5 was located on the area, situated just outside the medieval city walls, opened for development in 16th or 17th centuries. Until the end of 20th century waterlogged empty area (on the maps from the 30's of the 20th century signed as meadow). Build-up at the beginning of 21st century.

Site 5 – Technic Gleyic Podzol (Novic)

Selected soil properties

HORIZON	Auh1	Auh2	Auh3	Au	Es	Bs	CG	
DEPTH [cm]	0-15	15-32	32-48	48-68	68-84	84-125	125-150	
PARTICLE SIZE DISTRIBUTION								
ϕ [mm]				[%]				
>2	43	9	< 1	< 1	–	–	–	
2.0-1.0	26	19	17	33	34	34	34	
1.0-0.5	24	25	24	26	26	29	31	
0.5-0.25	16	25	25	16	17	18	22	
0.25-0.1	9	11	13	11	9	9	7	
0.1-0.05	7	10	10	11	9	7	3	
0.05-0.02	6	7	5	3	3	2	0	
0.02-0.002	9	3	6	0	2	1	1	
<0.002	3	0	0	0	0	0	2	
TEXTURE CLASS (USDA)	loamy sand	loamy sand	loamy sand	sand	sand	sand	sand	
SOIL MATRIX COLOUR	dry	2.5YR 4/4	10YR 3/3	10YR 2/2	7.5YR 4/3	2.5Y 8/1	5Y 7/6	5Y 7/4 5G 8/1
	wet	2.5YR 3/3	10YR 2/2	10YR 2/1	7.5YR 3/1	2.5Y 7/2	5Y 5/4	5Y 6/6 5G 7/1
BULK DENSITY [g·cm⁻³]	1.20	1.36	1.40	1.60	1.62	1.67	1.70	
OC [%]	5.79	4.21	3.91	0.89	0.10	0.16	–	
N_t [%]	0.56	0.41	0.39	0.05	0.01	0.01	–	
C:N	10	10	10	18	10	16	–	
P_t [mg·kg⁻¹]	4 800	3 300	3 100	800	n.d.	n.d.	n.d.	
pH	H ₂ O	7.7	7.7	6.8	6.2	6.3	6.4	6.1
	1M KCl	7.4	7.4	6.5	5.9	6.0	6.0	6.0
CaCO₃ [%]	1.5	1.1	0.4	0.2	–	–	–	
EC_{1:2} [mS·cm⁻¹]	0.32	0.28	0.26	0.20	0.17	0.18	0.29	
CEC [cmol·kg⁻¹]	24.7	24.5	12.5	5.8	2.5	1.8	5.6	
K_t [mg·kg⁻¹]	1.08	0.99	0.73	0.48	0.40	0.40	1.71	
Ca_t [mg·kg⁻¹]	7.77	7.40	2.00	0.37	0.19	0.19	0.11	

Site 5 – Technic Gleyic Podzol (Novic)

Selected soil properties cont.

HORIZON	Auh1	Auh2	Auh3	Au	Es	Bs	CG
DEPTH [cm]	0–15	15–32	32–48	48–68	68–84	84–125	125–150
HEAVY METALS SOLUBLE IN AQUA REGIA							
Fe	9 440	10 950	7 830	3 820	1 350	5 390	4 970
Mn	165	225	593	131	22	100	17
Zn	184	186	97	35	22	14	30
Pb	73	90	43	12	4	4	8
Cd	0.5	0.6	0.5	0.4	0.2	0.2	0.4
Cu	52	61	25	11	7	6	11
Ni	14	14	9	6	2	4	14
Co	n.d.	1.1	2.1	0.2	1.2	1.3	4.8
HEAVY METALS SOLUBLE IN 0.1M HCl							
Fe	1 300	1 200	875	753	356	751	1 020
Mn	109	138	558	118	12	88	14
Zn	14	51	26	7	3	3	5
Pb	4	4	27	10	1.8	0.6	5
Cd	0.1	0.2	n.d.	n.d.	n.d.	n.d.	n.d.
Cu	0.8	1.5	9	5	2	1.2	4
Ni	n.d.	1.7	2.4	0.8	0.6	1.4	2.8

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